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Pacific Northwest National Laboratory

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Evidence of Cost Growth Under Cost-Plus and Fixed-Price Contracting

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Prepared for the U.S. Department of Energy
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Summary

Currently, Department of Energy Headquarters (DOE-HQ) uses a bottom-up approach to estimate savings from privatization of Environmental Management projects. The benefits from this approach include the ability to withstand an engineering audit and compatibility with the approach delineated in Office of Management and Budget (OMB) Circular A-76, which applies to privatization of "commercial" activities traditionally performed by Federal personnel. However, there are several shortcomings to this approach, as well: a) cost estimates for privatized operations are likely to have wide confidence bands; b) the estimates are costly to perform; and c) the eventual cost at completion bears little relation to the specific estimates based on cost-plus contractor performance.

Based on a merger of three data sets, Figure S.1 shows the expected relationship between estimates and final cost at completion for cost-plus and fixed-price contracts. The three data sets came from a General Accounting Office (GAO) review of DOE Environmental Management projects, an Army Corps of Engineers data set on their environmental construction projects, and a Project Performance Corporation (PPC) data set on both Federal and non-Federal projects. The GAO data set consisted entirely of cost-plus contracts. The Army Corps data set was a mix of fixed-price and cost-plus contracts, but contained mainly fixed-price contracts. The PPC data set was valuable because it provided information on competition between outside firms and government cost-plus contracting.

The base for all of the cost estimates is a cost-plus contract, shown as 1.0 in Figure S. 1. Based on a sample of 44 projects when outside contractors bid against government employees, the average fixed-price bid was 14% below the government's in-house cost estimate; however, some estimates were as much as 80% lower. Figure S.1 also shows that based on samples of 15 cost-plus contracts and 121 fixed-price contracts, fixed-price contracts tend to overrun to a lesser extent than cost-plus contracts, so that the actual cost at completion on an "average" fixed-price contract would be 5% below the in-house cost-plus estimate and more than 60% below what the average actual cost would be on a cost-plus basis.

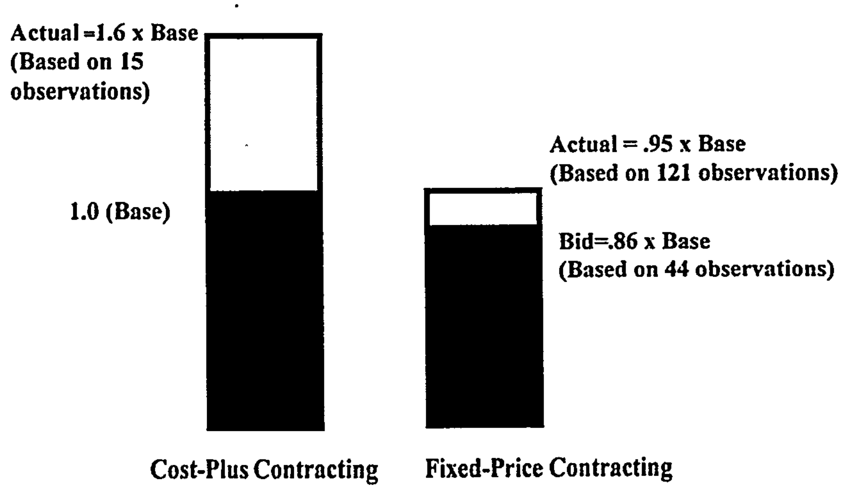

Figure S.1. Summary of Bid and Actual Costs for Cost-Plus and Fixed-Price Contracts

Although not shown in Figure S.1, the analysis also shows that savings can actually be predicted more accurately from historical data on relative savings than they can be with a detailed estimate based on conceptual design only. Through statistical analysis, given historical data, the distribution for predicted savings can be shown to be -19% to +30% for a 95% confidence interval, compared with –30% to +50% cost estimates from a conceptual design.

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1.0 Introduction

As defined by the U.S. Department of Energy (DOE), privatization refers to a shifting of responsibilities for the completion of projects from a cost-plus Management & Operations (M&O) contract, to incentive-based contracts with the private sector. Activities identified for privatization include both operations and capital construction activities, and range from routine activities involving no technology development to one-of-a-kind projects involving both research and technology development. M&O contractor revenues reflect cost reimbursements plus predetermined profit margins proportional to project budgets. The absence of competitive bidding for specific project outcomes creates insularity and protects the M&O's profit margins at the expense of taxpayers. In contrast, DOE's new vision is to arrange cleanup work around incentives-based contracts, which are won via competitive bidding. Competition in awarding cleanup contracts can make use of market incentives to lower project costs and reduce slippage time.

Fixed-price contracts encourage contractors to minimize schedule delays and cost overruns once the scope of a project has been negotiated. Conversely, cost-plus contracting offers weak incentives for contractors to select cost-minimizing production and management approaches. However, because fixed-price contracts distribute all of the project performance risk to the contractor, contractors are unlikely to seek fixed-price cleanup projects when project scope, goals, or methods are uncertain because of the significant cost and managerial risks involved. In most cases, government must either bear some portion of the risks or compensate the contractor for doing so by offering a higher rate of return. Therefore, contract agreements under cost-uncertainty may include both fixed-price and cost-plus elements.

Because privatization explicitly allocates more risk to the contractor, it forces the government to better define its goals and methods. Privatization potentially can save a substantial percentage for the following reasons:

- A better statement of work is prepared and negotiated.
- The bidding process results in access to a broader range of technologies and approaches.
- Fixed-price contracting controls cost increases.
- Government describes the "what"; the contractor is allowed to find the best "how."
- Better management occurs because financiers act as additional managers of performance.
- Presence of competition provides cost-minimizing incentives.
- Use of private sector financing commits the contractor to perform well in order to recoup investment.
- Regulatory requirements applicable to private contractors may be different (less costly) than those applying to government operations.

This study summarizes actual cost experiences with government contracts performed under cost-plus and fixed-price incentive structures at all levels of government. The next section provides some background on the problem of making contractor activity more cost-efficient. Following this are sections on the measurement of performance and the costs of projects, limitations on measurement, and findings of similar studies. The study concludes with appendices discussing the details of the performance measurement methodology and the project data sets used in the study.

2.0 Background

Since 1989, the DOE office of Environmental Restoration and Waste Management (EM) has used management contractors to perform cleanup projects and manage its major sites. EM offers fees for high-quality performance and has increasingly tied the level of fees to specific performance outcomes over the last few years. However, performance has lagged in many cases in controlling costs and schedules. For example, the company Independent Project Analysis (IPA 1993; 1996) found that cost increases and schedule performance were still sub-par, despite some improvements over the years. Cost overruns on EM projects in IPA's update report (IPA 1996) still ranged from 30% to 50%. The General Accounting Office (GAO) found that for 15 major systems acquisitions projects completed between 1980 and 1996, costs averaged 62% more than the original estimate and the projects were completed an average of 72 months late (GAO 1996). Although performance incentives in contract forms, such as cost-plus-incentive-fee, have proved useful under some circumstances, the DOE Inspector General has also found problems with the implementation of performance incentives.

For some years, DOE has turned over routine functions, such as laundries and selected support services, to the private sector. This activity is now being taken a step further. In an attempt to obtain better-cost control, EM has begun to privatize several of its major cleanup projects, and has requested that Congress set aside funds to reimburse the contractor in the event that the project is later cancelled. It is too soon to tell whether this approach will ultimately prove cost-effective in comparison with other approaches for complex "pioneer"[(a)] technical projects, even though it has proved efficacious for more routine activities. According to the GAO (1998), the following conditions are most conducive to form fixed-price contracts:

- a clearly defined statement of work;
- low probability of major changes to work scope or conditions to avoid costly re-negotiation of price;
- existence of proven technologies that can be applied with no more than limited modifications;
- high-quality cost and pricing data and/or multiple competing bidders to aid in determining a fair price for the work; i.e., a price that minimizes the cost to the government, while providing a fair profit to the contractor;
- easily verifiable performance measures to facilitate monitoring progress toward project completion; and
- thorough analysis of risks and appropriate allocation of sharing of risks so that the party bests able to manage each one is responsible for addressing it.

(a) Pioneer projects are first-of-a-kind or require major scaling up or adaptation of known technology.

Certainly, EM faces a particularly challenging set of circumstances in its major cleanup projects. However, major pioneer projects are not the only projects that DOE undertakes. In addition, because actual operating experience with privatization in EM is still scarce, it is worthwhile to combine DOE experience with experience of others to help develop expectations concerning what cost savings are possible with privatization. The next few sections expand on this thesis and summarize some of this prior experience.

3.0 Current Methodology: The Bottom-Up Approach

Currently, DOE-HQ uses a bottom-up approach for estimating cost savings from the privatization of EM projects and activities. This methodology requires that site personnel develop two initial cost estimates for each project under consideration for privatization. Each of these cost estimates is an aggregate of the individual cost elements associated with the project (i.e., the cost estimates are developed from the bottom up). Site personnel first estimate the costs for a project, assuming that the project is performed by a Management and Operations (M&O) contractor, typically operating under a cost-plus contract. They then develop a separate cost estimate, assuming the project is performed by a private vendor, typically operating under a fixed-price contract. Finally, they compare the two cost estimates to estimate the savings that would result if the project were privatized.

The major benefits of this approach are twofold. First, cost estimates developed using a bottom-up approach are more likely to withstand the scrutiny of engineering audits. Second, this approach is consistent with Office of Management and Budget (OMB) Circular No. A-76, which prescribes a similar bottom-up methodology for privatizing "commercial" activities traditionally, performed by Federal personnel.

The OMB A-76 process begins with defining the activity that is a candidate for privatization, and developing a bottom-up estimate of the current cost of performing that activity with Federal employees. This differs from the EM privatization initiatives, in which the work typically is not being performed by DOE when the cost estimate for the project is developed. The next step in the A-76 process is to aid the Federal employees currently performing the work to develop a "most efficient organization" (MEO) plan. The MEO is the current employees' attempt to define a more efficient, hence less costly, approach to performing the work being considered for privatization. The MEO process includes a second cost estimate to perform the Federal function that shows the anticipated savings if the MEO are put in place. Finally, a request for proposals (RFP) to perform the current Federal function is developed and the Federal MEO and private firms bid for the function. If the MEO approach wins the bid, the function is reorganized to achieve the estimated cost savings. Privatization only occurs if the private firm wins the bid to perform the function.

Because M&O contractors already perform the functions that EM plans to "privatize," OMB Circular No. A-76 does not apply to EM privatization. There are, however, several potential problems associated with the bottom-up approach, the most significant of which are described in Section 4.0, "Limitations of the Bottom-Up Approach."

4.0 Limitations of the Bottom-Up Approach

This section describes four limitations in the bottom-up approach to cost estimating. Two (privatization adjustments and uncertainty associated with early estimates) relate to the quality of the initial cost estimates, and another (cost of preparing estimates) relates to the methodology's cost-effectiveness. The last (cost at completion) is potentially most significant because it relates to a more fundamental flaw in the methodology that can result in savings estimates that are both imprecise and biased.

Privatization Adjustments - Site personnel often estimate the costs incurred by private vendors through simple adjustments to individual cost elements from the M&O scenario. For example, personnel at one site adjusted the general and administrative (G&A) rate from 29% in the M&O case to 16% in the privatized case. These adjustments often appear to be based on few observations.

Uncertainty Associated with Early Estimates - Initial estimates are also uncertain because they are typically developed at the conceptual or pre-conceptual phase of the project. The quality of the cost estimate is strongly affected by the clarity with which the project outcomes are defined. Both GAO (1998) and IPA (1993, 1996) repeatedly emphasize that although scope changes are not defined as "cost overruns," a vague scope of work will lead to subsequent scope corrections that typically expand the scope (and the cost) of the project and usually will involve schedule and effort increases that are counted as cost increases. The American Association of Cost Engineers (AACE) estimates an uncertainty range of -30% to +50% for cost estimates in the conceptual phase.

Cost of Preparing Estimates - Because site personnel must repeat the bottom-up process for each project proposed for privatization, it is burdensome and expensive to implement. If site personnel calculate the costs of a project twice, once under fixed price and once under cost-plus, the value in the exercise is understanding the scope of the project, the requirements for implementation, and the government's probable cost under a cost-plus contract. These are the activities discussed by advocates of "front-end loading" and better engineering design (IPA 1996). If there were sufficient competition, any potential or actual savings would have occurred without the detailed cost estimate for the private contractor, since such savings depend upon the adequate definition of the project and the size of the actual bid.

Cost at Completion - The true measure of success for privatization is whether the cost at completion for a privatization project is lower than if awarded through the traditional M&O approach. With the bottom-up approach, however, it is unlikely that the difference between the initial cost estimates will either accurately or precisely reflect actual cost savings because the incentive structure of an M&O cost-type contract differs significantly from that of a fixed-price contract. Because contractors bear no risk for cost overruns in cost-plus M&O contracts, it is not unusual under this type of contract for a project's actual cost at completion to significantly exceed the conceptual cost estimate. Under a fixed-price contract where, in the absence of change orders, the private vendor bears all of the cost risk, such deviations would be much smaller. Furthermore, actual savings can only be measured if cost-plus and fixed-price contractors were to perform exactly the same work in exactly the same circumstances.

5.0 An Alternative Methodology: The Top-Down Approach

An alternate approach for estimating the potential savings from privatization is to perform a high-level analysis of cost savings from similar efforts in the public and private sector and apply the findings to specific projects or groups of projects. The major benefits of this approach are that it would focus on predicting the difference in cost at completion rather than initial cost estimates and would be less costly to implement. The major drawbacks are related to data quality and the ease with which one could apply results of a general study of privatization to specific EM projects. The approach shown in Figure 5.1 was followed in this analysis.

The raw data for relative savings under privatization were first "binned" into histograms that depict actual costs in relation to the original estimates. Figure 5.2 illustrates that overruns are typically much lower for fixed-price than for cost-plus contracts. Specifically, Figure 5.2a illustrates that M&O projects managed under cost-plus contracts are typically characterized by larger cost overruns than privatized projects managed under fixed-price contracts, as shown in Figure 5.2b. Figure 5.2a is derived from a

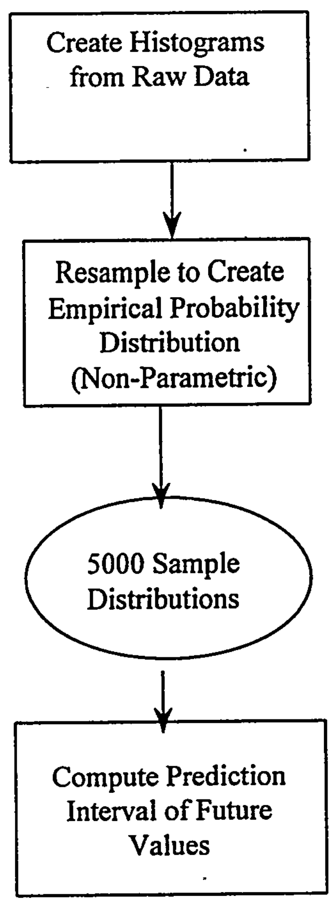
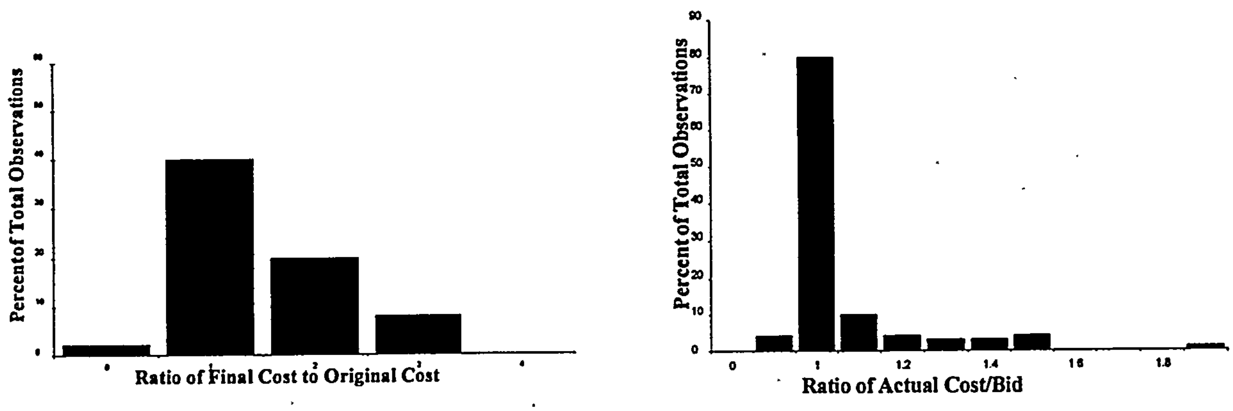


Figure 5.1. Top-Down Estimate of Cost Growth



a) Cost-Plus Estimates

b) Fixed-Cost Estimates

Figure 5.2. Distribution of Cost Estimate to Actual Cost Ratios

General Accounting Office data set on 15 large DOE cost-plus projects (Appendix B), while Figure 5.2b is derived from a data set on 121 fixed-price Corps of Engineers military construction contracts supplied by Lewis Berger and Associates (LBA). Although the final cost under cost-plus contracts can be higher than the estimated price by a factor of four or more, final costs for fixed-price contracts only exceed bids by a maximum factor of 1.6 or so. (The cost of one project was higher, as is discussed in Appendix B.) It is relatively rare that a government agency accepts a bid that exceeds the in-house cost estimate. Consequently, fixed-price bids tend to be lower (sometimes much lower) than the in-house estimate, as shown in Figure 5.3. Figure 5.3 was derived from a data set on 44 contracts provided by Project Performance Corporation (see Appendix B).

Next, the predicted value of final cost under fixed-price bid was calculated, given the in-house estimate, including confidence intervals. In order to make inferences about the ratio of actual cost to the in-house estimate, it was necessary to estimate the probability distribution of the data. The first step was to determine whether the data in the sample of projects fit any theoretical probability distribution for which the mathematical properties were known. Several attempts were made to identify possible probability density functions for the ratio of actual to in-house cost estimates. The data were highly skewed and could not be correlated to any known distribution having a similar appearance (e.g., Pareto, Weibull, Log normal, exponential), and there were no strong theoretical grounds for expecting any particular theoretical distribution.[a] The failure to identify a theoretical distribution could be related to relatively small sample size or the existence of sub-populations. For example, the ratio of actual cost to bid price may be different for small projects than for large ones. Combining the two sets of data might make a single probability density function hard to identify.

(a) Histograms of the data similar were plotted, and chi-squared goodness-of-fit estimates calculated. The null hypothesis that the data followed one of the theoretical distributions was consistently rejected. Residual Mean Life Deviance Function techniques (Hogg and Klugman 1984), which attempt to identify "tail" behavior of common distributions, also failed to yield a theoretical distribution.

Because the probability structure of the data could not be modeled using standard univariate probability distributions, a non-parametric approach was used, as follows. First, the observed values for the ratio of actual cost to the in-house cost estimate were plotted as a histogram with a reasonable number of intervals, as in Figure 5.2b. This histogram was assumed to reflect one possible sample of 121 projects from the whole universe of current and potential Corps of Engineers fixed-price projects. A Monte Carlo simulation was performed using the histogram as a probability model to obtain 100,000 observations. In sampling the histogram, all points within each interval were considered to be equally likely. From this simulated "universe" of 100,000 observations, we picked 5000 samples of 121 values representing different possible sets of fixed-price contracts.[a]

The statistical mean $(x_1,x_2,...,x_{120}) - x_{121}$ was computed for each of the 5000 samples. The reason for computing the above statistic was to be able to form a probability statement about x_{121}, the estimate of the ratio of actual cost to the in-house estimate of cost for some future project. The probability statement about the future estimate is as follows:

$$\text{probability (lower bound} \leq \text{mean}(x_1,x_2,...,x_{120}) - x_{121} \leq \text{upper bound}) = 1 - \alpha \qquad (5.1)$$

where α is the significance level, in this case, $\alpha = 0.05$.

That is, there is a 0.05 probability that the true value of x_{121} lies farther from the sample mean than the upper or lower bound. After isolating x_{121}, the above probability statement becomes:

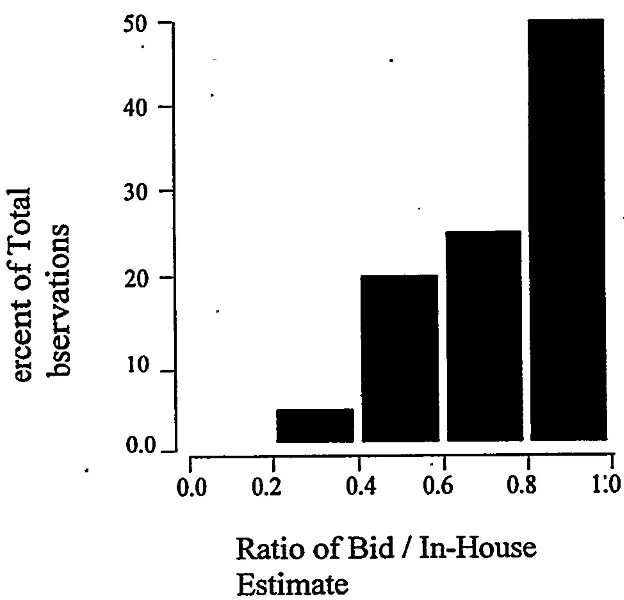


Figure 5.3. Distribution of Bid Amount to In-House Cost Estimate

(a) For example, for the fixed-price case, since our original data set had 121 observations, we drew 5000 samples of 121 observations to delineate other potential distributions.

$$\text{probability}(\text{mean}(x_1,x_2,\ldots,x_{120}) - \text{upper bound} \leq x_{121} \leq \text{mean}(x_1,x_2,\ldots,x_{120}) - \text{lower bound}) = 1-\alpha \qquad (5.2)$$

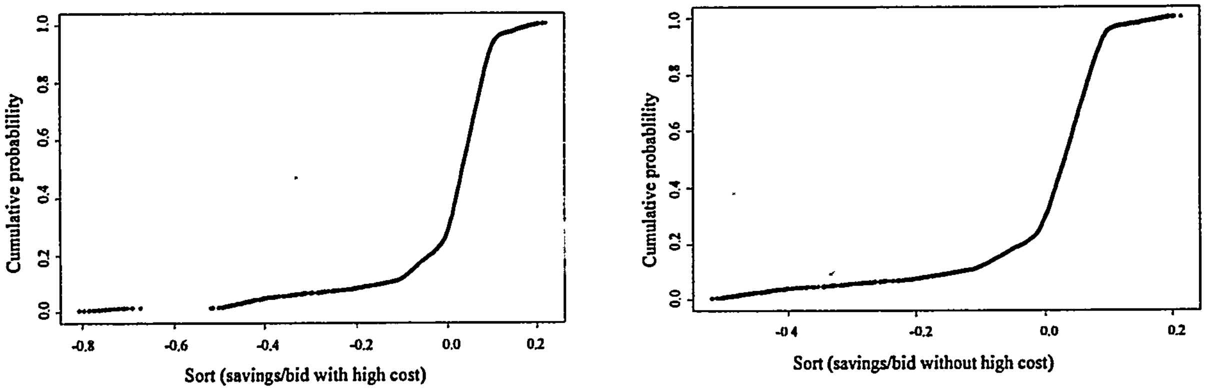
The corresponding lower and upper bounds are found and the width of the interval ([lower bound]-[upper bound]) is calculated. Table 5.1 below gives a partial listing of possible lower and upper tail probability combinations (such that the sum of the lower and upper tail probabilities = 5%) and the corresponding interval widths. A search of all such probability combinations and interval widths was employed to find the smallest width for the prediction interval of a future estimate.

In order to find the smallest width for the prediction interval of a future estimate, the cumulative distribution function (CDF) of the 5000 samples was computed and a "grid-search" approach was employed. The CDF using all the LBA data is given in Figure 5.4a and the CDF using all but one of the observations (#70) are given in Figure 5.4b. Observation #70 gives the largest ratio of 1.817647, which appears to be an outlier as compared to the rest of the data set. It can be shown that the lower and upper bounds which give the smallest width for the prediction interval are -.3088981 and .1951799, respectively.

Figure 5.5 illustrates the significance of the calculated prediction intervals. Engineering estimates at the conceptual stage, such as those produced in a detailed bottom-up estimate, are considered to be accurate within a range of -30% to +50%. However, the 95% prediction interval is actually narrower (-19% to

Table 5.1. Sample Probability Tail Distributions and Interval Widths

Lower Tail Probability (%)	Upper Tail Probability (%)	Interval Width
0.01	4.99	0.9184329
0.03	4.97	0.9164967
.	.	.
.	.	.
.	.	.
1.27	3.73	0.6155971
.	.	.
.	.	.
.	.	.
5.57	2.43	0.6041094
.	.	.
.	.	.
.	.	.
4.83	0.17	0.504078
.	.	.
.	.	.
.	.	.
4.99	0.01	0.5187795



a) With Outlier Values

b) Without Outlier Values

Figure 5.4. Cumulative Distribution Functions for Actual Costs Savings Relative to Bid Price, Based on Corps of Engineers Fixed-Price Projects

+30%), suggesting that a top-down estimate based on historical performance on fixed-price contracts, is a better (more accurate) and less expensive predictor of actual cost than is a detailed bottom-up estimate of cost savings.

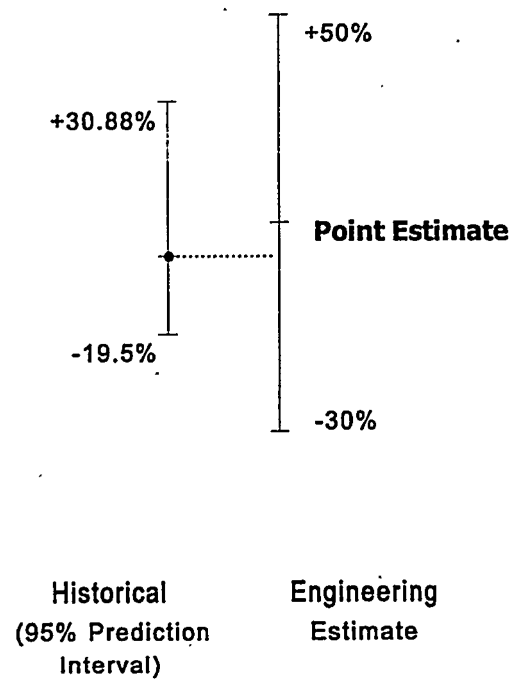


Figure 5.5. Relative Accuracy of Top-Down and Bottom-Up Estimates of Cost Savings

6.0 Comparison to Other Studies

Providing definite evidence that incentive contracts would reduce project costs requires comparing realized project costs under incentive contracts with realized project costs under cost- plus conditions. Because such a comparison is impossible for DOE, the present study compares DOE's cost overrun experience on cost-plus projects with "similar project experience" funded under fixed-price terms.

Such a comparative approach opens up arguments as to "How similar?" and "Similar in what respects?" Finessing the comparison of two distinct contract forms rests on the observation that cost overrun and schedule slippage are common occurrences in large-scale, pioneer construction projects. In this context, the literature on underestimation bias provides several well-known cases for evaluating cost overrun experiences involving fixed-price contracting under cost-risk: the construction of single-purpose hydroelectric projects (Merrow et al. 1990), the contracting of nuclear reactor construction (Burness et al. 1980), and the development of advanced weapons systems (Quirk and Teresawa 1986).

The work of Merrow et al., which is the most relevant, focuses on large, one-of-a-kind projects supported by the World Bank and completed between 1970 and 1990. In most cases, these projects experienced significant technical uncertainties from the time initial cost estimates were made up through completion of the projects. The study covered 49 hydroelectric projects with costs ranging between \$35 million and \$1.6 billion. The median project cost about \$221 million and took an average of six years to complete. Among the key findings in the study was that average project costs exceeded initial appraisal estimates by about 24%, with the average being skewed in the direction of higher cost overruns. Also, the projects exhibited substantial variability in cost growth, as measured by the standard deviation of 32%. Moreover, significant deviations existed between actual and scheduled completion dates, with the average schedule slip being about a year and a half beyond the scheduled completion date - some 25% over the initial appraisal. There was, however, significant variability in schedule slippage, as measured by the standard deviation of 27%. The correlation estimate between schedule slip and project cost reveals a moderate but positive relationship of 0.31.

The interesting feature of the cost overrun and schedule slippage problems reported by Merrow et al. (1990) is that they occurred under fixed-price contracts, where incentives for efficiency are presumably the greatest. The authors recognized that these problems reflected a significant bias in the preparation of initial cost estimates as opposed to realized cost growth (see pp. ii-iii). Technical and performance uncertainties were noted as key issues in the underestimation bias problem. From the perspective of the World Bank and its borrowers, the tendency to underestimate project costs is troublesome. Underestimates lead planners to proceed with uneconomic projects and subsequently create additional financing difficulties during the project completion phase. Consequently, the authors recommended more pre-appraisal effort on project evaluations and design work to permit more accurate cost and schedule assessments. The same advice can be given to DOE, where, by comparison, cost overruns reflect measurement bias and the absence of cost-minimizing incentives.

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Appendix A

Detailed Methodology for Predicted Interval on Savings

Appendix A

Detailed Methodology for Predicted Interval on Savings

This appendix gives the statistical theory and background to support the results given this report. The data sets used in the analyses are given in Tables B.1 through B.3 in Appendix B.

In order to make an inference (i.e., confidence interval, and hypothesis test) about the ratio of actual cost to bid (or to an in-house cost estimate) for the three data sets, it is necessary to identify the underlying probability density function (pdf) for the data. Several attempts were made to identify possible pdfs for the ratio of actual cost to bid (or in-house estimate) for the three data sets. Histograms of the data (see Section 5.0) were plotted and chi-square goodness-of-fit tests were performed. All chi-square tests had significant p-values, thus rejecting the null hypothesis that the data fit the underlying pdfs.

Another technique used to identify the underlying pdfs was the Residual Mean Life Deviance Function (Hogg and Klugman 1984). This function attempts to identify "tail" behavior of several common pdfs such as Weibull, lognormal, gamma (chi-square), and exponential (normal). It is given by:

$$\varepsilon(\delta) = E(X-\delta \mid X \geq \delta) = \int_{\delta}^{\infty} x-\delta \frac{f(x)}{\Pr(X \geq \delta)} dx \qquad \text{(A.1)}$$

where

$$\hat{\varepsilon}(\delta) = \frac{\sum_{i=1}^{n} I(x_i \geq \delta) x_i}{\sum_{i=1}^{n} I(x_i \geq \delta)} - \delta \qquad \text{(A.2)}$$

Once $\hat{\varepsilon}(\delta)$ is computed, it is plotted against the original data. If a theoretical pdf exists for the data, it will appear as one of the following curves (see Figure A.1)

None of the plots of the computed $\hat{\varepsilon}(\delta)$ versus original data for each of the three data sets showed any correlation to the above curves. Reasons why a pdf could not be identified include small sample size (e.g., GAO sample size = 15) and the possibility that sub-populations and sub-structure could exist in the data. For example, the pdf for the ratio of actual cost to bid for small projects could be different from the pdf structure for large projects. When the data for the two populations are combined, an overall pdf would be difficult to identify. More data are needed to investigate any sub-structure of the data.

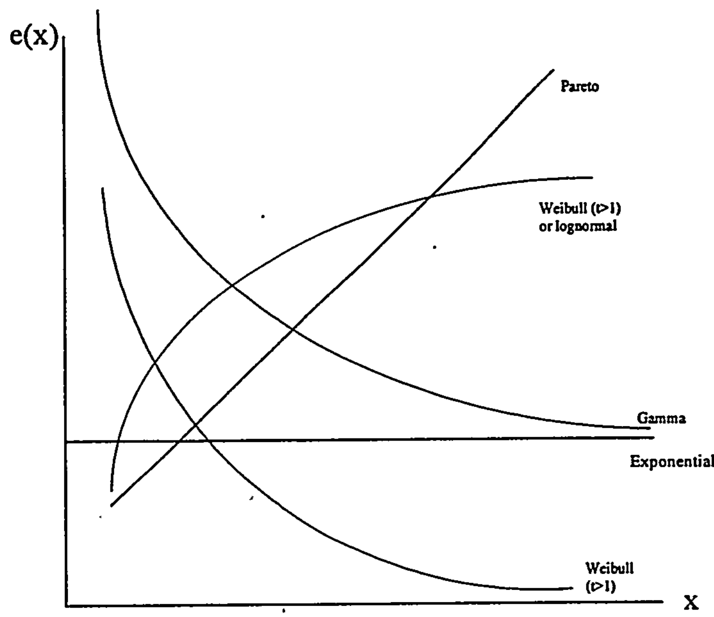

Figure A.1. Potential Theoretical Distributions for Savings from Fixed-Price Contracts

The "error" interval was computed using simulation to form a 95% predication interval for a future estimate. Since a pdf could not be identified (i.e., normality could not be assumed) for the ratio of actual cost to bid for the fixed-price contracts, a non-parametric approach was used for computing a 95% prediction interval. A large sample of size 100,000 was generated with the same probability structure given in Figure 5.2b. From this sample, 5000 samples of size 121 were chosen with replacement and a statistic was computed: $\text{mean}(x_1,x_2,\ldots,x_{120}) - x_{121}$ for each of the 5000 samples. The reason for computing the above statistic was to be able to form a probability statement about x_{121}, the future estimate. The probability statement about the future estimate is as follows:

$$\text{probability (lower bound} \leq \text{mean}(x_1, x_2,\ldots, x_{120}) - x_{121} \leq \text{upper bound}) = 1 - \alpha \qquad \text{(A.3)}$$

where α is the significance level, in this case, $\alpha = 0.05$.

After isolating x_{121}, the above probability statement becomes:

$$\text{probability}(\text{mean}(x_1, x_2,\ldots, x_{120}) - \text{upper bound} \leq x_{121} \leq \text{mean}(x_1, x_2,\ldots, x_{120}) - \text{lower bound}) = 1- \alpha \qquad \text{(A.4)}$$

Under the assumption of normality, it can be shown that the prediction interval with the smallest width is one that has equal probabilities in the upper and lower tails. For this example, since $\alpha = 0.05$ there would be .025 probability in the upper and lower tails. Since the normality assumption cannot be made for the LBA data, the smallest width for the prediction interval is not necessarily the one with equal probabilities in the upper and lower tails. In order to find the smallest width for the prediction interval of a future estimate, the cumulative distribution function (CDF) of the 5000 samples was computed and a "grid-search" approach was employed. The CDF using all the LBA data is given in Figure 5.4a and the CDF using all but one of the observations (#70) is given in Figure 5.4b. Observation #70 gives the largest ratio of 1.817647, which appears to be an outlier as compared to the rest of the data set. It can be shown that the lower and upper bounds that give the smallest width for the prediction interval are -0.3088981 and 0.1951799, respectively.

Appendix B

Descriptions of Data Sets Used in the Project

Appendix B

Descriptions of Data Sets Used in the Project

B.1 GAO Data Set

In 1996, the U.S. General Accounting Office (GAO) was asked to assess the U.S. Department of Energy's (DOE's) performance in completing major procurements (GAO 1996). In performing this study, the GAO collected and published cost and schedule data on 80 major systems acquisition actions of the DOE that occurred between 1980 and 1996.

All of the 80 systems acquisitions projects examined by GAO were large-scale, first-of-a-kind projects requiring substantial construction and other expenses. They involved a wide variety of types of projects, ranging from experimental nuclear reactors and specialized high-energy physics facilities to low-level nuclear waste disposal facilities, expansion of the Strategic Petroleum Reserves, and security or environmental enhancements at several facilities. All of the projects were conducted under DOE's standard cost-plus-fee approach.[a] Changes in mission and policy led to the cancellation of 31 of these projects. Fifteen had been completed by June 1996, when GAO completed their report. Thirty-four projects were still under way in June 1996, of which 15 were projected to be complete by the end of 1998.

For this project, we selected the 15 completed projects. In a few cases, data were not available on the relevant aspect of the project (e.g., original cost estimate in the case of the Stirling engine project). In these cases, the observation was dropped for analysis purposes.

These projects represent a broad cross-section of major actions by DOE and reflect many of the problems with the cost-plus approach when combined with incremental (that is, year-at-a-time) funding. They represent much of what DOE does as a mission. The environmental projects in particular are also representative of the type of major DOE projects that are currently candidates for privatization. They are limited in that they are generally a little larger and more complex than most of the environmental projects being contemplated for privatization, and are more representative of DOE's science mission than of its environmental restoration mission. However, the data are the best available. A list of the projects used is shown in Table B.1.

(a) GAO points out that most DOE contracts include built-in incentive mechanisms such as bonuses and penalties to prompt satisfactory contractor performance. However, these clauses have not always been used.

Table B.1. Original In-House Cost Estimate and Final Cost for Selected DOE Cost-Plus Acquisitions

Project Name and Construction Line Item Number[a]	Original Cost Estimate (millions $)	Final Cost (millions $)	Original Completion Date	Actual Completion Date
10MWe Central Receiver Solar Electric Power Plant (6-2-b)	108.0	139.6	NA	Jul 97
1-2 GeV Synchrotron Radiation Source (Advanced Light Source) (87-R-406)	145.3	146.0	Mar 92	Mar 93
GeV Synchrotron Radiation Source (Advanced Photon Source) (89-R-402)	626.9	798.9	Mar 96	Feb 96
Continuous Electron Beam Accelerator Facility (87-R-203)	262.6	513.1	Mar 92	Mar 95
Ebullated Bed (H-Coal) Pilot Plant	110.2	277.9	Mar 80	Sep 82
Fuels and Material Examination Facility (78-6-f)	167.6	233.8	Jun 83	Mar 84
Hanford Environmental Compliance (89-D-172)	262.3	242.4	Mar 96	Dec 95
High-Energy Laser Facility (NOVA) (78-4-a)	195.0[b]	177.7[b]	Sep 83	Dec 85
Mirror Fusion Test Facility (78-3-a)	132.5	363.8	Sep 81	Feb 86
Stirling Engine Systems Development	NA	130.0	NA	Dec 89
Defense Waste Processing Facility (81-T-105)	1529.5	2470.7	Mar 90	Nov 96
Strategic Petroleum Reserves	2499.0	2461.0	Jun 91	Sep 91
Tokamak Fusion Test Reactor (76-5-a)	390.6	497.5	Jun 81	Dec 82
Tritium Loading Facility (88-D-130)	125.4	409.2	Sep 89	Dec 93
Waste Isolation Pilot Plant (77-13-f)	737.0	709.9	Jun 88	Mar 91
West Valley Demonstration Project	446.0	1008.5	Mar 88	Aug 95

Notes:

(a) Projects that are not funded as construction projects do not have project numbers. All costs, unless otherwise specified, are "Total Project Costs." The project cost data were obtained from initial budget submissions, current cost reports, and other DOE data provided to GAO. The term "NA" means cost or schedule data were not available or not yet developed.

(b) These amounts represent the project's "Total Estimated Cost," which includes costs such as land; engineering, design, and construction. Other costs, such as research and development, conceptual design, startup, and initial training, were not available.

B.2 Army Corps of Engineers Data Set

The U.S. Army Corps of Engineers (USACE) routinely collects volumes of data on the hundreds of contracts which it manages annually. The data are compiled at various levels and in various databases. The lowest level is the district, the next is division, and the highest is the USACE headquarters. Unfortunately, there is not one single comprehensive database. Databases may be maintained for different types of contract, for different clients, or for different kinds of funding.

The strength of the USACE data are that they represent a large volume of contracts and are comprehensive in scope, due to the broad range of clients that the Corps serves. For many years, the Corps has emphasized fixed-price contracting as being the most advantageous to the government; even in those activities which by nature are exploratory (e.g., environmental remediation); the Corps attempts within variable price contracts to establish sub-projects that are fixed cost.

Cost and schedule increases from the original contract amount are fairly uniformly collected in all of the databases. On the other hand, the government estimate is not commonly included. It is interesting that most databases have a field for this information, but it is normally not populated; the government estimate is protected information and, therefore, many offices will not supply it. Project by project, at the district level, the government estimate can be found, but this level of effort was beyond the scope or time available.

The most accessible data fields are from military construction projects, which tend to be straightforward, fixed-bid construction contracts based on complete designs. Data on 121 contracts from the last year have been included (see Table B.2).

B.3 Project Performance Corporation Data Set

In 1996, Project Performance Corporation (PPC) of Germantown, Maryland, took on a task to analyze efforts to obtain cost savings by introducing competition in private and government settings. The database was to be used as a reference in order to judge the likelihood that EM would save money by adopting a private competitive contracting arrangement instead of a cost-plus management and operations (M&O) contract (see Table B.3). The PPC privatization database continues to grow, but the version used in this study has 106 observations and 22 variables. Observations consist of individual privatization projects identified by a unique project ID number, the names of the sponsoring organization and the contracting firm, the project name, and a functional description. Other variables include information on when and how the contract was let (year, duration, type); indicators of the presence or absence of some common contract provisions (incentives for savings or quality improvements, penalties for failure to meet specifications, interim performance evaluations); the winning bid, the number of bids received, and whether the selected firm had previous experience with privatization; the actual cost of the project, along with an estimate of what the project would have cost had it not been privatized; two estimates of the amount saved (*a priori* expected savings and the counterfactual estimate of what it would have cost less the actual realized cost); and some information on the final outcome of the project (whether it came in under budget, whether quality improvements were evident, how many change orders occurred, and whether it is completed or on-going).

Strengths of this database include the breadth of the coverage (multiple types of government organizations at several different levels of government. Weaknesses include the fact that the original data that PPC surveyed, while in most cases the best that could be obtained from the organizations studied, was not developed with a single cost-savings study in mind. Thus, the quality of data within the database and comparability with other databases may be a problem.

Table B.2. U.S. Corps of Engineers Projects

Sponsor (location of work)	Function (project Description)	Bid (contract value in 1000s)	Final Cost (1000s)	Original Duration (days)	Final Project Duration (days)
Air Force Academy, CO	Continuing Education Training Facility	$34,015	$34,729	730	730
Fitzsimons Army Medical Center, CO	Facility Engineering Compound	4,909	5,267	450	677
Fitzsimons Army Medical Center, CO	Gas Heat Plant	15,893	16,477	450	734
Buckley Air National Guard Base, CO	Data Processing	22,692	24,874	630	738
Air Force Academy, CO	Upgrade Engineering Management Contractor	1,539	1,652	450	615
Fort Carson Army Hospital, CO	Range Control CMP	3,072	3,416	360	487
Fort Carson Army Hospital, CO	Information System Facility	5,792	6,120	450	450
Fort Carson Army Hospital, CO	Information Systems	2,482	2,538	450	450
Warren AFB, WY	Security Police	5,413	6,226	540	576
Air Force Academy, CO	Addition or Alteration Wastewater Plant	6,888	7,228	500	516
Fort McCoy, WI	Hangar/Training Building	6,538	6,659	300	405
Grand Forks AFB, ND	Addition or Alteration Sewage Treatment Plant	1,937	1,937	360	360
Minot AFB, ND	BRAC III	889	928	270	270
Offutt AFB, NB	Crash/Fire Rescue Station	1,028	1,032	365	365
Mitchell Field, WI	Add Fire Protection Hangar	1,598	1,625	270	275
Mitchell Field, WI	HAZMAT	6,714	6,727	365	365
Peterson AFB, CO	Addition or Alteration Information System Facility	13,425	14,657	390	390
Offutt AFB, NB	Storm Drain Facility	1,507	1,588	300	340
Fort Meade, MD	Super Computer Facility	28,351	40,910	540	586
Wheeling, WV	New US Army Reserve Center	6,363	9,764	720	720
Fort Meade, MD	Covered STR Facility	8,477	9,960	365	670
Clarksburg, WV	US Army Reserve Center/OMS	4,388	4,408	660	789
Clarksburg, WV	AMSA 102 US Army Reserves	1,933	1,933	300	300
Army Research Lab, Adelphi, MD	Package5a PAR	577	612	300	300
Picatinny Arsenal, NJ	Electrical Distribution	2,348	2,734	720	759
Fort Monmouth, NJ	Child Support Center	3,349	3,660	540	540
Charleston, WV	US Army Reserve Center	4,825	4,873	540	540
Fort Eustic, VA	Life Safety Upgrade	3,042	3,255	600	600
Dover AFB, DE	93 Dormitories	6,013	7,866	480	685
Galena, AK	Underground Fuel Tanks	3,632	3,963	830	835
Elmendorf AFB, AK	Joint Mobilization Command	4,184	5,152	600	605
Fort Lewis, WA	Wells Phase 2	1,840	2,055	365	885

Table B.2. (contd)

Sponsor (location of work)	Function (project Description)	Bid (contract value in 1000s)	Final Cost (1000s)	Original Duration (days)	Final Project Duration (days)
McChord AFB, WA	Child Development Center	4,534	4,915	420	420
McChord AFB, WA	Fire Training Facility	1,009	1,184	210	331
Mt. Home AFB, ID	Dormitory	3,964	4,075	360	360
Fairchild AFB, WA	Storm Drain	2,178	2,356	330	355
Fort Lewis, WA	Family Housing, Noncommissioned Officers & Enlisted	704	706	420	420
McChord AFB, WA	Control Tower	1,939	2,018	329	329
Mt. Home AFB, ID	Parking Apron	8,372	8,783	400	400
Fairchild AFB, WA	Flight Simulator	3,272	3,615	515	515
Defense Construction Supply Center, Columbus, OH	Operations Center	64,899	71,552	910	910
Columbus, OH		10,331	10,631	740	740
Grissom AFB, IN	Alter Hangar	2,604	2,730	365	534
Fort Campbell, KY	Modify 3 Dining Facilities	3,675	3,933	365	650
Wright Patterson AFB, OH	Air Mobility Command, Phase II A	11,890	12,132	632	632
Fort Campbell, KY	New Family Housing Unit	9,066	9,176	600	1058
Youngstown Municipal Airport, OH	C-130 Maintenance Hangar	5,452	5,614	450	450
Fort Campbell, KY	Middle School Addition	1,549	1,615	400	502
Fort Campbell, KY	Campbell Army Airfield Improvements	4,077	4,394	480	821
Fort Campbell, KY	Special Operations Force Apron	2,365	2,411	270	270
Toledo, OH		9,316	9,377	540	540
Fort Campbell, KY	Pallet Warehouse	900	900	300	374
Fort Sheridan, IL	BC Conversion of 2	1,429	1,511	360	524
Defense Construction Supply Center, Columbus, OH	Child Development Center	3,236	3,404	540	540
Youngstown Municipal Airport, OH	Construct Air	2,900	2,886	210	210
Wright Patterson AFB, OH	Bldg 30 Defense Logistics Agency	1,663	1,784	255	255
Wright Patterson AFB, OH	Bldg 30207	1,689	1,816	255	255
Schofield Barracks, HI	Upgrade Bldg 158	248	356	440	1397
Wheeler AFB, HI	Renovate Bldg 20	1,278	1,515	304	640
Hickam AFB, HI	Underground Fuel Tank	800	1,236	320	747
Schofield Barracks, HI	Service Member	13,688	14,144	620	620
Sagamihara Army	AFH GEN SHA	997	1,009	464	464
Sagamihara Army	Improve Family Housing Quarters	308	311	507	507
Pope AFB, NC	After Life Support	489	544	210	411

Table B.2. (contd)

Sponsor (location of work)	Function (project Description)	Bid (contract value in 1000s)	Final Cost (1000s)	Original Duration (days)	Final Project Duration (days)
Robins AFB, GA	J-Stars Aircraft Hydrant	8,379	9,139	660	741
Dobbins AFB, GA	Base Support	2,468	2,941	365	601
Fort Benning, GA	Malone 5 SAW/	1,731	1,884	300	411
Beale AFB, CA	Fire Training Facility	1,057	1,067	270	728
Hill Defense Property Displsal Office	Conforming Storage Facility	1,281	1,478	400	497
Vandenburg AFB, CA	Underground Fuel Tank	850	1,545	405	432
Edwards AFB, CA	Child Development Center	4,197	4,720	614	614
Davis Monthan AFB, AZ	Vehicle Maintenance Facility	5,190	5,294	655	655
Nellis AFB, CA	Improve Family Housing-164	16,100	16,723	600	600
Fort Huachuca, AZ	Test & Evaluation Center	3,984	4,483	630	889
Vandenburg AFB, CA	Upgrade Electrical Power	4,919	6,014	560	1003
Yuma Proving Ground, AZ	Ammo Prep BCA	7,159	7,402	470	955
March AFB, CA	Underground Fuel Tank	1,381	1,442	360	729
Vandenburg AFB, CA	Upgrade Fire Protection	889	1,164	365	929
Fort Huachuca, AZ	EMI Test Facility	880	923	360	780
Yuma Proving Ground, AZ	Armor Operations BCA1	3,739	3,883	420	830
Fort Irwin, CA	Enlisted Barracks w/o Dining	4,922	5,125	365	558
Fort Huachuca, AZ	Physical Fitness Center	2,397	2,536	365	592
Vandenburg AFB, CA	Addition or Alteration Dining	1,271	1,908	420	605
Vandenburg AFB, CA	Addition or Alteration Dining	1,271	1,909	420	605
Luke AFB, AZ	Fire Training Facility	1,083	1,181	200	395
Vandenburg AFB, CA	Fire Training Facility	1,240	1,588	270	437
Nellis AFB, CA	Bomber Live Ordnance	3,678	3,949	330	330
Davis Monthan AFB, AZ	Wastewater Treatment Plant	2,082	2,156	360	360
March AFB, CA	Munitions CPL	1,466	1,477	250	259
Fort Polk, LA	Department of Logistics Maintenance Facility	13,909	14,409	720	1178
Red River Army Depot, TX	Hazardous Material	3,199	3,335	420	654
Fort Polk, LA	Airfield Upgrade	9,438	9,806	406	787
Fort Bliss, TX	Enlisted Barracks w/o Dining	8,262	8,359	725	725
Fort Hood, TX	Vehicle Maintenance Facility	49,137	51,322	730	730
Kelly AFB, TX	C-17 Depot	725	759	200	357
Kelly AFB, TX	C-17 Engine	2,612	2,861	364	521
Kelly AFB, TX	C-17 Addition or Alteration NDI	3,918	4,003	364	521
Fort Bliss, TX	Enlisted Barracks	9,750	10,073	767	767
Fort Polk, LA	Military Operations in Urban Terrain Training Villages	11,635	12,256	365	506
Lackland AFB, TX	Training Service	4,157	4,324	360	424
Fort Hood, TX	Battalion Headquarters	5,743	5,991	520	520
Fort Bliss, TX	Vehicle Maintenance Facility	12,860	13,067	548	548

Table B.2. (contd)

Sponsor (location of work)	Function (project Description)	Bid (contract value in 1000s)	Final Cost (1000s)	Original Duration (days)	Final Project Duration (days)
Lackland AFB, TX	Alter Base Support	4,217	4,761	365	520
Kelly AFB, TX	Alter Weapons	7,975	8,153	730	730
Lackland AFB, TX	Correctional Slope Facility	2,235	2,220	540	540
Kelly AFB, TX	Addition or Alteration Dormitories	2,486	2,519	644	690
Fort Bliss, TX	Sergeant Major Academy	6,136	6,334	428	428
White Sands Missile Range, NM	Child Support Center	3,348	3,471	365	365
White Sands Missile Range, NM	Aerial Cable	1,327	1,411	220	377
Lackland AFB, TX	BC Training Range	1,249	1,339	548	548
Little Rock AFB, AR	Fire Training Facility	706	721	240	240
Altus AFB, OK	Corrosion Control	13,618	14,269	673	771
Altus AFB, OK	Fuel Cell MTC	6,408	6,521	673	771
Tinker AFB, OK	Engineering and Construction Support	4,515	5,101	462	506
Fort Sill, OK	Barracks Rehabilitation 1st	15,166	15,383	942	942
Vance AFB, OK	Upgrade Airfield Lighting	2,218	2,793	365	534
Sheppard AFB, TX	BC Physical Fitness Center	4,307	4,453	480	660
Sheppard AFB, TX	Child Development Center	815	875	359	359
Vance AFB, OK	Child Development Center	439	463	359	359
Vance AFB, OK	Upgrade Storm Drain	1,716	1,832	442	442
Altus AFB, OK	C-17 Fire Station	1,061	1,141	408	408
Count 121	Totals	$695,375	$753,714		

Legend:
Sponsor = location of the work.
Function = description of general area of the project.
Bid = dollar amount of contract.
Original Duration = original contract period.
Final Contract Duration = Original contract period, plus extensions added to original contract period.

Table B.3. Project Performance Corporation Data Set

Project	Organization	Bid	In-House	Actual Cost	Contract Type
Mass Prison Health Care	State of Massachusetts	$26,000,000	$43,000,000	$26,000,000	fixed
Mass Highway Maintenance	State of Massachusetts	$4,600,000	$6,300,000	$4,600,000	fixed
Mass DMR Housekeeping	State of Massachusetts	$5,300,000	$9,700,000	$5,300,000	fixed
Mass DMR Dietary Services	State of Massachusetts	$7,750,000	$13,500,000	$7,750,000	fixed
Hanford Laundry Construction	Department of Energy	$5,000,000	$24,000,000	$5,000,000	fixed
State Prison Medical & Psych. Services	State of New Jersey	$2,800	$3,300	$62,000,000	fixed/unit
Indianapolis Information Services Systems	City of Indianapolis	$81,000,000	$107,000,000	$81,371,895	fixed
Aberdeen Motor Vehicle Maintenance	US Army	$9,584,806	$9,584,806	$9,584,806	NA
Fort Dix Laundry & Dry Cleaning	US Army	$4,142,286	$4,142,286	$4,142,286	NA
Fort Gordon Operations & Housing Services	US Army	$190,000,000	$190,000,000	$190,000,000	NA
Fort Hood Aircraft Maintenance	US Army	$11,010,944	$11,010,944	$11,010,944	NA
Brooke Army Medical Center	US Army	$4,863,462	$4,863,462	$4,863,462	NA
Fort Knox Food Services	US Army	$28,182,484	$28,182,484	$28,182,484	NA
Fort Lee Food Service	US Army	$38,453,000	$38,453,000	$38,453,000	NA
Hawthorne Army Ammunition Plant	US Army	$107,000,000	$107,000,000	$107,000,000	NA
St. Louis Area Support Center	US Army	$16,002,229	$16,002,229	$16,002,229	cost-plus
Vint Hill Farm Facilities	US Army	$6,203,573	$6,203,573	$6,203,573	NA
Air Force Academy Custodial Service	US Air Force	$3,944,589	$3,944,589	$3,944,589	NA
Seymour Johnson Ari Air Force Base Food Service	US Air Force	$1,551,200	$1,551,200	$1,551,200	NA
Arkansas Prisons	State of Arkansas	$11,388,000	$16,206,000	$11,388,000	fixed fee
Charlotte Water and Wastewater	City of Charlotte	$7,300,000	$12,000,000	$7,300,000	fixed
Fort Leavenworth Packing and Crating	US Army	$883,316	$1,110,392	$857,938	NA
Sharpe Army Depot Supplies	US Army	$4,234,410	$4,695,977	$6,990,990	NA
Tobyhanna Army Depot Custodial Services	US Army	$782,559	$2,131,336	$1,017,168	NA
Naval Air Propulsion Center Custodial Services	US Navy	$315,561	$540,884	$448,036	NA
Lemoore Naval Air Station Mess Services	US Navy	$1,851,567	$2,362,141	$2,322,674	NA

Table B.3. (contd)

Project	Organization	Bid	In-House	Actual Cost	Contract Type
Mayport Naval Air Station Motor Vehicle Maintenance	US Navy	$3,174,735	$3,693,845	$3,515,852	NA
Marine Corps Air Station Housing Maintenance	US Marine Corps	$859,035	$1,530,859	$794,477	NA
Eglin AFB AV and Library Services	US Air Force	$3,527,672	$3,596,231	$3,828,993	NA
Lowry AFB Stocking and Custodial Services	US Air Force	$682,641	$1,623,588	$774,442	NA
Lowry AFB Refuse Collection	US Air Force	$709,000	$1,521,000	$925,000	NA
Mather AFB Grounds Maintenance	US Air Force	$862,200	$1,198,158	$1,011,963	NA
McClellan AFB Equipment Lab	US Air Force	$2,558,607	$4,705,864	$3,059,411	NA
Air Force Academy Custodial Services	US Air Force	$338,656	$775,611	$440,231	NA
Vance AFB Flight Simulator Operations	US Air Force	$943,917	$1,359,664	$1,186,221	NA
Fort Belvoir Laundry	US Army	$1,757,328	$1,790,157	$1,763,328	firm fixed
Fort Leonard Wood Laundry	US Army	$3,875,640	$4,479,888	$3,919,640	firm fixed
Naval Parts Control Center Grounds Maintenance	US Navy	$1,623,000	$1,890,000	$1,623,000	firm fixed
Defense Fuel Support Liquid Storage Operations	US Navy	$2,982,504	$4,714,941	$3,015,954	firm fixed
Hill AFB Measurement Equipment Lab	US Air Force	$2,918,205	$3,516,302	$2,948,205	firm fixed
Keesler AFB Food Service	US Air Force	$13,451,676	$17,185,447	$14,120,283	firm fixed
McClellan AFB Equipment Laboratory	US Air Force	$2,856,859	$5,004,116	$2,856,859	firm fixed
Wright-Patterson AFB Bulk Liquid Storage	US Air Force	$2,934,602	$3,508,975	$2,992,273	firm fixed
Philadelphia Custodial Services	City of Philadelphia	$1,340,000	$1,380,000	$1,340,000	fixed/unit