COST ESTIMATING FOR AIR-TO-AIR MISSILES

The Congress of the United States

Congressional Budget Office

January 1983

PREFACE

Accurate estimates of the costs of weapon systems are essential requirements in structuring defense forces and managing procurement programs efficiently. In the case of air-to-air missiles, cost estimating is made more difficult by the technological uncertainties that accompany system development. Successive generations of missiles have been characterized by increasing technological sophistication and cost and, in many cases, by cost growth well above average as compared to other defense systems.

The Research and Development Subcommittee of the House Committee on Armed Services requested that the Congressional Budget Office study topics related to the procurement of the next-generation Advanced Medium-Range Air-to-Air Missile (AMRAAM) to aid the Subcommittee in deciding the future of the AMRAAM program. This paper is a partial fulfillment of that request. This study was undertaken to evaluate the suitability of a particular cost-estimating methodology and to inform the Congress about the validity of the cost estimates that it has received for AMRAAM. In accordance with CBO's mandate to provide objective and impartial analysis, the paper offers no recommendations.

This paper was prepared by Neil M. Singer of CBO's National Security and International Affairs Division, with the assistance of Alan H. Shaw and under the general supervision of Robert F. Hale and John J. Hamre. It was reviewed by principals from the U.S. Air Force and the RCA Corporation, proprietors of the cost-estimating methodology under review, and received internal CBO review. The cooperation of the Air Force in supplying data is gratefully acknowledged. The assistance of the Air Force and RCA Corporation implies no responsibility for the final product, which rests solely with CBO. Francis Pierce edited the paper.

COST ESTIMATING FOR AIR-TO-AIR MISSILES

Introduction and Summary

Accurate estimation of system cost is a key requirement for making correct decisions about defense programs. For many reasons, however, accurate cost estimation has proved to be very difficult for a wide variety of defense systems. Long lags between identification of the need for a system and its eventual deployment make cost estimation the victim of unforeseen economic changes, especially unanticipated inflation. The technological complexity characteristic of many systems introduces an element of engineering risk, not usually present in nondefense programs, that complicates cost estimation. Funding stringency or variability can also affect system cost and thus render cost estimates inaccurate.

Despite these difficulties, the need for cost projections as part of the system development decision has stimulated diverse approaches to the problem of estimating defense system costs. This paper reviews one technique, the development of "cost-estimating relationships," as it is applied to estimating the costs of air-to-air missiles. The focus of this review is a cost-estimating algorithm known as PRICE, a model used extensively by the Armaments Division of the Air Force Systems Command.

PRICE is a generalized model that relates the weight and complexity of the electronic and structural components of a system to its cost. Adjustments can be made to reflect engineering sophistication, the extent of new design, production phasing, technological changes, and other aspects of system procurement. Detailed information describing the components of a system can be incorporated in disaggregated estimates of component costs.

Principal findings of this review of PRICE were:

- Cost estimates are quite sensitive to variations in the values of the complexity parameters, especially electronics complexity.

- The extensive experience of the Armaments Division in using PRICE for weapon system costing provides a deep data base to specify the values of these key complexity parameters.

- Nevertheless, PRICE estimates for the unit costs of AMRAAM, the next-generation medium-range missile, have almost doubled as the missile has proceeded through development. The increases, however, appear to be more the result of evolutions in missile design than of errors in specifying PRICE parameter values.

Techniques for Cost Estimating

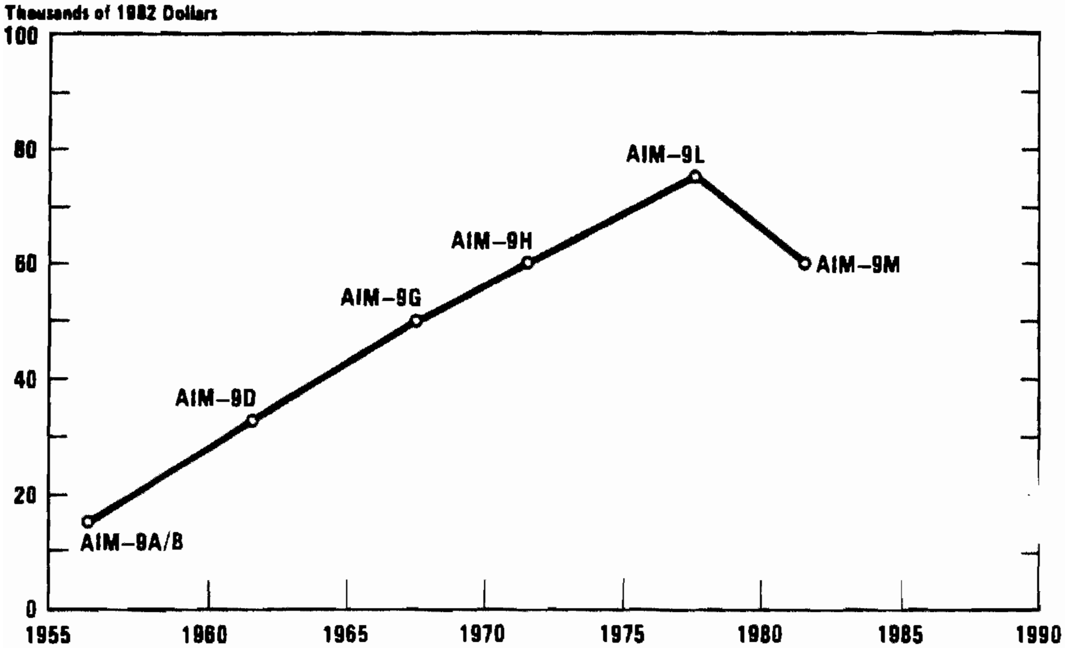
The three principal types of Air Intercept Missiles (AIMs) currently in the U.S. inventory are the short-range AIM-9L Sidewinder, medium-range AIM-7F Sparrow, and long-range AIM-54C Phoenix. Each of these missiles is the product of a development process that has resulted in earlier versions of the current missile. One approach to cost estimation simply extrapolates the trends in cost of successive generations of similar systems, in effect assuming that increments in capability, size, or complexity occur at relatively constant intervals. Figures 1 and 2 show how historical extrapolation applies to the AIM-9 and AIM-7 series. In neither case does the extrapolation provide an accurate guide for the next generation (AIM-9M or AMRAAM).

Because the extrapolation method is of little use for systems that constitute truly new developments, cost estimates are sometimes based on the physical characteristics of a system. Experienced production engineers can estimate the labor, equipment, and time required to produce system components and to assemble, test, integrate, and deliver them. Each of the steps involved in developing and producing a system can be subjected to this detailed engineering analysis and then the cost of each step can be calculated on the basis of the resources required.

Such "should cost" analysis is difficult to apply early in the development stage of a new defense system, since detailed engineering analyses generally have not been conducted at the time a cost estimate is first required. Moreover, a "should cost" estimate is subject to misjudgments that are particularly common in systems, such as AIMs, that are technologically sophisticated. The validity of "should cost" analysis for such systems is limited by engineers' inability to specify the characteristics of the systems in advance of their development.

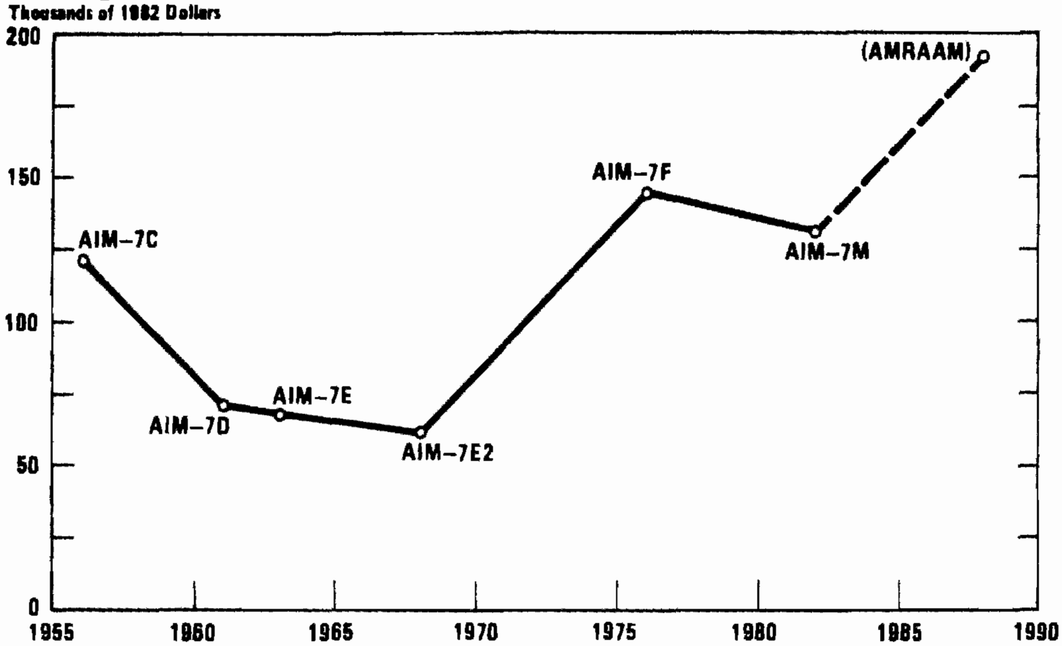
Cost Estimating Relationships (CERs). Instead of extrapolating or constructing "should cost" estimates, cost estimators can try to establish a link between the cost and some characteristics of a system or its components. The simplest CERs are those that relate a single characteristic such as weight or volume to the cost of a system. More complex CERs can include multiple characteristics such as weight, speed, payload, and range. In addition, CERs can be developed for different levels of complexity: major components such as wings or other structural

Figure 1.
Average Unit Cost of Each Sidewinder Model



SOURCE: Congressional Budget Office.

Figure 2.
Average Unit Costs of Sparrow Models and AMRAAM



SOURCE: Congressional Budget Office.

members might require only a single CER relating cost to weight or volume, while the cost of other assemblies--guidance units or detectors/detonators--might need to be estimated from CERs developed for numerous subassemblies.

The use of CERs among cost estimators is firmly established, but there is less unanimity on the nature of the particular form or value of the CER to use for any specific application. Both weight and volume might be needed to estimate aircraft cost, but perhaps only weight is significant for missile cost. Cost might be proportional to weight for ground vehicles, to the square of weight for aircraft, but to the cube of weight for missiles. Both identification of the parameters to use in CERs and selection of the functional form of the CERs typically remain matters of the cost estimator's art.

Development of CERs. Cost-estimating relationships can only be extracted from linkages found to exist in previously developed systems. Thus, there are two requirements for the development of a CER: data on cost and other parameters of other systems, and a model or analytical framework to identify the relationships between cost and the other parameters.

Both requirements can be troublesome. For missile systems, the relevant data base obviously is other missiles (rather than other weapons, or even aircraft). Air-to-air missiles in particular operate at higher speeds and stresses than most systems, at longer ranges, and with tighter physical constraints on key subsystems such as guidance sets. AIMs may have some commonality with other air-delivered systems (e.g., air-to-ground missiles) or precision-guided munitions (in subassemblies such as guidance or propulsion units), but overall cost data for these types of systems are likely to be less applicable than data for other AIMs. In addition, the sophistication of the threat environment for AIMs and the rapidity of that environment's change have stimulated rapid technological advances in the design and thus the capability of air-to-air missiles. Data from previous generations of AIMs, therefore, are less likely to be useful in developing CERs for current systems.

Development of CERs also poses some technical or methodological problems. The standard analytical framework for developing CERs is regression analysis, in which variation in cost is statistically related to variation in other key parameters. Regression analysis, however, is a valid projection technique only over the range of the underlying data. Thus, a missile with technological complexity far beyond that of its predecessors is unlikely to fit their CERs. A second problem is that the choice of a specification--the form of the regression model--can affect cost estimates dramatically, especially when projecting beyond the range of previous data. If a simple linear regression model is chosen, for example, the cost projection will be lower than if the model had used an exponential relationship between cost and other parameters such as weight or technological complexity. Finally, the cost estimator must inevitably exercise judgment in selecting the parameters to include in the analysis. The validity of the estimate thus will depend on both the choice of parameters and the stability of the relationship between cost and these parameters for the system being developed.

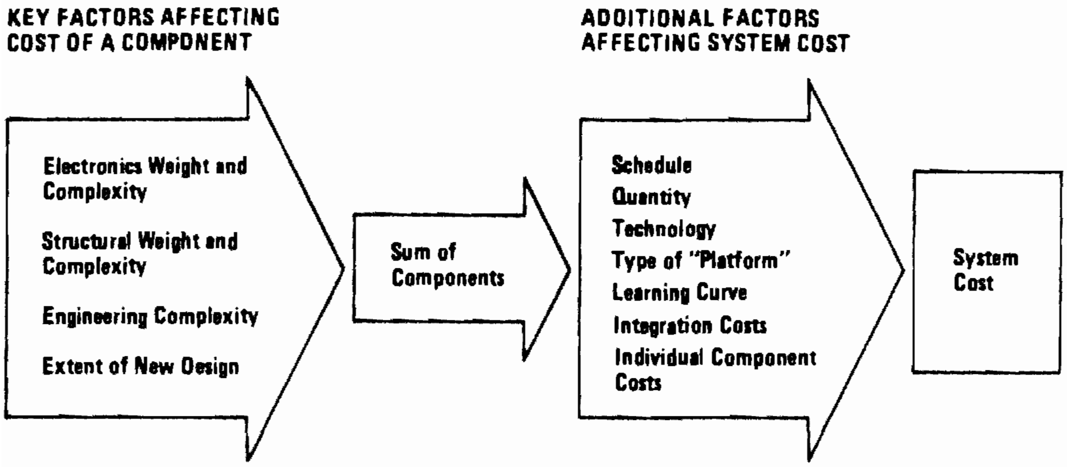
PRICE Overview

PRICE, a parametric cost-estimating model comprised of several distinct sets of algorithms, was developed and is maintained by the RCA Corporation. PRICE has been used extensively by the Armaments Division (AD), Air Force Systems Command, for the past six years in the cost evaluation of air-to-air missiles. The Armaments Division has responsibility for all phases of missile development through Full-Scale Development and procurement, but it makes use of PRICE primarily in the early stages of development, before detailed engineering drawings are prepared and prototype development is completed. PRICE thus substitutes for the use of other CERs or "should-cost" analysis in estimating the costs of missiles.

The Armaments Division's use of PRICE has been criticized for several reasons. Although it is extensively documented and its users are extensively trained, PRICE remains a proprietary system whose detailed mathematical specification is not provided to users. The cost estimator may choose values for descriptive parameters employed by PRICE (e.g., weight, volume, quantity, schedule), and further is able to offset known levels of deviation from the norm, but the embedded equations cannot be altered. Many parameters such as velocity or range that can affect cost are not input directly into the model. Other parameters may be adjusted, but the extent of adjustment requires a skilled operator and a sound historical data base. If data are limited, or if a new missile cannot be related in terms of its PRICE parameters to other weapons sytems, the cost estimator may be unable to select a valid PRICE parameter value for the system under development. These factors, combined with the tendencies for missiles generally to change specifications and experience cost growth in development, have led to criticism of PRICE's validity and of AD's use of it in preference to other CERs.

A brief description of PRICE can serve to put these drawbacks in perspective. PRICE consists of an integrated set of CERs, each of which relates a type or element of cost to key system parameters. Figure 3

Figure 3.
Structure of the PRICE Cost-Estimating Model



SOURCE: Congressional Budget Office.

provides a schematic representation of the structure of PRICE. A system is first characterized by apportioning the weight of each subassembly between electronics and structural content. A nondimensional parametric value is then assigned for the complexity of each subassembly's electronics and structure. A third nondimensional parametric value for engineering complexity reflects the subassembly's difficulty of design, which influences primarily development costs. PRICE permits additional adjustments for the system's environmental and reliability requirements--ground vehicle, manned or unmanned aircraft, or space platform--and for both technological change and "learning curve" savings. Given these parameter values and descriptions of the length of the development and production process and the number of units to be produced, PRICE generates an estimate of development and production costs at subassembly and system levels.

As a fully-automated algorithm, PRICE offers very rapid turnaround once the system parameters are specified. The user thus can test the sensitivity of the cost estimate to variation in any of the parameters, and can determine the effect of changing the schedule, production run, or physical characteristics of the system. PRICE offers the cost estimator the capability to evaluate a wide range of system configurations at minimal effort.

Although the basic physical characteristic used by PRICE to estimate system cost is weight (of structural and electronic components), the PRICE algorithm's cost estimates are quite sensitive to variations in the three complexity parameters. The structural and electronics complexity parameters appear in PRICE as exponents, so small absolute changes in their values can produce major changes in the cost estimate.

Since these parameters are nondimensional, the PRICE user or reviewer has little basis for relating their values to the physical world. Two approaches are suggested by RCA: a set of "standard" values that RCA has found to be good predictors of cost in previous applications to a wide range of systems, or implicit values that the user may discover as characteristic of systems similar to that being estimated. To discover these implicit values, PRICE can be run in reverse, in the so-called ECIRP mode, to estimate the values of the complexity parameters given system cost, weight, schedule, technology, and so forth. ECIRP thus can provide the analyst with values of the complexity parameters for previously-developed systems--such as AIMs--akin to that being evaluated. On the assumption that the complexity parameters for similar systems are the best guide to choosing complexity values for a new system, the analyst can then adjust the ECIRP values on the basis of trends, engineering studies, or other information.

Sensitivity of PRICE Estimates

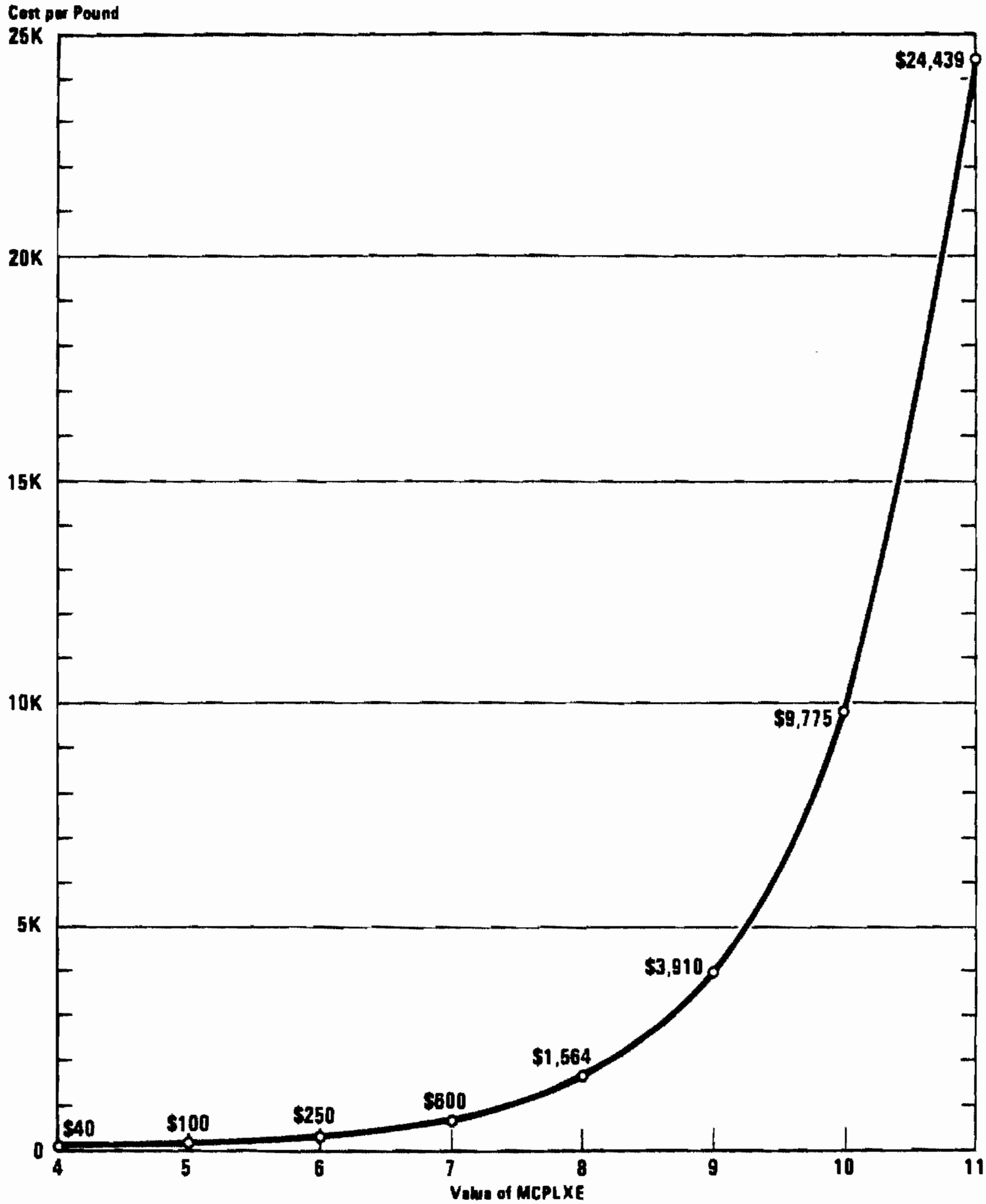
When PRICE is applied to estimate the costs of subassemblies or system components, the complexity of the resulting overall CER precludes quick identification of the parameters to which the cost estimate is most sensitive. To find this out, sensitivity analysis must be conducted by changing the values of different parameters incrementally and examining the resulting effect on overall estimated cost. The exponential specification of the role of the complexity parameters suggests that they are likely to be key in estimating overall cost. Figure 4 shows that this expectation is borne out for the electronics complexity factor, which causes sharp cost increases for values above about 8.0. (The curve in Figure 4 is actually only one of a family of such curves, one for each value of electronics weight. At low values of weight the curves would be less steep and at higher weight steeper than shown in the figure.)

Costs of technologically advanced weapon systems such as AIMs are very sensitive to the comparatively high values of the complexity parameters that appear empirically to fit best into PRICE. Inasmuch as PRICE is designed to provide acceptable cost estimates for a wide variety of systems of both military and non-military application, the values of the complexity parameters for technologically sophisticated military systems might be expected to be higher than those for other systems. Moreover, advances in technological complexity over time, or over successive generations of military systems, predictably increase the value of the parameters that yield the most accurate PRICE estimates.

The latter trend is shown in Table 1, which presents ECIRP estimates of system components for successive generations of missiles. Comparison with Figure 4 indicates that all of the complexity values in Table 1 are high enough to make the resulting cost estimate quite sensitive to small absolute changes in the parameters. Another aspect of the values in Table 1 is that they generally exceed the values that RCA suggests for "airborne" systems.

To assess the sensitivity of PRICE estimates to changes in critical parameter values, the Congressional Budget Office (CBO) ran PRICE for a notional AIM whose characteristics generally typified those of recent medium-range AIMs. Changes in selected parameter values then were made in keeping with the range of ECIRP estimates shown in Table 1. Other parameter values that were varied on the basis of discussions with experienced PRICE analysts included overall weight, weight of electronics, and learning curve savings.

Figure 4.
Sensitivity of PRICE Estimates to Electronics Complexity (MCPLXE)



SOURCE: Armaments Division, Air Force Systems Command.

TABLE 1. PRICE COMPLEXITY PARAMETER VALUES

Component	System "Generation" 1	2	3	RCA-Suggested Values
Mid-Course Guidance Unit				
(Electronic)		10.084	10.393	7.8-8.76 a/
(Structural)	7.257	7.223	7.453	6.8, 7.3-8, 5.5 b/
Safety/Arming Device (s) c/	6.427	7.260		5.3
Servo Section (s)	6.316	7.174		5.7-6.2
Fuse (s)	5.767	6.482	7.388	5.1-5.3
Rocket Motor (s)	4.713	5.311	4.190	6.1-6.5

SOURCE: Armaments Division, Air Force Systems Command; RCA PRICE Systems, PRICE Pocket Operating Guide

a. Analog, Digital, and Transmitter MCPLXEs

b. Gyro, Optics, Housing

c. (s) denotes structural

Table 2 summarizes these PRICE calculations as percentage changes from the notional baseline cost estimate in response to various percentage changes in selected PRICE parameters. Electronics complexity (MCPLXE) is plainly a critical parameter affecting both the research and development (R&D) cost estimate and the cost of the overall missile--a 10 percent increase in the parameter values drives up cost by 72 percent. Not surprisingly, the effect of an increase in electronics complexity appears primarily in the components that are weighted heavily with electronic equipment, the seeker and actuator units. But the role of these components in overall missile cost is so great, despite their small weight, that MCPLXE is also the most critical parameter in estimating total cost.

The calculations shown in Table 2 were made at a level of disaggregation typical of an early stage of the system development process. Thus, major components such as seeker, guidance unit, and rocket motor were treated as integral subsystems rather than as collections of subassemblies whose costs could themselves be estimated separately. At a later stage of development, such as Full-Scale Development, components would be specified in sufficient detail to permit the more disaggregated PRICE estimates. PRICE has proved most useful, however, at earlier stages of the development process when other techniques of cost estimation are not available. The calculations summarized in Table 2 therefore typify the estimates that would actually be made with PRICE for a particular missile such as AMRAAM.

Engineering complexity (ECMPLX) is a key parameter primarily at the R&D stage. The large percentage variation shown in the table was considered by PRICE analysts at AD to be within the range of previous experience. Nonetheless, engineering complexity does not exert much influence over the total cost estimate for the missile--a 50 percent increase raises cost by only 4 percent--since R&D costs are small (in this notional example) compared to production costs.

A change in missile weight can have quite different effects on costs depending on how the change is distributed, according to PRICE. When a 10 percent increase in weight was assumed to be distributed evenly between electronics and structural components, the overall increase in estimated cost was 7.1 percent. Apportioning the entire weight increase to electronics items, however, resulted in a 21.2 percent increase in estimated cost, owing principally to the much higher cost per pound of electronics equipment.

Table 2 also shows the effect of increasing both electronics and structural complexity parameters simultaneously. For purposes of the sensitivity analysis, all components were assumed to incur the same

TABLE 2. SENSITIVITY OF PRICE ESTIMATES OF MISSILE COST
(Percentage Changes from Baseline)

	Parameter Change a/				
Component	W_e +10%	W +10%	MCPLXE +10%	MCPLXE and MCPLXS +10%	ECMPLX +50%
R&D Only	20.2	7.8	38.5		55.6
Overall Missile (Representative Subassemblies)					
Seeker	25.5	9.5	125.5	125.5	6.1
Guidance		9.0		138.4	5.9
Actuators	65.0	8.5	43.6	43.6	8.0
Motor		8.0		85.7	7.0
Total	21.2	7.1	72.2	90.6	4.7

Learning Curve Parameter (Baseline = 90%)	95%	91%	85%
Change in Cost	+73.8	+11.6	-36.4

SOURCE: Armaments Division, Air Force Systems Command.

a. Key:
- W_e: Weight of electronics components
- W: Overall weight
- MCPLXE: Manufacturing complexity, electronics components
- MCPLXS: Manufacturing complexity, structural components
- ECMPLX: Engineering complexity

increase in complexity. Thus, a large component such as the rocket motor is shown in the table as experiencing a large (85 percent) increase in cost. In practice it is quite unlikely that all components would experience equal complexity increases. In particular, basically standard components (such as the rocket motor) would be especially unlikely to incur such large increases. Nonetheless, the table shows that the structural and electronics complexity parameters reinforce one another in their effect on overall system cost.

The range of complexity parameter values tested in Table 2 may, however, be an upper bound on the sensitivity of PRICE estimates. The uncertainty that a PRICE analyst is likely to have about the values to use in estimating AIM system cost is reduced by familiarity with the systems in question, and by the availability of a comprehensive data base relevant to missile costing. AIMs have been subjected to PRICE analysis for several generations of missile development, leading to the creation of a deep data base that can be used both to forecast trends in complexity parameter values and to choose point estimates for the complexity parameters.

One aspect of this AIM data base is summarized in Table 3, which shows the values of ECIRP complexity parameter estimates for a variety of missile components and missile generations. In most cases the range of complexity parameter variation is less than 10 percent between median and high value. It is also worth noting that most of the components in Table 3 are more disaggregated than the assemblies in Table 2. The average variation in complexity parameters at the more highly aggregated assembly level would usually be smaller than the variation in any one component's complexity parameter. This observation supports the proposition that the range of uncertainty in practice is likely to fall short of that postulated in the estimates in Table 2.

Other Issues in Using PRICE

A number of PRICE subroutines address particular aspects of the system development and acquisition process: development cost, technological change, integrating the separately-estimated costs of subassemblies to yield an overall estimate of system cost, and the timing or phasing of production (to include start-up, production rate, and the extent of competition). The Armaments Division, however, prefers not to use the PRICE subroutines for most of these purposes. Instead, AD has developed its own approaches to incorporating some of these development costs into an overall cost estimate.

Two of these PRICE extensions merit a brief discussion. One, technological change, is important for AIM development because of rapid

TABLE 3. COMPLEXITY PARAMETER RANGES

Component	Low	Median	High
Warhead (s) a/	3.5	5.1	6.5
Guidance Unit (e) b/	9.2	9.4	9.7
Guidance Unit (s)	6.5	7.3	7.4
Fuse (e)	5.8	6.6	7.1
Target Detector (e)	7.4	7.9	8.1
Inertial Platform (s)	5.9	7.0	7.1
Inertial Platform (e)	8.7	9.0	9.6
Rocket Motor			
(small) (s)	3.6	4.6	5.5
(large) (s)	4.1	5.0	6.0
Radome (e)	6.6	7.4	7.8
Gyro (e)	7.3	8.9	10.0
Fuselage (s)	5.7	6.1	6.4

SOURCE: Armaments Division, Air Force Systems Command

a. (s) denotes structural

b. (e) denotes electronic

advances in the state of the art for costly components such as seeker and guidance units. PRICE incorporates technological change by using a time trend and a base year chosen by the analyst. AD has found, however, that the higher costs associated with state-of-the-art technology are not simulated accurately through the PRICE approach. Accordingly, AD usually declines to use the technological change option in PRICE, and makes implicit judgments about technology instead through the values of the complexity parameters. AD's reluctance to use the PRICE subroutine stems in part from the absence of empirical validation in missile technology applications.

The other PRICE extension of interest is the learning curve adjustment. The learning curve describes the reduction in unit cost that occurs as production increases, due presumably to improved efficiencies and familiarity with the production process on the part of the work force. A baseline learning curve of 90 percent was used in the notional AIM estimates in Table 2. 1/ Selection of a 95 percent learning curve, indicating either slower learning or fewer opportunities for cost reduction, would have resulted in a dramatic 73.8 percent increase in total production costs. Conversely, an 85 percent learning curve would have meant a 36.4 percent saving in production costs. AD typically uses a 91 percent learning curve in its estimates; as shown in the table, even this modest change from the baseline would have increased estimated production costs by 11.6 percent.

There is no theoretically correct single learning curve parameter, since the learning curve reflects the skill and experience of the work force as well as the production process for the particular system. An 85 percent learning curve is frequently used in aerospace applications. AD's choice of 91 percent, therefore, is conservative in the sense that it should tend to overestimate actual costs. Further, maintenance of a constant learning curve parameter across PRICE estimates for different AIMs should minimize the importance of this factor in missile cost estimating.

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1. Under a 90 percent learning curve, the cost of the 100th unit is 90 percent of the cost of the 50th, that of the 200th unit is 90 percent of the cost of the 100th, and so forth for successive doublings of the production run.

Application to AMRAAM

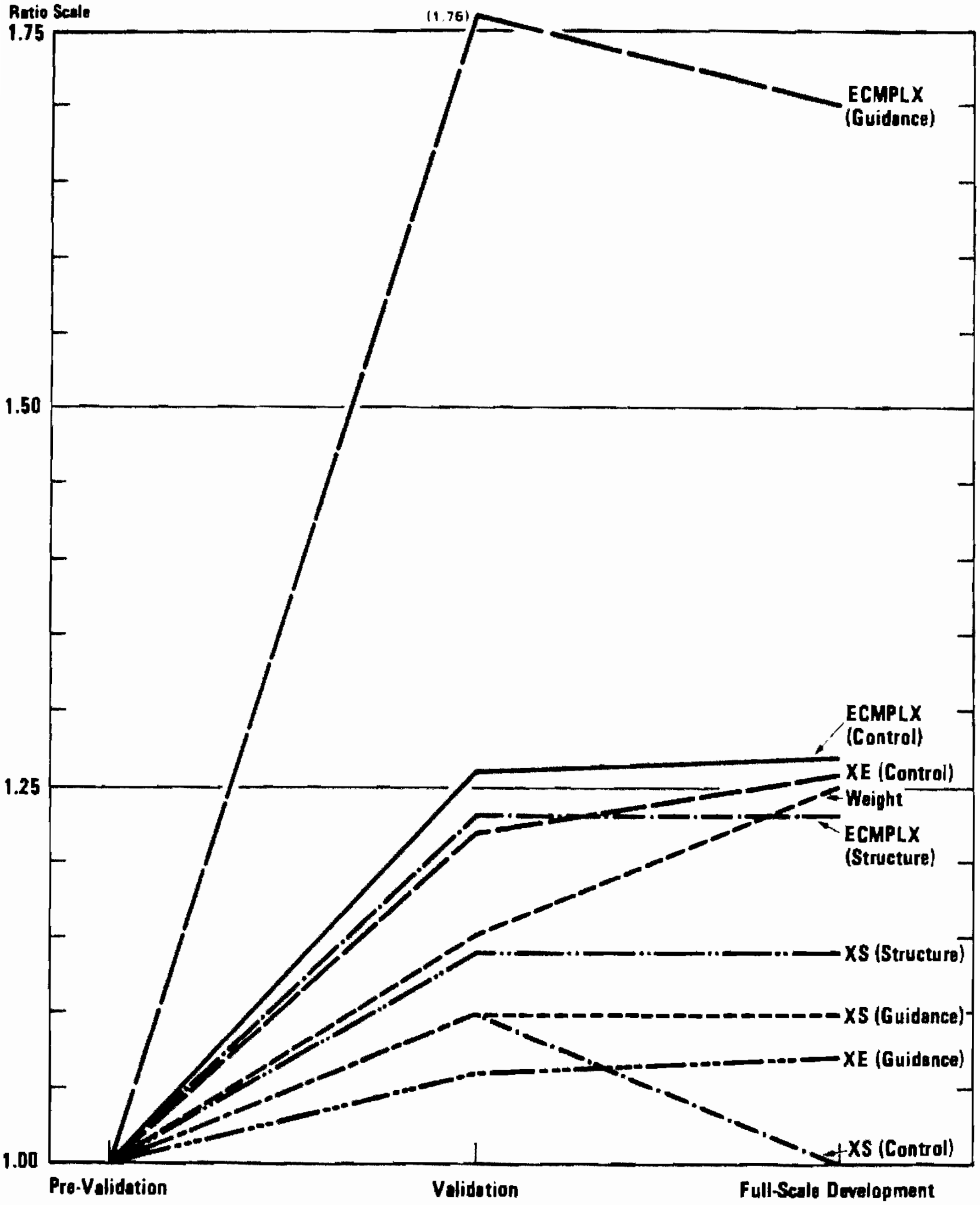
The Armaments Division has used PRICE most recently to estimate the cost of the Advanced Medium-Range Air-to-Air Missile (AMRAAM). CBO's review of PRICE suggests that it is likely to be an acceptable cost-estimating approach for AMRAAM, subject to the accuracy of the underlying data or parameter values. In practice, however, AD's estimates of the cost of AMRAAM have almost doubled between the initial planning phase and the current Full-Scale Development stage. In constant 1978 dollars and for the same total buy size, unit costs grew from $74,000 in December 1979 to $147,000 in December 1982.

Although it is designed as a replacement for the AIM-7 medium-range Sparrow missile, AMRAAM incorporates significant changes in its design intended to improve its performance sharply over that of Sparrow. One major change upgrades the missile's guidance unit to enable it to operate independently once it is fired. Using Sparrow, the aircraft has to lock its radar onto the target and guide the missile until impact. With AMRAAM, in contrast, the missile's own seeker will be able to home in on the target despite electronic countermeasures and other evasive or deceptive behavior. Further, AMRAAM is intended to operate at ranges greater than those of Sparrow, with attendant requirements for increased power and rocket motor range. Since AMRAAM must be able to fit on the aircraft launchers now used by Sparrow, the additional performance demanded of AMRAAM carries a further requirement for miniaturization and weight reduction.

Given the stringent operational requirements for AMRAAM's performance, it is not surprising that the design of the missile has evolved somewhat during the development process. The overall weight of AMRAAM has risen from 270 to 342 pounds, a 26 percent increase. The weight of electronics components has increased slightly more, by 29 percent. The missile's design has been specified in increasing detail, with the result that the complexity of its guidance unit has become more apparent.

All of these changes have been reflected in the increased cost estimates that AD has made using PRICE. The changes stem from incorporation of the new information about the missile's characteristics developed in the process of refining its design, as shown in Figure 5. The ratio scale in the figure establishes the initial PRICE estimate, at the notional or "pre-validation" stage, as the baseline. PRICE parameter values at the "validation" and Full-Scale Development stages are shown as ratios to their original, pre-validation estimates.

Figure 5.
Changes in AMRAAM PRICE Parameter Estimates



SOURCE: Armaments Division, Air Force Systems Command.

It is apparent from Figure 5 that increases in the cost estimates for AMRAAM reflect not an error in using PRICE, but rather a series of adjustments within the PRICE framework to reflect changes in the size, design, and complexity of the missile. In no case is a parameter value at FSD lower than the corresponding value at the pre-validation stage. Many of the parameter values have risen sharply, including weight, electronics complexity for the control section, and engineering complexity for all three major sections (guidance, control, and structure). Only the structural complexity parameter for the control section is at its initial value.

CBO's analysis of the use of PRICE to make AIM cost estimates at early stages of the missile development process does not suggest that the estimates themselves are biased, but only that the accuracy of the estimate is hostage to the specification of the missile's characteristics. As is typical of the weapons development process, early descriptions of AMRAAM now appear to have been overly optimistic and to have led to underestimates of its eventual cost.

Further growth in AMRAAM costs, if any, depends on what additional changes occur in its specifications. Growth in the size of AMRAAM may be constrained by the physical limitations imposed by the Sparrow launchers. In addition, the engineering development that has occurred to this point may have led to a feasible AMRAAM design, given its mission requirements. Thus costs may stabilize. To the extent that further technical changes result in greater complexity, however, the analysis of the sensitivity of PRICE estimates suggests that costs could grow still more.