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Impossible Certainty
Cost Risk Analysis for Air Force Systems

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Prepared for the United States Air Force

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Summary

Background

The Department of Defense (DoD) forecasts its expenditures several years into the future. An important element of that forecast is the estimated cost of weapon systems, which typically take many years to acquire and remain in operation for a long time. To make those estimates, the Office of the Secretary of Defense (OSD) and the military departments use cost analysis, a discipline that attempts to forecast the ultimate cost of a weapon system far in advance of actual expenditures. But estimates are just that—estimates—not certain predictions of future costs. An analyst does not have perfect knowledge about technology, economic conditions, and other future events. Thus, a cost estimate carries with it an uncertainty and, thereby, a risk that actual costs might be higher or lower than originally anticipated.\(^1\)

Uncertainty occurs for a number of reasons. For example, critical technical information or parameters might be unknown, poorly understood, poorly defined, or undefined when an estimate is prepared. This situation is particularly true early in a program’s acquisition cycle. For example, parametric estimating methodologies for aircraft cost use characteristic factors (weight, lines of code, etc.) to forecast cost. These values might be hard to define accurately or might evolve due to changing requirements over the program’s life.

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\(^1\) In this report, we define uncertainty as the indefiniteness in outcome—good or bad—whereas risk refers to the possibility of loss or injury, someone or something that creates or suggests a hazard, or the probability or likelihood of an adverse effect or event occurring.
Thus, the estimator must make some judgments about which values to use as a basis for estimate. Even if the actual values of these parameters could be known ahead of time, the parametric estimating method still cannot forecast cost with 100 percent certainty. Parametric forecasts contain error because parametric relationships only approximate actual cost behavior.

Uncertainty can also occur when a program uses new technologies or approaches. This situation is difficult for estimators because they have no historical analogy from which to make an estimate. Thus, an estimator must develop a new estimating approach based on limited experience or extrapolate using existing methods. New technologies and approaches also have the potential for failure, or they can encounter development difficulties leading to additional work or alternative solutions. Unfortunately, it is difficult to identify which technologies will have such problems and the resultant cost effect.

Another class of uncertainty relates to economic conditions. Some pertain specifically to a supplier or producer. For example, worker wage rates generally increase over the course of a program. However, it is difficult to forecast the magnitude of these increases because they are tied to national and local economic conditions, labor relations, and overall inflation. Another producer issue related to cost uncertainty corresponds to indirect costs. These costs, such as overhead, depend heavily on the business base of the firm. Thus, how successful the firm is in winning and holding other work not necessarily related to a program will influence indirect rates of that program.

Yet another class of uncertainty involves unusual or rare events. Examples of these types of risks are fire, earthquakes, and labor actions. Although uncommon, these types of events do occur and can have significant cost consequences on a program.

**Why Is It Important to Consider Cost Uncertainty?**

By and large, OSD and the military departments have historically underestimated and underfunded the cost of buying new weapon sys-
tems. Figure S.1 shows the cost growth factor (CGF) for programs dealing with systems that were similar in complexity to those procured by the Air Force (e.g., aircraft, missiles, electronics upgrades) and were either finished or nearly finished—that is, greater than 90 percent of production was completed. The CGF metric is the ratio of the final cost to the estimated costs using Milestone II estimates. A CGF of less than 1.0 indicates that the initial program budget was higher than the final cost—an underrun. When the CGF exceeds 1.0, the final costs were higher than the initial budget—an overrun.

Figure S.1
Distribution of Total Cost Growth from Milestone II, Adjusted for Production Quantity Changes

NOTE: Includes research and development, as well as production funding.

2 The data are drawn from Selected Acquisition Reports. They have been modified to account for inflation and changes in the number of systems produced.
Figure S.1 indicates both a systematic bias toward underestimating the costs and a substantial uncertainty in estimating the final cost of a weapon system. Our further analysis of the cost growth data indicates that the average adjusted total cost growth for a completed program was 46 percent from Milestone II and 16 percent from Milestone III. The bias toward cost growth does not disappear until about three-quarters of the way through production. Chapter Two of this report explores the cost growth in more detail.

Focus of This Project

In light of such cost growth and variability, senior leaders in the Air Force want to generate better cost estimates—that is, ones that provide decisionmakers with a better sense of the risk involved in the cost estimates they receive. To that end, the Air Force Cost Analysis Agency and the Air Force cost analysis community want to formulate and implement a cost uncertainty analysis policy. They asked RAND Project AIR FORCE to help. Since formulating a practical cost risk analysis policy involves more than selecting a methodology, RAND considered many issues relevant to its formulation. RAND conducted research that explored and reviewed various risk assessment methodologies that could be applied to cost estimating for major acquisition programs. RAND explored how these risk methods and policies relate to a total portfolio of programs. The research also explored how risk information can be communicated clearly to senior decisionmakers. This research was done through literature reviews; discussions with policymakers, cost estimators, and other researchers; and original research and analysis of historical cost data.

Policy Considerations

Cost uncertainty analysis is an important aspect of cost estimating and benefits decisionmaking. It helps decisionmakers understand not only the potential funding exposure but also the nature of risks for a
particular program. The process can also aid in the development of more-realistic cost estimates by critically evaluating program assumptions and identifying technical issues. While we do not measure or quantify the benefits in terms of effectiveness in improving decisions and cost estimating, it is axiomatic that additional information (when correctly gathered and presented well) is of value to the decisionmaker.

A poorly done uncertainty analysis has the potential to misinform, however. Therefore, any cost uncertainty analyses should be comprehensive and based on sound analysis and data. It should consider a broad range of potential risks to a program, not just those that are currently the main concerns of the program office or contractor. Furthermore, the analysis should be rigorous and follow accepted practice for the particular method or methods employed. To the extent possible, independent technical evaluation should aid in the assessment of program cost assumptions.

The Air Force should consider several issues in formulating a cost uncertainty analysis policy:

- **A single uncertainty analysis method should not be stipulated for all circumstances and programs.** It is not practical to stipulate one specific cost uncertainty analysis methodology in all cases. Rather, the policy should offer the flexibility to use different assessment methods. Moreover, a combination of methods might be desirable and more effective in communicating risks to decisionmakers. (See pp. 35–70.)

- **A uniform communications format should be used.** A consistent display of information to senior decisionmakers can be helpful in explaining results and also allows for comparisons among programs. RAND suggests a basic three-point format (low, base, and high values) as a minimum basis for displaying risk analysis. The three points are used to show the decisionmaker a reasonable range of possible outcomes. The advantage of such an approach is that it allows for a consistent format across a variety of risk analysis methods. (See pp. 81–86.)
• **A record of cost estimate accuracy should be tracked and updated periodically.** To ensure that both the cost estimating and uncertainty analysis processes provide accurate information, estimates and assessment records should be kept and compared with final costs when those data become available. Such a process will enable organizations to identify areas where they may have difficulty estimating and sources of risk that were not adequately examined. A retrospective analysis of a program at completion would be one way to formalize the process, and the results could recommend improvements to the risk analysis process. In addition, a comparison with a previous estimate for the same system would be useful in documenting why cost estimates have changed since a previous milestone or other major decision point. It should be part of a continuous improvement effort for cost estimating. (See pp. 71–80.)

• **Risk reserves should be an accepted acquisition and funding practice.** Any policy needs to provide for a risk reserve. 3 Reserves should be used to fund costs that arise from unforeseen circumstances. However, under the current DoD and congressional acquisition and budgeting process, this recommendation will be difficult to implement. Establishing an identified risk reserve involves cultural changes in the approach to risk, not regulatory or legislative changes. Today, the only viable approach to including a reserve is burying it in the elements of the estimate. Although pragmatic, this approach has drawbacks. The burying approach will make it difficult to do retrospective analysis of whether the appropriate level of reserve was set (or the uncertainty analysis was accurate). This approach also will make it difficult to move reserves, when needed, between elements of a large program. (See pp. 71–80, 135–145.)

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3 Nowhere in this report do we address an approach to setting a risk reserve. For example, some have argued for a uniform 80 percent confidence level, while others have developed analytic methods (Anderson, 2003). Ultimately, we feel that the reserve needs to be set by the decisionmaker responsible for setting funding levels informed by the uncertainty assessment. The nature of the program will determine the level of the reserve, and that level will vary across programs.