A COMPARATIVE STUDY OF LINEAR AND NONLINEAR ESTIMATE AT COMPLETION METHODS

THESIS

Todd D. Nystrom, Captain, USAF

AFIT/GSM/LAS/95S-5

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GSM/LAS/95S-5

A COMPARATIVE STUDY OF LINEAR AND NONLINEAR ESTIMATE AT COMPLETION METHODS

THESIS

Todd D. Nystrom, Captain, USAF

AFIT/GSM/LAS/95S-5

Approved for public release; distribution unlimited

AFIT/GSM/LAS/95S-5

A COMPARATIVE STUDY OF LINEAR AND NONLINEAR ESTIMATE AT COMPLETION METHODS

THESIS

Presented to the Faculty of the School of Logistics and

Acquisition Management

Air Education and Training Command

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management

Todd D. Nystrom, B.S.

Captain, USAF

September 1995

Approved for public release; distribution unlimited

Preface

The purpose of this study was to conduct a comparative analysis of Estimate at Completion (EAC) methods to determine if complex nonlinear regression-based EAC methods perform better than the simple index-based methods. This was done using a sample of 88 defense contracts extracted from the Defense Acquisition Executive Summary database. The overall results of the analysis were also tested to determine which EAC methods performed the best given such moderator variables as stage of contract completion, system type, program phase, contract type, DoD service component, and inflation effects.

I would like to thank my thesis advisor, Dr. David S. Christensen, for his guidance and support throughout the writing of this thesis. A special thanks is also due to Capt Mark Gallagher for his development of the Microsoft® Excel routine that was used to calculate the EACs for the Rayleigh curve Multiple Model Adaptive Estimation technique. Without his assistance and expertise, the analysis of that technique would not have been possible. Finally, and most importantly, I would like to thank my wife Lisa and my son David for their patience and understanding throughout the many long days and nights I spent working on this project.

Todd D. Nystrom

Table of Contents

Page

Page

List of Figures

List of Tables

Table | Page

Table | Page

Abstract

Controlling costs in the acquisition of new defense systems is a major challenge in today's environment of declining budgets and rapidly changing technology. One of the challenges faced by program managers and cost analysts is selecting the most appropriate Estimate at Completion (EAC) method for their program. This study compares the performance of the popular index-based EAC methods with several newer nonlinear, regression based EAC methods to determine whether the complex nonlinear methods perform better than the simpler index-based methods. In addition, the sensitivity of the results to stage of contract completion, system type, program phase, contract type, Department of Defense service component, and inflation effects are also investigated.

Eighty-eight contracts were examined in this study and it was found that overall the index-based EAC methods performed significantly better than the nonlinear regression based methods as measured by two criteria, the accuracy and stability of the EACs. In addition, the top performing method overall was determined to be the index-based method using the Composite Index ($0.2SPI_{cum}+0.8CPI_{cum}$). The best performing method was, however, sensitive to all of the factors investigated in the sensitivity analysis.

A COMPARATIVE STUDY OF LINEAR AND NONLINEAR ESTIMATE AT COMPLETION METHODS

I. Introduction

General Issue

Controlling costs in the acquisition of new weapon systems is a major challenge in today's environment of declining defense budgets and rapidly changing technology. In fact, research by The RAND Corporation found an average of 20 percent cost growth (excluding inflation effects and increased quantity buys) in the 197 defense programs it studied (Drezner, Jarvaise, Hess, Hough, and Norton, 1993). A key conclusion of this study was "that cost estimates are, on average, systematically biased downward, resulting in cost growth" (Drezner, *et al.*, 1993:49). The authors imply that the methods used to calculate the final costs of defense acquisition contracts, termed Estimates at Completion (EACs), are not accurate and generally underestimate the true final costs.

Recent examples of failure to control costs include the Navy's A-12 program, which was canceled in January of 1991 (Morrison, 1991), and the Air Force's C-17 program, which has faced constant criticism at the congressional level (Morrocco, 1993). One reason Defense Secretary Dick Cheney canceled the Navy's A-12 program was because no one could give him a good estimate of the final expected cost of the program (Morrison, 1991).

Background

Part of the problem is that there are numerous methods for calculating an EAC. These methods range from simple index-based methods to sophisticated statistical techniques. In Estimate-At-Completion Research–A Review and Evaluation, McKinney listed 47 EAC formulas from 18 sources (1991). In addition to the sources and methods reviewed by McKinney, others have proposed sophisticated nonlinear regression-based methods involving the Rayliegh probability distribution (Watkins, 1982; Abernathy, 1984), the Rayliegh probability distribution coupled with Multiple Model Adaptive Estimation (MMAE) (Gallagher and Lee, 1995), and a modified Beta distribution (Whitlock, 1982). With so many methods available, choosing the best one is difficult.

A number of studies have compared EAC methods using actual defense program cost data (Heydinger, 1977; Land and Preston, 1980; Covach, Haydon, and Riether, 1981; Bright and Howard, 1981; Riedel and Chance, 1989; Terry and Vanderburgh, 1993). Unfortunately, much of the comparative research has focused on the simpler index-based methods. The studies that did include other methods, such as regression-based methods, have produced inconclusive results (Heydinger, 1977; Land and Preston, 1980; Covach, *et al.*, 1981; Bright and Howard, 1981). In addition, none of these comparative studies included any of the more advanced regression-based methods involving the Rayleigh distribution or the modified Beta distribution. In "A Review of Estimate at Completion

Research," Christensen, Antolini, and McKinney conclude that there has been no real validation of the more complex EAC methods, and that "the accuracy of regression-based models over index-based formulas has not been established" (1992:220).

Research Problem

The primary objective of this research is to determine if the complex nonlinear regression-based EAC methods perform better than the simpler index-based EAC methods. In this study, the performance of the EAC methods was compared using a combined measure that ranked performance against two criteria, the accuracy and stability of the estimates generated by the method. The method that was the most accurate and stable overall was classed as the best performing method. A more detailed description of this combined measure is reserved for Chapter III.

Specific Problem Statement

Do complex nonlinear regression-based EAC methods perform better than simple index-based EAC methods? The primary hypothesis to be tested is:

> EACs calculated using complex nonlinear regression-based methods are not more accurate or stable than EACs calculated using simple index-based methods.

This hypothesis was tested using data extracted from the Defense Acquisition Executive Summary (DAES) database. This database is a collection of cost performance data from 541 completed or near completed defense contracts covering the period from June 1970 to October 1992. The database includes both development and production contracts from all three services and a variety of different system types. The data were screened to eliminate contracts with incomplete or insufficient data before performing the analysis.

Additional Research Objectives

Before addressing the primary research objective, two additional objectives needed to be accomplished. First, the impact of cost growth on DoD acquisition programs had to be established to illustrate the need for better performing EAC methods. And second, it was necessary to review previous research to determine which EAC methods would be included in this study. Both of these objectives were accomplished through a review of relevant literature.

In addition to answering the primary research question, it was also desirable to determine which EAC methods performed the best given such moderator variables as stage of contract completion, system type, program phase, contract type, DoD service component, and inflation effects.

Scope and Limitations

The data used for analysis in this study were limited to contracts extracted from the DAES database. No attempt was made to locate other data to include in the study due to time constraints. Due the nature of the database, it is considered to provide a sufficiently representative sample of all DoD contracts.

This study was limited to identifying the best performing EAC methods overall, and subject to the moderator variables previously discussed. No attempt was made to conduct further analysis to determine the underlying factors that influenced the performance of a given method. This additional analysis would have required much more time than was available to conduct this research.

The following chapters provide a review of previous literature relevant to this comparative EAC study, the methodology used in this study, an analysis of the results, conclusions, and recommendations for further research.

II. Literature Review

Introduction

Controlling costs in the acquisition of new weapon systems is a major challenge in today's environment of declining defense budgets and rapidly changing technology. One major aspect of controlling costs is accurately estimating the final cost of a defense acquisition contract, termed Estimate at Completion (EAC). There are many methods of calculating an EAC, ranging from very simple index-based methods to sophisticated regression-based and statistical techniques. With such a wide variety of methods, choosing the method that provides the most accurate forecast is not a simple matter. The objective of this thesis is to determine whether or not complex nonlinear regression-based EAC methods perform better than the simpler index-based methods based on two criteria, accuracy and stability. This literature review will focus on related EAC research and findings.

This chapter is divided into five sections. The first section addresses cost growth in DoD acquisition programs, stressing the need for accurate EACs. The second section describes the two major classes of EAC methods relevant to this study, and also includes a review of the EAC methods used in DoD's Performance Analyzer software package in order to demonstrate the popularity of these methods. The third section is a review of comparative EAC studies. The fourth section introduces two of the more significant nonlinear models that have been proposed, as well as methods of calculating EACs using these models, and the fifth section provides concluding remarks and discusses the implications and potential outcomes of this research effort.

Cost Growth in DoD Acquisition Programs

Cost growth, in its simplest form, can be defined as any increase over the original cost estimate for a program. Although some evidence suggests that cost growth has decreased since the 1950s (Biery, 1984), a 1993 study by RAND corporation contends that it has remained constant (Drezner, *et al.*, 1993). In fact, the RAND research found an average growth rate of 20 percent for the 197 programs studied (Drezner, *et al.*, 1993). To illustrate the significance of a 20 percent growth, consider the 1993 estimate of 41 billion dollars for the Air Force's C-17 program (Morrocco, 1993). A 20 percent increase is 8.2 billion dollars. Another alarming observation reported by Christensen, is that recovery from a cost overrun (i.e., cost growth) on a defense contract is highly unlikely, and that cost overruns tend to worsen as a contract progresses to completion (1993).

A major emphasis in DoD acquisition policy reforms since the early 1960s has been on ways to control cost growth (Gates, 1989). One of the key developments that evolved from these reforms is our current Cost/Schedule Control Systems Criteria (C/SCSC). These criteria were developed in the mid 1960s as the result of an Air Force study group known as the Cost/Schedule Planning and Control Specification Group (Fleming, 1992). C/SCSC are a set of 35 criteria, or standards, which are designed to:

> Provide and adequate basis for responsible decision making by both contractor management and DoD Component personnel by requiring that contractors' internal management control systems produce data that:

(a) Indicate work progress;

(b) Properly relate cost, schedule, and technical accomplishment;

(c) Are valid and timely, and able to be audited; and

(d) Provide DoD Component managers with information at a practical level of summarization (Department of Defense, 1991:11-B-1 - 11-B-2)

In other words, these criteria are designed to ensure that cost, schedule, and performance data provided by the contractor can be used to accurately monitor the progress of the contract and ultimately to forecast future contract performance. An EAC is simply a forecast of future cost performance, specifically, the Cost at Completion (CAC).

The importance of accurately forecasting contract completion costs cannot be overstated. In today's post-cold war environment defense budgets are shrinking, resulting in competition and dispute within DoD for the available funds (Jones, 1993). "Without more realistic estimates, senior management may be lulled into a false sense of security about their programs and fail to take appropriate action to correct problems" (Christensen, 1993). In other words, senior managers need accurate EACs to identify problems early so the problems can be corrected, or if they cannot be corrected, the program can be canceled before a significant investment is made.

Methods of Calculating EACs

There are many methods of calculating an EAC. The two major classes of EAC methods relevant to this study, index-based EAC formulas and regression-based EAC methods, are described in this section. The section concludes with a review of the EAC methods included in the DoD's Performance Analyzer (Cost Management Systems, Inc., 1994) software package.

Index-Based EAC Methods. The index-based methods are basically an algebraic formula that uses an index to calculate the EAC. An index is a measure of the level of performance attained in completing the work on a contract up to the current time. The general form for the index-based EAC formula is as follows:

$$EAC = ACWP_{cum} + \frac{(BAC - BCWP_{cum})}{Index} \quad (1)$$

where $ACWP_{cum}$ is the cumulative Actual Cost of Work Performed (i.e., the cost incurred to date in performing the contract), $BAC - BCWP_{cum}$ is the Budget at Completion minus the cumulative Budgeted Cost of Work Performed (i.e. total budget for the contract minus the budgeted cost of the work completed to date), and Index is one of several performance indices as defined below. For the reader unfamiliar with these terms, a glossary is provided in Appendix A.

The four major indices include the Cost Performance Index (CPI), Schedule Performance Index (SPI), Schedule Cost Index (SCI), and the Composite Index. The CPI can be calculated as a cumulative number

$$CPI_{cum} = \frac{BCWP_{cum}}{ACWP_{cum}} \quad (2)$$

or, in two different forms as a moving average

$$CPI_n = \frac{\sum BCWP_n}{\sum ACWP_n} \tag{3}$$

$$\overline{CPI}_n = \frac{\sum CPI_n}{n} \tag{4}$$

where n represents the number of months of data to be summed, beginning with the most recent month. The use of mathematical symbology to distinguish between these two forms of the CPI was inconsistent in the literature reviewed. Because the standard use of the $\overline{\text{(bar)}}$ symbol in math and science is to denote an average, I have chosen to use it in the same manner. Therefore, CPI_3 denotes the sum of the three most recent monthly BCWPs divided by the sum of the three most recent monthly ACWPs, and $\overline{CPI}_6$ denotes the average of the six most recent monthly CPIs. Note that in this study, CPI_m will be used to refer to the current month's CPI rather than CPI_1.

The SPI can be calculated as a cumulative number

$$SPI_{cum} = \frac{BCWP_{cum}}{BCWS_{cum}} \tag{5}$$

or, in two different forms as a moving average

$$SPI_n = \frac{\sum BCWP_n}{\sum BCWS_n} \tag{6}$$

$$\overline{SPI}_n = \frac{\sum SPI_n}{n} \tag{7}$$

where $\underline{n}$ again represents the number of months of data to be summed, beginning with the most recent month. Like the CPI_3, SPI_3 denotes the sum of the three most recent monthly BCWPs divided by the sum of the three most recent monthly BCWSs, while $\overline{SPI}_6$ denotes the average of the six most recent monthly SPIs.

The SCI is the product of the SPI and CPI and is calculated as follows:

$$SCI = SPI \times CPI \tag{8}$$

The SCI can be calculated using either the monthly, moving average, or cumulative SPI and CPI. For example, SCI_3 would be calculated using SPI_3 and CPI_3, and SCI_{cum} would be calculated using SPI_{cum} and CPI_{cum}. In addition, modified versions of the SCI can be calculated using various combinations of the monthly, moving average, and cumulative SPI and CPI. An example of this is the index-based EAC formula in Performance Analyzer that uses $SPI_{cum} \times CPI_6$ (Cost Management Systems, Inc., 1994).

The fourth index is the Composite Index, which is the weighted sum of the SPI and CPI, is calculated as follows:

$$\text{Composite Index} = W_1 \times SPI + W_2 \times CPI \tag{9}$$

where $\underline{W}_1$ and $\underline{W}_2$ are the weights assigned by the analyst to the SPI and CPI respectively. These weights can take on any value between zero and one, and typically sum to unity.

Note that in the convention used in this study an index value greater than one indicates good performance (i.e. under budget or ahead of schedule). For example:

$$BCWP_{cum} = \$10,000$$

$$ACWP_{cum} = \$9,000$$

$$CPI_{cum} = \frac{BCWP_{cum}}{ACWP_{cum}} = \frac{10,000}{9,000} = 1.11$$

In this case the actual cost to complete the work ($9,000) was less than originally budgeted ($10,000) resulting in a CPI greater than one. This would generally be seen as a positive indicator. Conversely, an index value less than one would indicate poor performance (i.e., over budget or behind schedule).

Regression-Based EAC Methods. These are methods used to calculate the EAC by regressing a dependent variable, typically ACWP, against an independent variable such as BCWP or time. The resulting regression equation is then used to calculate the EAC. Regression methods can either be linear (e.g., $ACWP = A \times BCWP + B$, where A and B are the coefficients of regression), or nonlinear (e.g., $ACWP = A \times BCWP^{B}$).

Review of Performance Analyzer EAC Methods. Performance Analyzer is the DoD's standard software package for analyzing C/SCSC data. One of the functions of the software allows the user to generate independent program office EACs based on the data submitted by the contractor in the monthly Cost Performance Reports (CPRs) or Cost/Schedule Status Reports (C/SSRs). There are 12 different methods the user can choose from to generate an EAC, including eight index-based methods (CPI_3, CPI_6, CPI_{cum}, CPI_m, SCI_{cum}, Composite Index, $SPI_{cum} \times CPI_6$, and a user determined performance factor), one linear regression technique where ACWP is regressed as a function of

BCWP, and a complex linear formula based on historical data from NAVSEA contracts. The two remaining methods allow the contract BAC or the contractor's LRE to be used as the EAC (Cost Management Systems, Inc., 1994). The heavy emphasis on the index-based methods demonstrates the popularity of these methods warranting their inclusion in a comparative study of EAC methods. It should also be noted that there no EAC methods involving nonlinear models in Performance Analyzer.

Comparative EAC Studies

The body of EAC research reviewed can be separated into two general categories: research which is aimed at validating or comparing previously developed methods, and research which is aimed at developing new EAC methods. This section focuses on several comparative studies that have been done, as well as two recent studies aimed at validating several index-based methods. The following section introduces two of the more significant nonlinear models that have been proposed for calculating EACs. Table 1 provides a summary of the comparative EAC studies that were reviewed.

TABLE 1

SUMMARY OF COMPARATIVE EAC STUDIES

Author (Year)	DoD Agency, # and Type of Contracts	EAC Methods	Evaluation Criteria	Significant Results
Heydinger (1977)	Air Force, 1 development	Index-based CPI_m, $\overline{CPI}_3$, CPI_{cum}, CPI_3 Regression 1 linear 2 nonlinear[1]	Consistently closest to final cost	Nonlinear regression method using modified Erlang equation most accurate
Land and Preston (1980)	Air Force, 20 aircraft programs	Index-based CPI_m, $\overline{CPI}_3$, CPI_{cum}, CPI_3 Regression 1 nonlinear[2]	Mean absolute percentage error (MAPE)	Nonlinear regression methods do not produce more accurate EACs; CPI_{cum} had lowest MAPE
Covach, *et al.* (1981)	Navy, 5 development 1 production	Index-based CPI_m, $\overline{CPI}_3$ $\overline{CPI}_6$, $\overline{CPI}_{12}$, CPI_{cum}, SCI_{cum}, CPI_3, CPI_6 Regression 2 linear 9 nonlinear[3]	# of months EAC within 10% of CAC; # of months EAC closer to CAC than BAC; # of months EAC closer to CAC than contractor's LRE	Best performing indices dependent on stage of contract completion; No comparison of index-based and regression methods; No single regression method demonstrated clear superiority
Bright and Howard (1981)	Army, 11 development	Index-based $\overline{CPI}_3$, $\overline{CPI}_6$, $\overline{CPI}_{12}$, CPI_{cum}, 50/50[4], 75/25[4], $SPI_{cum} \times \overline{CPI}_6$ Regression 1 linear 1 nonlinear[5]	Average percent error plotted as a function of time, plots of each EAC method compared to determine which was closest to final cost at each stage of completion	Most accurate method dependent on stage of contract completion; Index-based method using $\overline{CPI}_6 \times SPI_{cum}$ performed best overall
Riedel and Chance (1989)	Air Force, 16 development 48 production	Index-based CPI_{cum}, SCI_{cum}, 20/80[4], CPI_m, CPI_3, PC[6]	MAPE	Accuracy of EAC methods dependent on stage of completion, type of weapons system, and program phase

Notes:

[1] $ACWP = A \times BCWP^B$ and $ACWP = A \times X^B \times e^{CX}$, where X = months

[2] $ACWP = A \times BCWP^B$

[3] $Y=A+BX$; $Y=AX^B$; $Y=Ae^{BX}$; and, $Y=A+B\log_e X$ (where ACWP (Y) was regressed against BCWP (X), CPI (Y) was regressed against time (X), and both ACWP (Y) and BCWP (Y) were regressed separately against time (X))

[4] W1/W2: Composite Index = $W1 \times SPI_{cum} + W2 \times CPI_{cum}$ (e.g., 50/50 is $.50SPI_{cum}+.50CPI_{cum}$)

[5] $Y=AX^B$ where CPI (Y) was regressed against time (X)

[6] PC: Composite Index = $(PC)CPI_{cum}+(1-PC)SPI_{cum}$ where PC = Percent Complete

Heydinger. The earliest comparative EAC study reviewed was the Space and Missile Systems Organization (SAMSO) study done by Heydinger in 1977. This study tested four index-based methods and three regression models using 42 months of data from a single Air Force development contract. The index-based methods included CPI_m, $\overline{CPI}_3$, CPI_{cum}, and CPI_3. The three regression models included one where ACWP was regressed against BCWP in the nonlinear form $ACWP = A \times BCWP^B$, and two where BCWP and ACWP were regressed against time, first as linear functions of time, and then using the nonlinear form $A \times X^B \times e^{CX}$ (a modified Erlang equation), where $X = \text{month}$. Using the evaluation criterion of "consistently closest to final cost" as his measure of comparison, Heydinger found that the nonlinear regression model using the modified Erlang equation was the most accurate over the life of the program. Of the remaining methods, Heydinger found the regression model where ACWP was regressed against BCWP in the nonlinear form $ACWP = A \times BCWP^B$, to be a good estimator during the early (3rd to 7th months) and late (27th to 42nd months) stages of the contract, and the index-based method using $\overline{CPI}_3$ to be a good estimator during the middle stage (8th to 26th months).

Land and Preston. A second study done by Land and Preston in 1980, using data from 20 Air Force aircraft programs, tested the same four index-based methods as the Heydinger study (CPI_m, $\overline{CPI}_3$, CPI_{cum}, and CPI_3) and the regression model where ACWP was regressed against BCWP in the nonlinear form $ACWP = A \times BCWP^B$. The regression was run with the regression coefficients A and B unconstrained (i.e., the values of A and B were determined by the regression) and again with the coefficient B constrained (i.e., the value of B was fixed and only the value of A was determined by the regression). As a measure of EAC accuracy, Land and Preston used the Mean Absolute Percentage Error (MAPE), defined as "the estimated value minus the actual final cost at completion divided by the actual final cost" (Land and Preston, 1980:50). In general, the study found that the nonlinear regression-based methods did not result in more accurate EACs, and the method with the lowest MAPE was the index-based method using CPI_{cum}.

Covach, *et al.* A 1981 ManTech International Corporation study by Covach, *et al.*, tested 12 index-based methods and 12 regression equations using data from six Navy contracts (five research and development (R&D) and one production). The index-based methods included CPI_m, $\overline{CPI}_3$, $\overline{CPI}_6$, $\overline{CPI}_{12}$, CPI_{cum}, SCI_{cum}, CPI_3, and CPI_6. Four of the 12 index-based methods divided BAC by $\overline{CPI}_3$, SPI_{cum}, CPI_3, and CPI_6, which "is an incorrect algebraic simplification of the basic EAC formula," Equation (1) (Christensen, *et al.*, 1992:217). The 12 regression-based methods used the forms $Y=A+BX$, $Y=AX^B$, $Y=Ae^{BX}$, and $Y=A+B\log_e X$, and regressed ACWP against BCWP, CPI against time, and both ACWP and BCWP separately against time using each of these forms. Unfortunately, no comparisons were made between the index-based methods and the regression-based methods.

In this study, three different measures were used to compare the various methods. The first measure was the number of months that the EAC was within 10% of the actual CAC. The second was the number of months that the EAC was closer to the actual CAC than the BAC. The third was the number of months that the EAC was closer to the actual

CAC than the contractor's Latest Revised Estimate (LRE). Success was defined for each measure as the EAC being more accurate greater than or equal to 75% of the time. Failure was defined as the EAC being more accurate less than 50% of the time and the range from 50% to 74% was defined as indifferent. An overall score for each method was calculated by awarding +1 to each method for each success, 0 (zero) for each indifferent result, and -1 for each failure. In addition to an overall evaluation, the methods were evaluated at various stages of contract completion, as defined in Table 2.

The best performing index-based methods overall were CPI_6 and $\overline{CPI}_{12}$. The results for the index-based methods by stage of contract completion are shown in Table 2. It is significant to note that the best performing indices differed depending on the stage of contract completion, with only the CPI_3 index performing well in all three stages. Overall, the results from comparing the regression equations were inconclusive. No single method demonstrated clear superiority; however, once a given method started to perform well, it would typically remain the best method over the life of a contract (Covach, *et al.*, 1981).

TABLE 2

RESULTS OF EAC COMPARATIVE STUDY - COVACH, *et al.*, 1981
(Christensen, *et al.*, 1992)

Contract Completion Stage	Best Performing EAC Methods
Early (0% to 40% Complete)	CPI_3, CPI_{cum}, SCI_{cum}
Middle (20% to 80% Complete)	CPI_3, CPI_{cum}, $\overline{CPI}_6$, SCI_{cum}
Late (60% to 100% Complete)	CPI_3, CPI_6, $\overline{CPI}_{12}$

Bright and Howard. Another 1981 study, done by Bright and Howard from the Army Missile Command, confirmed the sensitivity of EAC accuracy to contract completion stage. This study examined eight index-based methods and two regression-based methods using data from 11 Army R&D contracts. The index-based methods included $\overline{CPI}_3$, $\overline{CPI}_6$, $\overline{CPI}_{12}$, CPI_{cum}, $0.5SPI_{cum}+0.5CPI_{cum}$, $0.75SPI_{cum}+0.25CPI_{cum}$, SPI_{cum}, and $SPI_{cum}\times\overline{CPI}_6$ (a modified version of the SCI). The regression-based methods included one linear model of the form $Y=A+BX$ and one nonlinear model of the form $Y=AX^B$. In both cases, the CPI was regressed against time and projected to obtain a CPI at completion, which was then used in the general EAC formula, given in Equation (1) of this paper, to arrive at the EAC. The various methods were compared by plotting the average percent error (relative to final costs) of each estimating technique as a function of time, and then comparing these plots for each method to determine which was the most accurate (closest to final cost) at each stage of contract completion. Summarized results of this study are presented in Table 3. Again, it is significant to note that the best performing EAC methods differ depending on the stage of contract completion. In this study, however, the most consistent method was found to be the index-based method using $SPI_{cum}\times\overline{CPI}_6$ (Bright and Howard, 1981).

TABLE 3

RESULTS OF EAC COMPARATIVE STUDY - BRIGHT AND HOWARD, 1981
(Christensen, *et al.*, 1992)

Contract Completion Stage	Best Performing EAC Methods
Early (0% to 30% Complete)	Regression, Composite, SPI_{cum}, $SPI_{cum} \times \overline{CPI}_6$
Middle (31% to 80% Complete)	$\overline{CPI}_3$, $\overline{CPI}_6$, $\overline{CPI}_{12}$, $SPI_{cum} \times \overline{CPI}_6$
Late (81% to 100% Complete)	CPI_{cum}, $SPI_{cum} \times \overline{CPI}_6$

Riedel and Chance. A 1989 study done at the Aeronautical Systems Division, by Riedel and Chance, further confirmed the sensitivity of EAC accuracy to contract completion stage. In addition, to contract completion stage, Riedel and Chance investigated sensitivity to the type of system (aircraft, engine, or avionics) and program phase (development or production). This study compared six index-based methods (CPI_{cum}, SCI_{cum}, $0.2SPI_{cum}+0.8CPI_{cum}$, CPI_m, CPI_3, and $(PC)CPI_{cum}+(1\text{-}PC)SPI_{cum}$ where PC is the contract Percent Complete) using data from 64 Air Force contracts (16 development and 48 production). As a measure of EAC accuracy the authors used the MAPE, with the EAC method having the lowest MAPE being classed as the most accurate. The results of this study, shown in Table 4, clearly demonstrate that the accuracy of a given EAC method is sensitive to the type of system and the phase of the program in addition to being sensitive to contract completion stage.

TABLE 4

RESULTS OF EAC COMPARATIVE STUDY - RIEDEL AND CHANCE, 1989
(Christensen, *et al.*, 1992)

			Contract Completion Stage				
System Type	Program Phase	Number of Contracts	25%	50%	75%	100%	Overall
Aircraft	Development	7	SCI_{cum}	CPI_3	CPI_3	20/80[1]	SCI_{cum}
Aircraft	Production	23	SCI_{cum}	CPI_3	SCI_{cum}	CPI_{cum}	SCI_{cum}
Avionics	Development	5	SCI_{cum}	CPI_3	CPI_3	CPI_{cum}	CPI_3
Avionics	Production	16	20/80	SCI_{cum}	20/80	SCI_{cum}	20/80
Engine	Development	4	CPI_m	SCI_{cum}	CPI_3	CPI_3	CPI_3
Engine	Production	9	PC[2]	CPI_{cum}	SCI_{cum}	PC	CPI_{cum}

Notes:
[1] 20/80: Composite Index = $0.2SPI_{cum}+0.8CPI_{cum}$
[2] PC: Composite Index = $(PC)CPI_{cum}+(1-PC)SPI_{cum}$ where PC = Percent Complete

The results of the comparative EAC studies discussed above are significant in three ways. First, they indicate that no single method will always produce the most accurate EAC. Second, these results establish the importance of including additional analysis in a comparative EAC study to determine the sensitivity of the results to such factors as program phase, system type, and contract completion stage. Third, with the exception of the Heydinger study (1977), the nonlinear EAC methods were not superior.

Two recent studies, although not comparative EAC studies, provide additional insight into the overall performance of index-based EAC formulas. In the first study, Christensen and Heise investigated the stability of the CPI and found that CPI_{cum} was a very stable indicator (within 0.2 of its final value as early as the 20 percent completion point). Based on this they concluded that any EACs lower than the EAC calculated using CPI_{cum} were questionable and should require strong justification (Christensen and Heise, 1993).

The second study, done by Terry and Vanderburgh, tested the widely held belief that the CPI-based EAC is a floor and the SCI-based EAC a ceiling for the final contract Cost at Completion (CAC). The authors found that the CPI-based EAC was the floor and the SCI-based EAC the ceiling for the range of EACs calculated; however, the overall range of EACs tended to underestimate the actual CAC by approximately five percent (Terry and Vanderburgh, 1993). This range of EACs was calculated using nine indices which included CPI_{cum}, CPI_6, CPI_3, SPI_{cum}, SPI_6, SPI_3, SCI_{cum}, SCI_6, and SCI_3. These two studies provide further justification for including the CPI- and SCI-based EAC formulas in a comparative study.

Based on this review of comparative EAC studies it is apparent that attempts to validate or compare regression-based methods have been limited, and the results have been inconclusive. While some of these results indicate that regression-based methods can produce accurate EACs (Heydinger, 1977; Covach, *et al.*, 1981; Bright and Howard, 1981), others completely discount the use of these methods (Land and Preston, 1980). One common factor among the regression-based methods examined in these studies is that the selection of a particular regression model, whether linear or nonlinear, did not appear to be based on any sound scientific evidence. The use of the nonlinear models was an attempt to approximate the nonlinear nature of cost expenditures on DoD contracts; however, the models do not appear to have been tested to determine just how accurately they duplicated this nonlinear trend. The next section describes two of the more popular nonlinear models that were found in this review.

Nonlinear EAC Methods

The use of nonlinear models to approximate cost expenditures and manpower usage on R&D projects is clearly not a new idea. In fact, Norden cites research studies from the early 1960s that were successful in describing what he calls the "regular patterns of manpower buildup and phase-out in complex projects" using several different "mathematical functions, generally in the family of exponential, gamma, beta, or logistic curves" (1980:218). While Norden's focus, as well as the focus of the other nonlinear research reviewed, was on R&D projects, no evidence was presented to suggest that these nonlinear models did not apply to production efforts as well. In fact, a study by Knepp and Stroble found that production efforts also displayed nonlinear cumulative cost curves (1994).

The two major nonlinear models discovered in this review included the Rayleigh distribution and a modified Beta distribution. This section will review both, in addition to describing several methods of calculating EACs using these nonlinear models.

Rayleigh Distribution EAC Methods. Several studies have investigated the application of the Rayleigh distribution to cost estimation (Abernethy, 1984; Gallagher and Lee, 1995; Watkins, 1982). All three studies found that ACWP on defense acquisition contracts (the focus of these studies was on research and development contracts) could be modeled accurately using the Rayleigh distribution. The results of these studies are summarized in Table 5.

TABLE 5

SUMMARY OF RAYLEIGH DISTRIBUTION STUDIES

Author (Year)	DoD Agency (# and Type of Contracts)	Purpose of Study	Significant Results
Watkins (1982)	Navy (3 R&D)	Fitted transformed cost data to Rayleigh distribution using least squares linear regression; Generated EACs using resulting regression equations	Coefficients of determination (r^2) ≥ 0.815 with all data included in the regression; EACs highly variable over the life of a contract; No comparison made to other EAC methods
Abernethy (1984)	Navy (21 R&D)	Fitted transformed cost data to Rayleigh distribution using both least squares and three group linear regression; Determined if Rayleigh parameters from regressions on yearly subsets of data converged on final regression parameters from complete data sets	Using Kolmogorov-Smirnov goodness-of-fit test with 5% significance level, Rayleigh distribution found to be a good fit for 14 of the 21 contracts; Convergence of regression parameters demonstrated on only one contract
Gallagher and Lee (1995)	Air Force (2 R&D) Navy (1 R&D)	Described application of Multiple Model Adaptive Estimation (MMAE) and Rayleigh distribution to generate likelihood curves for final cost and completion time on contracts; Compared EACs calculated with Rayleigh MMAE technique to EACs calculated using CPI_3, CPI_6, CPI_{cum}, and SCI_{cum}	Comparisons made only on individual contracts; No specific measure of EAC accuracy was used; Method producing EAC closest to actual CAC varied depending on contract and number of years of data used to calculate the EACs;

The two earlier studies by Watkins and Abernethy used the same basic form of the Rayleigh distribution,

$$C(t) = K(1 - e^{-at^2}) \qquad (10)$$

where C(t) is the cumulative cost ($ACWP_{cum}$) expended at time t , K is total cost at contract completion, a is the Rayleigh shape parameter which governs the time of peak contract expenditure, and t is the elapsed time from start of contract. Both Watkins and Abernethy used quarterly data and expressed elapsed time in quarters (any unit of time can be used). By taking the first derivative of the cumulative Rayleigh function, an equation expressing the rate of change of cumulative contract cost with respect time is obtained.

$$\frac{dC(t)}{dt} = 2Kate^{-at^2} \quad (11)$$

where dC(t) is the period cost expenditure (the period ACWP), dt is the length of the reporting period, K is total cost at contract completion, a is the Rayleigh shape parameter which governs the time of peak contract expenditure, and t is the elapsed time from start of contract.

In Watkin's study, the term dt was omitted from his calculations. Because all of his data were spaced in even quarterly increments (i.e., $dt = 1$) there was no effect on the results of his analysis. It is critical, however, to ensure that the term is not omitted if the length of the reporting period is anything other than one time unit as was the case in this study where days rather than quarters were used as the time unit.

Next, Equation (11) is divided by t to yield

$$\frac{dC(t)/dt}{t} = 2Kae^{-at^2} \quad (12)$$

By taking the natural logarithm

$$\ln\left(\frac{dC(t)/dt}{t}\right) = \ln(2Ka) - at^2 \qquad (13)$$

an equation in the linear form Y=A+BX is obtained, where

$$X = t^2 \qquad (14)$$

$$Y = \ln\left(\frac{dC(t)/dt}{t}\right) \qquad (15)$$

$$A = \text{intercept} = \ln(2Ka), \text{ and} \qquad (16)$$

$$B = \text{slope} = -a \qquad (17)$$

The slope and intercept can then be determined by regressing Y , as calculated in Equation (15), against t^2 , where dC(t) is the reporting period ACWP, dt is the elapsed time in the reporting period, and t is the elapsed time from the start of the contract.

Both Watkins and Abernethy applied standard least squares linear regression, details of which can be found in any basic statistics book. However, Abernethy also used a more robust regression technique known as "three group linear regression." An explanation can be found in Understanding Robust and Exploratory Data Analysis, by Hoaglin, Mosteller, and Tukey (1983).

Once the slope and intercept have been determined using one of these regression techniques, calculating the EAC is a simple matter. As noted earlier, K is the total cost at contract completion and is, therefore, the parameter of interest. By algebraically manipulating Equations (16) and (17), K can be expressed in terms of the know slope

(B) and intercept (A) determined by the regression, and the EAC can be calculated. The mathematical expression resulting from this manipulation is as follows:

$$EAC = K = e^{A}/(-2B) \tag{18}$$

Watkins was successful in using least squares linear regression to fit the non-cumulative Rayleigh distribution to actual data from three Navy contracts. In each of the three contracts analyzed, the resulting coefficient of determination (r^2) was at least 0.815 or higher when all of the data were included in the regression (Watkins, 1982). Watkins also tested the sensitivity of his results to the effect of inflation on one of the contracts by deflating the data to constant 1972 dollars and performing the regression on the deflated data. The regression on the deflated data resulted in only a slightly better fit; r^2 increased from 0.815 to 0.827 (Watkins, 1982).

Watkins also attempted to generate EACs using the resulting regression equations. However, these EACs varied significantly from one quarter to the next and even resulted in negative values during the early stages of one of the contracts. Although Watkins was not successful in generating EACs using this method, the study did demonstrate the feasibility of modeling contract expenditures using the Rayleigh distribution.

For his analysis, Abernethy used both regression techniques and fit data from 21 Navy contracts to the non-cumulative Rayleigh distribution. Using the Kolmogorov-Smirnov goodness-of-fit test with a significance level of five percent, Abernethy found that in 14 of the 21 contracts the Rayleigh distribution was a good fit for the actual data, with neither regression technique demonstrating clear superiority over the other (Abernethy, 1984).

Abernethy also tested the ability of the Rayleigh model to predict future contract performance by comparing the Rayleigh parameters from regressions done on yearly subsets of contract data with the parameters from the regressions done on the complete data sets. The purpose of the test was to determine if the regression parameters from the yearly subsets of contract data converged on the final regression parameters from the complete data sets. The results of this testing demonstrated convergence in only one of the contracts (Abernethy, 1984). Unfortunately, no comparisons were made to the actual CAC or to other EAC methods; and there is no way to determine the ability of the techniques to calculate EACs based on the results of this study.

The most recent study involving the Rayleigh distribution, done by Gallagher and Lee (1995), describes a methodology that uses Multiple Model Adaptive Estimation (MMAE) to determine a range values for the Rayleigh shape parameters and the probability that any one set of parameters is correct conditional on the actual cost data. A description of the MMAE technique can be found in Stochastic Models, Estimation, and Control: Volume 2 (Maybeck, 1982). This range of parameters and their associated probabilities are then used to generate a point estimate for the EAC, as well as probability distributions for the most likely range of final contract cost and completion time.

The authors tested the method using data from three DoD R&D contracts (two Air Force and one Navy) by plotting cumulative cost probability curves generated with yearly increments of data and comparing these plots to the actual contract cost at completion.

No specific measure of accuracy was used; however, an examination of the plots indicates that the estimated range was reasonably accurate after three to four years of data were included (Gallagher and Lee, 1995).

The authors also calculated EACs using four index-based methods (CPI_3, CPI_6, CPI_{cum}, and SCI_{cum}) which they compared to the point estimate EACs calculated with their method. For each method, EACs were calculated for yearly increments of data starting with either the second or third year of contract completion, and continuing through the final year of each contract. Unfortunately, no specific measure of accuracy was used to compare the methods. A comparison of the EACs calculated using each of the methods indicates that the method producing the EAC closest to the actual contract CAC varied depending on the contract and the number of years of data used (Gallagher and Lee, 1995). Unfortunately, due to the limited number of contracts (three), and the fact that no specific measure of accuracy was used for the comparisons, it is difficult to draw any meaningful conclusions from the results of this study.

A detailed description of this method is beyond the scope of this study and can be found in Gallagher and Lee's paper (1995). A copy of the software necessary to calculate EACs using this method was obtained from the authors and is one of the EAC methods evaluated in this study. A copy of the Microsoft® Excel Visual Basic® code used to implement the method is included as Appendix E of this paper.

The ability of the Rayleigh curve to accurately model actual contract cost expenditures was demonstrated in each of the three studies reviewed; however, only the Gallagher and Lee study attempted a comparison to other EAC methods, with inconclusive results. Therefore, the three nonlinear methods using the Rayleigh distribution, 1) least squares linear regression (Abernethy, 1984; Watkins, 1982), 2) three group linear regression (Abernethy 1984), and 3) MMAE (Gallagher and Lee, 1995) were included in this study.

Beta Curve EAC Method. The second nonlinear model was the Beta distribution. An EAC method using the Beta distribution was presented by Whitlock of the NASA Johnson Space Center in the Fall 1982 issue of the Journal of Parametrics. This method makes use of a modified Beta function with the following cumulative cost curve:

$$C(t) = A(10t^2-20t^3+10t^4)+B(10t^3-20t^4+10t^5)+(5t^4-4t^5) \qquad (19)$$

where $C(t)$ is the fraction of total contract cost consumed at time t, t is the fraction of time elapsed in the program, which is equal to the elapsed time as of the report date divided by the expected duration of the contract, and A and B are the weighting factors of the cumulative Beta function, subject to the constraints $A \geq 0$, $B \geq 0$, $A+B \leq 1$.

To determine the parameters (A and B) that achieve the best fit to the actual cost data, Whitlock proposed minimizing a weighted sum of the least squares (WSLS) expression with fractional time cubed used as the weighting factor. Fractional time cubed was chosen as the weighting factor because "the spending pattern becomes better defined the later into a program you are" (Whitlock, 1982:17).

The WSLS is expressed as follows:

$$WSLS = \Sigma[C(t_i) - YK_i]^2 t_i^3 \qquad (20)$$

where $\underline{C(t)}$ is the fractional cumulative cost curve as defined in Equation (19), $\underline{Y}$ is a scaling factor which expresses cumulative program cost (K_i) as a fractional cost, $\underline{K_i}$ is the cumulative program cost, or $ACWP_{cum}$, for the ith reporting period, and $\underline{t_i}$ is the fractional time elapsed as of the ith reporting period.

To solve for the three unknowns (A, B, and Y) Whitlock proposed four computational techniques, three of which were not practical for the purposes of this study. The first of these three techniques involved selecting values for A and B based on knowledge of the program, or of similar programs, and then solving for Y. This technique was determined to be impractical because it requires a level of familiarity with the program beyond the knowledge of this researcher and the information available in the DAES database.

The second technique involves setting up a system of linear equations in three unknowns using partial derivatives and then solving the system of equations. This technique was deemed impractical because it could not be easily automated. Given the large volume of data to be analyzed and the time constraints in this study, automation was considered to be essential.

The third technique involved the use of quadratic programming to minimize the WSLS. Although Microsoft® Excel has the capability to solve quadratic programming problems, the process is not easily automated. Therefore, this technique was also deemed impractical.

The fourth and most practical technique for the purposes of this study was an exhaustive search technique that involved writing a computer algorithm to test various values of the weighting factors A and B, in discrete increments, until the smallest WSLS value is found. This computer algorithm was easily implemented in Microsoft® Excel Visual Basic® and is fully discussed in Chapter III.

With the exhaustive search technique, the scaling factor Y is calculated using

$$Y_{opt} = \frac{\sum C(t_i)K_i t_i^3}{\sum t_i^3 K_i^3}, \tag{21}$$

which is obtained by setting the first derivative of Equation (20) equal to zero and solving for Y.

Once the values of the parameters A, B, and Y are determined, the final step is calculating the EAC. The following relationship exists for any data point:

$$YK_i = C(t_i) \tag{22}$$

Using this relationship, an estimate of cumulative program cost can be developed for any future point in time. At the point in time corresponding to the end of the program,

$$K_{end} = \frac{C(t_{end})}{Y} \tag{23}$$

However, K_{end}=EAC , and $C(t_{end})$=C(1)=1 . Therefore,

$$EAC = \frac{1}{Y} \tag{24}$$

Unfortunately, Whitlock made no attempt to verify the accuracy of this method or to compare its accuracy with other EAC methods.

Conclusions

This review of previous research demonstrates several key points. First, the index-based EAC formulas are widely used, have been extensively tested, and provide an excellent basis for comparing newer, and possibly better EAC methods that are being developed. Because the linear, index-based methods are easy to use they will likely continue to be the primary method of calculating EACs well into the future. In addition, all of the EAC methods included in the DoD's Performance Analyzer software package are linear methods (Cost Management Systems, Inc., 1994) demonstrating the popularity of the index-based methods.

Second, the accuracy of a given EAC method is dependent on such factors as contract completion stage, system type, and program phase. Including a sensitivity analysis to test for the effects of such factors on the overall results of a comparative EAC study is critical.

Finally, the performance of nonlinear EAC methods has rarely been compared to the performance of the index-based methods. In addition, the relative accuracy of the nonlinear regression-based EAC methods has not been established. For these reasons, a comparative study of nonlinear regression-based and index-based EAC methods is clearly needed. As more sophisticated EAC methods are developed, the only way they will gain acceptance is if they can be proven superior by comparison with accepted methods.

Whether these new methods are proven superior or not, this research still provides insight into the relative accuracy of the various EAC methods.

III. Methodology

Introduction

This chapter describes the procedures used to compare the performance of 15 EAC methods, including 11 index-based methods, and four nonlinear regression-based methods. The four nonlinear regression-based methods make use of the Rayleigh distribution and modified Beta distribution discussed in the previous chapter. The objective of this comparison, as stated earlier, is to determine if the complex nonlinear regression-based EAC methods perform better than the simpler index-based EAC methods.

The chapter begins with a description of the database used to compare the EAC methods, and the criteria that were used to screen the data. Next, the actual EAC methods that were tested are discussed, along with specific computational issues concerning each of the methods. A discussion of what constitutes "good" performance for an EAC method, and a presentation of the specific performance measures used to evaluate the EAC methods follows. Next, the specific procedures used to compare the methods, and to test for sensitivity of the results to stage of contract completion, system type, program phase, contract type, DoD service component, and the effects of inflation are described. Finally, the chapter concludes with a justification of the approach taken in this analysis.

The DAES Database

The DAES database contains cost performance data on 541 completed or near completed defense contracts covering the period from June 1970 to October 1992. This database includes both development and production contracts from all three services and a variety of different system types. The cost performance data for each contract are presented as a series of periodic (generally quarterly) reports. The data extracted from the database included several descriptive fields as well as the actual cost report data. The descriptive fields included the project number (PNO), the contract number (CNO), a description of the contract (PD), the branch of service administering the contract (SER), the contract type (CON), the program phase (PHA), and the date that work started on the contract (WSDATE). The actual cost report data included the submittal date for the cost report (SDATE), the Budgeted Cost of Work Scheduled (BCWS), the Budgeted Cost of Work Performed (BCWP), the Actual Cost of Work Performed (ACWP), the Budget at Completion (BAC), the Contract Budget Base (CBB), the Total Allocated Budget (TAB), and the percentage complete relative to the final cost of the contract (PCF).

Data Screening Criteria

In most cases the contracts contained in this database did not include a complete set of cost data through the 100 percent completion point, and in some cases the data stops earlier than the 90 percent completion point. Because the contract's CAC was required as a comparison point to evaluate the performance of each EAC method, an objective measure of the CAC was needed. For the purposes of this study, a contract's CAC was defined as the $ACWP_{cum}$ as of the final set of data for a given contract, and any contract not having data for the 90 percent completion point or greater was eliminated from the analysis. Ideally, only contracts with data through the 100 percent completion point would have been used; however, this would have severely limited the number of contracts analyzed in the study (only 10 contracts after satisfying the remaining screening criteria).

A second data screening criterion involved the elimination of contracts without data for the period earlier than the 10 percent completion point. This was necessary because of the need to evaluate the performance of the EAC methods over the entire life of a contract. As mentioned previously, a major purpose of the EAC is to provide senior managers with feedback to allow early identification and correction of problems. For this reason, the evaluation of the EAC methods during the early stages of contract completion was critical.

A third screening criterion involved the need for a definitive date that work started on the contract. This was necessary because all of the regression-based methods required a known start date to calculate the EAC. For this reason, any contracts that did not include a start date, any contracts that listed multiple start dates, and any contracts that listed start dates occurring after the initial cost report submittal date were also eliminated from the analysis. Another note regarding the start dates is in order. The start dates listed in the database included only the month and year. This required an assumption to be made regarding the actual date that work started on the contract. Without knowledge of whether a given contract started early or late in the month the best way to minimize the potential for error was to assume that all of the contracts began on the 15th of the month.

The fourth screening criterion involved contracts with that went over target baseline (OTB), that is, contracts where the contractor is "authorized to implement and report to a baseline or Total Allocated Budget (TAB) that exceeds the cost of authorized work or Contract Budget Base (CBB)" (Department of the Air Force, 1993:11-B-2). Because OTB contracts occur only in exceptional cases (Department of the Air Force, 1993), and because calculating an EAC for a contract that has gone OTB is difficult without a full understanding of the cause, any contracts where the CBB did not equal the TAB were eliminated from the analysis.

The final data screening criterion involves some peculiarities that occurred with 14 contracts that complicated the calculation of the index-based EACs. Specifically, these peculiarities involved contracts where either the BCWS, BCWP, or ACWP decreased from one reporting period to the next. In these cases, it was not possible to calculate the index-based EACs that required the use of the cost parameter that decreased. In order to simplify the analysis, and because the number of contracts where this situation occurred was limited, these contracts were also eliminated from the analysis.

After the data were screened based on the criteria discussed above, a total of 88 contracts remained. These contracts along with their descriptive data are listed in Appendix B. With the data screening complete, the next step was to calculate the EACs.

EAC Methods Tested

As discussed in Chapter II, the two basic categories of EAC methods relevant to this study were, the index-based methods, and the nonlinear regression-based methods. This section describes all of the methods that were tested in this study, as well as specific computational issues associated with each method.

Index-Based EAC Methods. Because of the ease of calculating the index-based EACs, and the popularity of these methods, 11 different indices were analyzed. Nine of these indices included the CPI, SPI, and SCI in both their cumulative form (CPI_{cum}, SPI_{cum}, and SCI_{cum}), as defined Equations (2), (5), and (8) respectively, and using the three, and six month moving average indices (CPI_3, CPI_6, SPI_3, SPI_6, SCI_3, and SCI_6), as defined in Equations (3) and (6), and (8). The tenth index was the modified form of the SCI where CPI_6 is multiplied by SPI_{cum}. This form of the SCI is similar to the form found to be the most accurate overall EAC by Bright and Howard in their 1981 study (they actually used $\overline{CPI}_6$ rather than CPI_6), and is also one of the methods included in Performance Analyzer (Cost Management Systems, Inc., 1994). The final index tested was the Composite Index, defined in Equation (9), with SPI_{cum} multiplied by a weighting factor (W_1) of 0.2 and added to CPI_{cum} multiplied by a weighting factor (W_2) of 0.8 ($0.2SPI_{cum}+0.8CPI_{cum}$). This is the same index that was found to perform well on some system types, at some stages of contract completion in the 1989 study by Reidel and Chance. This method is also highly recommended in Air Force Materiel Command's Financial Management Guide to Analysis of Contractor Cost Data (1994).

EACs were calculated for every cost reporting period on all contracts using each of the 11 index-based methods, except in the following cases. First, the three and six month indices could not be calculated for reporting periods that occurred less than three or six months into the contract. And second, EACs could not be calculated in cases where a division by zero occurred. This happened in the following situations: for EAC methods involving the moving average CPIs when the period ACWP was equal to zero, or methods involving CPI_{cum} when $ACWP_{cum}$ was equal to zero; for EAC methods involving the moving average SPIs when the period BCWS was equal to zero, or methods involving SPI_{cum} when $BCWS_{cum}$ was equal to zero; and, for all EAC methods when either the period BCWP or $BCWP_{cum}$ was equal to zero. Calculation of all index-based EACs was done with a user defined function written in Microsoft® Excel Visual Basic® (Microsoft® Corporation, 1993). A copy of the user defined function is included as Appendix C.

There were two issues involved with calculating the index-based EACs using the data from the DAES database. First, because the BCWS, BCWP, and ACWP data included in the database are cumulative, calculating the three and six month indices required special treatment (the cumulative indices could be calculated directly from the cumulative cost number included in the database using the equations previously mentioned). In cases where the reporting periods were spaced in even three and six month intervals the calculations involved only the following equations:

$$CPI_n = \frac{BCWP_{cum}(t_{now}) - BCWP_{cum}(t_{now} - n)}{ACWP_{cum}(t_{now}) - ACWP_{cum}(t_{now} - n)} \quad (25)$$

$$SPI_n = \frac{BCWP_{cum}(t_{now}) - BCWP_{cum}(t_{now} - n)}{BCWS_{cum}(t_{now}) - BCWS_{cum}(t_{now} - n)} \quad (26)$$

where $\underline{t}_{now}$ is the current period for which the index is being calculated and $\underline{n}$ is the number of months over which the index is being calculated (either three or six months). Where actual data existed, these indices could be calculated directly using these two equations. However, the second issue occurred in cases where a report was missing for the period either three or six months prior to the current period, either because is was not submitted, or because of odd reporting cycles. In these cases the missing data had to be interpolated. To minimize the number of data points that required interpolation, a criterion of ±15 days from the actual three or six month prior point was established. That is, if there was an actual report with a report date within ±15 days of the date three or six months prior to the report date for which the EAC was being calculated, the actual data from that report were used. When interpolation was required, simple linear interpolation was used. Because there is no way to know the actual nature of the cost expenditures over the missing report period, any interpolation technique will provide at best an approximation of the actual values. Therefore, to ease computations the simplest method available, linear interpolation, was chosen. Interpolation of the missing data points was done using the following equation:

$$C_x = \frac{(C_+ - C_-)(t_x - t_-)}{t_+ - t_-} + C_- \qquad (27)$$

where $\underline{C}_x$ is the unknown cost value (BCWS, BCWP, or ACWP) for the missing report, with a corresponding time, $\underline{t}_x$, $\underline{C}_+$ is the actual cost value for the period just after the missing report, with a corresponding time, $\underline{t}_+$, and $\underline{C}_-$ is the actual cost value for the period just prior to the missing report, with a corresponding time, $\underline{t}_-$. An example should help to illustrate this:

$t_- = 25$ April 77	$BCWP_- = \$53$ million
$t_x = 25$ May 77	$BCWP_x = ?$
$t_+ = 25$ August 77	$BCWP_+ = \$122$ million

In this case the missing data for three months prior to 25 August 77, which is 25 May 77, needs to be interpolated. The difference between t_x and t_- is 30 days, and the difference between t_+ and t_- is 122 days. Using Equation (27):

$$BCWP_x = \frac{(\$122 - \$53)(30)}{122} + \$53 = \$69.97$$

an interpolated BCWP value of \$70 million (rounded off) is calculated. Of course to calculate the performance indices, all three cost values (BCWS, BCWP, and ACWP) must be calculated. The interpolated cost values were then used in Equations (25) and (26) in place of the missing data. Calculation of the interpolated data points, and the non-cumulative three and six month values for BCWS, BCWP, and ACWP was done as part of the same user defined function (Appendix C) used to calculate the index-based EACs.

Nonlinear EAC Methods. Four nonlinear EAC methods were evaluated in this study. They include the least squares linear regression method using the Rayleigh distribution (Abernethy, 1984; Watkins, 1982), the three group linear regression method using the Rayleigh distribution (Abernethy, 1984), the MMAE method using the Rayleigh distribution (Gallagher and Lee, 1994), and the exhaustive search method using the modified Beta distribution (Whitlock, 1982). The details of calculating EACs with each of these methods will be discussed in the following paragraphs.

Because the two regression methods involving the Rayleigh distribution required non-cumulative data, the first step was to calculate the period ACWP values for each reporting period. This was done by subtracting the previous reporting period's $ACWP_{cum}$ from the current period's $ACWP_{cum}$. In the case of the first reporting period, $ACWP_{cum}$ is also the period ACWP; therefore, no subtraction was required.

After calculating the period ACWPs, the next step was to transform the data so the linear regressions could be done. This was done using Equation (15), and provided the dependent variable (Y) for the regression. The independent variable (X) in the regression is time squared (where time is measured from the start of the contract). To calculate the independent variables for regression, the number of days from the start of the contract was calculated and then squared. All of these calculations were done using basic mathematical manipulations in Microsoft® Excel (Microsoft® Corporation, 1993).

Once the regression variables had been calculated, both regression techniques were applied to calculate the intercept (A) and slope (B) for each reporting period. The least squares linear regression was done using the built-in SLOPE, and INTERCEPT commands in Microsoft® Excel (Microsoft® Corporation, 1993). The three group linear regression was done with a user defined function written in Visual Basic®. A copy of this user defined function is included as Appendix D.

After the slope and intercept were determined using each of the regression methods, the EACs were calculated using Equation (18). The least squares linear regression function in Microsoft® Excel requires at least two data points; therefore, EACs were calculated for this method beginning with the second reporting period for each contract. Because the three group linear regression technique requires a minimum of three data points, EACs were calculated for this method beginning with the third reporting period for each contract. Also, EACs for the three group regression method could not be calculated when the period ACWP was equal to zero. Other than the exceptions just noted, EACs were calculated for every cost reporting period on all contracts using both methods.

Calculating EACs with the Rayleigh MMAE method was done completely within the user defined function obtained from Gallagher. No special manipulations of the data were required. The only modification required to the user defined function was the substitution of the inflation indices used in this study for the inflation indices Gallagher used. A more detailed discussion of inflation indices is included in the section discussing the test for sensitivity of the results to the effects of inflation. A copy of the MMAE user defined function is included as Appendix E. EACs were calculated using this method for every cost reporting period beginning with the second cost report on all contracts. The method required a minimum of two data points so an EAC could not be calculated with only the first cost report.

To calculate EACs with the modified Beta distribution proposed by Whitlock (1982), a user defined function was developed using Visual Basic® (included as Appendix F). The inputs to this function were fractional time and $ACWP_{cum}$. Calculating fractional time required a known end date for each contract. Because this information was not available in the DAES database, the submittal date for the final cost report was used. Calculating fractional time was done by dividing the number of days elapsed from the start of the contract as of the report submittal date by the total number of days in the contract. The user defined function was then used to determine the values of the parameters A and B [Equation (19)] that minimized the WSLS [Equation (20)]. This was done by testing various values of A and B (subject to the constraints $A \geq 0$, $B \geq 0$, and $A+B \leq 1$) first in increments of 0.1, and then in increments of 0.01 around the initial set of parameters. Once the values of A and B producing the minimum WSLS were determined, the value of Y was calculated using Equation (21), followed by the EAC using Equation (24). As with the other methods, an EAC was calculated for every cost reporting period on all contracts. The only case where the Beta EAC could not be calculated was in periods where $ACWP_{cum}$ was equal to zero.

EAC Evaluation Criteria

After the EACs were calculated, the next step was to compare the methods to determine which ones produced the best estimates. Covach, *et al.*, provide three criteria for evaluating the performance of EAC methods.

> Accuracy - A method's estimate of costs at completion (EAC) should generally be equal or close to the contractor actual cost a completion (CAC).
>
> Timeliness - A method should be capable of producing a reliable EAC as early as possible in the life of the contract.
>
> Stability - A method should not produce EACs which, on a month to month basis, vary widely. (Covach, et al., 1981:21)

These three criteria provide a good basis for evaluating the performance of EAC methods. The specific measures that were used to compare the performance of the EAC methods will be discussed in the next section.

Measures of EAC Performance

Accuracy. Several different measures are available to test the accuracy of an estimating method. Two of these, suggested by Nahmias, are the Mean Absolute Deviation (MAD) and the Mean Squared Error (MSE) (1993). The problem with using either of these measures is that they are dependent on the magnitude of the error, and therefore are not useful for comparing results across series of data with differing magnitudes. For example, an error of $10 million would be highly significant on a contract with a final cost of $50 million; however, this error would be minimal on a contract with a final cost of $1 billion. Because the final costs of the contracts in the DAES database are so variable, a measure that was not dependent on the magnitude of the error was required. In this situation, Nahmias suggests the use of the Mean Absolute Percentage Error (1993). Makridakis and Wheelwright also suggest the use of the MAPE rather than the Mean Percentage Error (MPE) because the tendency of the MPE is to underestimate the true magnitude of the errors due to the cancellation effects of positive and negative error values (1978). The use of the MAPE to compare the accuracy of estimating methods is also supported by Armstrong and Collopy. The major drawback to the MAPE suggested in their study is that it is only relevant for data with a meaningful zero (Armstrong and Collopy, 1992). Because a zero value is relevant for the data in this study, this drawback is not a factor.

To calculate the MAPE for a series of EACs, the first step is to calculate the Absolute Percentage Error (APE) for each EAC. This is done using the following formula:

$$\text{APE} = \left| \frac{\text{EAC} - \text{CAC}}{\text{CAC}} \right| \tag{28}$$

where EAC is the Estimate at Completion for a given cost reporting period, and CAC is the Cost at Completion of the contract for which the EAC was calculated. The MAPE is then calculated for a given data series using the following formula:

$$\text{MAPE} = \frac{\sum_{i=1}^{n} \text{APE}_i}{n} \tag{29}$$

where APE_i is the Absolute Percentage Error of the ith EAC in the series, and n is the total number of estimates included in the series for which the MAPE is being calculated.

Timeliness. No specific measure of the timeliness was developed. However, the timeliness of the EAC methods will be examined by separately analyzing the data during four distinct stages of contract completion. These four stages include: zero to 25 percent complete; greater than 25 percent to 50 percent complete; greater than 50 percent to 75 percent complete; and, greater than 75 percent to 100 percent complete.

Stability. None of the comparative EAC studies or material on forecasting methods reviewed suggested any measures to test the stability of an estimating method. The common measure of the variability of a data series used by statisticians is the standard deviation (Devore, 1991); therefore, the measure chosen for this study was the Standard Deviation of the Absolute Percentage Error (SDAPE). Calculating the SDAPE for a series of data is done using the following formula:

$$\text{SDAPE} = \sqrt{\frac{\sum_{i=1}^{n}(\text{APE}_i - \text{MAPE})^2}{n-1}} \tag{30}$$

where APE_i is the Absolute Percentage Error of the ith EAC in the series, MAPE is the Mean Absolute Percentage Error for the overall data series, and n is the total number of estimates included in the series for which the MAPE and SDAPE are being calculated.

Combined Measure of Performance. Because each method was being evaluated based on its performance relative to two different measures (MAPE and SDAPE), a combined measure was needed to directly compare the overall performance of the methods. This was done by ranking the methods according to increasing values of the MAPE and then according to increasing values of SDAPE. Once the rankings were done, each method was assigned two separate scores, one according to its position in the rankings for the MAPE, and one according to its position in the rankings for the SDAPE. If a method had the lowest MAPE or SDAPE it received a score of one. The method with the next highest value of MAPE or SDAPE received a score of two, and so on, until all of the methods received a score for MAPE and a score for SDAPE. In cases where two or more methods had equal values for the MAPE or SDAPE, all of the tied methods received the same score, and the method with the next highest MAPE or SDAPE value was assigned the next highest score. For example, if two methods were tied with the lowest MAPE, both would receive a score of one. The method with the next highest MAPE then received a score of two.

After the rankings were done and the scores assigned, the combined measure of performance was calculated by adding the two individual scores (one for MAPE and one for SDAPE) together. The lowest possible score was two, which was achieved if a method had both the lowest MAPE and the lowest SDAPE. The highest possible score was 30 which would only be achieved if there were no ties and the method had the highest MAPE and highest SDAPE.

Test Procedures

When comparisons are made between data sets the typical approach is to use one of several statistical techniques such as the t-test or ANOVA. The drawback to these techniques is that they require independent data sets for the results to be valid (Devore, 1991). In this study the condition of independence is not met, because the same set of data is used for calculating the EACs with all of the methods. Because this condition of independence was not satisfied, a direct comparison of the combined measure of performance discussed in the previous section was used to determine which methods produced the best EACs.

Evaluation of Performance With All Contracts Included. To compare the performance of the EAC methods overall, the MAPE and SDAPE for each method was calculated with all data points included. The combined score, as described above, was then calculated for each method, and the method with the lowest score was classed as the best performing method.

Sensitivity of Results to Stage of Contract Completion. The sensitivity of the results to stage of contract completion was tested at four stages (quartiles): zero to 25 percent complete (first quartile); greater than 25 percent to 50 percent complete (second quartile); greater than 50 percent to 75 percent complete (third quartile); and, greater than 75 percent to 100 percent complete (fourth quartile). Testing the sensitivity of the results to stage of contract completion also served as an evaluation of the timeliness of the methods and provided data on which methods performed the best during the early stages of contract completion. To compare the performance of the EAC methods in each stage of contract completion, the data were divided into four subsets according to the quartiles just defined. The MAPE and SDAPE were then calculated for each EAC method within each of these data subsets. The combined score was then calculated for each EAC method within each quartile, and the method with the lowest score in each quartile was classed as the best performing method.

Sensitivity of Results to Type of System. Sensitivity of the results to nine categories of system type was tested. These categories included: Aircraft (nine contracts); Armored Vehicles (two contracts); Ballistic Missiles (18 contracts); Electronic Warfare Systems (nine contracts); Helicopters (16 contracts); Other Missiles (19 contracts); Satellites (three contracts); Ships (eight contracts); and, Torpedoes (four contracts). To compare the performance of the EAC methods according to system type, the data were divided into nine subsets according to each of the system types just defined. Next, the MAPE and SDAPE were calculated for each EAC method within each of these data subsets. Then the combined score was calculated for each EAC method within each category, and the method with the lowest score in each category was classed as the best performing method. In addition to evaluating the overall performance of the methods for each system type, the sensitivity of each system type result to stage of contract completion was also tested using the procedure previously described.

Sensitivity of Results to Program Phase. Sensitivity of the results to three categories of program phase was tested. These categories included: Development (24 contracts); Production (53 contracts); and, Other (11 contracts), which included those contracts that could not be categorized in either of the first two categories. To compare the performance of the EAC methods according to program phase, the data were divided into three subsets according to each the phases just defined. Next, the MAPE and SDAPE were calculated for each EAC method within each of these data subsets. Then the combined score was calculated for each method within each category, and the method with the lowest score in each category was classed as the best performing method. In addition to evaluating the overall performance of the methods for each program phase, the sensitivity of each program phase result to stage of contract completion was also tested using the procedure previously described.

Sensitivity of Results to Contract Type. Sensitivity of the results to three categories of contract type was tested. These categories included: Cost Plus (21 contracts); Fixed Price (66 contracts); and, Mixed (one contract), which included one contract that had both cost plus and fixed price components. To compare the performance of the EAC methods according to contract type, the data were divided into three subsets according to the categories just defined. Next, the MAPE and SDAPE were calculated for each EAC method within each of these data subsets. Then the combined score was calculated for each method within each category, and the method with the lowest score in each category was classed as the best performing method. In addition to evaluating the overall performance of the methods for each contract type, the sensitivity of each contract type result to stage of contract completion was also tested using the procedure previously described.

Sensitivity of Results to DoD Service Component. Sensitivity of the results to three categories of DoD service component was tested. These categories included: Army (30 contracts); Air Force (36 contracts); and, Navy (22 contracts). To compare the performance of the EAC methods according to DoD service component, the data were divided into three subsets according to the categories just defined. Next, the MAPE and SDAPE were calculated for each EAC method within each of these data subsets. Then the combined score was calculated for each method within each category, and the method with the lowest score in each category was classed as the best performing method. In addition to evaluating the overall performance of the methods for each DoD service component, the sensitivity of each service component result to stage of contract completion was also tested using the procedure previously described.

Sensitivity to the Effects of Inflation. To test for sensitivity of the results to the effects of inflation, the test procedures were run using both the actual cost numbers in Then Year Dollars (TY$) contained in the DAES database, and again after converting the numbers to Constant Year 1995 Dollars (CY95$). This adjustment for inflation was done using raw inflation indices provided by SAF/FMCE (Appendix G). Two different sets of inflation indices were used depending on the program phase of a contract. For development contracts, the raw inflation indices for R&D (3600) appropriations were used; and, for production and other contracts, the raw inflation indices for Other Procurement (3080) appropriations were used.

Because the cost data included in the DAES database were cumulative TY$, the inflation adjustment process involved three steps. First, the cumulative cost data ($BCWS_{cum}$, $BCWP_{cum}$, and $ACWP_{cum}$) were converted to non-cumulative values by subtracting the previous reporting period's cumulative cost value from the current period's cumulative cost value. In the case of the first reporting period, the cumulative cost value is also the period cost value; therefore, no subtraction was required. Next, the non-cumulative TY$ values were converted to non-cumulative CY95$ by dividing the TY$ values by the appropriate raw inflation index based on the date of the cost report and the program phase. Finally, the cumulative CY95$ cost values were calculated by summing the non-cumulative CY95$ cost values through each cost reporting period.

All of the index-based EAC methods use the BAC; so BAC also had to be converted to CY95$. Because there is no straightforward procedure to convert the BAC to a non-cumulative number the simplest approach was to directly divide the TY$ BAC value by the appropriate raw inflation index based on the date of the cost report and the program phase.

Once all of the cost data were adjusted for inflation, the CY95$ data were entered into duplicates of the Microsoft® Excel spreadsheets used to calculate the TY$ EACs in place of the original TY$ data, and a complete set of CY95$ EACs was calculated. The procedures used to compare the non-inflation adjusted data were then duplicated to determine the best performing EAC methods using the inflation adjusted data.

The conversion from TY$ to CY$ is done as an integral part of the Rayleigh MMAE method. Therefore, evaluation of the performance of this method could only be done after the data had been adjusted for inflation (i.e., converted to CY95$). Consequently, this method was not included in the evaluation using TY$.

Justification of Approach

Although the use of traditional statistical techniques such as the t-test or ANOVA would be desirable, the need for independent data sets ruled out the use of these techniques. To provide a more thorough comparison, two aspects of an EAC method's performance were evaluated, accuracy and stability. The MAPE was selected as the measure of accuracy based on its popularity and its ability to compare estimates across data series of differing magnitudes (Armstrong and Collopy, 1992; Makridakis and

Wheelwright, 1978; Nahmias, 1993). The SDAPE was selected as the measure of stability based on its common use as a measure of the variability in a data series by statisticians (Devore, 1991).

Because each method was evaluated based on two different measures of performance, a combined measure had to be developed. The combined measure chosen was to rank order all of the methods according to both performance measures and calculate a combined score based on the sum of the rank orderings for each method. The method with the lowest combined score was classed as the best performing method for a given data series. This combined performance measure was felt to be the simplest and most meaningful way to rate a method's performance based on two different aspects of performance. Tests for sensitivity to stage of contract completion, system type, program phase, contract type, DoD service component, and the effects of inflation were also included to strengthen the significance and usefulness of the overall results.

The next chapter presents the results of the overall performance of the EAC methods and the sensitivity of these results to stage of contract completion, system type, program phase, contract type, DoD service component, and the effects of inflation.

IV. Analysis of Results

Results of Overall Performance

The results for the performance of the EAC methods with all contracts included in the analysis are summarized in Table 6. This table lists the best performing EAC methods overall and by stage of contract completion, for both the inflation adjusted (CY95$) and the non-inflation adjusted (TY$) data. The scores, MAPE values, and SDAPE values for all of the EAC methods and all data subsets are too voluminous to include in the body of the text and therefore will only be included for the overall results (Table 7). The complete set of scores, MAPE values, and SDAPE values, for the overall results as well as the results for each of the data subsets used in the sensitivity analysis, have been included as Appendix H.

TABLE 6

BEST PERFORMING EAC METHODS WITH ALL CONTRACTS INCLUDED
(88 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	CPI_{cum}	Composite
>50% to 75%	CPI_6	CPI_6
>75% to 100%	SPI_6	CPI_{cum}, Composite

The best performing EAC method with all contracts included in the analysis was the index-based method using the Composite Index ($0.2SPI_{cum}+0.8CPI_{cum}$). This result held for both the inflation adjusted data and the non-inflation adjusted data. The fact that this method was a top performer in the first quartile for the inflation adjusted data, and in the first, second, and fourth quartiles for the non-inflation adjusted data strengthens the significance of this overall result. The overall results were sensitive to stage of contract completion, although this sensitivity was less significant for the non-inflation adjusted data. The first and third quartile results were not sensitive to the effects of inflation; however, the second and fourth quartile results were.

TABLE 7

RESULTS FOR OVERALL PERFORMANCE

	Inflation Adjusted Data			Non-Inflation Adjusted Data		
EAC Method	Score*	MAPE	SDAPE	Score	MAPE	SDAPE
CPI_3	10	13.0%	19.3%	14	12.9%	19.3%
CPI_6	5	11.7%	14.4%	4	11.4%	14.6%
CPI_{cum}	4	11.6%	14.4%	6	11.6%	14.9%
SPI_3	16	15.2%	24.2%	17	14.7%	23.1%
SPI_6	7	13.0%	17.0%	8	12.5%	16.5%
SPI_{cum}	9	13.0%	19.0%	10	12.5%	17.7%
SCI_3	18	19.4%	92.3%	19	19.0%	94.9%
SCI_6	13	14.1%	19.7%	14	13.4%	18.9%
SCI_{cum}	13	13.6%	20.0%	12	12.9%	18.6%
$CPI_6 \times SPI_{cum}$	9	13.6%	18.0%	10	12.9%	17.1%
Composite	2	11.3%	14.0%	2	11.2%	14.5%
Rayleigh Least Squares	23	237.0%	>500%	21	206.6%	>500%
Rayleigh Three Group	23	300.8%	>500%	23	449.9%	>500%
Rayleigh MMAE	20	235.6%	494.7%	N/A	N/A	N/A
Beta	26	>500%	>500%	25	>500%	>500%

* Score calculated by rank ordering EAC methods by increasing value of MAPE and SDAPE and summing rankings. Method with lowest score is best performing method.

Table 7 has been included to allow a more detailed discussion and analysis of the overall results. In addition, the combined scores for the overall results are shown graphically in Figure 1. It can be seen from an examination of the MAPE and SDAPE values in Table 7, and of Figure 1, that the index-based EAC methods overall performed significantly better than any of the nonlinear regression-based methods. A comparison of the results for the inflation adjusted data highlights this point. The worst performing index-based method was the CPI_3 with a MAPE of 19.4 percent and an SDAPE of 92.3 percent. On the other hand, the best performing nonlinear regression-based method was the Rayleigh MMAE method with a MAPE of 235.6 percent and an SDAPE of 494.7 percent. A similar observation can be made for the non-inflation adjusted data. These results support the hypothesis that the complex nonlinear regression-based EAC methods do not perform better than the simple index-based methods, as stated in Chapter I.

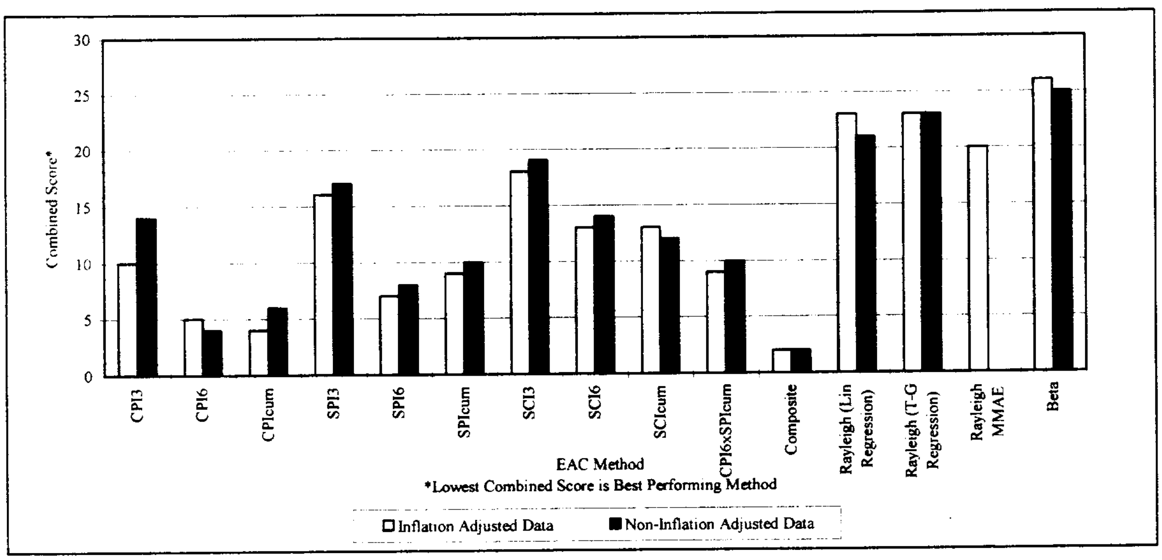

Figure 1. Relative Performance of EAC Methods

The modified version of the SCI ($CPI_6 \times SPI_{cum}$), while not the top performing method overall, did perform better than the index-based methods using CPI_3, SPI_3, SCI_3, SCI_6, and SCI_{cum}. For the remaining index-based methods two observations can be made. First, the index-based methods using the six month and cumulative indices performed better than the index-based methods using the three month indices. Second, the CPI and SPI-based methods generally outperformed the SCI with the exception of the SPI_3 which was outperformed by both the SCI_6 and SCI_{cum}. These observations hold for both the inflation adjusted and non-inflation adjusted data. Both of these trends are highlighted graphically in Figure 2.

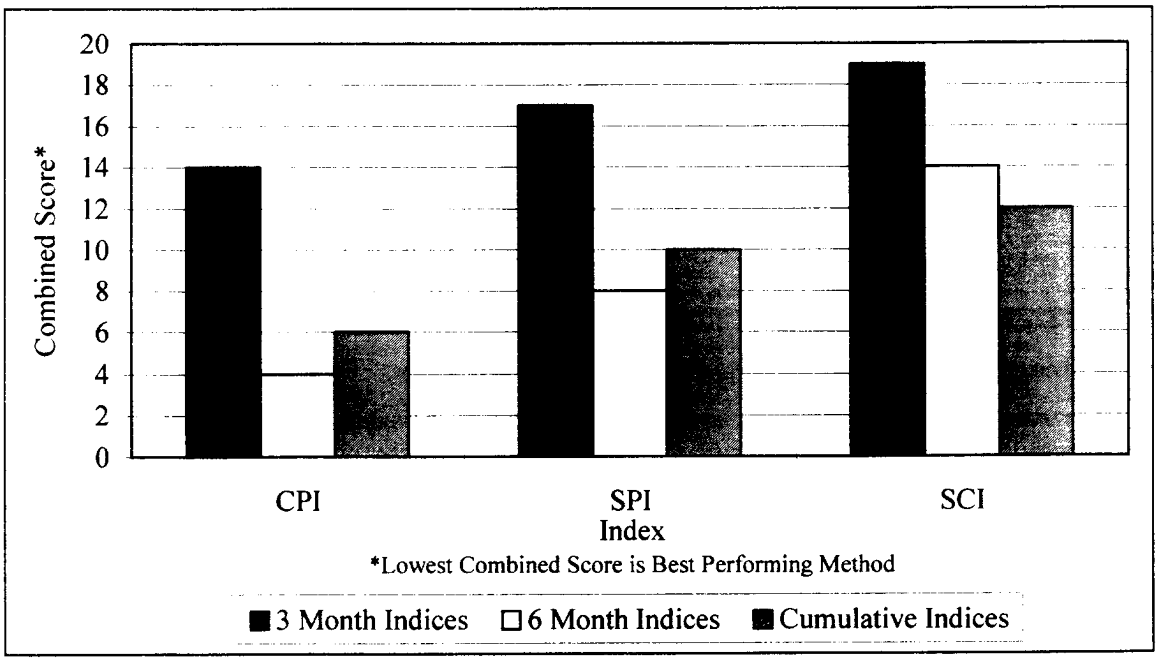

Figure 2. Comparison of Three Month, Six Month, and Cumulative Indices

With the exception of the Rayleigh three group linear regression method and the index-based method using CPI_{cum}, the non-inflation adjusted EACs were slightly more accurate (as measured by the MAPE) than those calculated using the inflation adjusted data. The methodology used to adjust the BAC for inflation may, however, have an effect on the accuracy of the inflation adjusted EACs and could be the cause of this effect. A comparison of the accuracy of the inflation adjusted data and the non-inflation adjusted data for the index-based EAC methods is shown graphically in Figure 3. The nonlinear regression-based EAC methods were not included in this figure because the large differential in MAPE values made the inclusion of these results on the same graph with the index-based EAC methods difficult. The difference in accuracy for the nonlinear regression-based EAC methods can be seen from an examination of the MAPE values in Table 7. While the use of non-inflation adjusted data produces slightly more accurate EACs overall, an analysis of the detailed results for the various data subsets included in Appendix H, shows that this observation does not always hold.

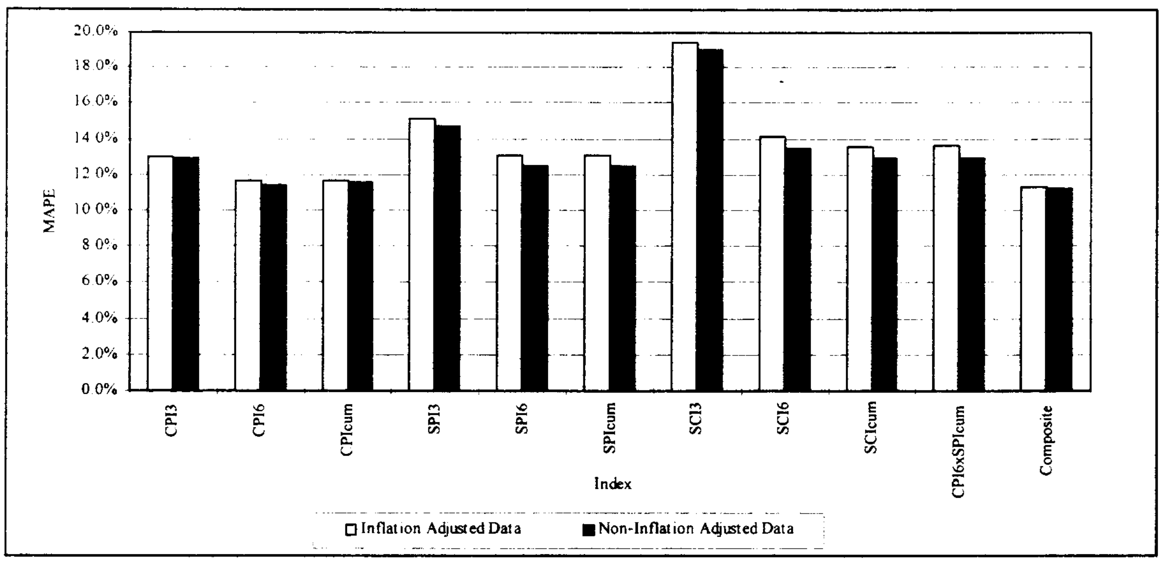

Figure 3. Comparison of Index-Based EAC Method Accuracy Using Inflation Adjusted Data and Non-Inflation Adjusted Data

The remainder of this chapter is devoted to presenting the results of the sensitivity analysis, followed by a comparison of the results of this study to previous comparative EAC studies and some concluding remarks.

Sensitivity of Results to Type of System

The best performing EAC methods for each of the nine System Types (Aircraft, Armored Vehicles, Ballistic Missiles, Electronic Warfare, Helicopter, Other Missiles, Satellites, Ships, and Torpedoes) are shown in Tables 8 through 16, and each table is followed by a brief discussion of the results. A review of these tables shows that the overall results were sensitive to the System Type.

TABLE 8

BEST PERFORMING EAC METHODS FOR AIRCRAFT CONTRACTS
(9 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	SPI_6	$CPI_6 \times SPI_{cum}$
0% to 25%	$CPI_6 \times SPI_{cum}$	$CPI_6 \times SPI_{cum}$
>25% to 50%	CPI_3, CPI_6, CPI_{cum}	CPI_3, CPI_6
>50% to 75%	CPI_{cum}, SCI_{cum}, Composite	SCI_{cum}
>75% to 100%	SPI_6	CPI_{cum}, SPI_6, Composite

Overall, the best performing method for the Aircraft Contracts depended on whether the data were adjusted for inflation. For the inflation adjusted data, the best performing EAC method was the index-based method using SPI_6. For the non-inflation adjusted data, the best performing method was the index-based method using $CPI_6 \times SPI_{cum}$. In general, these results were sensitive to both the stage of contract completion and the effects of inflation.

TABLE 9

BEST PERFORMING EAC METHODS FOR ARMORED VEHICLE CONTRACTS (2 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	$CPI_6 \times SPI_{cum}$	$CPI_6 \times SPI_{cum}$
0% to 25%	SPI_6	SPI_6
>25% to 50%	CPI_3, CPI_6, SCI_{cum}, $CPI_6 \times SPI_{cum}$	CPI_3, $CPI_6 \times SPI_{cum}$
>50% to 75%	CPI_3	CPI_3
>75% to 100%	SCI_3	SPI_3

Overall, the best performing method for the Armored Vehicle contracts was the index-based method using $CPI_6 \times SPI_{cum}$. This overall result was not sensitive to the effects of inflation. The results for the armored vehicle data were sensitive to stage of contract completion. Sensitivity of the results to the effects of inflation was dependent on stage of contract completion. Unfortunately the small number of contracts in this category limits the ability to generalize these results.

TABLE 10

BEST PERFORMING EAC METHODS FOR BALLISTIC MISSILE CONTRACTS
(18 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	CPI_3, CPI_6, SCI_6	CPI_6, SCI_6
>50% to 75%	CPI_3	CPI_3
>75% to 100%	SCI_3	SCI_3

Overall, the best performing method for the Ballistic Missile contracts was the index-based method using the Composite Index. This overall result was not sensitive to the effects of inflation. The results for the Ballistic Missile data were sensitive to stage of contract completion. Generally these results were not sensitive to the effects of inflation.

TABLE 11

BEST PERFORMING EAC METHODS FOR ELECTRONIC WARFARE SYSTEM CONTRACTS
(9 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	SPI_{cum}	SPI_{cum}
0% to 25%	SPI_{cum}	SPI_{cum}
>25% to 50%	SPI_{cum}	SPI_{cum}
>50% to 75%	CPI_6	CPI_6
>75% to 100%	SPI_3, SPI_{cum}	CPI_{cum}, Composite

Overall, the best performing method for the Electronic Warfare System contracts was the index-based method using SPI_{cum}. This overall result was not sensitive to the effects of inflation. Stage of contract completion only affected the results in the last two stages of contract completion. Only the result for the last stage of contract completion was sensitive to the effects of inflation.

TABLE 12

BEST PERFORMING EAC METHODS FOR HELICOPTER CONTRACTS
(16 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	Composite	SPI_{cum}
>50% to 75%	CPI_{cum}, Composite	CPI_{cum}, Composite
>75% to 100%	Beta	SPI_6, SPI_{cum}

Overall, the best performing method for the Helicopter contracts was the index-based method using the Composite Index. This overall result was not sensitive to the effects of inflation. The results were sensitive to stage of contract completion. In two of the four stages of contract completion the results were sensitive to the effects of inflation. In fact, in the final stage of contract completion using the inflation adjusted data, the nonlinear Beta curve method was the best performing method. Given the reasonably large sample size (16 contracts), this is a compelling result. Unfortunately, because the method only performs well during the final stage of contract completion its usefulness is limited. And, in fact, a review of the detailed Helicopter contract results in Appendix H indicates that it is the worst performing method during the first two stages of contract completion further limiting the usefulness of the method.

TABLE 13

BEST PERFORMING EAC METHODS FOR OTHER MISSILE CONTRACTS
(19 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	SPI_{cum}	SPI_{cum}
>25% to 50%	CPI_3	CPI_3
>50% to 75%	$CPI_6 \times SPI_{cum}$	CPI_6
>75% to 100%	SPI_6	CPI_{cum}

Overall, the best performing method for the Other Missile contracts was the index-based method using the Composite Index. This overall result was not sensitive to the effects of inflation. The results were sensitive to stage of contract completion. During the first half of the contracts the results were not sensitive to the effects of inflation.

TABLE 14

BEST PERFORMING EAC METHODS FOR SATELLITE CONTRACTS
(3 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	SPI_6, SPI_{cum}
0% to 25%	CPI_6, CPI_{cum}	SPI_6
>25% to 50%	CPI_{cum}	Composite
>50% to 75%	SCI_{cum}	SPI_{cum}
>75% to 100%	Beta	SPI_6

Overall, the best performing method for the Satellite contracts depended on the effects of inflation. For the inflation adjusted data, the best performing method was the index-based method using the Composite Index. For the non-inflation adjusted data, two methods were the top performers. They were the index-based methods using SPI_6 and SPI_{cum}. The results were sensitive to stage of contract completion, and to the effects of inflation. Once again the nonlinear Beta curve method was the best performing method in the final stage of contract completion for the inflation adjusted data. The ability to generalize these results is limited by the small number of contracts in this category.

TABLE 15

BEST PERFORMING EAC METHODS FOR SHIP CONTRACTS
(8 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	Composite	CPI_{cum}, Composite
>50% to 75%	CPI_6	CPI_6
>75% to 100%	SPI_6, SPI_{cum}, Composite	CPI_{cum}, Composite

Overall, the best performing method for the Ship contracts was the index-based method using the Composite Index. This result was not sensitive to the effects of inflation. In fact, the Composite Index was a top performer in all but one stage of contract completion, demonstrating limited sensitivity to both factors. The only time the Composite Index was not a top performer was in the third quartile for both the inflation adjusted and non-inflation adjusted data.

TABLE 16

BEST PERFORMING EAC METHODS FOR TORPEDO CONTRACTS
(4 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	CPI_6, CPI_{cum}, SPI_{cum}, Composite	CPI_6
0% to 25%	SPI_{cum}	SPI_{cum}
>25% to 50%	CPI_3, SPI_{cum}, SCI_{cum}	CPI_3, SCI_{cum}
>50% to 75%	CPI_3, CPI_{cum}, SCI_3	CPI_3, SCI_3, SCI_{cum}
>75% to 100%	SPI_6	SPI_6

Overall, the best performing method for the Torpedo contracts depended on the effects of inflation. The index-based method using CPI_6 performed well in both cases; however, three other index-based methods were also top performers using the inflation adjusted data. They were: CPI_{cum}; SPI_{cum}; and, the Composite index. Generally, the results for the Torpedo contracts were sensitive to the effects of inflation and stage of contract completion. The small number of contracts limits the ability to generalize these results.

Sensitivity of Results to Program Phase

The best performing EAC methods for each of the three categories of Program Phase (Development, Production, and Other) are shown in Tables 17 through 19. Each table is followed by a brief discussion of the results. A review of these tables shows that the overall results were sensitive to Program Phase.

TABLE 17

BEST PERFORMING EAC METHODS FOR DEVELOPMENT CONTRACTS
(24 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	SPI_6, SPI_{cum}	$CPI_6 \times SPI_{cum}$
0% to 25%	SPI_{cum}	SPI_{cum}
>25% to 50%	SPI_3	SCI_3
>50% to 75%	$CPI_6 \times SPI_{cum}$	$CPI_6 \times SPI_{cum}$
>75% to 100%	SPI_{cum}	CPI_{cum}, Composite

Overall, the best performing method for the Development contracts depended on the effects of inflation. For the inflation adjusted data, the two index-based methods using SPI_6, and SPI_{cum} were the top performing methods. For the non-inflation adjusted data, the index-based method using $CPI_6 \times SPI_{cum}$ was the top performer. The results were sensitive to stage of contract completion. However, the only results sensitive to the effects of inflation were the overall result and the result for fourth quartile.

TABLE 18

BEST PERFORMING EAC METHODS FOR PRODUCTION CONTRACTS
(53 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	CPI_6, Composite	Composite
>50% to 75%	CPI_6, CPI_{cum}, Composite	CPI_6, CPI_{cum}
>75% to 100%	CPI_{cum}	CPI_{cum}, Composite

Overall, the best performing method for the Production contracts was the index-based method using the Composite Index. This result was not sensitive to the effects of inflation. In fact, the Composite Index was a top performer in all but one stage of contract completion for the inflation adjusted data (the fourth quartile), and the non-inflation adjusted data (the third quartile), demonstrating limited sensitivity to both factors.

TABLE 19

BEST PERFORMING EAC METHODS FOR OTHER CONTRACTS
(11 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	CPI_6	SCI_{cum}, $CPI_6 \times SPI_{cum}$
0% to 25%	SCI_6	SCI_6
>25% to 50%	CPI_6, CPI_{cum}, SCI_{cum}	CPI_6, CPI_{cum}, SCI_{cum}
>50% to 75%	CPI_3	CPI_{cum}
>75% to 100%	Beta	Beta

Overall, the best performing method for the Other contracts depended on the effects of inflation. For the inflation adjusted data, the index-based method using CPI_6, was the top performing method. For the non-inflation adjusted data, the index-based methods using SCI_{cum} and $CPI_6 \times SPI_{cum}$ were the top performers. The results were sensitive to stage of contract completion. The quartile results were generally not sensitive to the effects of inflation except in the third quartile. Again, the Beta method was the best performing method in the fourth quartile. In this case, it was the best performing method for both the inflation adjusted and the non-inflation adjusted data. As in the other cases, a review of the detailed results in Appendix H indicates that this method was a poor performer in the early stages of contract completion, limiting its usefulness.

Sensitivity of Results to Contract Type

The best performing EAC methods for each of the three categories of Contract Type (Cost Plus, Fixed Price, and Mixed) are shown in Tables 20 through 22. Each table is followed by a brief discussion of the results. A review of these tables shows that the overall results were sensitive to Contract Type.

TABLE 20

BEST PERFORMING EAC METHODS FOR COST PLUS CONTRACTS
(21 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	SPI_6	$CPI_6 \times SPI_{cum}$
0% to 25%	$CPI_6 \times SPI_{cum}$	SPI_{cum}, SCI_6, $CPI_6 \times SPI_{cum}$
>25% to 50%	SPI_{cum}	SPI_{cum}, $CPI_6 \times SPI_{cum}$
>50% to 75%	SCI_{cum}	SCI_{cum}
>75% to 100%	SPI_3	CPI_{cum}

Overall, the best performing method for the Cost Plus contracts depended on the effects of inflation. For the inflation adjusted data, the index-based method using SPI_6, was the top performing method. For the non-inflation adjusted data, the index-based method using $CPI_6 \times SPI_{cum}$ was the top performer. The results were sensitive to stage of contract completion and the effects of inflation except the third quartile result.

TABLE 21

BEST PERFORMING EAC METHODS FOR FIXED PRICE CONTRACTS
(66 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	CPI_3, CPI_6	CPI_6
>50% to 75%	CPI_6	CPI_6
>75% to 100%	CPI_{cum}, Composite	CPI_{cum}, Composite

Overall, the best performing method for the Fixed Price contracts was the index-based method using the Composite Index. This result was not sensitive to the effects of inflation. The results were sensitive to stage of contract completion; however, they generally were not sensitive to the effects of inflation except for the addition of the index-based method using CPI_3 to the third quartile result for the inflation adjusted data.

TABLE 22

BEST PERFORMING EAC METHODS FOR MIXED TYPE CONTRACTS
(1 CONTRACT)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	SPI_3	SPI_6, SPI_{cum}
0% to 25%	SPI_3, SPI_{cum}	SPI_{cum}
>25% to 50%	$CPI_6 \times SPI_{cum}$	$CPI_6 \times SPI_{cum}$
>50% to 75%	Rayleigh Linear Regression	SPI_3
>75% to 100%	SCI_6	SCI_6

Overall, the best performing method for the single Mixed Type contract depended on the effects of inflation. For the inflation adjusted data the best performing method was the index-based method using SPI_3. For the non-inflation adjusted data, the best performing methods were the index-based methods using SPI_6 and SPI_{cum}. The results were sensitive to stage of contract completion and to the effects of inflation except in the second and fourth quartiles. It is interesting to note that in the third quartile for the inflation adjusted data the Rayliegh Linear Regression technique is the best performing method. However, a review of the detailed results in Appendix H shows that it is a poor performer in all of the remaining quartiles and overall. Because there was only one contract in this category, the ability to generalize these results is severely limited.

Sensitivity of Results to DoD Service Component

The best performing EAC methods for each of the three categories of DoD service component (Army, Air Force, and Navy) are shown in Tables 23 through 25. Each table is followed by a brief discussion of the results. A review of these tables shows that the overall results were sensitive to DoD Service Component.

TABLE 23

BEST PERFORMING EAC METHODS FOR ARMY CONTRACTS
(30 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	CPI_6, Composite	CPI_6
>50% to 75%	CPI_6	CPI_6
>75% to 100%	SPI_{cum}, Composite	CPI_{cum}, SPI_6, Composite

Overall, the best performing method for the Army contracts was the index-based method using the Composite Index. This result was not sensitive to the effects of inflation. The results were sensitive to stage of contract completion. The quartile results were sensitive to the effects of inflation except in the first and third quartiles.

TABLE 24

BEST PERFORMING EAC METHODS FOR AIR FORCE CONTRACTS
(36 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	Composite	Composite
0% to 25%	Composite	Composite
>25% to 50%	CPI_3, CPI_6	CPI_6
>50% to 75%	CPI_3, CPI_6	CPI_6
>75% to 100%	SPI_3	CPI_{cum}

Overall, the best performing method for the Air Force contracts was the index-based method using the Composite Index. This result was not sensitive to the effects of inflation. The results were sensitive to stage of contract completion. The quartile results were sensitive to the effects of inflation except in the first quartile.

TABLE 25

BEST PERFORMING EAC METHODS FOR NAVY CONTRACTS
(22 CONTRACTS)

Contract Completion Stage	Inflation Adjusted Data	Non-Inflation Adjusted Data
Overall	CPI_6, Composite	CPI_6
0% to 25%	Composite	CPI_6
>25% to 50%	CPI_3, CPI_6	CPI_6, CPI_{cum}, SPI_{cum}, SCI_{cum}, Composite
>50% to 75%	CPI_{cum}	CPI_{cum}
>75% to 100%	SPI_6	SPI_{cum}, Composite

Overall, the best performing method for the Navy contracts depended on the effects of inflation. For the inflation adjusted data, the index-based methods using CPI_6 and the Composite Index were the top performing methods. For the non-inflation adjusted data, the index-based method using CPI_6 was the top performing method. The results were sensitive to stage of contract completion. Only the quartile result for the third quartile was not sensitive to the effects of inflation.

Comparison of Results to Previous Research

The comparison of the results of this study to the results of previous comparative EAC research is difficult because the diversity of the data included in this study is much greater than was used in the studies that were reviewed. There are, however, two sets of results from the sensitivity analyses that are comparable to two of the previous studies.

First, the sensitivity results for all Navy contracts can be compared to the results of the Covach, *et al.* study (1981). Recall from Chapter II that the study, using data from six Navy contracts (five Development and one Production), found the index-based methods using CPI_6 and $\overline{CPI}_{12}$ to be the best performing methods overall (Covach, *et al.*, 1981). The index-based method using $\overline{CPI}_{12}$ was not tested in this study. However, the method using CPI_6 was tested, and found to be the best performing method overall for the 22 Navy contracts analyzed in this study, which is supported by the results from the Covach, *et al.* study. This comparison was made using the results from the non-inflation adjusted data because adjustment for inflation was not done in the Covach *et al.* study. A comparison of the quartile results was not possible due to the differing stages of contract completion used in the two studies.

The second case where a comparison was possible was the Land and Preston study (1980). Recall from Chapter II that the study, using data from 20 Air Force aircraft programs, found the index-based method using CPI_{cum} to be the best performing method overall (Land and Preston, 1980). Because the sensitivity results for aircraft contracts in this study included contracts from all three DoD Service Components, it was concluded that the results would not be comparable. A comparison to the sensitivity results from the overall Air Force contracts seemed more appropriate. In this study, the best performing method for the overall Air Force contracts was the index-based method using the Composite Index. This method was not, however, tested by Land and Preston. On the other hand, if the index-based method using the Composite Index was excluded from the results of this study, the top performing method would be the index-based method using CPI_6, which is supported by the results of Land and Preston's research. Because Land and Preston did not analyze their results based on stage of contract completion, a comparison of the quartile results was not possible.

A comparison to the remaining comparative EAC studies was concluded to be meaningless. First, Heydinger only used data from a single Air Force Development contract making the results from that study relatively insignificant (1977). Second, the Bright and Howard study only used data from 11 Army R&D contracts (1981). Because the data in this study were only analyzed using a category which included all Army contracts, and did not analyze the data by program phase, a comparison was concluded to be inappropriate. The final study by Reidel and Chance, which included data from 64 Air Force contracts, only presented quartile and overall results based on system type (Aircraft, Avionics, and Engines) and program phase (Development and Production), no overall result for all contracts was included in the study (1989). Because the results in this study were only categorized at the overall Air Force level, a comparison was concluded to be inappropriate.

Summary

With the exception of the Beta method in three cases, and the Rayleigh Linear Regression Method in one case, the index-based methods were always the top performing methods. Other than the exceptions noted the results for the nonlinear regression based methods were significantly worse than the results for the index-based methods. The original hypothesis that the complex nonlinear regression-based EAC methods do not perform better than the simple index-based EAC methods was supported by the results of this study.

While no single index-based method was always the top performer after the data were broken down for sensitivity analysis, the overall and early quartile performance of the method using the Composite Index, for all contracts and in a number of the sensitivity analyses, is notable. Generally, however, the stage of contract completion, system type, program phase, contract type, DoD service component, and inflation effects play a major role in determining which EAC method is the top performer. Based on the results of this study, it is clear that all of these factors should be considered when selecting an EAC method for a particular program.

Chapter V. Conclusions and Recommendations

The purpose of this study was to determine if the complex nonlinear regression-based EAC methods performed better than the simpler index-based EAC methods. This chapter summarizes the research conducted in this study by first reviewing the hypothesis. Next the analysis methods and results are reviewed. Finally, the chapter concludes with a discussion of the findings and recommendations for further research.

Review of Hypothesis

The primary hypothesis tested in this research, as stated in Chapter I, was:

> EACs calculated using complex nonlinear regression-based methods are not more accurate or stable than EACs calculated using simple index-based methods.

In addition to testing this hypothesis, the study also investigated the sensitivity of the results to such moderator variables as stage of contract completion, system type, program phase, contract type, DoD service component, and inflation effects.

Review of Analysis Methodology and Results

This hypothesis was tested using a sample of 88 contracts extracted from the DAES database. These contracts were assumed to be a representative sample of defense contracts from all three DOD service components. The original database included over 541 contracts; however, the data needed to be screened to eliminate contracts with insufficient or problematic data. One of the major requirements was the need for an objective measure of the CAC for each contract. This was required as a comparison point to evaluate the performance of the EAC methods. The $ACWP_{cum}$ as of the final cost report was chosen as the most representative measure of a contract's CAC, and any contracts without data beyond the 90 percent completion point were eliminated from the analysis. In addition, contracts without data prior to the 10 percent completion point, contracts without a definitive start date, and contracts with an unstable baseline (i.e., contracts that went OTB) were eliminated from the analysis. Because only contracts with a stable baseline were included in the analysis, it is important to note that the results of this study are only applicable to future contracts with a stable baseline.

Fifteen different EAC methods were tested in this study, including 11 index-based methods (CPI_3, CPI_6, CPI_{cum}, SPI_3, SPI_6, SPI_{cum}, SCI_3, SCI_6, SCI_{cum}, $CPI_6 \times SPI_{cum}$, and $0.2SPI_{cum}+0.8CPI_{cum}$) and four nonlinear regression-based methods (Rayleigh Least Squares Linear Regression, Rayleigh Three Group Linear Regression, Rayleigh MMAE, and Beta).

The performance of each method was rated against two criteria, the accuracy and stability of the EACs calculated with the method. The MAPE [Equation (28)] was used as the measure of accuracy, and the SDAPE [Equation (29)] was used as the measure of stability. Because the performance of the methods was rated against two criteria, it was necessary to develop a combined measure of performance. This was done by separately ranking the methods according to increasing values of the MAPE and SDAPE and then summing the individual rankings to arrive at the combined score for each method. The method with the lowest score was classed as the best performing method.

The first step in comparing the performance of the EAC methods was to calculate an EAC for every method using the cost data from each reporting period on all 88 contracts. Next, the MAPE, SDAPE, and combined score were calculated for each EAC method using the complete set of data to determine the best performing method overall. Then, the data were divided into subsets according to four stages (quartiles) of contract completion (0% to 25% complete, >25% to 50% complete, >50% to 75% complete, and >75% to 100% complete) and the MAPE values, SDAPE values, and combined scores for each method were calculated within each of these data subsets. This was done to test for the sensitivity of the overall results to stage of contract completion.

The overall results were also tested for sensitivity to system type (Aircraft, Armored Vehicle, Ballistic Missile, Electronic Warfare, Helicopter, Other Missile, Satellite, Ship, and Torpedo), program phase (Development, Production, Other), contract type (Cost Plus, Fixed Price, Mixed Type), and DoD service component (Army, Air Force, and Navy). To do this, the data were divided into the appropriate subsets and the MAPE values, SDAPE values, and combined scores for each EAC method were calculated within each of these data subsets. The results for each of these categories, were also tested for sensitivity to stage of contract completion. The final stage of analysis was testing for sensitivity to the effects of inflation. To do this, the complete analysis was first done using non-inflation adjusted data (TY$), and then repeated using data which was adjusted to CY95$.

Overall the hypothesis was supported by the results. The index-based methods performed significantly better than the nonlinear regression-based methods at the overall level, and within each of the data subsets used in the sensitivity analysis. There were only four cases where a nonlinear regression-based method was found to be the top performer. The four cases were: 1) the Beta method using inflation adjusted data for the Helicopter contracts in the fourth quartile; 2) the Beta method using inflation adjusted data for the Satellite contracts in the fourth quartile; 3) the Beta method using both inflation adjusted and non-inflation adjusted data for the Other phase contracts in the fourth quartile; and, 4) the Rayleigh Least Squares Linear Regression method using inflation adjusted data in the third quartile. Unfortunately, in each of these cases the methods were poor performers during the earlier stages of contract completion which limits their usefulness as management tools.

Overall, the best performing EAC method was found to be the index-based method using the Composite Index ($0.2SPI_{cum}+0.8CPI_{cum}$). This result held for both the inflation adjusted data and the non-inflation adjusted data. This method was also a top performer in the first quartile for the inflation adjusted data, and the first, second, and fourth quartiles for the non-inflation adjusted data. It is important to note, however, that the top performing method was sensitive to all of the moderator variables that were investigated in the sensitivity analysis and no single EAC method was always the top performer.

Discussion of Findings

The results of this study are significant in three ways. First, they support the continued use of the index-based EAC methods by DoD managers and cost analysts. Because they are easy to use, the index-based EAC methods will likely continue to be the most popular methods until newer methods are developed that can demonstrate better performance levels.

Second, the results of this study support the results of previous studies with regards to the sensitivity of results to such factors as stage of contract completion, system type, program phase, contract type, DoD service component, and inflation effects. Given the sensitivity of the results to these factors, no single EAC method should be relied on in every situation. While the results of this study can serve as a guide for the program manager or cost analyst selecting an EAC method for their program, the practice of using multiple methods to calculate a range of EACs cannot be ignored.

Third, although the nonlinear regression-based EAC methods were not found to be more accurate than the index-based methods, the results of this study still provide insight into the relative accuracy of the EAC methods that were tested. The detailed results provided in Appendix H provide a useful tool which can be used by program managers and cost analysts to assess the potential accuracy of a particular EAC method given their particular situation.

Recommendations

This study has demonstrated the superiority of the index-based EAC methods over several of the newer nonlinear regression-based methods. While this is significant, the overall accuracy of the index-based methods during the early stages of contract completion is still relatively poor. Research is still needed to find EAC methods which can accurately predict the CAC early in a program's life at a point where changes can be made and actions taken to correct problems and prevent costly overruns.

Finally, as new EAC methods are developed, there will be a continuing need for comparative studies such as this one, to evaluate the performance of the new methods relative to the popular index-based methods. These, future studies will be able to take advantage of updated versions of the DAES database and will likely be able to include a much larger sample of contracts than was analyzed in this study, thereby increasing the significance of the results.

Appendix A: Cost/Schedule Control Systems Definitions

This Appendix presents the official definitions of C/SCS terms which were extracted from DoDI 5000.2. Although some of the terms presented here are not used in the body of this thesis, many of the terms are used to define other terms. Therefore, all of the terms from 5000.2 have been included in this Appendix.

1. Actual Cost of Work Performed (ACWP). The cost incurred and recorded in accomplishing the work performed within a given time period.

2. Actual Direct Costs. Those costs identified specifically with a contract, based upon the contractor's cost identification and accumulation system as accepted by the cognizant Defense Contract Audit Agency representatives. (See definition 14 below.)

3. Allocated Budget. (See definition 32, below.)

4. Applied Direct Cost. The amount recognized in the time period associated with the consumption of labor, material, and other direct resources, without regard to the date of commitment or the date of payment. These amounts are to be charged to work-in-progress in the time period that any one of the following occurs:

   a. When labor, material, and other direct resources are actually consumed.

   b. When material resources are withdrawn from inventory for use.

   c. When material resources are received that are identified uniquely to the contract and scheduled for use within 60 days.

   d. When major components or assemblies are received on a line flow basis that are identified specifically and uniquely to a single serially numbered end item.

5. Apportioned Effort. Effort that is not readily divisible into work packages, but is related proportionally to measured effort.

6. Authorized Work. Effort that has been definitized and is on contract, plus that for which definitized contract costs have not been agreed to, but for which written authorization has been received.

7. Baseline. (See definition 24, below.)

8. Budgeted Cost of Work Performed (BCWP). The sum of the budgets for completed work packages and completed portions of open work packages, plus the applicable portion of the budgets for level of effort and apportioned effort.

9. Budgeted Cost of Work Scheduled (BCWS). The sum of budgets for all work packages, planning packages, etc., scheduled to be accomplished (including in-process work packages), plus the amount of level-of-effort and apportioned effort scheduled to be accomplished within a given time period.

10. Budgets for Work Packages. (See definition 36, below.)

11. Contract Budget Base. The negotiated contract cost plus the estimated cost of authorized unpriced work.

12. Contractor. An entity in private industry which enters into contracts with the Government. In this Instruction, the word also may apply to Government-owned, Government-operated activities that perform work on defense programs.

13. Cost Account. A management control point at which actual costs may be accumulated and compared to the budgeted cost of the work performed. A cost account is a natural control point for cost/schedule planning and control, since it represents the work assigned to one responsible organizational element on one contract work breakdown structure element.

14. Direct Costs. Any costs that may be identified specifically with a particular final cost objective. This term is explained in the Federal Acquisition Regulation.

15. Estimate at Completion (EAC). Actual direct costs, plus indirect costs allocable to the contract, plus estimate of costs (direct and indirect) for authorized work remaining.

16. Indirect Costs. Costs, which because of their incurrence for common or joint objectives, are not subject readily to treatment as direct costs. This term is further defined in the Federal Acquisition Regulation.

17. Initial Budget. (See definition 22, below.)

18. Internal Replanning. Replanning actions performed by the contractor for remaining effort within the recognized total allocated budget.

19. Level-of-Effort (LOE). Effort of a general or supportive nature that does not produce definite end products.

20. Management Reserve or Management Reserve Budget. An amount of the total allocated budget withheld for management control purposes, rather than designated for the accomplishment of a specific task or set of tasks. It is not a part of the performance measurement baseline.

21. Negotiated Contract Cost. The estimated cost negotiated in a cost plus fixed fee contract, or the negotiated contract target cost in either a fixed price incentive contract or a cost plus incentive fee contract.

22. Original Budget. The budget established at, or near, the time that the contract was signed and based on the negotiated contract cost.

23. Overhead. (See definition 16, above.)

24. Performance Measurement Baseline. The time phased budget plan against which contract performance is measured. It is formed by the budgets assigned to scheduled cost accounts and the applicable indirect budgets. For future effort, not planned to the cost account level, the performance measurement baseline also includes budgets assigned to higher level contract work breakdown structure elements and undistributed budgets. It equals the total allocated budget less management reserve.

25. Performing Organization. A defined unit within the contractor's organizational structure, which applies the resources to perform the work.

26. Planning Package. A logical aggregation of far term work within a cost account which may be identified and budgeted in early baseline planning, but is not yet defined into work packages.

27. Procuring Activity. The subordinate command in which the Procurement Contracting Officer is located. It may include the program office, related functional support offices, and procurement offices. Examples of procuring activities are the Army Missile Command, Naval Sea Systems Command, and Air Force Electronic Systems Division.

28. Replanning. (See definition 18, above.)

29. Reprogramming. Replanning of the effort remaining in the contract, resulting in a new budget allocation that exceeds the contract budget base.

30. Responsible Organization. A defined unit within the contractor's organizational structure that is assigned responsibility for accomplishing specific tasks.

31. Significant Variances. Those differences between planned and actual performance requiring further review, analysis, or action. Thresholds should be established as to the magnitude of variances that will require variance analysis, and the thresholds should be revised as needed to provide meaningful analysis during execution of the contract.

32. Total Allocated Budget. The sum of all budgets allocated to the contract. Total allocated budget consists of the performance measurement baseline and all management reserve. The total allocated budget will reconcile directly to the contract budget base. Any differences will be documented as to quantity and cause.

33. Undistributed Budget. Budget applicable to contract effort that has not yet been identified to contract work breakdown structure elements at, or below, the lowest level of reporting to the Government.

34. Variances. (See definition 31, above.)

35. Work Breakdown Structure (WBS). (See Section 6-B.)

36. Work Package Budgets. Resources that are assigned formally by the contractor to accomplish a work package, expressed in dollars, hours, standards, or other definitive units.

37. Work Packages. Detailed tasks or material items identified by the contractor for accomplishing work required to complete the contract. A work package has the following characteristics:

a. It represents unit of work at levels where work is performed.

b. It is clearly distinguishable from all other work packages.

c. It is assignable to a single organizational element.

d. It has scheduled start and completion dates and, as applicable, interim milestones; all of which are representative of physical accomplishment.

e. It has a budget or assigned value expressed in terms of dollars, manhours, or other measurable units.

f. Its duration is limited to a relatively short time span or it is subdivided by discrete value milestones to ease the objective measurement of work performed.

g. It is integrated with detailed engineering, manufacturing, or other schedules. (Department of Defense, 1991:11-B-2-1 - 11-B-2-4)

Appendix B: List of Contracts Used in Analysis

Program Name: A-10 (THUNDERBOLT II)
PNO: 102
System Type: Aircraft
DoD Service Component: Air Force

PD: Airframe (Options 3-6)
CNO: 1
Program Phase: Other
Contract Type: FPI

Program Name: EF-111A (TJS)
PNO: 104
System Type: Electronic Warfare
DoD Service Component: Air Force

PD: Tactical Jamming System
CNO: 1
Program Phase: Development
Contract Type: CP

PD: Production
CNO: 2
Program Phase: Production
Contract Type: FPI

Program Name: PATRIOT Surface-to-Air Missile System
PNO: 106
System Type: Other Missile
DoD Service Component: Army

PD: FY85 Missile Prod
CNO: 2
Program Phase: Production
Contract Type: FPI

PD: Init Prod Fac (Buy 7)
CNO: 3
Program Phase: Production
Contract Type: CPIF

PD: FY86 Missile Prod
CNO: 4
Program Phase: Production
Contract Type: FPI

PD: FY83 Eng Services
CNO: 92
Program Phase: Other
Contract Type: CP

PD: FY81 Missile Prod
CNO: 94
Program Phase: Production
Contract Type: CP

Program Name: PERSHING II Field Artillery Missile System
PNO: 107
System Type: Other Missile
DoD Service Component: Army

PD: MSL & GSE Development
CNO: 1
Program Phase: Development
Contract Type: CP

PD: MSL & GSE Production
CNO: 2
Program Phase: Production
Contract Type: CP

Program Name: ALCM (Air-Launched Cruise Missile) (AGM-86B)
PNO: 111
System Type: Other Missile
DoD Service Component: Navy

PD: FY81 Prod Air Vehicle
CNO: 54
Program Phase: Production
Contract Type: FPI

Program Name: CH-47D (CHINOOK Helicopter Modernization Program)
PNO: 115
System Type: Helicopter

DoD Service Component: Army

PD: FY82 Medium Lift Heli
CNO: 95
Program Phase: Other
Contract Type: CP

PD: FY81 Medium Lift Heli
CNO: 96
Program Phase: Other
Contract Type: FPI

PD: IPF/LLT
CNO: 97
Program Phase: Other
Contract Type: FPI

PD: PEP
CNO: 98
Program Phase: Other
Contract Type: CP

Program Name: C/MH-53E Super Stallion Helicopter
PNO: 116
System Type: Helicopter
DoD Service Component: Navy

PD: FY78 Buy 6 A/C
CNO: 98
Program Phase: Production
Contract Type: FPI

Program Name: DSCS III (Defense Satellite Communication System) SHF Space Segment
PNO: 120
System Type: Satellite
DoD Service Component: Air Force

PD: IABS Development
CNO: 2
Program Phase: Development
Contract Type: FPIF

Program Name: F-14D TOMCAT All-Weather, Carrier-Based Air-Superiority Fighter

PNO: 123
System Type: Aircraft
DoD Service Component: Navy

PD: Airframe Production
CNO: 96
Program Phase: Production
Contract Type: FFP

Program Name: F-15 EAGLE Air-Superiority/Dual-Role Fighter
PNO: 124
DoD Service Component: Air Force

PD: ALQ-135 Update Lot III
CNO: 8
System Type: Electronic Warfare
Program Phase: Production
Contract Type: FPIF

PD: Engine (Lot VIII)
CNO: 91
System Type: Aircraft
Program Phase: Production
Contract Type: FPI

PD: Airframe Development
CNO: 93
System Type: Aircraft
Program Phase: Development
Contract Type: CP

PD: FY77 Prod & Support
CNO: 95
System Type: Aircraft
Program Phase: Production
Contract Type: FPIF

Program Name: F-16 FIGHTING FALCON Multi-Mission Fighter (Includes F-16 Derivatives)
PNO: 125

PD: ASPJ Lot I Production
CNO: 24
System Type: Electronic Warfare

Program Phase: Production
Contract Type: FPIF
DoD Service Component: Navy

PD: Engine (Lot VIII)
CNO: 88
System Type: Aircraft
Program Phase: Production
Contract Type: FPI
DoD Service Component: Air Force

PD: FY80 - 175 A/C
CNO: 90
System Type: Aircraft
Program Phase: Production
Contract Type: FPI
DoD Service Component: Air Force

PD: Airframe Development
CNO: 96
System Type: Aircraft
Program Phase: Development
Contract Type: FPI
DoD Service Component: Air Force

Program Name: FFG-7 PERRY Class Frigate
PNO: 127
System Type: Ship
DoD Service Component: Navy

PD: FY79 Buy (3 Ships)
CNO: 81
Program Phase: Production
Contract Type: FPI

PD: Three Ships
CNO: 91
Program Phase: Production
Contract Type: FPI

Program Name: BRADLEY FVS (Fighting Vehicle System - M2/M3)
PNO: 128
System Type: Armored Vehicle
DoD Service Component: Army

PD: 25MM Gun Option 1
CNO: 88
Program Phase: Other
Contract Type: FPI

Program Name: MLRS (Multiple-Launch Rocket System)
PNO: 130
System Type: Other Missile
DoD Service Component: Army

PD: FY81 LRP Buy II A/V
CNO: 91
Program Phase: Production
Contract Type: FPI

PD: Maturation R&D
CNO: 97
Program Phase: Development
Contract Type: CP

Program Name: SH-60B SEAHAWK LAMPS MK III (Light Airborne Multi-Purpose System)
PNO: 134
System Type: Helicopter
DoD Service Component: Navy

PD: Engine Development
CNO: 94
Program Phase: Development
Contract Type: CP

PD: Airframe Development
CNO: 95
Program Phase: Development
Contract Type: CP

Program Name: MAVERICK Close Air Support Weapon System (IIR) (AGM-65D/F/G)
PNO: 137
System Type: Other Missile
DoD Service Component: Air Force

PD: Raytheon Production
CNO: 1

Program Phase: Production
Contract Type: FPIF

PD: Missile Development
CNO: 99
Program Phase: Development
Contract Type: FPIF

Program Name: MK-48 Advanced Capability (ADCAP) Torpedo
PNO: 138
System Type: Torpedo
DoD Service Component: Navy

PD: L3 Test Equipment
CNO: 5
Program Phase: Production
Contract Type: FPI

Program Name: SIDEWINDER AIM-9L, NV
PNO: 144
System Type: Other Missile
DoD Service Component: Navy

PD: Guidance Development
CNO: 97
Program Phase: Development
Contract Type: CP

Program Name: STINGER Man-Portable Surface-to-Air Missile (FIM-92A/B)
PNO: 150
System Type: Other Missile
DoD Service Component: Army

PD: STINGER RMP RDT&E
CNO: 92
Program Phase: Development
Contract Type: FPI

PD: FY82 Prod
CNO: 94
Program Phase: Production
Contract Type: FPI

Program Name: UH-60A BLACKHAWK Helicopter

PNO: 156
System Type: Helicopter
DoD Service Component: Army

PD: 4th Year Production
CNO: 85
Program Phase: Production
Contract Type: FPI

PD: Third YR Airframe Prod
CNO: 86
Program Phase: Production
Contract Type: FPI

PD: Second YR Airframe Prod
CNO: 87
Program Phase: Production
Contract Type: FPI

PD: FSD-Maturity
CNO: 90
Program Phase: Development
Contract Type: CP

PD: Engine Production
CNO: 94
Program Phase: Production
Contract Type: FPI

PD: First Year Airframe Prod
CNO: 95
Program Phase: Production
Contract Type: FPI

PD: Engine Development
CNO: 98
Program Phase: Development
Contract Type: CP

Program Name: M1/M1A1 ABRAMS Tank (w/120mm Gun)
PNO: 157
System Type: Armored Vehicle
DoD Service Component: Army

PD: Tank Development
CNO: 87
Program Phase: Development
Contract Type: CP

Program Name: AH-64A APACHE (Advanced Attack Helicopter)
PNO: 158
System Type: Helicopter
DoD Service Component: Army

PD: TADS/PNVS Lot III
CNO: 86
Program Phase: Production
Contract Type: FPIF

PD: Engine Development
CNO: 98
Program Phase: Development
Contract Type: CP

Program Name: CG-47 (TICONDEROGA Class AEGIS Guided Missile Cruiser)
PNO: 159
System Type: Ship
DoD Service Component: Navy

PD: CG 66/8 Construction
CNO: 5
Program Phase: Production
Contract Type: FPI

PD: CG 67 Construction
CNO: 6
Program Phase: Production
Contract Type: FPI

Program Name: NAVSTAR GPS/UE (Global Positioning System/User Equipment)
PNO: 166
System Type: Satellite
DoD Service Component: Air Force

PD: User Equipment
CNO: 95
Program Phase: Other
Contract Type: FPI

Program Name: B-1B Strategic Bomber
PNO: 168
DoD Service Component: Air Force:

PD: Offensive Avionics Lot 2
CNO: 2
System Type: Electronic Warfare
Program Phase: Production
Contract Type: FPIF

PD: Offensive Avionics Lot 5
CNO: 3
System Type: Electronic Warfare
Program Phase: Production
Contract Type: FPIF

PD: Defensive Avionics Lot 2
CNO: 93
System Type: Electronic Warfare
Program Phase: Production
Contract Type: FPIF

PD: Offensive Avionics Lot 1
CNO: 99
System Type: Electronic Warfare
Program Phase: Production
Contract Type: FPIF

Program Name: TRIDENT II D5 SLBM (Sea Launched Ballistic Missile) (UGM-133A)
PNO: 178
System Type: Ballistic Missile
DoD Service Component: Navy

PD: Guidance System Dev
CNO: 4
Program Phase: Development
Contract Type: CPFF

PD: Launcher Oper System
CNO: 11
Program Phase: Other
Contract Type: CPIF/FF

Program Name: MK-50 Advanced Lightweight Torpedo (ALWT)

PNO: 192
System Type: Torpedo
DoD Service Component: Navy

PD: MK 50 FSED
CNO: 2
Program Phase: Development
Contract Type: CPAF/FF

PD: MK 50 Torpedo LRIP I
CNO: 3
Program Phase: Production
Contract Type: FPI

PD: MK 50 Torpedo LRIP II
CNO: 5
Program Phase: Production
Contract Type: FPI

Program Name: ATACMS (Army Tactical Missile System)
PNO: 211
System Type: Other Missile
DoD Service Component: Army

PD: FSD LCHR & GSE Integ
CNO: 2
Program Phase: Development
Contract Type: FPIF

Program Name: V-22 OSPREY Joint Advanced Vertical Lift Aircraft
PNO: 212
System Type: Aircraft
DoD Service Component: Navy

PD: Prelim Design Stage I
CNO: 99
Program Phase: Development
Contract Type: CP

Program Name: LCAC (Landing Craft, Air Cushion)
PNO: 216
System Type: Ship
DoD Service Component: Navy

PD: LCAC 24-33 Construction
CNO: 3
Program Phase: Production
Contract Type: FPI

PD: LCAC 15-23 Construction
CNO: 4
Program Phase: Production
Contract Type: FPI

PD: LCAC 37-48 Construction
CNO: 5
Program Phase: Production
Contract Type: FPI

PD: LCAC 34-36 Construction
CNO: 6
Program Phase: Production
Contract Type: FPI

Program Name: PEACEKEEPER ICBM (Intercontinental Ballistic Missile) (MX; LGM-118A)
PNO: 225
System Type: Ballistic Missile
DoD Service Component: Air Force

PD: Assembly & Checkout A&C
CNO: 10
Program Phase: Production
Contract Type: FPIF

PD: Inertial Meas Unit FY84
CNO: 12
Program Phase: Production
Contract Type: FPIF

PD: Stage II, FY85
CNO: 16
Program Phase: Production
Contract Type: FPIF

PD: Stage IV, FY85
CNO: 19
Program Phase: Production

Contract Type: FPIF

PD: Stage III, FY85
CNO: 22
Program Phase: Production
Contract Type: FPIF

PD: Guidance & Control, FY85
CNO: 25
Program Phase: Production
Contract Type: FPIF

PD: Reentry System, FY88/89
CNO: 31
Program Phase: Production
Contract Type: Mixed (FPIF/CPF)

PD: Reentry System & Reentry Vehicle, FY84
CNO: 59
Program Phase: Production
Contract Type: FPIF

PD: Stage III
CNO: 68
Program Phase: Production
Contract Type: FPIF

PD: Stage I
CNO: 70
Program Phase: Production
Contract Type: FPIF

PD: Reentry Sys Follow-on
CNO: 72
Program Phase: Development
Contract Type: FPIF

PD: TGG (Follow-on Dev)
CNO: 83
Program Phase: Development
Contract Type: FPIF

PD: SFIR (Follow-on Dev)
CNO: 84

Program Phase: Development
Contract Type: FPI

PD: MK-12A
CNO: 94
Program Phase: Other
Contract Type: FPI

Program Name: OTH-B (Over-the-Horizon Backscatter Radar)
PNO: 227
System Type: Electronic Warfare
DoD Service Component: Air Force

PD: AN/FPS-118 Radar Sec 4
CNO: 2
Program Phase: Production
Contract Type: FPIF

Program Name: SMALL MISSILE (ICBM)
PNO: 267
System Type: Ballistic Missile
DoD Service Component: Air Force

PD: G&C Integration (FSD)
CNO: 3
Program Phase: Development
Contract Type: FPIF/AF

PD: Hard Mobile Basing
CNO: 11
Program Phase: Development
Contract Type: FPIF/AF

Program Name: LANCE (MGM-52C)
PNO: 304
System Type: Other Missile
DoD Service Component: Army

PD: Fourth Buy
CNO: 99
Program Phase: Production
Contract Type: FPI

Program Name: STINGER-Reprogrammable Microprocessor (RMP)

PNO: 532
System Type: Other Missile
DoD Service Component: Army

PD: RMP FY85-Production
CNO: 2
Program Phase: Production
Contract Type: FPI/FFP

PD: RMP FY86-Production
CNO: 3
Program Phase: Production
Contract Type: FPI

Appendix C: Routine Used to Calculate Index-Based EACs

```
'*************************************************************************
'UDF Name:    Index_EAC
'Written by:  Capt Todd D. Nystrom
'Date:        5 May 1995
'
'This Microsoft® Excel user defined function (UDF) calculates index-based EACs
'for eleven different performance indices
'
'Input Variables:
' row_first:  indicates the first row of data for this contract
' row_current: indicates the row number of cell calling this function
' index_flag:  indicates which index to use in calculating the EAC
'
'     1 = CPI3           where CPI3 = BCWP3/ACWP3
'     2 = CPI6           where CPI6 = BCWP6/ACWP6
'     3 = CPIcum         where CPIcum = BCWPcum/ACWPcum
'     4 = SPI3           where SPI3 = BCWP3/BCWS3
'     5 = SPI6           where SPI6 = BCWP6/BCWS6
'     6 = SPIcum         where SPIcum = BCWPcum/BCWScum
'     7 = SCI3           where SCI3 = SPI3*CPI3
'     8 = SCI6           where SCI6 = SPI6*CPI6
'     9 = SCIcum         where SCIcum = SPIcum*CPIcum
'    10 = SCIspecial     where SCIspecial = SPIcum x CPI6
'    11 = Composite      where Composite = .8CPIcum + .2 SPIcum
'
' Note: contract start_date, BAC, report_date, BCWS_cum, BCWP_cum, and
' ACWP_cum are also inputs to this function, however, these are accessed directly from
' the spreadsheet rather that being provided as specific inputs to the function.  The
' location of these values within the spreadsheet is critical.  The column where each
' input must be located is follows:
'
'     start_date:    column 10 (J)
'     BAC:           column 14 (N)
'     report_date:   column 4 (D)
'     BCWS_cum:      column 11 (K)
'     BCWP_cum:      column 12 (L)
'     ACWP_cum:      column 13 (M)
'
'Output:  this function outputs the index-based EAC for the index indicated by index_flag
```

```
'       to the cell calling the function, and EAC is calculated using the following:
'
'         EAC = ACWPcum + ((BAC - BCWPcum) / Index)
'
'************************************************************************

Function Index_EAC(row_first, row_current, index_flag)

    'declare date variables
    Dim start_date As Date

    'dimension arrays
    Dim report_date(60) As Date
    Dim BCWS_cum(60) As Double
    Dim BCWP_cum(60) As Double
    Dim ACWP_cum(60) As Double

    'initialize variables
    flag_3_mo = 1
    flag_6_mo = 1

    'determine number of data points (n) for this contract at current time
    n = row_current - row_first + 1

    'contract start date must be in column 10 (J) of spreadsheet
    start_date = cells(row_current, 10)
    'BAC values must be in column 14 (N) of spreadsheet
    BAC = cells(row_current, 14)

    'place report_dates, BCWS_cum, BCWP_cum, and ACWP_cum values in arrays
    For i = 1 To n
        'report dates must be in column 4 (D) of spreadsheet
        report_date(i) = cells(row_first + i - 1, 4)
        'cumulative BCWS values must be in column 11 (K) of spreadsheet
        BCWS_cum(i) = cells(row_first + i - 1, 11)
        'cumulative BCWP values must be in column 12 (L) of spreadsheet
        BCWP_cum(i) = cells(row_first + i - 1, 12)
        'cumulative ACWP values must be in column 13 (M) of spreadsheet
        ACWP_cum(i) = cells(row_first + i - 1, 13)
    Next i

    'calculate 3 or 6 month BCWS, BCWP, ACWP values as required for Index
    'indicated by index_flag
    '  1 (CPI3), 4 (SPI3), and 7 (SCI3) require 3 month data
```

```
' 2 (CPI6), 5 (SPI6), 8 (SCI6), and 10 (SPIcum x CPI6) require 6 month data
' Remaining indices 3 (CPIcum), 6 (SPIcum), 9 (SCIcum), and 11 (Composite)
' require only cumulative data.
Select Case index_flag
   Case 1, 4, 7    'indices requiring 3 month data

      'calculates 3 month non-cumulative BCWS, BCWP, and ACWP values
      int_flag = 1 'default interpolate flag to 1 (where 1=interpolate)

      For i = 1 To n

         'check for actual report date within plus or minus 15 days of
         'current report_date - 3 months
         If report_date(i) - 15 <= report_date(n) - d_3(report_date(n)) And report_date(i)
+ 15 >= report_date(n) - d_3(report_date(n)) Then
            int_flag = 0 'don't need to interpolate since actual exists
            BCWS_3 = BCWS_cum(n) - BCWS_cum(i)
            BCWP_3 = BCWP_cum(n) - BCWP_cum(i)
            ACWP_3 = ACWP_cum(n) - ACWP_cum(i)
         End If
      Next i

      'if int_flag=1 then values must be interpolated
      If int_flag = 1 Then

         'if 3 month prior date is earlier than start_date then 3
         'month EACs cannot be calculated
         If report_date(n) - d_3(report_date(n)) < start_date Then
            flag_3_mo = 0
         End If

         'if 3 month prior date is earlier than first report then use first report and zero
         'values in the interpolation
         If report_date(n) - d_3(report_date(n)) < report_date(1) Then
            BCWS_3 = BCWS_cum(n) - interpolate(BCWS_cum(1), 0, report_date(1),
report_date(n) - d_3(report_date(n)), start_date)
            BCWP_3 = BCWP_cum(n) - interpolate(BCWP_cum(1), 0, report_date(1),
report_date(n) - d_3(report_date(n)), start_date)
            ACWP_3 = ACWP_cum(n) - interpolate(ACWP_cum(1), 0, report_date(1),
report_date(n) - d_3(report_date(n)), start_date)

         'otherwise determine actuals to use in the interpolation
         Else
            For i = n To 2 Step -1
```

```
            If report_date(i - 1) < report_date(n) - d_3(report_date(n)) And
report_date(i) > report_date(n) - d_3(report_date(n)) Then
                BCWS_3 = BCWS_cum(n) - interpolate(BCWS_cum(i), BCWS_cum(i
- 1), report_date(i), report_date(n) - d_3(report_date(n)), report_date(i - 1))
                BCWP_3 = BCWP_cum(n) - interpolate(BCWP_cum(i), BCWP_cum(i
- 1), report_date(i), report_date(n) - d_3(report_date(n)), report_date(i - 1))
                ACWP_3 = ACWP_cum(n) - interpolate(ACWP_cum(i), ACWP_cum(i
- 1), report_date(i), report_date(n) - d_3(report_date(n)), report_date(i - 1))
                Exit For
            End If
          Next i
        End If
      End If

    Case 2, 5, 8, 10    'indices requiring 6 month data

      'calculates 6 month non-cumulative BCWS, BCWP, and ACWP values
      int_flag = 1 'default interpolate flag to 1 (where 1=interpolate)

      For i = 1 To n

        'check for actual report date within plus or minus 15 days of the current
        'report_date - 6 months
        If report_date(i) - 15 <= report_date(n) - d_6(report_date(n)) And report_date(i)
+ 15 >= report_date(n) - d_6(report_date(n)) Then
          int_flag = 0 'don't need to interpolate since actual exists
          BCWS_6 = BCWS_cum(n) - BCWS_cum(i)
          BCWP_6 = BCWP_cum(n) - BCWP_cum(i)
          ACWP_6 = ACWP_cum(n) - ACWP_cum(i)
        End If
      Next i

      'if int_flag = 1 then values must be interpolated
      If int_flag = 1 Then

        'if 6 month prior date is earlier than start_date then 6 month EACs cannot be
        'calculated
        If report_date(n) - d_6(report_date(n)) < start_date Then
          flag_6_mo = 0
        End If

        'if 6 month prior date is earlier than first report then use first report and zero
        'values in the interpolation
        If report_date(n) - d_6(report_date(n)) < report_date(1) Then
```

```
            BCWS_6 = BCWS_cum(n) - interpolate(BCWS_cum(1), 0, report_date(1),
report_date(n) - d_6(report_date(n)), start_date)
            BCWP_6 = BCWP_cum(n) - interpolate(BCWP_cum(1), 0, report_date(1),
report_date(n) - d_6(report_date(n)), start_date)
            ACWP_6 = ACWP_cum(n) - interpolate(ACWP_cum(1), 0, report_date(1),
report_date(n) - d_6(report_date(n)), start_date)

          'otherwise determine actuals to use in the interpolation
          Else
            For i = n To 2 Step -1
              If report_date(i - 1) < report_date(n) - d_6(report_date(n)) And
report_date(i) > report_date(n) - d_6(report_date(n)) Then
                BCWS_6 = BCWS_cum(n) - interpolate(BCWS_cum(i), BCWS_cum(i
- 1), report_date(i), report_date(n) - d_6(report_date(n)), report_date(i - 1))
                BCWP_6 = BCWP_cum(n) - interpolate(BCWP_cum(i), BCWP_cum(i
- 1), report_date(i), report_date(n) - d_6(report_date(n)), report_date(i - 1))
                ACWP_6 = ACWP_cum(n) - interpolate(ACWP_cum(i), ACWP_cum(i
- 1), report_date(i), report_date(n) - d_6(report_date(n)), report_date(i - 1))
                Exit For
              End If
            Next i
          End If
        End If
  End Select

  'calculates EAC for Index indicated by index_flag
  '  1 = CPI3              7 = SCI3
  '  2 = CPI6              8 = SCI6
  '  3 = CPIcum        9 = SCIcum
  '  4 = SPI3              10 = SPIcum x CPI6
  '  5 = SPI6              11 = Composite (.8CPIcum + .2SPIcum)
  Select Case index_flag
    Case 1     'CPI3
      'if any of the listed conditions are met CPI3 cannot be calculated
      If flag_3_mo = 0 Or BCWP_3 <= 0 Or ACWP_3 <= 0 Then
        Index_EAC = ""
      'otherwise calculate the index and the EAC
      Else
        CPI3 = BCWP_3 / ACWP_3
        Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), CPI3)
      End If
    Case 2     'CPI6
      'if any of the listed conditions are met CPI6 cannot be calculated
      If flag_6_mo = 0 Or BCWP_6 <= 0 Or ACWP_6 <= 0 Then
```

```
      Index_EAC = ""
    'otherwise calculate the index and the EAC
    Else
      CPI6 = BCWP_6 / ACWP_6
      Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), CPI6)
    End If
  Case 3     'CPIcum
    'if any of the listed conditions are met CPIcum cannot be calculated
    If BCWP_cum(n) <= 0 Or ACWP_cum(n) <= 0 Then
      Index_EAC = ""
    'otherwise calculate the index and the EAC
    Else
      CPIcum = BCWP_cum(n) / ACWP_cum(n)
      Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), CPIcum)
    End If
  Case 4     'SPI3
    'if any of the listed conditions are met SPI3 cannot be calculated
    If flag_3_mo = 0 Or BCWP_3 <= 0 Or BCWS_3 <= 0 Then
      Index_EAC = ""
    'otherwise calculate the index and the EAC
    Else
      SPI3 = BCWP_3 / BCWS_3
      Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), SPI3)
    End If
  Case 5     'SPI6
    'if any of the listed conditions are met SPI6 cannot be calculated
    If flag_6_mo = 0 Or BCWP_6 <= 0 Or BCWS_6 <= 0 Then
      Index_EAC = ""
    'otherwise calculate the index and the EAC
    Else
      SPI6 = BCWP_6 / BCWS_6
      Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), SPI6)
    End If
  Case 6     'SPIcum
    'if any of the listed conditions are met SPIcum cannot be calculated
    If BCWP_cum(n) <= 0 Or BCWS_cum(n) <= 0 Then
      Index_EAC = ""
    'otherwise calculate the index and the EAC
    Else
      SPIcum = BCWP_cum(n) / BCWS_cum(n)
      Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), SPIcum)
    End If
  Case 7     'SCI3 = SPI3 * CPI3
    'if any of the listed conditions are met SCI3 cannot be calculated
```

```
        If flag_3_mo = 0 Or BCWP_3 <= 0 Or BCWS_3 <= 0 Or ACWP_3 <= 0 Then
          Index_EAC = ""
        'otherwise calculate the index and the EAC
        Else
          SCI3 = (BCWP_3 / BCWS_3) * (BCWP_3 / ACWP_3)
          Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), SCI3)
        End If
      Case 8     'SCI6 = SPI6 * CPI6
        'if any of the listed conditions are met SCI6 cannot be calculated
        If flag_6_mo = 0 Or BCWP_6 <= 0 Or BCWS_6 <= 0 Or ACWP_6 <= 0 Then
          Index_EAC = ""
        'otherwise calculate the index and the EAC
        Else
          SCI6 = (BCWP_6 / BCWS_6) * (BCWP_6 / ACWP_6)
          Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), SCI6)
        End If
      Case 9     'SCIcum = SPIcum * CPIcum
        'if any of the listed conditions are met SCIcum cannot be calculated
        If BCWP_cum(n) <= 0 Or BCWS_cum(n) <= 0 Or ACWP_cum(n) <= 0 Then
          Index_EAC = ""
        'otherwise calculate the index and the EAC
        Else
          SCIcum = (BCWP_cum(n) / BCWS_cum(n)) * (BCWP_cum(n) /
ACWP_cum(n))
          Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), SCIcum)
        End If
      Case 10    'SCIspecial = SPIcum * CPI6
        'if any of the listed conditions are met SCIspecial cannot be calculated
        If flag_6_mo = 0 Or BCWP_6 <= 0 Or ACWP_6 <= 0 Or BCWP_cum(n) <= 0 Or
BCWS_cum(n) <= 0 Then
          Index_EAC = ""
        'otherwise calculate the index and the EAC
        Else
          SCIspecial = (BCWP_cum(n) / BCWS_cum(n)) * (BCWP_6 / ACWP_6)
          Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), SCIspecial)
        End If
      Case 11    'Composite = .8CPIcum + .2SPIcum
        'if any of the listed conditions are met Composite cannot be calculated
        If BCWP_cum(n) <= 0 Or BCWS_cum(n) <= 0 Or ACWP_cum(n) <= 0 Then
          Index_EAC = ""
        'otherwise calculate the index and the EAC
        Else
          Composite = 0.8 * (BCWP_cum(n) / ACWP_cum(n)) + 0.2 * (BCWP_cum(n) /
BCWS_cum(n))
```

```
        Index_EAC = EAC(ACWP_cum(n), BAC, BCWP_cum(n), Composite)
      End If
  End Select
End Function


'************************************************************************
'function calculates EAC using standard index-based EAC formula [Equation (1)]
'************************************************************************

Function EAC(ACWPcum, BACnow, BCWPcum, Index)
  EAC = ACWPcum + ((BACnow - BCWPcum) / Index)
End Function


'************************************************************************
'function interpolates BCWS, BCWP, or ACWP value based on given input values
'************************************************************************

Function interpolate(value_plus, value_minus, date_plus, date_x, date_minus)
  interpolate = (((value_plus - value_minus) * (date_x - date_minus)) / (date_plus -
date_minus)) + value_minus
End Function


'************************************************************************
'function determines offset value in days for 3 months prior
'Note:  these offsets do not factor in leap year
'************************************************************************

Function d_3(c_date)

  Select Case Month(c_date)
    'May
    Case 5
      d_3 = 89
    'March, April
    Case 3, 4
      d_3 = 90
    'July, December
    Case 7, 12
      d_3 = 91
    'January, February, June, August, September, October, November
    Case 1, 2, 6, 8, 9, 10, 11
```

```
        d_3 = 92
    End Select

End Function

'*************************************************************************
'function determines offset value in days for 6 months prior
'Note:  these offsets do not factor in leap year
'*************************************************************************

Function d_6(c_date)

    Select Case Month(c_date)
        'March, May, July, August
        Case 3, 5, 7, 8
            d_6 = 181
        'April, June
        Case 4, 6
            d_6 = 182
        'October, December
        Case 10, 12
            d_6 = 183
        'January, February, September, November
        Case 1, 2, 9, 11
            d_6 = 184
    End Select

End Function
```

Appendix D: Routine Used to Calculate Rayleigh Three Group Linear Regression EACs

```
'************************************************************************
'UDF Name:     Rayleigh_TG
'Written by:   Capt Todd D. Nystrom
'Date:         1 May 1995
'
'This Microsoft® Excel user defined function (UDF) calculates an EAC by fitting actual
'contract data to a non-cumulative Rayleigh distribution curve using three group linear
'regression
'
'Input Variables:
' row_first:      indicates the first row of data for the contract
' row_current:    indicates the row number of cell calling this function
' column:         indicates the column number of cell calling this function
'
' Note: x(i) (t^2) values must be located one column to the left of cell
' calling this function, and y(i) values (ln[(dACWP/dt)/t]) must be located
' two columns to the left of cell calling this function.
'
'
'Output: this function outputs the three group linear regression Rayleigh curve EAC
'        to the cell calling the function
'
'************************************************************************

Function Rayleigh_TG(row_first, row_current, column)

    'dimension arrays
    Dim x(60) As Double
    Dim y(60) As Double
    Dim y_sort(60) As Double
    Dim a(50) As Double
    Dim b(50) As Double
    Dim residual(50, 60) As Double

    'determine number of data points (n) for this contract
    n = row_current - row_first + 1

    'place t-squared values in x(i), ln[(dACWP/dt)/t] values in y(i), and
    'y(i) values in y_sort(i)
```

```
'there is no need for x_ordered(i) because t-squared (x) values are already in ascending
'order
For i = 1 To n
   'x(i) values must be one column to the left of cell calling function
   x(i) = Cells(row_first + i - 1, column - 1)
   'y(i) values must be two columns to the left of cell calling function
   y(i) = Cells(row_first + i - 1, column - 2)
   y_sort(i) = y(i)
Next i

'if there are less than 3 data points EAC cannot be calculated so exit the function
If n < 3 Then
   Rayleigh_TG = ""
   Exit Function
End If

'if dACWP at this point is <= 0 [i.e., y(n) = 99999] EAC cannot be calculated so
'exit the function
If y(n) = 99999 Then
   Rayleigh_TG = ""
   Exit Function
End If

'filter out any data points where dACWP is <= 0 [y(i) = 99999]
For h = 1 To n - 1
   For i = h To n - 1
      If y(h) = 99999 Then
         For j = h To n - 1
            x(j) = x(j + 1)
            y(j) = y(j + 1)
            y_sort(j) = y_sort(j + 1)
         Next j
         n = n - 1
      End If
   Next i
Next h

'if there are now less than 3 data points EAC cannot be calculated so exit the function
If n < 3 Then
   Rayleigh_TG = ""
   Exit Function
End If

'calculate the base number of points in each group (k) and the remainder (m)
```

```
k = Int(n / 3)
m = n Mod 3

'Sets the number of points in each group (L)eft, (M)iddle, (R)ight
If m = 0 Then
   k_L = k
   k_M = k
   k_R = k
ElseIf m = 1 Then
   k_L = k
   k_M = k + 1
   k_R = k
Else
   k_L = k + 1
   k_M = k
   k_R = k + 1
End If

'place (L)eft group y values in ascending order
For i = 1 To k_L - 1
   For j = i + 1 To k_L
      If y_sort(j) < y_sort(i) Then
         y_temp = y_sort(i)
         y_sort(i) = y_sort(j)
         y_sort(j) = y_temp
      End If
   Next j
Next i

'calculate median values for (L)eft group
If k_L Mod 2 = 0 Then
   x_L = (x(k_L / 2) + x((k_L / 2) + 1)) / 2
   y_L = (y_sort(k_L / 2) + y_sort((k_L / 2) + 1)) / 2
ElseIf k_L Mod 2 = 1 Then
   x_L = x(Int(k_L / 2) + 1)
   y_L = y_sort(Int(k_L / 2) + 1)
End If

'place (M)iddle group y values in ascending order
For i = k_L + 1 To k_L + k_M - 1
   For j = i + 1 To k_L + k_M
      If y_sort(j) < y_sort(i) Then
         y_temp = y_sort(i)
         y_sort(i) = y_sort(j)
```

```
        y_sort(j) = y_temp
      End If
    Next j
Next i

'calculate median values for (M)iddle group
If k_M Mod 2 = 0 Then
    x_M = (x(k_L + (k_M / 2)) + x(k_L + (k_M / 2) + 1)) / 2
    y_M = (y_sort(k_L + (k_M / 2)) + y_sort(k_L + (k_M / 2) + 1)) / 2
ElseIf k_M Mod 2 = 1 Then
    x_M = x(k_L + Int(k_M / 2) + 1)
    y_M = y_sort(k_L + Int(k_M / 2) + 1)
End If

'place (R)ight group y values in ascending order
For i = k_L + k_M + 1 To n - 1
    For j = i + 1 To n
      If y_sort(j) < y_sort(i) Then
        y_temp = y_sort(i)
        y_sort(i) = y_sort(j)
        y_sort(j) = y_temp
      End If
    Next j
Next i

'calculate median values for (R)ight group
If k_R Mod 2 = 0 Then
    x_R = (x(k_L + k_M + (k_R / 2)) + x(k_L + k_M + (k_R / 2) + 1)) / 2
    y_R = (y_sort(k_L + k_M + (k_R / 2)) + y_sort(k_L + k_M + (k_R / 2) + 1)) / 2
ElseIf k_R Mod 2 = 1 Then
    x_R = x(k_L + k_M + Int(k_R / 2) + 1)
    y_R = y_sort(k_L + k_M + Int(k_R / 2) + 1)
End If

'calculate initial slope [a(0)] and intercept [b(0)]
a(0) = (y_R - y_L) / (x_R - x_L)
b(0) = ((y_L - a(0) * x_L) + (y_M - a(0) * x_M) + (y_R - a(0) * x_R)) / 3

'initialize Slope and Intercept values
Slope = 0
Intercept = 0

'iteratively calculate residuals to refine Slope and Intercept estimates
'loop executes 50 times or until adjustment is <= 0.01% of slope
```

```
For h = 1 To 50
   Slope = Slope + a(h - 1)
   Intercept = Intercept + b(h - 1)

   'calculate residuals and assign values to y(i) and y_sort(i)
   For i = 1 To n
      residual(h, i) = y(i) - (b(h - 1) + a(h - 1) * (x(i)))
      y(i) = residual(h, i)
      y_sort(i) = y(i)
   Next i

   'place (L)eft group y (residual) values in ascending order
   For i = 1 To k_L - 1
      For j = i + 1 To k_L
         If y_sort(j) < y_sort(i) Then
            y_temp = y_sort(i)
            y_sort(i) = y_sort(j)
            y_sort(j) = y_temp
         End If
      Next j
   Next i

   'calculate median values for (L)eft group using residuals for y values
   If k_L Mod 2 = 0 Then
      x_L = (x(k_L / 2) + x((k_L / 2) + 1)) / 2
      y_L = (y_sort(k_L / 2) + y_sort((k_L / 2) + 1)) / 2
   ElseIf k_L Mod 2 = 1 Then
      x_L = x(Int(k_L / 2) + 1)
      y_L = y_sort(Int(k_L / 2) + 1)
   End If

   'place (M)iddle group y (residual) values in ascending order
   For i = k_L + 1 To k_L + k_M - 1
      For j = i + 1 To k_L + k_M
         If y_sort(j) < y_sort(i) Then
            y_temp = y_sort(i)
            y_sort(i) = y_sort(j)
            y_sort(j) = y_temp
         End If
      Next j
   Next i

   'calculate median values for (M)iddle group using residuals for y values
   If k_M Mod 2 = 0 Then
```

```
        x_M = (x(k_L + (k_M / 2)) + x(k_L + (k_M / 2) + 1)) / 2
        y_M = (y_sort(k_L + (k_M / 2)) + y_sort(k_L + (k_M / 2) + 1)) / 2
    ElseIf k_M Mod 2 = 1 Then
        x_M = x(k_L + Int(k_M / 2) + 1)
        y_M = y_sort(k_L + Int(k_M / 2) + 1)
    End If

    'place (R)ight group y (residual) values in ascending order
    For i = k_L + k_M + 1 To n - 1
        For j = i + 1 To n
            If y_sort(j) < y_sort(i) Then
                y_temp = y_sort(i)
                y_sort(i) = y_sort(j)
                y_sort(j) = y_temp
            End If
        Next j
    Next i

    'calculate median values for (R)ight group using residuals for y values
    If k_R Mod 2 = 0 Then
        x_R = (x(k_L + k_M + (k_R / 2)) + x(k_L + k_M + (k_R / 2) + 1)) / 2
        y_R = (y_sort(k_L + k_M + (k_R / 2)) + y_sort(k_L + k_M + (k_R / 2) + 1)) / 2
    ElseIf k_R Mod 2 = 1 Then
        x_R = x(k_L + k_M + Int(k_R / 2) + 1)
        y_R = y_sort(k_L + k_M + Int(k_R / 2) + 1)
    End If

    'calculate slope [a(h)] and intercept [b(h)]
    a(h) = (y_R - y_L) / (x_R - x_L)
    b(h) = ((y_L - a(0) * x_L) + (y_M - a(0) * x_M) + (y_R - a(0) * x_R)) / 3

    'if adjustment value [a(h)] results in less than a 0.01% change then Slope is
    'sufficiently accurate so exit for loop
    If a(h) / Slope <= 0.0001 Then
        Exit For
    End If
Next h

'calculate Rayleigh parameters (a,K) and EAC (where EAC=K)
Rayleigh_a = -Slope
Rayleigh_K = Exp(Intercept) / (-2 * Slope)
Rayleigh_TG = Rayleigh_K

End Function
```

Appendix E: Routine Used to Calculate Rayleigh MMAE EACs

This Appendix contains the original Visual Basic® routine, provided by Capt Mark Gallagher, used to calculate the Rayleigh MMAE EACs. Modifications were made to the original code to allow the use of the SAF/FMCE inflation indices that were used to calculate the inflation adjusted EACs for the other EAC methods. These modifications have been noted with comments.

```
'**********************************************************************
Option Explicit
Option Base 1

Const MaxData = 100          ' Maximum data points process by procedure
Const Numd = 20              ' Number of cost parameters considered
Const NumAlpha = 20          ' Number of time parameters considered
Const NumK = 5               ' Number of Kalman filter gains applied
Const NumFilters = Numd * NumAlpha * NumK  ' Number of Kalman filters applied

Dim Inflaters(0 To 64) As Single     ' Navy RDT&E inflators from 1960 (index 0) to
2024
Dim AlphaArray(NumAlpha, 2) As Single ' Alpha values and constant-to-current dollar
conversions

Dim StartDay As Date         ' Program start date
Dim NumData As Integer       ' Number of cost reports (data points)
Dim ACWP(0 To MaxData, 2) As Single ' First is time index and Second
                        ' is Actual Cost of Work Performed (ACWP) in base-year dollars

'**********************************************************************
'This code has been added to allow the use of the SAF/FMCE inflation indices that
'were used for the other EAC Methods
Dim row As Integer
'**********************************************************************

Dim MinTime As Single        ' Minimum time for program completion
Dim MaxTime As Single        ' Maximum time for program completion
```

```
Dim MinAlpha As Single        ' Alpha parameter for minimum time (MinTime, but
Largest Alpha)
Dim MaxAlpha As Single        ' Alpha parameter for maximum time (MaxTime, but
smallest Alpha)

Dim MinCost As Single        ' Minimum cost at program completion
Dim MaxCost As Single        ' Maximum cost at program completion
Dim Mind As Single        ' Minimum parameter d
Dim Maxd As Single        ' Maximum parameter d

Dim ResidVar As Single        ' Kalman filter residual variance
Dim Resid As Single   ' Kalman filter residual
Dim Prob As Single   ' Filter probability (Leading term cancels in normalization)
Dim ProbSum As Single  ' Sum of filter probabilities

Dim MMAED As Single     ' MMAE probabilistic weighted estimate for final cost
Dim MMAEDTY As Single   ' MMAE probabilistic weighted final cost in current
dollars
Dim MMAETime As Single  ' MMAE probabilistic weighted estimate for final time


Function MyTrunc(Value As Single) As Integer
' Truncates a real number to an integer
  If (Value >= 0) Then
    MyTrunc = Value - Decimal(Value)
  Else
    MyTrunc = Value + Decimal(Value)
  End If
End Function

Function Decimal(Value As Single) As Single
' Returns the decimal portion of a real number
  If (((Value - Int(Value)) >= 0) And (Value > 0)) Then ' rounded down
    Decimal = Value - Int(Value)
  ElseIf (((Value - Int(Value)) < 0) And (Value > 0)) Then  ' rounded up
    Decimal = Value - Int(Value - 1)
  ElseIf (((Value - Int(Value)) >= 0) And (Value < 0)) Then  ' rounded down
    Decimal = Int(Value + 1) - Value
  ElseIf (((Value - Int(Value)) < 0) And (Value < 0)) Then  ' rounded up
    Decimal = Int(Value) - Value
  Else
    Decimal = 0
  End If
End Function
```

```
Function Translator(Start As Date, alpha As Single) As Single
  ' Determines the translation factor from a constant dollar Rayleigh expenditure
  ' profile to a current dollar total
  Dim Duration As Single
  Dim Time As Single
  Dim LastTime As Single
  Dim YrIndex As Integer
  Dim Sum As Single

  ' Initial '(call to Procedure Initial needed if not called from MMAECost )

  Duration = Sqr(3.5 / alpha)
  Sum = 0

  YrIndex = MyTrunc((Start - #10/1/59#) / 365.25)
  LastTime = 0
  Time = Decimal((Start - #10/1/59#) / 365.25)

  While (Time < Duration)
    Sum = Sum + Inflaters(YrIndex) * (Exp(-1 * alpha * LastTime * LastTime) - Exp(-1
* alpha * Time * Time))
    LastTime = Time
    Time = Time + 1
    YrIndex = YrIndex + 1
  Wend
  Sum = Sum + Inflaters(YrIndex) * (Exp(-1 * alpha * LastTime * LastTime) - Exp(-1 *
alpha * Duration * Duration))
  Translator = Sum
End Function

Sub Initial(row)
   Dim I As Integer

'**************************************************************************
'This section of code has been substituted to allow the use of the SAF/FMCE
'inflation indices that were used for the other EAC methods
'Note that the inflation indices for development contracts (3600) must be located in
'column 25 (Y) of the spreadsheet, and the indices for production contracts (3080) must
'be located in column 26 (Z) of the spreadsheet.  The inflation indices for 1960 are located
'in row 13.

   For I = 0 To 64
      If Cells(row, 9) = "D" Then
```

```
      Inflaters(I) = Cells(I + 13, 25)
    Else
      Inflaters(I) = Cells(I + 13, 26)
    End If
  Next I
'**********************************************************************


'**********************************************************************
'This section has been commented out of the original code to allow use of the
'SAF/FMCE inflation indices that were used for the other EAC methods

  'Inflaters(0) = 0.2108 ' 1960 Navy Raw RDT&E Inflation Indice (NCA Mar 1994)
  'Inflaters(1) = 0.2131
  'Inflaters(2) = 0.2161
  'Inflaters(3) = 0.2198
  'Inflaters(4) = 0.223
  'Inflaters(5) = 0.2271
  'Inflaters(6) = 0.2332
  'Inflaters(7) = 0.2407
  'Inflaters(8) = 0.2494
  'Inflaters(9) = 0.2612
  'Inflaters(10) = 0.2772 ' 1970 Navy Raw RDT&E Inflation Indice (NCA Mar 1995)
  'Inflaters(11) = 0.2915
  'Inflaters(12) = 0.3049
  'Inflaters(13) = 0.3182
  'Inflaters(14) = 0.3435
  'Inflaters(15) = 0.3811
  'Inflaters(16) = 0.4063
  'Inflaters(17) = 0.4288
  'Inflaters(18) = 0.458
  'Inflaters(19) = 0.4964
  'Inflaters(20) = 0.549 ' 1980 Navy Raw RDT&E Inflation Indice (NCA Mar 1995)
  'Inflaters(21) = 0.6073
  'Inflaters(22) = 0.6534
  'Inflaters(23) = 0.6854
  'Inflaters(24) = 0.7115
  'Inflaters(25) = 0.7357
  'Inflaters(26) = 0.7563
  'Inflaters(27) = 0.7767
  'Inflaters(28) = 0.8
  'Inflaters(29) = 0.8336
  'Inflaters(30) = 0.8669 ' 1990 Navy Raw RDT&E Inflation Indice (NCA Mar 1995)
  'Inflaters(31) = 0.9042
```

```
  'Inflaters(32) = 0.9295
  'Inflaters(33) = 0.9546
  'Inflaters(34) = 0.9737
  'Inflaters(35) = 1
  'Inflaters(36) = 1.03

  'For I = 37 To 64
    'Inflaters(I) = Inflaters(I - 1) * 1.03
  'Next I
'*************************************************************************

End Sub


Sub Kalman(d As Single, alpha As Single, gain As Single, sumsqresids As Single)
  Dim XMinus As Single
  Dim XPlus As Single
  Dim I As Integer

  sumsqresids = 0
  ' Propagate through time from initial time and no cost - Eq( 7)
  XMinus = d * (1 - Exp(-1 * alpha * (ACWP(1, 1)) ^ 2))
  Resid = ACWP(1, 2) - XMinus
  sumsqresids = sumsqresids + Resid * Resid
  ' First update state mean distribution estimate - Eq (9)
  XPlus = XMinus + gain * Resid

  ' Check that in Visual Basic LOG is the natural logarithm function - It is!

  For I = 2 To NumData ' for each datum
    ' Propagate through time - Eq( 7)
    XMinus = d * (1 - Exp(-1 * alpha * (ACWP(I, 1) - ACWP(I - 1, 1) + ((-1 / alpha) *
Log(1 - (XPlus / d))) ^ 0.5) ^ 2))
    ' Determine residual - Eq (8)
    Resid = ACWP(I, 2) - XMinus
    sumsqresids = sumsqresids + Resid * Resid
    ' Update state mean distribution estimate - Eq (9)
    XPlus = XMinus + gain * Resid
  Next I
End Sub

Sub Algorithm()
  Dim I As Integer   ' Cost parameter (d)index
  Dim J As Integer   ' Time parameter (Alpha) index
```

```
   Dim K As Integer    ' Kalman filter gain (k) index
   Dim L As Integer    ' Filter counter

   Dim Filter(NumFilters, 5) As Single
       ' 1 is parameter d
       ' 2 is parameter Alpha
       ' 3 is Kalman filter gain
       ' 4 is sum residuals squared and filter probability for second pass
       ' 5 is the constant-to-current dollar converter
   Dim XHat(NumFilters) As Single   ' Filter state estimates

   Dim DeltaD As Single     ' Delta between filters' parameters d
   Dim DeltaAlpha As Single ' Delta between filters' parameters Alpha
   Dim Temp As Single       ' Temporary variable

'***** STEP 2 *****

   ' Set defaults for time range
   MinTime = ACWP(NumData, 1)
   MaxTime = 15

   ' Query analyst to revise default final-time range

   MinAlpha = 3.5 / (MinTime * MinTime)  ' Eq (4)
   MaxAlpha = 3.5 / (MaxTime * MaxTime)  ' Eq (4)

   ' Set defaults for cost range
   MinCost = ACWP(NumData, 2)
   MaxCost = ACWP(NumData, 2) / (1 - Exp(-1 * MaxAlpha * ACWP(NumData, 1) *
ACWP(NumData, 1))) ' Eq (11)

   ' Query analyst to revise default final-cost range

   Mind = MinCost '/ 0.97    ' Eq (3)
   Maxd = MaxCost '/ 0.97    ' Eq (3)


'***** STEP 3 *****

   DeltaD = (Maxd - Mind) / (Numd - 1)
   DeltaAlpha = (MaxAlpha - MinAlpha) / (NumAlpha - 1)  ' negative number since
MinAlpha > MaxAlpha

   L = 0
```

```
For I = 1 To Numd
  For J = 1 To NumAlpha
    For K = 1 To NumK
      L = L + 1
      Filter(L, 1) = Mind + (I - 1) * DeltaD
      Filter(L, 2) = MinAlpha + (J - 1) * DeltaAlpha
      Filter(L, 3) = (K - 1) / NumK
      Filter(L, 4) = 0
    Next K
  Next J
Next I

' ***** STEP 5 *****

Kalman Filter(1, 1), Filter(1, 2), Filter(1, 3), Filter(1, 4)
ResidVar = Filter(1, 4)

For L = 2 To NumFilters
  Kalman Filter(L, 1), Filter(L, 2), Filter(L, 3), Filter(L, 4)
  If (Filter(L, 4) < ResidVar) Then
    ResidVar = Filter(L, 4)
  End If
Next L

' Reduce parameter range

Temp = Mind
Mind = Maxd
Maxd = Temp
Temp = MinAlpha
MinAlpha = MaxAlpha
MaxAlpha = Temp

For L = 1 To NumFilters
  If (Filter(L, 4) <= 3 * ResidVar) Then ' Retain parameters in reduced parameter range
    If (Mind > Filter(L, 1)) Then
      Mind = Filter(L, 1)
    End If
    If (Maxd < Filter(L, 1)) Then
      Maxd = Filter(L, 1)
    End If
    If (MinAlpha < Filter(L, 2)) Then
      MinAlpha = Filter(L, 2)
    End If
```

```
      If (MaxAlpha > Filter(L, 2)) Then
        MaxAlpha = Filter(L, 2)
      End If
    End If
  Next L


  MaxTime = (3.5 / MaxAlpha) ^ 0.5 ' Relationship in Eq (4)
  MinTime = (3.5 / MinAlpha) ^ 0.5 ' Relationship in Eq (4)


  ResidVar = (1 / (NumData - 1)) * ResidVar


  ' Equally space filter parameters across reduced range and
  ' Reset prior mens and set filter probabilities

  DeltaD = (Maxd - Mind) / (Numd - 1)
  DeltaAlpha = (MaxAlpha - MinAlpha) / (NumAlpha - 1)  ' negative number since
MinAlpha > MaxAlpha

  L = 0
  For I = 1 To Numd
    For J = 1 To NumAlpha
      For K = 1 To NumK
        L = L + 1
        Filter(L, 1) = Mind + (I - 1) * DeltaD
        Filter(L, 2) = MinAlpha + (J - 1) * DeltaAlpha
        Filter(L, 3) = (K - 1) / NumK
        XHat(L) = 0   ' set prior state distribution means for each filter to zero
        Filter(L, 4) = 1 / NumFilters ' set filter prior probabilities
        Filter(L, 5) = Translator(StartDay, Filter(L, 2))
      Next K
    Next J
  Next I

'***** STEP 6 *****

  ' First data point through all the filters
  ProbSum = 0
  For L = 1 To NumFilters
    XHat(L) = Filter(L, 1) * (1 - Exp(-1 * Filter(L, 2) * (ACWP(1, 1)) ^ 2))
    Resid = ACWP(1, 2) - XHat(L)
    ' First update state mean distribution estimate - Eq (9)
```

```
    XHat(L) = XHat(L) + Filter(L, 3) * Resid
    Prob = Exp(-1 * Resid * Resid / (2 * ResidVar))
    Filter(L, 4) = Filter(L, 4) * Prob
    ProbSum = ProbSum + Filter(L, 4)
  Next L

  For L = 1 To NumFilters
    Filter(L, 4) = Filter(L, 4) / ProbSum
    If (Filter(L, 4) < 0.001) Then
      Filter(L, 4) = 0.001
    End If
  Next L

  For I = 2 To NumData ' for each datum after the first datum
   ProbSum = 0
   For L = 1 To NumFilters ' for each Kalmam filter
     ' Propagate through time - Eq( 7)
     If (XHat(L) > Filter(L, 1)) Then
       XHat(L) = Filter(L, 1)
     Else
       XHat(L) = Filter(L, 1) * (1 - Exp(-1 * Filter(L, 2) * (ACWP(I, 1) - ACWP(I - 1, 1)
+ ((-1 / Filter(L, 2)) * Log(1 - (XHat(L) / Filter(L, 1)))) ^ 0.5) ^ 2))
     End If
     ' Determine residual - Eq (8)
     Resid = ACWP(I, 2) - XHat(L)
     ' Update state mean distribution estimate - Eq (9)
     XHat(L) = XHat(L) + Filter(L, 3) * Resid
     Prob = Exp(-1 * Resid * Resid / (2 * ResidVar))
     Filter(L, 4) = Filter(L, 4) * Prob
     ProbSum = ProbSum + Filter(L, 4)
  Next L

  For L = 1 To NumFilters
    Filter(L, 4) = Filter(L, 4) / ProbSum
    If ((Filter(L, 4) < 0.001) And (I < NumData)) Then
      Filter(L, 4) = 0.001
    End If
  Next L
 Next I

'***** STEP 7 *****

 MMAED = 0
 MMAETime = 0
```

```
    MMAEDTY = 0   ' Initial current (then-year) summation term

    For L = 1 To NumFilters
      Temp = 0.97 * Filter(L, 1)   ' Relationship from Eq (3)
      If (Temp < ACWP(NumData, 2)) Then
        Temp = ACWP(NumData, 2)
      End If

      MMAED = MMAED + Temp * Filter(L, 4)
      MMAETime = MMAETime + Filter(L, 2) * Filter(L, 4)
      MMAEDTY = MMAEDTY + Filter(L, 1) * Filter(L, 4) * Filter(L, 5)
    Next L

    MMAETime = (3.5 / MMAETime) ^ 0.5 ' Relationship from Eq (4)

    L = 0
    For I = 1 To Numd
      For J = 1 To NumAlpha
        ProbSum = 0
        For K = 1 To NumK
          L = L + 1
          ProbSum = ProbSum + Filter(L, 4)
        Next K
      Next J
    Next I
    For J = 1 To NumAlpha
      I = 1 + (J - 1) * NumK
    Next J
End Sub


Function MMAECost(StartDate, CumCostRpts, RptDates, row)
  ' See QUE Excel version 5 Book on page 1234 for an example
  ' CumCostRpts is either numbers or references to cumulative current (Then-Year) dollar
expenditures
  ' RptDates is either cost report dates or references to the dates of cost data reports
'**********************************************************************
'The additional parameter, row, has been added to allow use of the SAF/FMCE
'inflation indices that were used for the other EAC methods
'**********************************************************************

  Dim I As Integer
  Dim Imin As Integer
```

```
Dim Imax As Integer
Dim J As Integer
Dim RptDate As Date
Dim TempI As Integer
Dim Temp As Single

Initial (row)  ' Initializes inflation indices

If TypeName(StartDate) = "range" Then
  StartDay = StartDate.Value
Else
  StartDay = StartDate
End If

ACWP(0, 1) = 0 ' The program starts at time index of zero
ACWP(0, 2) = 0 ' The program starts with no expenditures


' See what is being passed in RptDates
' If it is a Range object, transfer the data in the reference cells to the ACWP array.
If TypeName(RptDates) = "Range" Then
 If (RptDates.Columns.Count = 1) Then ' data are in a column
   ' Find the number of rows
   NumData = RptDates.Rows.Count

  ' Adjust dates to program time indices
  For I = 1 To NumData
    ACWP(I, 1) = (RptDates.Cells(I, 1).Value - StartDay) / 365.25
  Next I
 ElseIf (RptDates.Rows.Count = 1) Then  ' data are in a row
   ' Find the number of columns
   NumData = RptDates.Columns.Count

  ' Copy the data from the range into the array
  For I = 1 To NumData
    ACWP(I, 1) = (RptDates.Cells(1, I).Value - StartDay) / 365.25
  Next I
 ElseIf ((RptDates.Columns.Count > 1) And (RptDates.Rows.Count > 1)) Then  ' error
  MMAECost = Array(CVErr(xlErrValue))
  Exit Function
 End If

ElseIf (VarType(RptDates) >= 8192) Then  'an array so return an error and quit
  Imin = LBound(RptDates, 1)
```

```
    Imax = UBound(RptDates, 1)
    NumData = Imax - Imin + 1
    J = 1
    For I = Imin To Imax
      ACWP(J, 1) = RptDates(I)
      J = J + 1
    Next I

  ElseIf (VarType(RptDates) < 8192) Then  'not an array so return an error and quit
   MMAECost = Array(CVErr(xlErrValue))
   Exit Function
  End If


  ' See what is being passed in CumCostRpts
  ' If it is a Range object, transfer the data in the reference cells to the ACWP array.
  If TypeName(CumCostRpts) = "Range" Then
    If (CumCostRpts.Columns.Count = 1) Then ' data are in a column
      ' Find the number of rows
      NumData = CumCostRpts.Rows.Count

     ' Copy the data from the range into the array
     For I = 1 To NumData
       RptDate = StartDay + ACWP(I, 1) * 365.25
       TempI = MyTrunc((RptDate - #3/1/60#) / 365.25) ' Inflater index for mid-fiscal
year
       Temp = Decimal((RptDate - #3/1/60#) / 365.23)  ' Interpolation between annual
indices
       Temp = Inflaters(TempI) + Temp * (Inflaters(TempI + 1) - Inflaters(TempI))
       If (I = 1) Then
         ACWP(1, 2) = CumCostRpts.Cells(1, 1).Value / Temp
       Else
         ACWP(I, 2) = ACWP(I - 1, 2) + (CumCostRpts.Cells(I, 1).Value -
CumCostRpts.Cells(I - 1, 1).Value) / Temp
       End If
     Next I
    ElseIf (CumCostRpts.Rows.Count = 1) Then  ' data are in a row
      ' Find the number of columns
      NumData = CumCostRpts.Columns.Count

     ' Copy the data from the range into the array
     For I = 1 To NumData
       RptDate = StartDay + ACWP(I, 1) * 365.25
```

```
      TempI = MyTrunc((RptDate - #3/1/60#) / 365.25) ' Inflater index for mid-fiscal
year
      Temp = Decimal((RptDate - #3/1/60#) / 365.23)  ' Interpolation between annual
indices
      Temp = Inflaters(TempI) + Temp * (Inflaters(TempI + 1) - Inflaters(TempI))
      If (I = 1) Then
        ACWP(1, 2) = CumCostRpts.Cells(1, 1).Value / Temp
      Else
        ACWP(I, 2) = ACWP(I - 1, 2) + (CumCostRpts.Cells(1, I).Value -
CumCostRpts.Cells(1, I - 1).Value) / Temp
      End If
    Next I

  ElseIf ((CumCostRpts.Columns.Count > 1) And (CumCostRpts.Rows.Count > 1))
Then  ' error
    MMAECost = Array(CVErr(xlErrValue))
    Exit Function
  End If

  ElseIf (VarType(CumCostRpts) >= 8192) Then  'an array
    Imin = LBound(CumCostRpts, 1)
    Imax = UBound(CumCostRpts, 1)
    NumData = Imax - Imin + 1
    J = 1
    For I = Imin To Imax
      RptDate = StartDay + ACWP(I, 1) * 365.25
      TempI = MyTrunc((RptDate - #3/1/60#) / 365.25) ' Inflater index for mid-fiscal
year
      Temp = Decimal((RptDate - #3/1/60#) / 365.23)  ' Interpolation between annual
indices
      Temp = Inflaters(TempI) + Temp * (Inflaters(TempI + 1) - Inflaters(TempI))
      If (J = 1) Then
        ACWP(1, 2) = CumCostRpts(I) / Temp
      Else
        ACWP(J, 2) = ACWP(J - 1, 2) + (CumCostRpts(I) - CumCostRpts(I - 1)) / Temp
      End If
      J = J + 1
    Next I

  ElseIf (VarType(CumCostRpts) < 8192) Then  'not an array so return an error and quit
    MMAECost = Array(CVErr(xlErrValue))
    Exit Function
  End If
```

Algorithm

MMAECost = MMAEDTY

End Function

Appendix F: Routine Used to Calculate Beta EACs

```
'**********************************************************************
'UDF Name:     Beta_EAC
'Written by:   Capt Todd D. Nystrom
'Date:         3 May 1995
'
'This Microsoft® Excel user defined function (UDF) calculates an EAC using the
'modified Beta function described in Whitlock, 1982. The modified Beta function
'(Equation [19]) expresses cumulative fractional cost as a function of fractional time and
'is given by the following:
'
' C(t)=A(10t^2 - 20t^3 + 10t^4) + B(10t^3 - 20t^4 + 10t^5) + (5t^4 - 4t^5)
'
'subject to the constraints:
'
' A+B <= 1, A >= 0, B >= 0
'
'The routine attempts to minimize the weighted sum of least squares (WSLS)
'(Equation [20]) given by the following:
'
' WSLS = SUM[C(t(i)) - Y * K(i)]^2 * t(i)^3
'
'The optimum value of Y (Y_opt) is calculated for given values of A and B
'using Equation (21) as follows:
'
' Y_opt = SUM[C(t(i)) * K(i) * t(i)^3] / SUM[t(i)^3 * K(i)^2]
'
'A and B are first tested at .1 increments, if a given combination produces a lower value
'for WSLS than the previous values of Y, A and B then the old values are replaced and A
'and B are tested at .01 increments. If the refined values result in a lower WSLS the old
'are again replaced and the routine moves on to the next increments of A and B.
'
'Input Variables
' row_first:   indicates the first row of data for this contract
' row_current: indicates the row number of cell calling this function
' column:      indicates the column number of cell calling this function
'
' Note: fractional time values [t(i)] must be located one column to the left of the cell
' calling this function, and ACWP values [K(i)] must be located six columns to the left
' of the cell calling this function.
```

```
'
'Output:  the modified Beta curve EAC [Equation (24)] is output directly to the cell
'         calling this function and is given by the following equation:
'
'      EAC = 1 / Y
'
'*********************************************************************

Function Beta_EAC(row_first, row_current, column)

   'dimension arrays
   Dim t(60) As Double     'array for fractional time values
   Dim K(60) As Double     'array for ACWP values

   'determine number of data points (n) for the contract at the current time
   n = row_current - row_first + 1

   'place fractional t values in t(i), ACWP values in K(i)
   For i = 1 To n
      't(i) values must be one column to the left of cell calling function
      t(i) = Cells(row_first + i - 1, column - 1)
      'ACWP values must be 6 columns to the left of cell calling function
      K(i) = Cells(row_first + i - 1, column - 6)
   Next i

   'initialize WSLS to a high number (because WSLS must be minimized)
   WSLS = 999999999

   'test values of A and B at .1 increments
   For A_pick = 0 To 1 Step 0.1
      For B_pick = 0 To 1 Step 0.1

         'if A + B <= 1 solution meets constraints so check for min WSLS
         If A_pick + B_pick <= 1 Then

            'initialize numerator, denominator, and Y_opt to 0
            numerator = 0
            denominator = 0
            Y_opt = 0

            'calculate Y_opt per Equation (21)
            For i = 1 To n
               numerator = numerator + C_t(t(i), A_pick, B_pick) * K(i) * (t(i) ^ 3)
               denominator = denominator + (K(i) ^ 2) * (t(i) ^ 3)
```

```
        Next i
        Y_opt = numerator / denominator

        'initialize WSLS_temp to 0
        WSLS_temp = 0

        'calculate WSLS per Equation (20)
        For i = 1 To n
            WSLS_temp = WSLS_temp + ((C_t(t(i), A_pick, B_pick) - Y_opt * K(i)) ^
2) * (t(i) ^ 3)
        Next i

        'if WSLS_temp < WSLS then Y_opt, A_pick, and B_pick are a
        'better solution so replace old values and check for better
        'solution at .01 increments
        If WSLS_temp < WSLS Then
            'replace with new values
            y = Y_opt
            A = A_pick
            B = B_pick
            WSLS = WSLS_temp

            'test values of A and B at .01 increments from A - 0.05
            'to A + 0.05 and B - 0.05 to B + 0.05
            For A_refined = A_pick - 0.05 To A_pick + 0.05 Step 0.01
                For B_refined = B_pick - 0.05 To B_pick + 0.05 Step 0.01
                    'if A + B <= 1 solution meets constraints so
                    'check for min WSLS
                    If A_refined + B_refined <= 1 Then

                        'initialize numerator, denominator, and Y_opt
                        'to 0
                        numerator = 0
                        denominator = 0
                        Y_opt = 0

                        'calculate Y_opt per Equation (21)
                        For i = 1 To n
                            numerator = numerator + C_t(t(i), A_refined, B_refined) * K(i) *
(t(i) ^ 3)

                            denominator = denominator + (K(i) ^ 2) * (t(i) ^ 3)
                        Next i
                        Y_opt = numerator / denominator
```

```
                'initialize WSLS_temp to 0
                WSLS_temp = 0

                'calculate WSLS per Equation (20)
                For i = 1 To n
                   WSLS_temp = WSLS_temp + ((C_t(t(i), A_refined, B_refined) -
Y_opt * K(i)) ^ 2) * (t(i) ^ 3)
                Next i

                'if WSLS_temp < WSLS then Y_opt, A_refined,
                'and B_refined are a better solution so
                'replace old values
                If WSLS_temp < WSLS Then
                   y = Y_opt
                   A = A_refined
                   B = B_refined
                   WSLS = WSLS_temp
                End If
              End If
            Next B_refined
          Next A_refined
        End If
      End If
    Next B_pick
  Next A_pick

  'calculate Beta EAC per Equation (24)
  Beta_EAC = 1 / y
```

End Function

```
'*************************************************************************
'this function calculates C(t) per Equation (19) and is used to simplify calculations
'in the main routine
'*************************************************************************
```

Function C_t(t_temp, a_temp, b_temp)

```
  C_t = a_temp * (10 * (t_temp ^ 2) - 20 * (t_temp ^ 3) + 10 * (t_temp ^ 4)) + b_temp *
(10 * (t_temp ^ 3) - 20 * (t_temp ^ 4) + 10 * (t_temp ^ 5)) + (5 * (t_temp ^ 4) - 4 *
(t_temp ^ 5))
```

End Function

Appendix G: Raw Inflation Indices

Year	3600	3080
1960	0.208	0.205
1961	0.211	0.208
1962	0.213	0.210
1963	0.214	0.214
1964	0.222	0.217
1965	0.230	0.221
1966	0.240	0.227
1967	0.258	0.234
1968	0.272	0.243
1969	0.277	0.254
1970	0.287	0.268
1971	0.300	0.282
1972	0.311	0.295
1973	0.325	0.308
1974	0.361	0.332
1975	0.382	0.368
1976	0.404	0.393
1977	0.425	0.420
1978	0.449	0.448
1979	0.485	0.487
1980	0.521	0.535
1981	0.646	0.598
1982	0.685	0.653
1983	0.714	0.685
1984	0.737	0.711
1985	0.758	0.736
1986	0.776	0.756
1987	0.794	0.777
1988	0.815	0.800
1989	0.843	0.834
1990	0.869	0.867
1991	0.899	0.904
1992	0.931	0.930
1993	0.960	0.955
1994	0.978	0.974
1995	1.000	1.000

Appendix H: Detailed Results

This appendix contains the detailed results for the performance of the 15 EAC methods evaluated in this study. Each sheet contains the overall results for each EAC method within a given category of data as well as the quartile results within the category. The first sheet for each category shows the results for the non-inflation adjusted data (TY). While a second sheet shows the results for the inflation adjusted data (CY95). The data shown for each set of results includes the MAPE value, the SDAPE value, and the combined score for each of the EAC methods.

Results for All Contracts Using Non-Inflation Adjusted Data

TY Results for Overall Performance			
	Score	MAPE	SDAPE
CPI3	14	12.9%	19.3%
CPI6	4	11.4%	14.6%
CPIcum	6	11.6%	14.9%
SPI3	17	14.7%	23.1%
SPI6	8	12.5%	16.5%
SPIcum	10	12.5%	17.7%
SCI3	19	19.0%	94.9%
SCI6	14	13.4%	18.9%
SCIcum	12	12.9%	18.6%
CPI6 x SPIcum	10	12.9%	17.1%
Composite	2	11.2%	14.5%
Rayleigh (Lin Reg)	21	206.6%	1225.8%
Rayleigh (T-G Reg)	23	449.9%	5870.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	63284.5%	2096489.2%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	Composite
>50% - 75%	CPI6
>75% - 100%	CPIcum Composite

TY Results for 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	14	24.0%	30.4%
CPI6	5	21.7%	19.7%
CPIcum	5	21.9%	19.2%
SPI3	19	27.4%	37.0%
SPI6	8	23.5%	22.7%
SPIcum	10	23.5%	26.2%
SCI3	23	40.6%	183.4%
SCI6	16	26.6%	28.4%
SCIcum	14	25.6%	27.4%
CPI6 x SPIcum	11	25.4%	24.8%
Composite	2	20.7%	18.6%
Rayleigh (Lin Reg)	22	107.1%	55.9%
Rayleigh (T-G Reg)	24	112.0%	113.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	248145.4%	4156601.3%

TY Results for >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	5	14.9%	17.4%
CPI6	5	14.4%	17.5%
CPIcum	6	14.3%	17.9%
SPI3	17	18.7%	18.9%
SPI6	15	17.7%	18.9%
SPIcum	11	16.2%	18.0%
SCI3	20	20.4%	21.4%
SCI6	17	18.0%	19.2%
SCIcum	12	15.3%	18.5%
CPI6 x SPIcum	12	16.2%	18.2%
Composite	4	14.2%	17.8%
Rayleigh (Lin Reg)	22	200.4%	519.6%
Rayleigh (T-G Reg)	24	309.1%	1155.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	26	882.9%	4851.4%

TY Results for >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	5	9.3%	9.0%
CPI6	3	8.5%	9.2%
CPIcum	4	8.5%	9.4%
SPI3	16	11.2%	10.9%
SPI6	12	9.9%	10.0%
SPIcum	7	9.0%	9.5%
SCI3	18	12.1%	11.9%
SCI6	14	10.1%	10.4%
SCIcum	7	8.9%	9.6%
CPI6 x SPIcum	10	9.3%	9.8%
Composite	4	8.5%	9.4%
Rayleigh (Lin Reg)	23	303.8%	1421.1%
Rayleigh (T-G Reg)	23	366.9%	1110.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	20	48.2%	83.2%

TY Results for >75% to100% Complete			
	Score	MAPE	SDAPE
CPI3	15	5.6%	5.0%
CPI6	11	5.2%	4.5%
CPIcum	3	4.7%	3.5%
SPI3	9	4.9%	4.4%
SPI6	5	4.5%	3.9%
SPIcum	6	4.8%	3.8%
SCI3	17	5.9%	7.4%
SCI6	11	4.9%	4.7%
SCIcum	6	4.9%	3.7%
CPI6 x SPIcum	14	5.6%	4.9%
Composite	3	4.7%	3.5%
Rayleigh (Lin Reg)	21	212.2%	1657.2%
Rayleigh (T-G Reg)	23	695.7%	9132.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	19	12.8%	52.4%

Results for All Contracts Using Inflation Adjusted Data

CY95 Results for Overall Performance	Score	MAPE	SDAPE
CPI3	10	13.0%	19.3%
CPI6	5	11.7%	14.4%
CPIcum	4	11.6%	14.4%
SPI3	16	15.2%	24.2%
SPI6	7	13.0%	17.0%
SPIcum	9	13.0%	19.0%
SCI3	18	19.4%	92.3%
SCI6	13	14.1%	19.7%
SCIcum	13	13.6%	20.0%
CPI6 x SPIcum	9	13.6%	18.0%
Composite	2	11.3%	14.0%
Rayleigh (Lin Reg)	23	237.0%	2986.7%
Rayleigh (T-G Reg)	23	300.8%	2406.3%
Rayleigh MMAE	20	235.6%	494.7%
Beta	26	71382.6%	2399586.0%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPIcum
>50% - 75%	CPI6
>75% - 100%	SPI6

CY95 Results for 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	10	22.2%	30.6%
CPI6	5	19.4%	19.5%
CPIcum	4	19.4%	18.9%
SPI3	17	27.2%	39.7%
SPI6	8	23.0%	24.8%
SPIcum	10	23.0%	29.8%
SCI3	21	40.9%	178.2%
SCI6	14	26.4%	30.6%
SCIcum	14	25.4%	31.2%
CPI6 x SPIcum	10	25.1%	27.4%
Composite	2	18.2%	18.2%
Rayleigh (Lin Reg)	22	109.1%	65.2%
Rayleigh (T-G Reg)	20	102.4%	43.8%
Rayleigh MMAE	25	468.0%	765.8%
Beta	27	279733.6%	4757726.5%

CY95 Results for >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	5	14.3%	17.5%
CPI6	5	13.6%	17.7%
CPIcum	4	13.3%	18.1%
SPI3	17	18.1%	19.4%
SPI6	15	17.1%	19.4%
SPIcum	10	15.5%	18.5%
SCI3	20	20.0%	22.0%
SCI6	17	17.7%	19.7%
SCIcum	11	15.1%	18.8%
CPI6 x SPIcum	12	16.1%	18.6%
Composite	5	13.4%	18.1%
Rayleigh (Lin Reg)	26	612.9%	6426.9%
Rayleigh (T-G Reg)	22	203.4%	501.0%
Rayleigh MMAE	24	353.5%	615.7%
Beta	28	1219.0%	6831.2%

CY95 Results for >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	5	9.2%	9.0%
CPI6	3	8.7%	9.3%
CPIcum	6	8.8%	9.5%
SPI3	16	11.2%	10.4%
SPI6	14	10.0%	9.9%
SPIcum	8	9.4%	9.4%
SCI3	18	11.4%	11.4%
SCI6	14	9.8%	10.4%
SCIcum	8	9.0%	9.7%
CPI6 x SPIcum	10	9.2%	9.8%
Composite	6	8.8%	9.5%
Rayleigh (Lin Reg)	23	156.9%	478.8%
Rayleigh (T-G Reg)	26	411.2%	3011.8%
Rayleigh MMAE	23	187.6%	317.4%
Beta	20	47.5%	82.0%

CY95 Results for >75% to100% Complete	Score	MAPE	SDAPE
CPI3	13	7.6%	7.8%
CPI6	12	7.6%	7.5%
CPIcum	6	6.8%	6.0%
SPI3	5	6.7%	6.0%
SPI6	3	6.5%	5.9%
SPIcum	4	6.8%	5.8%
SCI3	13	7.5%	8.6%
SCI6	9	7.2%	7.3%
SCIcum	7	7.0%	6.0%
CPI6 x SPIcum	13	7.8%	7.5%
Composite	5	6.8%	5.9%
Rayleigh (Lin Reg)	21	139.5%	564.3%
Rayleigh (T-G Reg)	23	365.8%	3022.6%
Rayleigh MMAE	19	83.3%	144.9%
Beta	17	20.2%	134.4%

Results for Aircraft Contracts Using Non-Inflation Adjusted Data

TY Results for All Aircraft Data

	Score	MAPE	SDAPE
CPI3	10	15.1%	18.8%
CPI6	3	13.7%	18.1%
CPIcum	13	15.1%	19.5%
SPI3	17	15.8%	19.8%
SPI6	6	14.1%	18.7%
SPIcum	14	15.4%	19.4%
SCI3	16	16.2%	19.4%
SCI6	6	14.2%	18.4%
SCIcum	12	15.3%	19.2%
CPI6 x SPIcum	2	13.7%	17.8%
Composite	11	15.0%	19.4%
Rayleigh (Lin Reg)	20	104.6%	292.7%
Rayleigh (T-G Reg)	22	2138.5%	18310.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	627763.6%	6700589.2%

Best Performing Method(s)

Overall	CPI6 x SPIcum
0% - 25%	CPI6 x SPIcum
>25% - 50%	CPI3 CPI6
>50% - 75%	SCIcum
>75% - 100%	CPIcum SPI6 Composite

TY Results for Aircraft Data 0% to 25% Complete

	Score	MAPE	SDAPE
CPI3	10	29.0%	22.9%
CPI6	13	29.9%	22.7%
CPIcum	14	29.8%	23.0%
SPI3	15	30.9%	22.9%
SPI6	4	28.5%	21.5%
SPIcum	9	29.2%	22.0%
SCI3	13	31.2%	21.7%
SCI6	5	27.5%	21.7%
SCIcum	7	29.2%	21.6%
CPI6 x SPIcum	2	27.5%	21.4%
Composite	13	29.3%	23.0%
Rayleigh (Lin Reg)	20	87.7%	23.3%
Rayleigh (T-G Reg)	20	86.6%	28.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	2241748.2%	12649935.8%

TY Results for Aircraft Data >25% to 50% Complete

	Score	MAPE	SDAPE
CPI3	4	23.4%	22.5%
CPI6	4	23.2%	22.9%
CPIcum	5	23.0%	23.5%
SPI3	13	24.7%	24.8%
SPI6	18	26.8%	24.9%
SPIcum	14	25.4%	24.2%
SCI3	11	25.1%	24.1%
SCI6	17	27.0%	24.4%
SCIcum	11	25.2%	23.9%
CPI6 x SPIcum	11	25.4%	23.5%
Composite	6	23.4%	23.4%
Rayleigh (Lin Reg)	21	62.4%	47.7%
Rayleigh (T-G Reg)	25	420.7%	1311.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	227.0%	358.6%

TY Results for Aircraft Data >50% to 75% Complete

	Score	MAPE	SDAPE
CPI3	11	7.5%	2.8%
CPI6	11	7.0%	3.1%
CPIcum	6	6.4%	2.9%
SPI3	10	7.2%	2.9%
SPI6	9	6.8%	3.0%
SPIcum	8	6.3%	3.2%
SCI3	12	8.0%	2.8%
SCI6	9	7.4%	2.6%
SCIcum	5	6.0%	3.0%
CPI6 x SPIcum	10	6.7%	3.2%
Composite	6	6.3%	3.0%
Rayleigh (Lin Reg)	20	228.0%	613.7%
Rayleigh (T-G Reg)	22	467.5%	806.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	18	127.2%	190.8%

TY Results for Aircraft Data >75% to 100% Complete

	Score	MAPE	SDAPE
CPI3	9	4.6%	3.6%
CPI6	7	4.4%	3.4%
CPIcum	3	4.2%	3.2%
SPI3	10	4.6%	3.8%
SPI6	3	4.1%	3.3%
SPIcum	4	4.2%	3.3%
SCI3	12	5.0%	4.2%
SCI6	7	4.4%	3.4%
SCIcum	6	4.3%	3.4%
CPI6 x SPIcum	9	4.6%	3.6%
Composite	3	4.2%	3.2%
Rayleigh (Lin Reg)	16	92.7%	276.2%
Rayleigh (T-G Reg)	18	4252.3%	26931.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	14	39.3%	145.1%

Results for Aircraft Contracts Using Inflation Adjusted Data

CY95 Results for All Aircraft Data			
	Score	MAPE	SDAPE
CPI3	6	16.7%	17.7%
CPI6	8	16.3%	18.0%
CPIcum	12	17.0%	18.1%
SPI3	14	17.2%	18.8%
SPI6	2	16.1%	17.6%
SPIcum	12	17.3%	17.9%
SCI3	17	17.7%	19.0%
SCI6	3	16.2%	17.6%
SCIcum	10	17.2%	17.8%
CPI6 x SPIcum	7	16.3%	17.9%
Composite	10	16.9%	18.0%
Rayleigh (Lin Reg)	19	83.7%	146.3%
Rayleigh (T-G Reg)	21	164.8%	251.1%
Rayleigh MMAE	23	350.2%	598.9%
Beta	25	713681.7%	7670335.1%

Best Performing Method(s)

Overall	SPI6
0% - 25%	CPI6 x SPIcum
>25% - 50%	CPI3 CPI6 CPIcum
>50% - 75%	CPIcum SCIcum Composite
>75% - 100%	SPI6

CY95 Results for Aircraft Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	8	27.5%	20.4%
CPI6	9	26.5%	21.9%
CPIcum	12	26.9%	22.2%
SPI3	13	29.0%	22.1%
SPI6	5	26.1%	20.5%
SPIcum	8	26.9%	20.5%
SCI3	12	29.7%	20.8%
SCI6	5	24.8%	20.8%
SCIcum	7	26.2%	20.8%
CPI6 x SPIcum	2	24.5%	20.4%
Composite	10	26.5%	22.1%
Rayleigh (Lin Reg)	18	87.4%	25.4%
Rayleigh (T-G Reg)	18	86.1%	30.9%
Rayleigh MMAE	21	596.6%	786.0%
Beta	23	2548471.1%	14483026.6%

CY95 Results for Aircraft Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	4	22.5%	23.4%
CPI6	4	22.3%	23.7%
CPIcum	4	22.0%	24.0%
SPI3	10	24.0%	24.7%
SPI6	17	26.1%	25.0%
SPIcum	13	24.5%	24.6%
SCI3	12	24.2%	24.7%
SCI6	17	26.0%	25.1%
SCIcum	10	24.1%	24.6%
CPI6 x SPIcum	12	24.3%	24.6%
Composite	6	22.3%	24.1%
Rayleigh (Lin Reg)	20	63.6%	51.7%
Rayleigh (T-G Reg)	23	205.5%	418.1%
Rayleigh MMAE	26	540.9%	691.7%
Beta	23	264.3%	370.3%

CY95 Results for Aircraft Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	13	7.7%	3.4%
CPI6	10	7.7%	3.0%
CPIcum	5	7.3%	2.6%
SPI3	12	7.4%	3.4%
SPI6	9	7.2%	3.3%
SPIcum	6	6.8%	3.2%
SCI3	14	8.2%	3.3%
SCI6	14	7.8%	3.4%
SCIcum	5	6.9%	2.8%
CPI6 x SPIcum	11	7.4%	3.3%
Composite	5	7.2%	2.7%
Rayleigh (Lin Reg)	17	116.3%	170.7%
Rayleigh (T-G Reg)	20	191.1%	176.6%
Rayleigh MMAE	23	318.0%	579.0%
Beta	20	122.7%	188.0%

CY95 Results for Aircraft Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	9	10.0%	9.3%
CPI6	16	11.8%	12.5%
CPIcum	10	11.0%	8.5%
SPI3	5	9.5%	8.6%
SPI6	3	9.8%	8.1%
SPIcum	8	10.8%	8.3%
SCI3	9	9.9%	11.2%
SCI6	10	10.5%	9.3%
SCIcum	11	11.1%	8.5%
CPI6 x SPIcum	17	11.9%	12.5%
Composite	10	11.0%	8.5%
Rayleigh (Lin Reg)	19	80.5%	198.8%
Rayleigh (T-G Reg)	23	166.8%	215.4%
Rayleigh MMAE	23	148.6%	338.8%
Beta	23	111.3%	396.7%

Results for Armored Vehicle Contracts Using Non-Inflation Adjusted Data

TY Results for All Armored Vehicle Data			
	Score	MAPE	SDAPE
CPI3	15	17.4%	18.6%
CPI6	12	16.0%	18.1%
CPIcum	20	19.6%	19.6%
SPI3	13	17.7%	16.4%
SPI6	10	16.5%	15.3%
SPIcum	12	17.8%	14.9%
SCI3	16	18.7%	17.0%
SCI6	4	14.2%	13.0%
SCIcum	6	14.8%	14.4%
CPI6 x SPIcum	2	12.6%	11.3%
Composite	19	19.6%	18.6%
Rayleigh (Lin Reg)	22	106.1%	120.0%
Rayleigh (T-G Reg)	24	157.8%	209.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	26	325.8%	926.3%

Best Performing Method(s)

Overall	CPI6 x SPIcum
0% - 25%	SPI6
>25% - 50%	CPI3 CPI6 x SPIcum
>50% - 75%	CPI3
>75% - 100%	SPI3

TY Results for Armored Vehicle Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	18	40.6%	18.0%
CPI6	20	45.1%	16.7%
CPIcum	19	44.1%	16.7%
SPI3	11	26.5%	14.9%
SPI6	4	25.6%	10.3%
SPIcum	11	33.0%	14.3%
SCI3	8	30.6%	14.0%
SCI6	7	22.1%	14.6%
SCIcum	11	31.7%	14.4%
CPI6 x SPIcum	8	25.4%	14.6%
Composite	17	42.5%	16.2%
Rayleigh (Lin Reg)	24	88.5%	31.2%
Rayleigh (T-G Reg)	14	73.0%	13.2%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	26	1117.9%	1542.0%

TY Results for Armored Vehicle Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	5	17.4%	6.5%
CPI6	6	16.7%	8.8%
CPIcum	10	22.0%	9.1%
SPI3	20	32.0%	21.1%
SPI6	22	32.3%	21.5%
SPIcum	16	24.3%	10.1%
SCI3	16	23.7%	16.9%
SCI6	15	22.6%	18.1%
SCIcum	7	14.7%	9.4%
CPI6 x SPIcum	5	14.4%	9.1%
Composite	10	22.8%	8.0%
Rayleigh (Lin Reg)	25	118.4%	108.3%
Rayleigh (T-G Reg)	27	313.3%	368.2%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	16	20.0%	25.5%

TY Results for Armored Vehicle Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	7	6.1%	4.2%
CPI6	10	7.1%	4.8%
CPIcum	12	8.3%	5.3%
SPI3	9	10.4%	3.5%
SPI6	10	11.7%	3.4%
SPIcum	11	11.5%	3.7%
SCI3	23	15.5%	19.6%
SCI6	21	13.0%	7.3%
SCIcum	9	8.8%	3.8%
CPI6 x SPIcum	18	11.5%	7.2%
Composite	11	9.2%	4.1%
Rayleigh (Lin Reg)	27	93.9%	120.7%
Rayleigh (T-G Reg)	25	75.2%	94.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	11	6.8%	6.0%

TY Results for Armored Vehicle Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	8	3.5%	3.1%
CPI6	11	3.7%	3.5%
CPIcum	3	3.1%	2.9%
SPI3	2	3.1%	2.7%
SPI6	8	3.7%	3.0%
SPIcum	6	3.4%	3.0%
SCI3	11	3.8%	3.3%
SCI6	12	4.3%	3.3%
SCIcum	4	3.1%	3.0%
CPI6 x SPIcum	12	3.7%	3.6%
Composite	4	3.2%	2.9%
Rayleigh (Lin Reg)	17	119.7%	178.4%
Rayleigh (T-G Reg)	17	151.3%	148.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	8	3.5%	3.1%

Results for Armored Vehicle Contracts Using Inflation Adjusted Data

CY95 Results for All Armored Vehicle Data			
	Score	MAPE	SDAPE
CPI3	16	16.2%	15.6%
CPI6	14	15.2%	15.7%
CPIcum	20	19.1%	16.5%
SPI3	13	15.6%	14.9%
SPI6	9	15.0%	13.7%
SPIcum	12	16.2%	12.1%
SCI3	13	15.8%	14.6%
SCI6	4	11.0%	11.0%
SCIcum	6	13.1%	11.3%
CPI6 x SPIcum	2	10.7%	8.1%
Composite	17	18.8%	15.6%
Rayleigh (Lin Reg)	22	150.0%	225.6%
Rayleigh (T-G Reg)	26	585.2%	1059.3%
Rayleigh MMAE	28	588.1%	1217.9%
Beta	24	180.9%	380.4%

Best Performing Method(s)

Overall	CPI6 x SPIcum
0% - 25%	SPI6
>25% - 50%	CPI3 CPI6 SCIcum CPI6 x SPIcum
>50% - 75%	CPI3
>75% - 100%	SCI3

CY95 Results for Armored Vehicle Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	18	35.6%	16.0%
CPI6	18	40.5%	15.1%
CPIcum	19	39.2%	15.5%
SPI3	12	19.4%	15.2%
SPI6	3	18.7%	8.1%
SPIcum	12	26.9%	13.0%
SCI3	16	24.4%	16.6%
SCI6	4	15.9%	9.8%
SCIcum	10	25.8%	12.1%
CPI6 x SPIcum	6	19.3%	9.8%
Composite	15	37.4%	14.8%
Rayleigh (Lin Reg)	25	90.2%	28.7%
Rayleigh (T-G Reg)	14	73.5%	8.4%
Rayleigh MMAE	29	1474.0%	2519.7%
Beta	27	610.9%	517.5%

CY95 Results for Armored Vehicle Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	5	15.5%	3.5%
CPI6	5	14.9%	5.8%
CPIcum	11	19.3%	9.4%
SPI3	22	28.8%	22.0%
SPI6	24	29.2%	22.5%
SPIcum	15	20.9%	10.8%
SCI3	18	21.8%	16.0%
SCI6	15	19.5%	18.5%
SCIcum	5	12.5%	7.2%
CPI6 x SPIcum	5	14.2%	7.0%
Composite	12	19.9%	8.6%
Rayleigh (Lin Reg)	26	139.6%	125.9%
Rayleigh (T-G Reg)	30	1003.8%	1430.8%
Rayleigh MMAE	28	828.2%	843.2%
Beta	19	21.3%	19.4%

CY95 Results for Armored Vehicle Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	5	7.8%	3.4%
CPI6	8	7.8%	4.9%
CPIcum	9	11.3%	3.4%
SPI3	9	12.6%	2.5%
SPI6	14	13.7%	4.1%
SPIcum	14	13.4%	4.5%
SCI3	20	13.7%	10.6%
SCI6	13	8.8%	5.3%
SCIcum	12	8.0%	5.5%
CPI6 x SPIcum	11	8.2%	5.1%
Composite	9	12.0%	3.1%
Rayleigh (Lin Reg)	25	172.7%	229.4%
Rayleigh (T-G Reg)	22	104.8%	134.2%
Rayleigh MMAE	25	269.7%	156.3%
Beta	9	6.1%	5.3%

CY95 Results for Armored Vehicle Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	12	4.2%	3.1%
CPI6	12	4.7%	2.9%
CPIcum	13	5.1%	2.8%
SPI3	5	3.6%	2.5%
SPI6	12	4.2%	3.1%
SPIcum	10	4.6%	2.8%
SCI3	2	2.8%	2.3%
SCI6	10	3.9%	3.0%
SCIcum	14	5.1%	2.9%
CPI6 x SPIcum	13	4.7%	3.0%
Composite	11	5.0%	2.7%
Rayleigh (Lin Reg)	20	177.9%	356.0%
Rayleigh (T-G Reg)	22	876.9%	1330.4%
Rayleigh MMAE	18	102.9%	162.7%
Beta	6	3.1%	2.8%

Results for Ballistic Missile Contracts Using Non-Inflation Adjusted Data

TY Results for All Ballistic Missile Data	Score	MAPE	SDAPE
CPI3	18	14.4%	33.0%
CPI6	6	12.2%	19.7%
CPIcum	4	11.6%	19.1%
SPI3	20	15.7%	36.9%
SPI6	12	12.9%	22.5%
SPIcum	8	12.6%	21.0%
SCI3	22	27.9%	209.0%
SCI6	16	14.0%	27.8%
SCIcum	10	12.7%	21.4%
CPI6 x SPIcum	14	13.9%	23.4%
Composite	2	11.3%	19.0%
Rayleigh (Lin Reg)	24	184.8%	578.5%
Rayleigh (T-G Reg)	26	314.2%	1477.4%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	1294.7%	8799.6%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI6 SCI6
>50% - 75%	CPI3
>75% - 100%	SCI3

TY Results for Ballistic Missile Data 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	17	28.9%	60.8%
CPI6	6	22.0%	27.3%
CPIcum	4	20.2%	24.9%
SPI3	21	33.0%	68.8%
SPI6	13	25.8%	34.4%
SPIcum	9	22.9%	29.8%
SCI3	24	87.0%	437.9%
SCI6	18	31.8%	49.1%
SCIcum	11	24.4%	30.7%
CPI6 x SPIcum	16	29.0%	36.6%
Composite	2	18.9%	24.8%
Rayleigh (Lin Reg)	25	116.7%	105.4%
Rayleigh (T-G Reg)	16	97.5%	28.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	5016.1%	18459.3%

TY Results for Ballistic Missile Data >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	7	15.2%	26.1%
CPI6	6	14.2%	26.6%
CPIcum	9	14.2%	27.5%
SPI3	9	17.0%	25.7%
SPI6	11	15.3%	26.8%
SPIcum	15	15.5%	28.0%
SCI3	16	17.8%	27.5%
SCI6	6	14.4%	26.2%
SCIcum	13	14.7%	28.1%
CPI6 x SPIcum	10	14.7%	27.1%
Composite	8	14.0%	27.5%
Rayleigh (Lin Reg)	22	269.5%	764.2%
Rayleigh (T-G Reg)	20	163.9%	335.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	1018.6%	3432.8%

TY Results for Ballistic Missile Data >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	4	10.5%	12.5%
CPI6	7	10.6%	13.5%
CPIcum	9	10.4%	14.0%
SPI3	14	11.1%	14.1%
SPI6	8	10.3%	14.0%
SPIcum	16	10.6%	13.9%
SCI3	8	11.1%	13.2%
SCI6	7	10.4%	13.8%
SCIcum	12	10.5%	14.2%
CPI6 x SPIcum	9	10.9%	13.7%
Composite	8	10.4%	13.9%
Rayleigh (Lin Reg)	19	96.2%	136.8%
Rayleigh (T-G Reg)	21	381.2%	1486.4%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	17	49.4%	99.3%

TY Results for Ballistic Missile Data >75% to 100% Complete	Score	MAPE	SDAPE
CPI3	12	6.1%	4.2%
CPI6	14	6.2%	4.3%
CPIcum	8	5.8%	4.0%
SPI3	9	5.6%	4.2%
SPI6	9	5.4%	4.4%
SPIcum	14	6.0%	4.5%
SCI3	2	5.3%	3.8%
SCI6	5	5.5%	3.9%
SCIcum	11	6.0%	4.2%
CPI6 x SPIcum	17	6.5%	4.5%
Composite	9	5.8%	4.1%
Rayleigh (Lin Reg)	21	219.3%	732.1%
Rayleigh (T-G Reg)	23	441.7%	2089.4%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	19	10.7%	21.9%

Results for Ballistic Missile Contracts Using Inflation Adjusted Data

CY95 Results for All Ballistic Missile Data	Score	MAPE	SDAPE
CPI3	17	13.5%	33.4%
CPI6	6	11.3%	20.6%
CPIcum	4	10.6%	19.9%
SPI3	19	15.4%	37.8%
SPI6	12	12.5%	24.0%
SPIcum	8	12.1%	22.6%
SCI3	21	27.1%	202.4%
SCI6	16	13.5%	28.7%
SCIcum	10	12.2%	22.9%
CPI6 x SPIcum	14	13.3%	24.8%
Composite	2	10.4%	19.8%
Rayleigh (Lin Reg)	25	183.9%	640.7%
Rayleigh (T-G Reg)	25	198.5%	523.1%
Rayleigh MMAE	25	214.1%	418.9%
Beta	29	2855.8%	33005.4%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI3 CPI6 SCI6
>50% - 75%	CPI3
>75% - 100%	SCI3

CY95 Results for Ballistic Missile Data 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	17	28.1%	61.1%
CPI6	6	21.2%	28.4%
CPIcum	4	18.7%	26.2%
SPI3	21	33.8%	70.0%
SPI6	13	26.3%	37.4%
SPIcum	9	23.9%	32.8%
SCI3	24	86.1%	423.5%
SCI6	18	32.1%	50.3%
SCIcum	11	25.3%	33.1%
CPI6 x SPIcum	16	29.6%	38.8%
Composite	2	17.9%	26.1%
Rayleigh (Lin Reg)	25	115.0%	85.6%
Rayleigh (T-G Reg)	16	99.0%	29.9%
Rayleigh MMAE	28	510.8%	708.5%
Beta	30	12362.9%	71375.1%

CY95 Results for Ballistic Missile Data >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	6	15.1%	27.3%
CPI6	6	14.2%	27.9%
CPIcum	10	14.2%	28.8%
SPI3	8	17.2%	27.0%
SPI6	10	15.5%	28.3%
SPIcum	15	15.8%	29.5%
SCI3	15	17.9%	28.5%
SCI6	6	14.8%	27.5%
SCIcum	13	15.1%	29.5%
CPI6 x SPIcum	10	15.1%	28.4%
Composite	9	14.1%	28.8%
Rayleigh (Lin Reg)	22	308.0%	1079.3%
Rayleigh (T-G Reg)	19	126.3%	143.7%
Rayleigh MMAE	22	331.5%	526.2%
Beta	25	1050.4%	3560.0%

CY95 Results for Ballistic Missile Data >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	2	10.3%	12.9%
CPI6	6	10.6%	13.8%
CPIcum	10	10.7%	14.1%
SPI3	14	11.1%	14.2%
SPI6	8	10.6%	14.0%
SPIcum	9	10.9%	13.8%
SCI3	7	10.8%	13.4%
SCI6	8	10.5%	14.1%
SCIcum	11	10.6%	14.3%
CPI6 x SPIcum	9	10.8%	13.9%
Composite	9	10.7%	14.0%
Rayleigh (Lin Reg)	18	76.4%	95.0%
Rayleigh (T-G Reg)	23	327.4%	890.8%
Rayleigh MMAE	21	131.8%	177.4%
Beta	18	50.3%	99.9%

CY95 Results for Ballistic Missile Data >75% to 100% Complete	Score	MAPE	SDAPE
CPI3	8	4.0%	3.5%
CPI6	8	4.0%	3.5%
CPIcum	4	3.8%	3.2%
SPI3	7	3.9%	3.5%
SPI6	8	3.6%	3.8%
SPIcum	7	3.9%	3.5%
SCI3	3	3.5%	3.3%
SCI6	6	3.6%	3.6%
SCIcum	6	3.9%	3.3%
CPI6 x SPIcum	11	4.2%	3.7%
Composite	5	3.8%	3.3%
Rayleigh (Lin Reg)	20	201.9%	564.3%
Rayleigh (T-G Reg)	18	187.2%	388.5%
Rayleigh MMAE	16	76.2%	108.6%
Beta	14	10.5%	21.7%

Results for Electronic Warfare System Contracts Using Non-Inflation Adjusted Data

TY Results for All Electronic Warfare Data

	Score	MAPE	SDAPE
CPI3	7	13.1%	15.2%
CPI6	4	12.8%	15.1%
CPIcum	8	13.0%	15.5%
SPI3	14	13.8%	16.5%
SPI6	7	12.8%	15.5%
SPIcum	2	12.6%	14.3%
SCI3	16	15.4%	17.7%
SCI6	12	13.6%	16.3%
SCIcum	9	13.2%	15.3%
CPI6 x SPIcum	5	13.0%	15.1%
Composite	4	12.8%	15.1%
Rayleigh (Lin Reg)	19	237.5%	1296.3%
Rayleigh (T-G Reg)	19	398.4%	1154.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	22	1702.5%	13846.9%

Best Performing Method(s)

Overall	SPIcum
0% - 25%	SPIcum
>25% - 50%	SPIcum
>50% - 75%	CPI6
>75% - 100%	CPIcum Composite

TY Results for Electronic Warfare Data 0% to 25% Complete

	Score	MAPE	SDAPE
CPI3	9	24.6%	21.7%
CPI6	11	24.6%	22.1%
CPIcum	12	25.1%	21.8%
SPI3	13	24.0%	24.7%
SPI6	8	22.6%	23.1%
SPIcum	2	21.6%	20.6%
SCI3	18	28.5%	24.4%
SCI6	15	25.0%	24.2%
SCIcum	10	24.5%	22.1%
CPI6 x SPIcum	10	24.1%	22.2%
Composite	5	23.9%	21.7%
Rayleigh (Lin Reg)	22	126.3%	59.3%
Rayleigh (T-G Reg)	22	115.6%	69.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	7563.3%	29266.1%

TY Results for Electronic Warfare Data >25% to 50% Complete

	Score	MAPE	SDAPE
CPI3	9	19.3%	15.0%
CPI6	6	19.1%	14.9%
CPIcum	8	19.2%	15.0%
SPI3	14	21.3%	15.2%
SPI6	15	21.3%	15.6%
SPIcum	5	19.8%	13.8%
SCI3	18	21.8%	15.7%
SCI6	18	21.6%	15.9%
SCIcum	7	19.9%	14.0%
CPI6 x SPIcum	9	20.0%	14.1%
Composite	6	19.2%	14.8%
Rayleigh (Lin Reg)	23	287.7%	462.9%
Rayleigh (T-G Reg)	25	787.5%	1908.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	272.6%	300.9%

TY Results for Electronic Warfare Data >50% to 75% Complete

	Score	MAPE	SDAPE
CPI3	4	12.5%	12.0%
CPI6	2	12.3%	11.9%
CPIcum	9	12.5%	12.6%
SPI3	17	15.0%	13.4%
SPI6	11	13.2%	12.5%
SPIcum	10	13.4%	12.1%
SCI3	19	15.9%	15.2%
SCI6	14	13.3%	13.1%
SCIcum	11	13.4%	12.3%
CPI6 x SPIcum	10	12.9%	12.5%
Composite	8	12.6%	12.4%
Rayleigh (Lin Reg)	25	663.2%	2752.1%
Rayleigh (T-G Reg)	23	525.5%	1390.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	57.2%	63.7%

TY Results for Electronic Warfare Data >75% to 100% Complete

	Score	MAPE	SDAPE
CPI3	12	5.1%	4.4%
CPI6	9	4.9%	3.6%
CPIcum	2	4.6%	2.7%
SPI3	6	4.7%	3.1%
SPI6	5	4.7%	3.0%
SPIcum	4	4.7%	2.8%
SCI3	16	5.6%	6.7%
SCI6	14	5.3%	4.5%
SCIcum	6	4.8%	3.0%
CPI6 x SPIcum	11	5.1%	4.0%
Composite	2	4.6%	2.7%
Rayleigh (Lin Reg)	20	51.4%	104.4%
Rayleigh (T-G Reg)	22	257.7%	654.2%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	18	11.6%	29.4%

Results for Electronic Warfare System Contracts Using Inflation Adjusted Data

CY95 Results for All Electronic Warfare Data			
	Score	MAPE	SDAPE
CPI3	10	14.0%	14.1%
CPI6	6	13.6%	14.0%
CPIcum	8	13.7%	14.1%
SPI3	14	14.4%	15.9%
SPI6	10	13.8%	14.9%
SPIcum	2	13.4%	13.2%
SCI3	17	16.1%	17.1%
SCI6	15	14.7%	15.9%
SCIcum	11	14.1%	14.1%
CPI6 x SPIcum	11	14.1%	14.1%
Composite	4	13.5%	13.8%
Rayleigh (Lin Reg)	23	765.8%	7858.8%
Rayleigh (T-G Reg)	21	214.7%	470.6%
Rayleigh MMAE	19	135.8%	282.1%
Beta	25	1006.3%	8606.8%

Best Performing Method(s)

Overall	SPIcum
0% - 25%	SPIcum
>25% - 50%	SPIcum
>50% - 75%	CPI6
>75% - 100%	SPI3 SPIcum

CY95 Results for Electronic Warfare Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	8	23.9%	19.5%
CPI6	9	23.4%	20.3%
CPIcum	9	23.8%	20.0%
SPI3	18	24.4%	23.9%
SPI6	10	22.8%	22.2%
SPIcum	2	21.4%	18.9%
SCI3	21	28.1%	24.0%
SCI6	18	24.7%	23.3%
SCIcum	12	24.1%	20.2%
CPI6 x SPIcum	11	23.7%	20.6%
Composite	5	22.8%	19.6%
Rayleigh (Lin Reg)	25	141.2%	116.9%
Rayleigh (T-G Reg)	23	111.9%	80.7%
Rayleigh MMAE	27	422.8%	564.0%
Beta	29	4347.9%	18264.4%

CY95 Results for Electronic Warfare Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	8	17.8%	13.3%
CPI6	7	17.4%	13.4%
CPIcum	8	17.6%	13.4%
SPI3	13	19.9%	13.9%
SPI6	14	19.9%	14.1%
SPIcum	5	18.4%	12.1%
SCI3	17	20.4%	14.3%
SCI6	17	20.1%	14.4%
SCIcum	7	18.5%	12.2%
CPI6 x SPIcum	8	18.5%	12.4%
Composite	6	17.6%	13.1%
Rayleigh (Lin Reg)	26	3735.4%	18689.8%
Rayleigh (T-G Reg)	23	269.9%	345.0%
Rayleigh MMAE	20	131.1%	125.5%
Beta	23	285.0%	334.7%

CY95 Results for Electronic Warfare Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	4	12.6%	12.0%
CPI6	2	12.5%	11.9%
CPIcum	8	12.8%	12.4%
SPI3	17	15.1%	13.1%
SPI6	12	13.5%	12.4%
SPIcum	10	13.8%	11.9%
SCI3	19	15.8%	14.8%
SCI6	12	13.4%	12.9%
SCIcum	11	13.6%	12.2%
CPI6 x SPIcum	10	13.1%	12.4%
Composite	8	12.9%	12.3%
Rayleigh (Lin Reg)	27	233.2%	815.8%
Rayleigh (T-G Reg)	25	167.3%	384.4%
Rayleigh MMAE	23	106.6%	116.7%
Beta	21	57.5%	62.8%

CY95 Results for Electronic Warfare Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	17	8.3%	7.8%
CPI6	13	8.1%	7.0%
CPIcum	9	7.4%	6.0%
SPI3	3	6.7%	5.8%
SPI6	8	7.2%	6.7%
SPIcum	3	7.1%	5.7%
SCI3	16	8.1%	9.0%
SCI6	20	8.5%	9.3%
SCIcum	10	7.5%	6.0%
CPI6 x SPIcum	15	8.2%	7.1%
Composite	7	7.3%	5.9%
Rayleigh (Lin Reg)	26	75.7%	248.7%
Rayleigh (T-G Reg)	28	245.8%	602.7%
Rayleigh MMAE	24	37.9%	53.4%
Beta	22	11.5%	29.6%

Results for Helicopter Contracts Using Non-Inflation Adjusted Data

TY Results for All Helicopter Data			
	Score	MAPE	SDAPE
CPI3	11	14.1%	14.4%
CPI6	4	11.4%	11.3%
CPIcum	7	12.0%	11.7%
SPI3	18	16.3%	26.1%
SPI6	8	11.8%	16.0%
SPIcum	14	13.8%	26.2%
SCI3	22	21.5%	31.0%
SCI6	12	14.0%	19.7%
SCIcum	19	15.0%	27.8%
CPI6 x SPIcum	15	14.2%	19.9%
Composite	2	11.0%	10.7%
Rayleigh (Lin Reg)	24	152.9%	405.3%
Rayleigh (T-G Reg)	26	171.2%	696.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	1506.2%	8369.6%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	SPIcum
>50% - 75%	CPIcum, Composite
>75% - 100%	SPI6, SPIcum

TY Results for Helicopter Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	8	24.0%	18.9%
CPI6	5	21.5%	14.2%
CPIcum	5	22.9%	13.2%
SPI3	19	33.1%	42.3%
SPI6	10	25.3%	26.3%
SPIcum	18	30.6%	44.2%
SCI3	24	42.9%	46.9%
SCI6	15	31.4%	31.6%
SCIcum	22	33.5%	46.1%
CPI6 x SPIcum	14	30.1%	33.7%
Composite	2	19.7%	12.5%
Rayleigh (Lin Reg)	22	108.6%	42.2%
Rayleigh (T-G Reg)	18	105.9%	26.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	3774.7%	13170.8%

TY Results for Helicopter Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	16	17.3%	13.3%
CPI6	12	15.6%	12.0%
CPIcum	9	15.5%	11.0%
SPI3	13	17.2%	11.1%
SPI6	7	15.2%	10.7%
SPIcum	3	13.9%	10.5%
SCI3	21	22.7%	16.9%
SCI6	17	18.1%	13.3%
SCIcum	9	13.6%	14.5%
CPI6 x SPIcum	16	16.9%	14.7%
Composite	5	14.9%	10.6%
Rayleigh (Lin Reg)	25	315.5%	842.7%
Rayleigh (T-G Reg)	23	102.3%	67.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	2696.2%	10980.3%

TY Results for Helicopter Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	12	9.7%	7.5%
CPI6	7	8.0%	6.0%
CPIcum	3	7.7%	5.3%
SPI3	18	11.1%	9.0%
SPI6	12	9.5%	7.8%
SPIcum	4	7.6%	5.9%
SCI3	21	12.8%	10.8%
SCI6	17	9.8%	10.0%
SCIcum	9	8.3%	6.9%
CPI6 x SPIcum	16	9.9%	8.9%
Composite	3	7.6%	5.4%
Rayleigh (Lin Reg)	26	107.3%	112.8%
Rayleigh (T-G Reg)	26	116.9%	97.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	31.4%	32.2%

TY Results for Helicopter Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	17	7.0%	6.9%
CPI6	11	5.5%	5.2%
CPIcum	6	4.3%	3.9%
SPI3	10	4.3%	5.6%
SPI6	3	3.6%	3.9%
SPIcum	3	3.9%	3.8%
SCI3	19	7.1%	12.3%
SCI6	7	4.2%	4.6%
SCIcum	8	4.9%	4.3%
CPI6 x SPIcum	14	6.2%	5.8%
Composite	4	4.2%	3.8%
Rayleigh (Lin Reg)	21	124.1%	260.6%
Rayleigh (T-G Reg)	23	265.5%	1101.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	13	4.9%	6.8%

Results for Helicopter Contracts Using Inflation Adjusted Data

CY95 Results for All Helicopter Data			
	Score	MAPE	SDAPE
CPI3	8	13.9%	15.0%
CPI6	5	11.9%	10.0%
CPIcum	5	12.1%	9.9%
SPI3	17	18.2%	30.9%
SPI6	9	13.9%	18.3%
SPIcum	14	15.9%	31.0%
SCI3	21	23.6%	36.7%
SCI6	13	16.7%	23.1%
SCIcum	18	17.4%	32.9%
CPI6 x SPIcum	13	16.6%	23.2%
Composite	2	11.2%	8.9%
Rayleigh (Lin Reg)	23	138.0%	402.1%
Rayleigh (T-G Reg)	27	409.7%	3594.8%
Rayleigh MMAE	25	357.2%	588.4%
Beta	29	2043.6%	10289.6%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	Composite
>50% - 75%	CPIcum Composite
>75% - 100%	Beta

CY95 Results for Helicopter Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	8	19.8%	21.6%
CPI6	4	16.7%	12.4%
CPIcum	6	18.0%	12.6%
SPI3	19	35.1%	52.8%
SPI6	11	27.1%	33.0%
SPIcum	17	32.5%	54.5%
SCI3	24	47.0%	58.8%
SCI6	15	34.3%	40.2%
SCIcum	22	35.8%	56.9%
CPI6 x SPIcum	15	32.9%	41.6%
Composite	2	15.1%	11.2%
Rayleigh (Lin Reg)	22	110.5%	45.4%
Rayleigh (T-G Reg)	17	107.0%	28.8%
Rayleigh MMAE	28	724.9%	937.9%
Beta	30	5433.7%	16285.8%

CY95 Results for Helicopter Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	14	15.8%	12.2%
CPI6	10	14.0%	10.9%
CPIcum	5	13.4%	10.0%
SPI3	12	15.2%	12.0%
SPI6	7	13.8%	10.6%
SPIcum	5	12.2%	10.8%
SCI3	21	22.0%	18.6%
SCI6	17	17.9%	14.5%
SCIcum	13	13.8%	14.6%
CPI6 x SPIcum	18	17.3%	15.3%
Composite	3	13.0%	9.5%
Rayleigh (Lin Reg)	26	265.7%	820.4%
Rayleigh (T-G Reg)	23	141.2%	267.3%
Rayleigh MMAE	26	429.8%	404.1%
Beta	29	3156.1%	13002.1%

CY95 Results for Helicopter Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	8	9.5%	6.2%
CPI6	4	8.5%	5.8%
CPIcum	2	8.4%	5.3%
SPI3	15	11.5%	7.9%
SPI6	11	9.8%	7.2%
SPIcum	4	8.4%	6.1%
SCI3	19	12.0%	10.5%
SCI6	15	10.0%	9.8%
SCIcum	8	9.2%	6.7%
CPI6 x SPIcum	15	10.6%	8.5%
Composite	2	8.4%	5.3%
Rayleigh (Lin Reg)	23	124.2%	147.3%
Rayleigh (T-G Reg)	27	1248.9%	7162.7%
Rayleigh MMAE	25	362.4%	569.9%
Beta	21	31.5%	32.0%

CY95 Results for Helicopter Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	18	10.7%	11.9%
CPI6	14	10.1%	8.8%
CPIcum	8	9.1%	7.0%
SPI3	8	9.2%	6.9%
SPI6	4	8.7%	6.7%
SPIcum	4	8.9%	6.6%
SCI3	20	11.0%	12.2%
SCI6	14	9.7%	8.9%
SCIcum	11	9.4%	7.1%
CPI6 x SPIcum	15	10.5%	8.8%
Composite	7	9.1%	6.9%
Rayleigh (Lin Reg)	24	96.9%	283.7%
Rayleigh (T-G Reg)	25	128.6%	130.4%
Rayleigh MMAE	23	107.9%	123.4%
Beta	2	4.4%	6.6%

Results for Other Missile Contracts Using Non-Inflation Adjusted Data

TY Results for All Other Missile Data			
	Score	MAPE	SDAPE
CPI3	14	11.4%	12.6%
CPI6	7	10.6%	11.5%
CPIcum	7	10.5%	11.6%
SPI3	15	12.6%	11.9%
SPI6	10	11.5%	11.2%
SPIcum	5	10.7%	9.4%
SCI3	19	14.4%	14.6%
SCI6	15	12.1%	12.4%
SCIcum	8	11.1%	11.2%
CPI6 x SPIcum	8	11.1%	11.2%
Composite	3	10.3%	10.8%
Rayleigh (Lin Reg)	21	134.0%	287.5%
Rayleigh (T-G Reg)	23	235.6%	681.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	1070.6%	6820.5%

Best Performing Method(s)	
Overall	Composite
0% - 25%	SPIcum
>25% - 50%	CPI3
>50% - 75%	CPI6
>75% - 100%	CPIcum

TY Results for Other Missile Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	17	22.6%	17.6%
CPI6	14	21.7%	16.0%
CPIcum	10	20.9%	15.8%
SPI3	8	21.2%	13.6%
SPI6	6	21.0%	13.3%
SPIcum	2	17.6%	11.3%
SCI3	18	24.9%	17.5%
SCI6	14	23.3%	15.7%
SCIcum	8	21.0%	14.2%
CPI6 x SPIcum	10	21.2%	14.5%
Composite	6	19.9%	14.2%
Rayleigh (Lin Reg)	21	108.2%	46.5%
Rayleigh (T-G Reg)	23	154.1%	228.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	3303.7%	12510.4%

TY Results for Other Missile Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	2	9.8%	7.4%
CPI6	4	10.3%	7.7%
CPIcum	7	10.5%	9.0%
SPI3	19	15.4%	11.3%
SPI6	17	15.0%	10.6%
SPIcum	11	13.8%	9.3%
SCI3	21	15.7%	11.7%
SCI6	15	14.7%	10.3%
SCIcum	12	12.9%	10.0%
CPI6 x SPIcum	10	12.8%	9.7%
Composite	6	10.5%	8.9%
Rayleigh (Lin Reg)	23	123.0%	106.7%
Rayleigh (T-G Reg)	25	164.3%	333.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	961.8%	4411.2%

TY Results for Other Missile Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	8	8.3%	5.8%
CPI6	2	7.2%	4.7%
CPIcum	7	7.6%	5.9%
SPI3	17	11.1%	9.1%
SPI6	15	9.7%	8.3%
SPIcum	11	8.9%	6.3%
SCI3	19	11.5%	12.2%
SCI6	13	9.0%	7.7%
SCIcum	6	7.8%	5.5%
CPI6 x SPIcum	3	7.2%	4.9%
Composite	7	7.6%	5.9%
Rayleigh (Lin Reg)	23	266.9%	543.2%
Rayleigh (T-G Reg)	25	624.9%	1444.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	65.0%	69.9%

TY Results for Other Missile Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	14	5.3%	5.3%
CPI6	17	5.4%	5.7%
CPIcum	3	4.7%	3.6%
SPI3	11	5.1%	5.2%
SPI6	5	4.6%	4.0%
SPIcum	11	5.2%	4.2%
SCI3	21	6.5%	8.1%
SCI6	13	5.1%	5.6%
SCIcum	7	4.9%	3.8%
CPI6 x SPIcum	19	5.8%	6.0%
Composite	5	4.8%	3.7%
Rayleigh (Lin Reg)	26	95.4%	254.7%
Rayleigh (T-G Reg)	26	130.6%	140.2%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	14.5%	28.5%

Results for Other Missile Contracts Using Inflation Adjusted Data

CY95 Results for All Other Missile Data	Score	MAPE	SDAPE
CPI3	12	11.3%	12.1%
CPI6	7	10.6%	10.8%
CPIcum	7	10.3%	11.1%
SPI3	14	12.6%	11.5%
SPI6	9	11.3%	10.9%
SPIcum	4	10.5%	9.0%
SCI3	17	14.5%	14.2%
SCI6	14	12.2%	12.1%
SCIcum	10	11.3%	11.1%
CPI6 x SPIcum	9	11.4%	10.8%
Composite	3	10.0%	10.2%
Rayleigh (Lin Reg)	19	127.1%	412.2%
Rayleigh (T-G Reg)	23	438.2%	4139.1%
Rayleigh MMAE	21	239.0%	557.0%
Beta	25	2230.1%	17675.3%

Best Performing Method(s)

Overall	Composite
0% - 25%	SPIcum
>25% - 50%	CPI3
>50% - 75%	CPI6 x SPIcum
>75% - 100%	SPI6

CY95 Results for Other Missile Data 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	17	19.4%	18.4%
CPI6	12	18.5%	16.7%
CPIcum	9	17.8%	16.3%
SPI3	9	18.9%	14.3%
SPI6	6	18.4%	13.8%
SPIcum	2	14.8%	11.6%
SCI3	18	23.9%	18.0%
SCI6	15	21.5%	16.3%
SCIcum	11	19.2%	15.0%
CPI6 x SPIcum	12	19.2%	15.1%
Composite	5	16.8%	14.3%
Rayleigh (Lin Reg)	22	107.4%	60.1%
Rayleigh (T-G Reg)	22	111.2%	52.0%
Rayleigh MMAE	25	358.0%	626.5%
Beta	27	6836.4%	33071.5%

CY95 Results for Other Missile Data >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	2	9.4%	7.0%
CPI6	5	9.9%	7.4%
CPIcum	5	9.8%	8.9%
SPI3	18	15.5%	11.7%
SPI6	15	14.6%	11.5%
SPIcum	10	13.3%	9.9%
SCI3	20	16.0%	12.2%
SCI6	15	14.8%	11.1%
SCIcum	10	12.7%	10.6%
CPI6 x SPIcum	10	12.9%	10.2%
Composite	5	9.8%	8.9%
Rayleigh (Lin Reg)	22	138.3%	148.7%
Rayleigh (T-G Reg)	24	231.8%	827.4%
Rayleigh MMAE	26	474.8%	1001.6%
Beta	28	2162.9%	9756.8%

CY95 Results for Other Missile Data >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	6	8.2%	5.6%
CPI6	3	7.3%	5.0%
CPIcum	8	7.6%	6.2%
SPI3	17	11.0%	8.2%
SPI6	15	9.5%	8.0%
SPIcum	10	9.1%	6.0%
SCI3	19	11.1%	10.7%
SCI6	12	8.8%	7.2%
SCIcum	6	7.6%	5.9%
CPI6 x SPIcum	2	7.1%	5.0%
Composite	9	7.6%	6.3%
Rayleigh (Lin Reg)	24	126.8%	148.1%
Rayleigh (T-G Reg)	27	215.7%	249.4%
Rayleigh MMAE	24	187.7%	118.0%
Beta	21	61.4%	66.5%

CY95 Results for Other Missile Data >75% to 100% Complete	Score	MAPE	SDAPE
CPI3	15	7.7%	6.6%
CPI6	12	7.6%	6.3%
CPIcum	6	6.6%	5.5%
SPI3	9	6.7%	6.1%
SPI6	3	6.0%	5.3%
SPIcum	4	6.7%	5.1%
SCI3	15	7.6%	7.5%
SCI6	7	6.6%	5.9%
SCIcum	8	6.8%	5.5%
CPI6 x SPIcum	15	7.9%	6.4%
Composite	5	6.6%	5.4%
Rayleigh (Lin Reg)	23	132.0%	639.2%
Rayleigh (T-G Reg)	25	762.3%	6282.5%
Rayleigh MMAE	21	87.9%	92.4%
Beta	19	14.0%	28.0%

Results for Satellite Contracts Using Non-Inflation Adjusted Data

TY Results for All Satellite Data

	Score	MAPE	SDAPE
CPI3	18	10.4%	12.6%
CPI6	9	7.2%	11.5%
CPIcum	11	7.4%	11.6%
SPI3	15	8.4%	11.9%
SPI6	4	6.2%	11.2%
SPIcum	4	6.7%	9.4%
SCI3	20	13.7%	14.6%
SCI6	14	7.7%	12.4%
SCIcum	5	6.5%	11.2%
CPI6 x SPIcum	11	7.9%	11.2%
Composite	6	7.0%	10.8%
Rayleigh (Lin Reg)	22	82.9%	287.5%
Rayleigh (T-G Reg)	24	464.2%	681.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	26	617.3%	6820.5%

Best Performing Method(s)

Overall	SPI6 SPIcum
0% - 25%	SCI6
>25% - 50%	Composite
>50% - 75%	SPIcum
>75% - 100%	SPI6

TY Results for Satellite Data 0% to 25% Complete

	Score	MAPE	SDAPE
CPI3	12	17.5%	7.9%
CPI6	12	14.4%	9.7%
CPIcum	10	14.8%	7.8%
SPI3	12	14.0%	9.9%
SPI6	6	11.0%	9.1%
SPIcum	7	13.0%	7.9%
SCI3	17	20.9%	15.1%
SCI6	4	12.5%	7.7%
SCIcum	7	13.0%	7.9%
CPI6 x SPIcum	5	13.6%	7.6%
Composite	7	14.0%	7.7%
Rayleigh (Lin Reg)	20	91.0%	27.6%
Rayleigh (T-G Reg)	20	79.3%	52.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	2768.8%	2353.4%

TY Results for Satellite Data >25% to 50% Complete

	Score	MAPE	SDAPE
CPI3	16	10.6%	11.5%
CPI6	7	6.4%	4.9%
CPIcum	5	6.5%	2.8%
SPI3	14	11.0%	7.6%
SPI6	8	9.1%	4.5%
SPIcum	8	7.8%	4.8%
SCI3	19	17.6%	17.0%
SCI6	14	9.7%	9.3%
SCIcum	5	3.5%	4.9%
CPI6 x SPIcum	11	7.8%	7.8%
Composite	3	6.3%	2.8%
Rayleigh (Lin Reg)	23	222.9%	326.2%
Rayleigh (T-G Reg)	25	1518.9%	3888.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	86.1%	61.1%

TY Results for Satellite Data >50% to 75% Complete

	Score	MAPE	SDAPE
CPI3	17	7.2%	4.2%
CPI6	11	4.5%	3.9%
CPIcum	7	4.0%	2.4%
SPI3	17	6.7%	5.1%
SPI6	7	3.8%	2.5%
SPIcum	2	2.6%	1.9%
SCI3	23	12.5%	6.8%
SCI6	16	6.2%	5.3%
SCIcum	11	4.7%	2.8%
CPI6 x SPIcum	18	6.3%	5.6%
Composite	4	3.7%	2.2%
Rayleigh (Lin Reg)	26	31.7%	27.6%
Rayleigh (T-G Reg)	28	61.4%	47.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	12.6%	6.2%

TY Results for Satellite Data >75% to 100% Complete

	Score	MAPE	SDAPE
CPI3	23	7.7%	7.0%
CPI6	18	5.9%	4.1%
CPIcum	12	5.3%	2.4%
SPI3	5	4.1%	2.0%
SPI6	3	3.4%	1.9%
SPIcum	7	4.4%	2.2%
SCI3	23	7.6%	7.1%
SCI6	13	5.0%	3.4%
SCIcum	14	5.4%	2.9%
CPI6 x SPIcum	20	6.3%	4.3%
Composite	10	5.1%	2.3%
Rayleigh (Lin Reg)	26	13.6%	14.4%
Rayleigh (T-G Reg)	28	52.8%	46.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	8	3.0%	3.1%

Results for Satellite Contracts Using Inflation Adjusted Data

CY95 Results for All Satellite Data			
	Score	MAPE	SDAPE
CPI3	15	10.1%	12.1%
CPI6	5	7.0%	10.8%
CPIcum	6	6.9%	11.1%
SPI3	15	10.2%	11.5%
SPI6	8	8.1%	10.9%
SPIcum	7	8.5%	9.0%
SCI3	18	14.4%	14.2%
SCI6	14	8.6%	12.1%
SCIcum	8	7.5%	11.1%
CPI6 x SPIcum	8	8.3%	10.8%
Composite	3	6.9%	10.2%
Rayleigh (Lin Reg)	20	88.5%	412.2%
Rayleigh (T-G Reg)	23	150.5%	4139.1%
Rayleigh MMAE	23	251.9%	557.0%
Beta	26	371.3%	17675.3%

Best Performing Method(s)

Overall	Composite
0% - 25%	CPI6 CPIcum
>25% - 50%	CPIcum
>50% - 75%	SCIcum
>75% - 100%	Beta

CY95 Results for Satellite Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	17	15.9%	12.3%
CPI6	3	11.2%	4.7%
CPIcum	3	10.5%	6.9%
SPI3	17	17.0%	11.4%
SPI6	7	11.9%	8.3%
SPIcum	11	14.1%	10.6%
SCI3	26	24.7%	21.7%
SCI6	11	13.4%	11.0%
SCIcum	14	14.4%	11.1%
CPI6 x SPIcum	13	12.8%	12.3%
Composite	4	10.5%	7.3%
Rayleigh (Lin Reg)	23	91.9%	28.6%
Rayleigh (T-G Reg)	23	77.2%	58.9%
Rayleigh MMAE	27	782.4%	1287.1%
Beta	27	1619.6%	720.3%

CY95 Results for Satellite Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	16	9.2%	9.9%
CPI6	5	4.7%	3.7%
CPIcum	3	4.4%	2.9%
SPI3	16	11.0%	7.3%
SPI6	10	9.1%	5.6%
SPIcum	9	8.1%	5.7%
SCI3	20	17.3%	15.1%
SCI6	16	9.5%	8.5%
SCIcum	6	4.8%	3.7%
CPI6 x SPIcum	11	8.2%	6.6%
Composite	4	4.8%	2.6%
Rayleigh (Lin Reg)	25	258.6%	407.2%
Rayleigh (T-G Reg)	28	398.9%	755.3%
Rayleigh MMAE	25	343.2%	342.1%
Beta	22	89.3%	77.6%

CY95 Results for Satellite Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	11	6.4%	2.6%
CPI6	6	3.7%	3.1%
CPIcum	7	4.7%	2.5%
SPI3	14	7.7%	4.5%
SPI6	11	5.8%	3.1%
SPIcum	9	4.8%	2.6%
SCI3	17	9.7%	6.4%
SCI6	8	4.8%	2.5%
SCIcum	2	3.2%	1.5%
CPI6 x SPIcum	5	4.4%	2.5%
Composite	7	4.6%	2.6%
Rayleigh (Lin Reg)	26	20.7%	23.0%
Rayleigh (T-G Reg)	22	46.2%	25.8%
Rayleigh MMAE	24	128.1%	171.7%
Beta	17	10.8%	5.2%

CY95 Results for Satellite Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	18	9.1%	5.5%
CPI6	14	8.4%	3.5%
CPIcum	9	7.6%	3.1%
SPI3	8	7.1%	3.3%
SPI6	8	6.8%	3.4%
SPIcum	6	7.4%	3.0%
SCI3	18	8.8%	5.8%
SCI6	12	7.6%	3.4%
SCIcum	9	7.5%	3.2%
CPI6 x SPIcum	15	8.4%	3.7%
Composite	8	7.5%	3.1%
Rayleigh (Lin Reg)	21	10.0%	13.3%
Rayleigh (T-G Reg)	24	55.1%	52.7%
Rayleigh MMAE	24	44.9%	62.0%
Beta	2	2.6%	2.4%

Results for Ship Contracts Using Non-Inflation Adjusted Data

TY Results for All Ship Data			
	Score	MAPE	SDAPE
CPI3	8	8.1%	8.6%
CPI6	5	7.3%	7.3%
CPIcum	5	6.6%	7.6%
SPI3	20	14.9%	18.0%
SPI6	15	12.6%	14.4%
SPIcum	11	11.1%	14.0%
SCI3	22	16.1%	20.0%
SCI6	17	13.5%	15.1%
SCIcum	15	11.4%	15.2%
CPI6 x SPIcum	12	11.7%	13.7%
Composite	2	6.5%	6.7%
Rayleigh (Lin Reg)	28	517.5%	3137.5%
Rayleigh (T-G Reg)	26	161.0%	179.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	78.0%	135.3%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPIcum, Composite
>50% - 75%	CPI6
>75% - 100%	CPIcum, Composite

TY Results for Ship Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	10	13.4%	12.4%
CPI6	7	12.4%	10.5%
CPIcum	7	11.3%	12.0%
SPI3	21	26.4%	23.0%
SPI6	14	22.1%	18.3%
SPIcum	16	23.2%	19.5%
SCI3	23	28.6%	23.6%
SCI6	15	24.4%	18.1%
SCIcum	19	25.4%	21.8%
CPI6 x SPIcum	15	25.4%	17.6%
Composite	3	11.1%	9.7%
Rayleigh (Lin Reg)	14	103.3%	9.9%
Rayleigh (T-G Reg)	13	104.5%	5.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	203.1%	193.6%

TY Results for Ship Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	8	8.5%	6.7%
CPI6	6	8.2%	5.3%
CPIcum	3	6.7%	4.5%
SPI3	19	17.2%	20.7%
SPI6	15	15.5%	16.8%
SPIcum	12	11.6%	8.5%
SCI3	21	19.2%	27.0%
SCI6	17	16.4%	18.2%
SCIcum	10	9.9%	7.3%
CPI6 x SPIcum	13	11.6%	9.1%
Composite	3	6.5%	4.7%
Rayleigh (Lin Reg)	24	122.7%	33.9%
Rayleigh (T-G Reg)	27	127.2%	59.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	81.0%	58.6%

TY Results for Ship Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	11	5.7%	4.6%
CPI6	2	3.8%	2.5%
CPIcum	4	4.1%	2.6%
SPI3	19	10.8%	10.4%
SPI6	14	8.6%	5.7%
SPIcum	9	4.9%	4.4%
SCI3	17	10.7%	9.3%
SCI6	14	8.4%	6.0%
SCIcum	7	4.8%	3.4%
CPI6 x SPIcum	5	4.1%	3.2%
Composite	4	4.1%	2.6%
Rayleigh (Lin Reg)	25	223.4%	265.7%
Rayleigh (T-G Reg)	23	179.3%	137.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	17.0%	21.5%

TY Results for Ship Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	10	4.8%	3.9%
CPI6	9	4.6%	3.9%
CPIcum	3	4.0%	3.1%
SPI3	15	5.7%	5.2%
SPI6	13	5.1%	5.0%
SPIcum	5	3.9%	3.4%
SCI3	20	6.7%	7.4%
SCI6	18	5.8%	6.4%
SCIcum	6	4.1%	3.3%
CPI6 x SPIcum	11	4.8%	4.1%
Composite	3	3.9%	3.2%
Rayleigh (Lin Reg)	24	1233.9%	5355.5%
Rayleigh (T-G Reg)	22	196.7%	267.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	13	4.6%	5.8%

Results for Ship Contracts Using Inflation Adjusted Data

CY95 Results for All Ship Data			
	Score	MAPE	SDAPE
CPI3	8	8.5%	10.0%
CPI6	6	7.3%	8.1%
CPIcum	4	6.9%	7.6%
SPI3	19	14.6%	18.8%
SPI6	14	12.2%	15.3%
SPIcum	10	11.4%	14.9%
SCI3	21	15.9%	21.7%
SCI6	17	13.3%	16.4%
SCIcum	14	11.9%	16.4%
CPI6 x SPIcum	14	12.0%	15.5%
Composite	2	6.4%	5.8%
Rayleigh (Lin Reg)	27	219.2%	740.1%
Rayleigh (T-G Reg)	29	397.1%	1244.2%
Rayleigh MMAE	23	97.2%	112.8%
Beta	25	99.8%	239.4%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	Composite
>50% - 75%	CPI6
>75% - 100%	SPI6 SPIcum Composite

CY95 Results for Ship Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	9	14.4%	15.0%
CPI6	7	12.4%	12.4%
CPIcum	5	12.1%	11.6%
SPI3	21	27.0%	24.4%
SPI6	12	22.4%	20.2%
SPIcum	15	23.3%	21.7%
SCI3	23	30.0%	26.5%
SCI6	15	25.2%	21.4%
SCIcum	18	26.4%	24.3%
CPI6 x SPIcum	17	26.5%	21.4%
Composite	2	10.1%	8.1%
Rayleigh (Lin Reg)	18	106.0%	19.4%
Rayleigh (T-G Reg)	15	106.1%	9.4%
Rayleigh MMAE	27	128.3%	193.5%
Beta	29	275.8%	392.4%

CY95 Results for Ship Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	7	8.6%	7.1%
CPI6	5	7.8%	5.6%
CPIcum	3	6.1%	4.6%
SPI3	19	16.9%	21.9%
SPI6	15	14.6%	17.6%
SPIcum	11	10.6%	9.6%
SCI3	21	18.9%	28.7%
SCI6	17	16.1%	18.8%
SCIcum	9	9.8%	7.4%
CPI6 x SPIcum	13	11.2%	9.7%
Composite	2	6.1%	4.4%
Rayleigh (Lin Reg)	24	132.0%	52.5%
Rayleigh (T-G Reg)	29	151.3%	148.9%
Rayleigh MMAE	27	145.7%	72.5%
Beta	24	86.0%	57.4%

CY95 Results for Ship Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	12	4.9%	[illegible]
CPI6	2	3.4%	[illegible]
CPIcum	6	3.7%	[illegible]
SPI3	18	9.3%	9.1%
SPI6	15	6.9%	6.4%
SPIcum	11	4.9%	4.0%
SCI3	18	8.4%	9.2%
SCI6	14	6.9%	6.3%
SCIcum	9	4.3%	3.2%
CPI6 x SPIcum	4	3.5%	2.9%
Composite	6	3.6%	3.0%
Rayleigh (Lin Reg)	25	171.2%	90.4%
Rayleigh (T-G Reg)	27	336.9%	639.9%
Rayleigh MMAE	23	83.8%	58.5%
Beta	21	17.6%	21.8%

CY95 Results for Ship Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	14	5.6%	4.6%
CPI6	9	5.4%	4.1%
CPIcum	5	5.0%	3.6%
SPI3	13	5.6%	4.4%
SPI6	4	5.1%	3.4%
SPIcum	4	5.1%	3.4%
SCI3	18	6.7%	6.5%
SCI6	13	5.8%	4.2%
SCIcum	7	5.1%	3.7%
CPI6 x SPIcum	11	5.5%	4.2%
Composite	4	5.0%	3.5%
Rayleigh (Lin Reg)	22	381.6%	1262.3%
Rayleigh (T-G Reg)	24	724.5%	1959.3%
Rayleigh MMAE	20	56.5%	49.9%
Beta	10	4.4%	5.3%

Results for Torpedo Contracts Using Non-Inflation Adjusted Data

TY Results for All Torpedo Data			
	Score	MAPE	SDAPE
CPI3	11	14.2%	15.3%
CPI6	5	13.1%	14.6%
CPIcum	8	13.4%	15.1%
SPI3	19	17.8%	17.1%
SPI6	15	15.6%	15.4%
SPIcum	6	14.8%	13.8%
SCI3	22	20.2%	22.7%
SCI6	19	17.1%	17.2%
SCIcum	8	15.3%	14.0%
CPI6 x SPIcum	11	15.8%	14.1%
Composite	8	13.5%	14.8%
Rayleigh (Lin Reg)	26	372.2%	1804.2%
Rayleigh (T-G Reg)	24	165.4%	296.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	18109.6%	137492.9%

Best Performing Method(s)

Overall	CPI6
0% - 25%	SPIcum
>25% - 50%	CPI3 SCIcum
>50% - 75%	CPI3 SCI3 SCIcum
>75% - 100%	SPI6

TY Results for Torpedo Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	16	25.0%	18.9%
CPI6	11	21.0%	19.0%
CPIcum	11	23.0%	18.8%
SPI3	15	27.8%	16.8%
SPI6	11	24.7%	16.5%
SPIcum	7	23.0%	16.2%
SCI3	21	32.4%	23.2%
SCI6	12	26.6%	16.2%
SCIcum	10	23.9%	16.8%
CPI6 x SPIcum	8	24.1%	16.1%
Composite	9	22.9%	18.3%
Rayleigh (Lin Reg)	14	90.9%	14.5%
Rayleigh (T-G Reg)	12	89.5%	14.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	56928.4%	243646.3%

TY Results for Torpedo Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	7	17.2%	14.0%
CPI6	9	18.0%	14.3%
CPIcum	8	16.6%	14.5%
SPI3	19	31.5%	16.4%
SPI6	16	25.8%	15.0%
SPIcum	8	22.1%	11.2%
SCI3	22	36.7%	26.6%
SCI6	19	29.0%	19.7%
SCIcum	7	22.7%	9.7%
CPI6 x SPIcum	9	24.9%	10.6%
Composite	8	16.9%	14.4%
Rayleigh (Lin Reg)	25	102.8%	66.4%
Rayleigh (T-G Reg)	25	100.4%	79.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	164.5%	493.9%

TY Results for Torpedo Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	6	10.2%	8.3%
CPI6	14	10.8%	9.7%
CPIcum	7	8.8%	9.1%
SPI3	9	11.0%	8.3%
SPI6	10	11.0%	8.4%
SPIcum	7	10.2%	8.4%
SCI3	6	10.8%	8.1%
SCI6	16	12.8%	9.5%
SCIcum	6	10.5%	8.2%
CPI6 x SPIcum	17	11.7%	9.8%
Composite	7	8.9%	9.0%
Rayleigh (Lin Reg)	22	1763.7%	4284.7%
Rayleigh (T-G Reg)	20	392.9%	627.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	15	12.8%	9.2%

TY Results for Torpedo Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	12	4.0%	3.4%
CPI6	10	4.0%	3.0%
CPIcum	7	4.0%	2.6%
SPI3	10	3.5%	3.3%
SPI6	3	3.1%	2.5%
SPIcum	8	4.0%	2.8%
SCI3	12	3.4%	4.1%
SCI6	8	2.9%	3.4%
SCIcum	10	4.3%	2.9%
CPI6 x SPIcum	15	4.4%	3.5%
Composite	7	4.0%	2.6%
Rayleigh (Lin Reg)	19	76.5%	100.7%
Rayleigh (T-G Reg)	21	139.3%	158.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	14	3.5%	5.5%

Results for Torpedo Contracts Using Inflation Adjusted Data

CY95 Results for All Torpedo Data			
	Score	MAPE	SDAPE
CPI3	10	14.7%	14.2%
CPI6	6	13.4%	13.4%
CPIcum	6	13.1%	14.0%
SPI3	17	18.2%	16.0%
SPI6	13	16.1%	14.2%
SPIcum	6	14.8%	12.7%
SCI3	20	20.8%	22.5%
SCI6	17	17.8%	16.2%
SCIcum	8	15.5%	13.0%
CPI6 x SPIcum	10	16.3%	13.0%
Composite	6	13.2%	13.7%
Rayleigh (Lin Reg)	26	192.2%	689.5%
Rayleigh (T-G Reg)	24	138.4%	262.0%
Rayleigh MMAE	22	134.1%	198.3%
Beta	28	878.3%	3127.5%

Best Performing Method(s)

Overall	CPI6 CPIcum SPIcum Composite
0% - 25%	SPIcum
>25% - 50%	CPI3 SPIcum SCIcum
>50% - 75%	CPI3 CPIcum SCI3
>75% - 100%	SPI6

CY95 Results for Torpedo Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	16	24.0%	18.1%
CPI6	9	19.6%	17.7%
CPIcum	10	21.1%	17.5%
SPI3	11	27.7%	14.4%
SPI6	10	24.1%	14.8%
SPIcum	5	21.8%	14.4%
SCI3	21	32.4%	24.0%
SCI6	14	26.1%	15.2%
SCIcum	9	23.6%	15.1%
CPI6 x SPIcum	8	23.7%	14.8%
Composite	8	21.0%	17.1%
Rayleigh (Lin Reg)	18	90.6%	15.2%
Rayleigh (T-G Reg)	15	88.9%	14.9%
Rayleigh MMAE	25	205.3%	330.5%
Beta	27	2640.1%	5190.6%

CY95 Results for Torpedo Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	7	17.2%	13.0%
CPI6	9	17.6%	13.9%
CPIcum	8	16.1%	14.4%
SPI3	19	31.2%	16.6%
SPI6	16	25.9%	14.5%
SPIcum	7	22.4%	10.2%
SCI3	22	36.4%	27.0%
SCI6	19	28.9%	19.7%
SCIcum	7	22.9%	8.8%
CPI6 x SPIcum	10	24.7%	10.5%
Composite	8	16.6%	14.1%
Rayleigh (Lin Reg)	24	111.2%	94.1%
Rayleigh (T-G Reg)	27	111.6%	118.6%
Rayleigh MMAE	27	140.2%	105.9%
Beta	30	180.1%	523.8%

CY95 Results for Torpedo Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	7	10.5%	7.7%
CPI6	16	11.1%	9.2%
CPIcum	7	8.9%	8.8%
SPI3	8	10.5%	8.0%
SPI6	10	11.1%	8.0%
SPIcum	8	9.8%	8.5%
SCI3	7	10.7%	7.3%
SCI6	17	12.8%	9.1%
SCIcum	8	10.0%	8.4%
CPI6 x SPIcum	15	12.0%	8.9%
Composite	8	9.0%	8.8%
Rayleigh (Lin Reg)	26	709.3%	1636.1%
Rayleigh (T-G Reg)	23	117.5%	116.6%
Rayleigh MMAE	23	114.5%	138.7%
Beta	20	13.0%	9.9%

CY95 Results for Torpedo Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	14	6.2%	4.6%
CPI6	13	6.1%	4.6%
CPIcum	6	5.2%	3.7%
SPI3	7	5.3%	3.7%
SPI6	3	5.1%	3.2%
SPIcum	7	5.3%	3.7%
SCI3	11	5.6%	4.1%
SCI6	8	5.5%	3.6%
SCIcum	8	5.4%	3.7%
CPI6 x SPIcum	15	6.4%	4.6%
Composite	6	5.2%	3.7%
Rayleigh (Lin Reg)	18	67.8%	85.8%
Rayleigh (T-G Reg)	22	195.8%	417.0%
Rayleigh MMAE	20	82.9%	101.9%
Beta	7	3.1%	5.9%

Results for Development Contracts Using Non-Inflation Adjusted Data

TY Results for All Development Data

	Score	MAPE	SDAPE
CPI3	16	15.3%	19.6%
CPI6	9	13.5%	18.9%
CPIcum	15	14.7%	19.6%
SPI3	9	14.5%	18.7%
SPI6	3	13.0%	18.7%
SPIcum	7	13.4%	18.8%
SCI3	18	15.7%	20.3%
SCI6	7	13.1%	19.0%
SCIcum	9	13.3%	19.4%
CPI6 x SPIcum	2	12.6%	18.7%
Composite	12	14.4%	19.4%
Rayleigh (Lin Reg)	20	100.8%	389.8%
Rayleigh (T-G Reg)	22	178.9%	507.4%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	185964.5%	3664211.4%

Best Performing Method(s)

Overall	CPI6 x SPIcum
0% - 25%	SPIcum
>25% - 50%	SCI3
>50% - 75%	CPI6 x SPIcum
>75% - 100%	CPIcum Composite

TY Results for Development Data 0% to 25% Complete

	Score	MAPE	SDAPE
CPI3	14	31.1%	24.0%
CPI6	12	30.6%	23.5%
CPIcum	11	31.4%	21.8%
SPI3	7	26.9%	22.6%
SPI6	9	26.8%	24.3%
SPIcum	3	25.9%	22.3%
SCI3	17	30.6%	26.0%
SCI6	14	28.1%	25.4%
SCIcum	9	27.0%	23.5%
CPI6 x SPIcum	9	26.6%	25.3%
Composite	8	30.3%	21.8%
Rayleigh (Lin Reg)	21	115.0%	92.9%
Rayleigh (T-G Reg)	23	136.8%	198.4%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	825464.4%	7724578.7%

TY Results for Development Data >25% to 50% Complete

	Score	MAPE	SDAPE
CPI3	12	23.4%	24.9%
CPI6	12	23.1%	25.7%
CPIcum	15	23.1%	26.5%
SPI3	8	22.8%	24.6%
SPI6	10	22.7%	25.8%
SPIcum	12	22.6%	26.6%
SCI3	5	22.6%	24.1%
SCI6	7	22.3%	25.7%
SCIcum	10	20.9%	27.4%
CPI6 x SPIcum	8	21.8%	26.4%
Composite	15	22.9%	26.6%
Rayleigh (Lin Reg)	20	250.3%	793.7%
Rayleigh (T-G Reg)	22	329.1%	870.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	1783.5%	7781.9%

TY Results for Development Data >50% to 75% Complete

	Score	MAPE	SDAPE
CPI3	8	11.3%	10.8%
CPI6	5	10.1%	11.2%
CPIcum	11	10.4%	11.7%
SPI3	15	12.0%	11.9%
SPI6	14	11.1%	12.0%
SPIcum	8	10.4%	11.3%
SCI3	19	12.7%	13.1%
SCI6	13	10.2%	12.1%
SCIcum	6	9.9%	11.5%
CPI6 x SPIcum	4	9.7%	11.3%
Composite	10	10.4%	11.6%
Rayleigh (Lin Reg)	23	111.8%	322.3%
Rayleigh (T-G Reg)	25	239.8%	621.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	60.6%	116.7%

TY Results for Development Data >75% to 100% Complete

	Score	MAPE	SDAPE
CPI3	15	4.8%	5.0%
CPI6	9	4.3%	3.9%
CPIcum	2	3.9%	3.4%
SPI3	12	4.4%	4.3%
SPI6	3	3.9%	3.5%
SPIcum	6	4.0%	3.7%
SCI3	17	5.3%	6.4%
SCI6	6	4.2%	3.6%
SCIcum	5	4.0%	3.6%
CPI6 x SPIcum	12	4.5%	4.2%
Composite	2	3.9%	3.4%
Rayleigh (Lin Reg)	20	17.8%	23.2%
Rayleigh (T-G Reg)	23	90.9%	113.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	20	15.4%	80.9%

Results for Development Contracts Using Inflation Adjusted Data

CY95 Results for All Development Data			
	Score	MAPE	SDAPE
CPI3	16	16.7%	19.5%
CPI6	9	15.7%	18.5%
CPIcum	12	16.2%	18.6%
SPI3	6	15.3%	18.1%
SPI6	3	14.5%	18.3%
SPIcum	3	14.9%	18.1%
SCI3	18	17.2%	20.5%
SCI6	11	15.3%	19.0%
SCIcum	9	15.2%	18.7%
CPI6 x SPIcum	8	15.1%	18.7%
Composite	10	15.8%	18.5%
Rayleigh (Lin Reg)	24	338.4%	5079.9%
Rayleigh (T-G Reg)	22	264.4%	2424.0%
Rayleigh MMAE	20	236.1%	536.9%
Beta	26	210541.1%	4194158.9%

Best Performing Method(s)

Overall	SPI6 SPIcum
0% - 25%	SPIcum
>25% - 50%	SPI3
>50% - 75%	CPI6 x SPIcum
>75% - 100%	SPIcum

CY95 Results for Development Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	17	26.7%	26.4%
CPI6	13	25.7%	25.2%
CPIcum	10	26.0%	23.4%
SPI3	6	22.7%	23.8%
SPI6	8	22.0%	25.9%
SPIcum	3	21.2%	23.5%
SCI3	21	28.0%	28.4%
SCI6	15	24.5%	26.7%
SCIcum	9	23.4%	24.3%
CPI6 x SPIcum	12	22.9%	26.5%
Composite	8	24.9%	23.4%
Rayleigh (Lin Reg)	25	111.7%	88.4%
Rayleigh (T-G Reg)	23	105.6%	64.1%
Rayleigh MMAE	27	746.9%	1001.8%
Beta	29	933891.2%	8842693.4%

CY95 Results for Development Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	12	21.8%	26.1%
CPI6	12	21.6%	27.0%
CPIcum	14	21.3%	27.9%
SPI3	7	21.1%	25.9%
SPI6	10	21.0%	27.2%
SPIcum	11	20.7%	28.1%
SCI3	9	21.7%	25.0%
SCI6	10	21.3%	26.9%
SCIcum	11	20.0%	28.4%
CPI6 x SPIcum	10	20.9%	27.6%
Composite	13	21.1%	27.9%
Rayleigh (Lin Reg)	25	1533.0%	11511.0%
Rayleigh (T-G Reg)	22	266.3%	764.0%
Rayleigh MMAE	22	352.8%	450.6%
Beta	27	2829.1%	11516.0%

CY95 Results for Development Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	6	11.3%	10.7%
CPI6	6	10.6%	11.5%
CPIcum	9	11.1%	11.8%
SPI3	13	12.4%	11.9%
SPI6	13	11.6%	12.0%
SPIcum	6	11.1%	11.4%
SCI3	17	12.5%	12.3%
SCI6	11	10.6%	12.2%
SCIcum	6	10.4%	11.7%
CPI6 x SPIcum	4	10.1%	11.5%
Composite	8	11.1%	11.7%
Rayleigh (Lin Reg)	21	67.7%	120.3%
Rayleigh (T-G Reg)	25	672.3%	5035.9%
Rayleigh MMAE	23	104.1%	126.5%
Beta	19	59.7%	115.5%

CY95 Results for Development Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	14	11.4%	9.8%
CPI6	14	11.7%	9.3%
CPIcum	6	10.8%	6.9%
SPI3	5	9.9%	7.0%
SPI6	5	9.9%	7.0%
SPIcum	3	10.6%	6.5%
SCI3	14	11.1%	10.8%
SCI6	10	11.0%	9.2%
SCIcum	7	10.9%	6.9%
CPI6 x SPIcum	15	11.9%	9.3%
Composite	5	10.8%	6.8%
Rayleigh (Lin Reg)	19	14.1%	15.4%
Rayleigh (T-G Reg)	24	100.6%	128.5%
Rayleigh MMAE	21	36.7%	55.6%
Beta	24	36.8%	222.0%

Results for Production Contracts Using Non-Inflation Adjusted Data

TY Results for All Production Data

	Score	MAPE	SDAPE
CPI3	13	11.6%	20.0%
CPI6	6	10.3%	11.8%
CPIcum	4	9.8%	11.4%
SPI3	20	15.1%	26.5%
SPI6	10	12.5%	15.7%
SPIcum	11	12.1%	17.9%
SCI3	22	21.5%	124.7%
SCI6	17	14.1%	19.7%
SCIcum	14	13.1%	19.1%
CPI6 x SPIcum	13	13.3%	16.9%
Composite	2	9.4%	10.7%
Rayleigh (Lin Reg)	26	284.4%	1605.2%
Rayleigh (T-G Reg)	24	264.2%	835.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	4037.4%	79274.1%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	Composite
>50% - 75%	CPI6 CPIcum
>75% - 100%	CPIcum Composite

TY Results for Production Data 0% to 25% Complete

	Score	MAPE	SDAPE
CPI3	15	21.0%	34.0%
CPI6	6	18.3%	17.0%
CPIcum	4	17.2%	16.4%
SPI3	22	28.3%	44.1%
SPI6	9	22.7%	23.0%
SPIcum	14	22.9%	29.1%
SCI3	24	47.6%	233.3%
SCI6	19	27.1%	30.7%
SCIcum	17	26.0%	30.5%
CPI6 x SPIcum	13	25.8%	25.5%
Composite	2	15.8%	15.2%
Rayleigh (Lin Reg)	20	105.1%	28.5%
Rayleigh (T-G Reg)	17	101.5%	24.4%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	14549.5%	152444.3%

TY Results for Production Data >25% to 50% Complete

	Score	MAPE	SDAPE
CPI3	7	10.7%	10.6%
CPI6	4	10.4%	9.9%
CPIcum	4	10.2%	10.0%
SPI3	19	16.9%	15.6%
SPI6	15	15.4%	14.3%
SPIcum	9	13.4%	11.4%
SCI3	21	19.5%	20.6%
SCI6	17	16.4%	15.5%
SCIcum	11	13.5%	12.0%
CPI6 x SPIcum	13	14.1%	12.5%
Composite	3	10.1%	10.0%
Rayleigh (Lin Reg)	23	165.5%	296.2%
Rayleigh (T-G Reg)	25	234.1%	874.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	529.8%	2852.2%

TY Results for Production Data >50% to 75% Complete

	Score	MAPE	SDAPE
CPI3	6	8.4%	8.0%
CPI6	4	7.7%	7.9%
CPIcum	4	7.5%	8.1%
SPI3	19	11.2%	10.3%
SPI6	14	9.6%	8.8%
SPIcum	9	8.5%	8.3%
SCI3	21	11.8%	11.2%
SCI6	17	10.2%	9.6%
SCIcum	11	8.7%	8.7%
CPI6 x SPIcum	14	9.0%	9.3%
Composite	5	7.6%	8.1%
Rayleigh (Lin Reg)	26	469.4%	1912.9%
Rayleigh (T-G Reg)	26	476.8%	1410.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	47.1%	62.9%

TY Results for Production Data >75% to 100% Complete

	Score	MAPE	SDAPE
CPI3	12	6.0%	4.8%
CPI6	10	5.8%	4.7%
CPIcum	3	5.1%	3.1%
SPI3	6	5.1%	4.0%
SPI6	4	4.8%	3.6%
SPIcum	5	5.2%	3.4%
SCI3	15	6.1%	6.4%
SCI6	11	5.4%	5.1%
SCIcum	6	5.4%	3.4%
CPI6 x SPIcum	15	6.2%	5.1%
Composite	3	5.1%	3.1%
Rayleigh (Lin Reg)	22	367.9%	2256.9%
Rayleigh (T-G Reg)	20	231.8%	450.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	18	12.6%	27.1%

Results for Production Contracts Using Inflation Adjusted Data

CY95 Results for All Production Data	Score	MAPE	SDAPE
CPI3	10	11.0%	19.9%
CPI6	6	9.6%	11.4%
CPIcum	4	9.1%	11.0%
SPI3	20	15.3%	28.3%
SPI6	10	12.4%	17.1%
SPIcum	12	12.2%	20.5%
SCI3	22	21.5%	121.2%
SCI6	17	14.1%	21.1%
SCIcum	16	13.2%	21.8%
CPI6 x SPIcum	13	13.3%	18.5%
Composite	2	8.7%	10.3%
Rayleigh (Lin Reg)	25	197.5%	623.8%
Rayleigh (T-G Reg)	28	326.5%	2592.6%
Rayleigh MMAE	25	209.6%	360.1%
Beta	30	3828.9%	86582.3%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI6 Composite
>50% - 75%	CPI6 CPIcum Composite
>75% - 100%	CPIcum

CY95 Results for Production Data 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	12	20.1%	33.9%
CPI6	6	17.0%	16.6%
CPIcum	4	16.0%	15.7%
SPI3	21	29.9%	47.4%
SPI6	9	23.8%	25.7%
SPIcum	15	24.2%	34.1%
SCI3	24	49.0%	226.4%
SCI6	16	28.3%	33.3%
SCIcum	18	27.4%	35.7%
CPI6 x SPIcum	12	26.9%	28.8%
Composite	2	14.6%	14.2%
Rayleigh (Lin Reg)	25	109.6%	55.7%
Rayleigh (T-G Reg)	18	101.6%	29.1%
Rayleigh MMAE	28	295.7%	513.2%
Beta	30	13764.6%	166637.2%

CY95 Results for Production Data >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	7	10.6%	10.0%
CPI6	3	10.0%	9.3%
CPIcum	4	9.8%	9.5%
SPI3	19	16.9%	15.8%
SPI6	15	15.3%	14.4%
SPIcum	9	13.3%	11.5%
SCI3	21	19.5%	21.2%
SCI6	17	16.5%	15.6%
SCIcum	11	13.7%	12.1%
CPI6 x SPIcum	13	14.2%	12.7%
Composite	3	9.8%	9.4%
Rayleigh (Lin Reg)	26	206.3%	687.3%
Rayleigh (T-G Reg)	23	153.0%	194.8%
Rayleigh MMAE	26	312.1%	451.5%
Beta	29	546.2%	2917.8%

CY95 Results for Production Data >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	4	8.2%	8.0%
CPI6	3	7.6%	8.0%
CPIcum	3	7.5%	8.2%
SPI3	17	10.8%	9.8%
SPI6	12	9.2%	8.8%
SPIcum	7	8.5%	8.3%
SCI3	19	11.0%	11.2%
SCI6	15	9.8%	9.7%
SCIcum	9	8.6%	8.7%
CPI6 x SPIcum	12	8.9%	9.3%
Composite	3	7.5%	8.2%
Rayleigh (Lin Reg)	26	224.6%	637.0%
Rayleigh (T-G Reg)	26	233.2%	439.3%
Rayleigh MMAE	23	207.0%	250.3%
Beta	21	46.9%	61.6%

CY95 Results for Production Data >75% to 100% Complete	Score	MAPE	SDAPE
CPI3	14	5.2%	5.2%
CPI6	11	5.0%	4.6%
CPIcum	2	4.3%	3.7%
SPI3	7	4.6%	4.4%
SPI6	3	4.3%	3.8%
SPIcum	4	4.4%	3.8%
SCI3	16	5.3%	6.2%
SCI6	9	4.8%	4.5%
SCIcum	6	4.6%	3.9%
CPI6 x SPIcum	13	5.2%	4.8%
Composite	3	4.4%	3.7%
Rayleigh (Lin Reg)	22	232.1%	753.7%
Rayleigh (T-G Reg)	24	572.9%	4119.9%
Rayleigh MMAE	20	109.2%	177.5%
Beta	18	12.4%	26.9%

Results for Other Contracts Using Non-Inflation Adjusted Data

TY Results for All Other Data	Score	MAPE	SDAPE
CPI3	13	12.4%	13.4%
CPI6	5	10.8%	12.6%
CPIcum	11	11.6%	13.1%
SPI3	15	13.0%	14.4%
SPI6	7	11.2%	12.6%
SPIcum	8	11.4%	12.6%
SCI3	17	15.4%	16.8%
SCI6	5	11.1%	12.1%
SCIcum	3	10.4%	12.1%
CPI6 x SPIcum	3	10.8%	11.4%
Composite	9	11.4%	12.7%
Rayleigh (Lin Reg)	19	133.1%	260.4%
Rayleigh (T-G Reg)	23	2355.4%	18148.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	1573.3%	11203.0%

Best Performing Method(s)

Overall	SCIcum CPI6 x SPIcum
0% - 25%	SCI6
>25% - 50%	CPI6 CPIcum SCIcum
>50% - 75%	CPIcum
>75% - 100%	Beta

TY Results for Other Data 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	15	23.1%	18.0%
CPI6	15	22.0%	19.3%
CPIcum	15	23.3%	17.6%
SPI3	11	23.1%	17.2%
SPI6	4	20.4%	15.8%
SPIcum	6	20.4%	16.5%
SCI3	14	26.2%	17.3%
SCI6	3	19.4%	16.3%
SCIcum	6	19.6%	16.8%
CPI6 x SPIcum	6	19.4%	16.9%
Composite	12	22.0%	17.4%
Rayleigh (Lin Reg)	21	95.6%	24.6%
Rayleigh (T-G Reg)	21	95.3%	37.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	5768.8%	21503.2%

TY Results for Other Data >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	12	13.6%	12.6%
CPI6	4	10.9%	10.5%
CPIcum	4	11.0%	10.1%
SPI3	18	16.3%	15.5%
SPI6	16	15.6%	14.3%
SPIcum	10	13.2%	11.0%
SCI3	20	18.5%	17.2%
SCI6	14	14.0%	13.3%
SCIcum	4	9.0%	10.7%
CPI6 x SPIcum	7	11.9%	10.5%
Composite	5	11.4%	10.1%
Rayleigh (Lin Reg)	22	244.5%	479.9%
Rayleigh (T-G Reg)	26	656.0%	2486.2%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	254.9%	589.5%

TY Results for Other Data >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	7	8.1%	7.2%
CPI6	10	8.1%	7.6%
CPIcum	2	7.1%	7.1%
SPI3	15	8.9%	10.1%
SPI6	12	8.0%	9.0%
SPIcum	11	7.6%	9.0%
SCI3	19	11.4%	12.2%
SCI6	14	9.4%	8.8%
SCIcum	6	7.3%	7.5%
CPI6 x SPIcum	14	9.5%	8.2%
Composite	5	7.3%	7.4%
Rayleigh (Lin Reg)	23	119.2%	175.3%
Rayleigh (T-G Reg)	25	243.7%	469.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	19.2%	25.3%

TY Results for Other Data >75% to 100% Complete	Score	MAPE	SDAPE
CPI3	17	6.2%	6.2%
CPI6	9	5.6%	5.3%
CPIcum	6	5.5%	5.0%
SPI3	13	5.4%	6.9%
SPI6	10	5.1%	6.0%
SPIcum	10	5.5%	5.8%
SCI3	20	7.3%	13.9%
SCI6	10	5.4%	5.9%
SCIcum	9	5.7%	5.2%
CPI6 x SPIcum	12	5.9%	5.5%
Composite	7	5.5%	5.2%
Rayleigh (Lin Reg)	22	93.8%	153.4%
Rayleigh (T-G Reg)	24	5554.0%	29187.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	2	3.4%	4.8%

Results for Other Contracts Using Inflation Adjusted Data

CY95 Results for All Other Data			
	Score	MAPE	SDAPE
CPI3	15	11.9%	12.6%
CPI6	3	10.4%	11.5%
CPIcum	11	11.3%	12.2%
SPI3	18	13.6%	14.2%
SPI6	10	11.7%	11.8%
SPIcum	15	12.0%	12.3%
SCI3	20	14.9%	15.9%
SCI6	6	10.7%	11.5%
SCIcum	6	10.5%	11.9%
CPI6 x SPIcum	4	10.6%	10.9%
Composite	9	11.1%	11.9%
Rayleigh (Lin Reg)	22	119.7%	203.1%
Rayleigh (T-G Reg)	24	283.3%	738.1%
Rayleigh MMAE	26	377.6%	851.1%
Beta	28	3287.0%	24172.5%

Best Performing Method(s)

Overall	CPI6
0% - 25%	SCI6
>25% - 50%	CPI6 CPIcum SCIcum
>50% - 75%	CPI3
>75% - 100%	Beta

CY95 Results for Other Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	14	22.4%	17.1%
CPI6	12	19.9%	17.8%
CPIcum	14	21.1%	17.4%
SPI3	17	24.1%	17.8%
SPI6	7	20.4%	14.0%
SPIcum	10	21.1%	16.5%
SCI3	19	27.7%	19.3%
SCI6	4	18.7%	16.0%
SCIcum	8	19.6%	16.9%
CPI6 x SPIcum	5	18.6%	16.7%
Composite	11	20.0%	17.1%
Rayleigh (Lin Reg)	22	98.1%	27.5%
Rayleigh (T-G Reg)	22	97.0%	41.9%
Rayleigh MMAE	25	688.4%	960.1%
Beta	27	12279.8%	46424.3%

CY95 Results for Other Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	12	12.6%	12.0%
CPI6	5	10.2%	10.2%
CPIcum	5	10.0%	10.3%
SPI3	19	16.2%	15.1%
SPI6	17	15.4%	14.4%
SPIcum	12	13.0%	11.4%
SCI3	21	17.8%	16.5%
SCI6	15	13.6%	12.9%
SCIcum	5	9.3%	10.4%
CPI6 x SPIcum	6	12.1%	10.1%
Composite	8	10.4%	10.4%
Rayleigh (Lin Reg)	23	167.9%	284.5%
Rayleigh (T-G Reg)	27	295.1%	664.7%
Rayleigh MMAE	29	578.9%	1354.8%
Beta	25	258.7%	610.3%

CY95 Results for Other Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	4	7.8%	6.4%
CPI6	6	7.9%	6.8%
CPIcum	6	8.2%	6.1%
SPI3	19	9.9%	8.9%
SPI6	16	9.1%	8.0%
SPIcum	14	8.8%	7.8%
SCI3	19	9.7%	9.9%
SCI6	10	8.1%	7.5%
SCIcum	5	6.9%	6.9%
CPI6 x SPIcum	10	8.2%	7.0%
Composite	8	8.3%	6.4%
Rayleigh (Lin Reg)	24	113.6%	155.3%
Rayleigh (T-G Reg)	28	445.0%	1132.2%
Rayleigh MMAE	26	330.5%	682.6%
Beta	22	17.5%	22.0%

CY95 Results for Other Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	6	6.2%	5.0%
CPI6	8	6.3%	5.1%
CPIcum	5	6.2%	4.7%
SPI3	7	6.0%	5.2%
SPI6	8	5.9%	5.4%
SPIcum	7	6.2%	5.1%
SCI3	11	6.2%	5.8%
SCI6	8	6.0%	5.3%
SCIcum	5	6.2%	4.7%
CPI6 x SPIcum	10	6.4%	5.2%
Composite	5	6.2%	4.7%
Rayleigh (Lin Reg)	16	105.8%	227.8%
Rayleigh (T-G Reg)	19	233.2%	559.0%
Rayleigh MMAE	16	108.9%	119.2%
Beta	2	3.1%	4.7%

Results for Cost Plus Contracts Using Non-Inflation Adjusted Data

TY Results for All Cost Plus Data

	Score	MAPE	SDAPE
CPI3	16	13.2%	15.6%
CPI6	6	11.2%	13.6%
CPIcum	13	12.0%	14.5%
SPI3	13	12.8%	14.3%
SPI6	5	11.1%	13.6%
SPIcum	9	12.0%	13.7%
SCI3	18	13.9%	16.6%
SCI6	4	10.9%	13.6%
SCIcum	7	11.1%	13.8%
CPI6 x SPIcum	2	10.8%	13.0%
Composite	10	11.8%	14.2%
Rayleigh (Lin Reg)	20	108.0%	368.4%
Rayleigh (T-G Reg)	22	205.4%	656.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	6510.5%	60060.2%

Best Performing Method(s)

Overall	CPI6 x SPIcum
0% - 25%	SPIcum SCI6 CPI6 x SPIcum
>25% - 50%	SPIcum CPI6 x SPIcum
>50% - 75%	SCIcum
>75% - 100%	CPIcum

TY Results for Cost Plus Data 0% to 25% Complete

	Score	MAPE	SDAPE
CPI3	20	28.3%	20.0%
CPI6	13	26.2%	16.9%
CPIcum	14	26.9%	16.6%
SPI3	10	27.1%	15.3%
SPI6	8	26.3%	15.3%
SPIcum	6	24.6%	15.9%
SCI3	20	29.9%	19.6%
SCI6	6	24.5%	16.2%
SCIcum	10	23.0%	17.2%
CPI6 x SPIcum	6	22.8%	16.5%
Composite	9	25.8%	16.4%
Rayleigh (Lin Reg)	23	111.0%	65.1%
Rayleigh (T-G Reg)	25	164.9%	235.4%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	29043.1%	129841.1%

TY Results for Cost Plus Data >25% to 50% Complete

	Score	MAPE	SDAPE
CPI3	11	20.5%	16.8%
CPI6	8	19.8%	16.8%
CPIcum	9	18.8%	17.3%
SPI3	10	19.9%	16.9%
SPI6	13	20.7%	16.9%
SPIcum	7	20.2%	16.2%
SCI3	9	20.2%	16.7%
SCI6	11	20.7%	16.7%
SCIcum	9	18.0%	17.4%
CPI6 x SPIcum	7	19.9%	16.4%
Composite	9	18.9%	17.2%
Rayleigh (Lin Reg)	19	178.7%	595.2%
Rayleigh (T-G Reg)	19	192.4%	468.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	22	2488.4%	8981.7%

TY Results for Cost Plus Data >50% to 75% Complete

	Score	MAPE	SDAPE
CPI3	17	8.6%	6.8%
CPI6	9	7.4%	5.9%
CPIcum	6	7.1%	5.8%
SPI3	14	7.9%	6.1%
SPI6	12	7.4%	6.5%
SPIcum	12	7.8%	6.0%
SCI3	19	8.7%	8.3%
SCI6	8	6.9%	6.5%
SCIcum	3	7.0%	5.5%
CPI6 x SPIcum	8	7.5%	5.7%
Composite	7	7.2%	5.8%
Rayleigh (Lin Reg)	23	183.8%	515.2%
Rayleigh (T-G Reg)	25	295.3%	695.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	64.9%	112.7%

TY Results for Cost Plus Data >75% to 100% Complete

	Score	MAPE	SDAPE
CPI3	12	4.5%	4.9%
CPI6	14	4.4%	5.2%
CPIcum	3	3.7%	3.4%
SPI3	11	4.3%	5.0%
SPI6	4	3.6%	3.6%
SPIcum	7	3.9%	3.7%
SCI3	19	4.9%	8.8%
SCI6	11	4.0%	5.1%
SCIcum	5	3.9%	3.5%
CPI6 x SPIcum	17	4.6%	5.4%
Composite	4	3.7%	3.5%
Rayleigh (Lin Reg)	23	34.8%	98.7%
Rayleigh (T-G Reg)	25	176.9%	775.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	21	20.3%	89.4%

Results for Cost Plus Contracts Using Inflation Adjusted Data

CY95 Results for All Cost Plus Data			
	Score	MAPE	SDAPE
CPI3	14	14.6%	15.5%
CPI6	10	13.4%	13.3%
CPIcum	11	13.5%	13.3%
SPI3	11	13.8%	13.2%
SPI6	2	12.7%	12.7%
SPIcum	6	13.4%	12.7%
SCI3	16	15.5%	16.2%
SCI6	8	13.3%	13.2%
SCIcum	4	13.1%	12.8%
CPI6 x SPIcum	6	13.4%	12.7%
Composite	6	13.2%	13.0%
Rayleigh (Lin Reg)	22	419.7%	5649.4%
Rayleigh (T-G Reg)	20	325.6%	2715.1%
Rayleigh MMAE	18	260.8%	657.6%
Beta	24	5380.7%	34021.8%

Best Performing Method(s)

Overall	SPI6
0% - 25%	CPI6 x SPIcum
>25% - 50%	SPIcum
>50% - 75%	SCIcum
>75% - 100%	SPI3

CY95 Results for Cost Plus Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	20	23.7%	23.0%
CPI6	13	21.0%	18.3%
CPIcum	15	21.5%	17.8%
SPI3	14	22.5%	17.1%
SPI6	8	21.1%	16.7%
SPIcum	7	20.1%	17.0%
SCI3	26	27.7%	22.7%
SCI6	8	21.3%	16.4%
SCIcum	6	20.1%	16.8%
CPI6 x SPIcum	2	19.7%	16.0%
Composite	10	20.4%	17.2%
Rayleigh (Lin Reg)	23	109.6%	77.3%
Rayleigh (T-G Reg)	25	121.7%	77.7%
Rayleigh MMAE	27	781.1%	1062.7%
Beta	29	22353.3%	71408.9%

CY95 Results for Cost Plus Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	11	19.2%	16.9%
CPI6	8	18.7%	16.8%
CPIcum	9	17.3%	17.5%
SPI3	9	18.4%	17.2%
SPI6	13	19.1%	17.4%
SPIcum	7	18.5%	16.8%
SCI3	10	19.4%	16.6%
SCI6	14	20.1%	17.0%
SCIcum	8	17.4%	17.2%
CPI6 x SPIcum	9	19.4%	16.4%
Composite	9	17.3%	17.5%
Rayleigh (Lin Reg)	23	1729.8%	12478.5%
Rayleigh (T-G Reg)	19	220.2%	771.1%
Rayleigh MMAE	21	434.5%	955.1%
Beta	25	3776.9%	12851.9%

CY95 Results for Cost Plus Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	12	8.4%	6.2%
CPI6	8	7.8%	6.0%
CPIcum	7	7.8%	5.9%
SPI3	12	8.6%	5.9%
SPI6	12	8.1%	6.3%
SPIcum	10	8.5%	5.8%
SCI3	15	8.5%	7.1%
SCI6	7	7.2%	6.3%
SCIcum	3	7.3%	5.7%
CPI6 x SPIcum	5	7.6%	5.8%
Composite	8	7.9%	5.9%
Rayleigh (Lin Reg)	20	92.0%	169.9%
Rayleigh (T-G Reg)	24	950.8%	5651.8%
Rayleigh MMAE	22	152.7%	186.3%
Beta	18	62.3%	109.6%

CY95 Results for Cost Plus Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	16	11.0%	10.3%
CPI6	16	11.3%	10.0%
CPIcum	8	10.3%	7.5%
SPI3	3	9.7%	6.8%
SPI6	4	9.3%	7.4%
SPIcum	5	10.1%	7.0%
SCI3	15	10.8%	10.3%
SCI6	10	10.4%	9.6%
SCIcum	10	10.5%	7.5%
CPI6 x SPIcum	16	11.4%	9.9%
Composite	7	10.3%	7.4%
Rayleigh (Lin Reg)	25	70.4%	540.3%
Rayleigh (T-G Reg)	24	113.4%	146.6%
Rayleigh MMAE	21	48.9%	80.9%
Beta	22	44.7%	240.6%

Results for Fixed Price Contracts Using Non-Inflation Adjusted Data

TY Results for All Fixed Price Data			
	Score	MAPE	SDAPE
CPI3	12	12.7%	20.7%
CPI6	4	11.4%	15.0%
CPIcum	5	11.4%	15.2%
SPI3	17	15.4%	25.7%
SPI6	8	13.0%	17.5%
SPIcum	9	12.7%	19.1%
SCI3	19	20.9%	110.7%
SCI6	14	14.4%	20.5%
SCIcum	12	13.6%	20.2%
CPI6 x SPIcum	10	13.6%	18.4%
Composite	2	11.0%	14.7%
Rayleigh (Lin Reg)	21	243.0%	1426.6%
Rayleigh (T-G Reg)	23	550.1%	6940.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	85417.6%	2470694.6%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI6
>50% - 75%	CPI6
>75% - 100%	CPIcum Composite

TY Results for Fixed Price Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	14	23.0%	32.7%
CPI6	6	20.8%	20.2%
CPIcum	4	20.6%	19.8%
SPI3	21	27.7%	41.0%
SPI6	9	23.1%	24.1%
SPIcum	13	23.3%	28.6%
SCI3	24	43.7%	206.6%
SCI6	18	27.2%	30.4%
SCIcum	16	26.5%	29.8%
CPI6 x SPIcum	13	26.1%	26.3%
Composite	2	19.3%	19.1%
Rayleigh (Lin Reg)	25	105.8%	53.5%
Rayleigh (T-G Reg)	17	97.2%	24.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	312849.5%	4729493.2%

TY Results for Fixed Price Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	4	12.9%	17.4%
CPI6	3	12.4%	17.5%
CPIcum	5	12.5%	18.0%
SPI3	17	18.2%	19.8%
SPI6	14	16.6%	19.6%
SPIcum	9	14.7%	18.6%
SCI3	20	20.5%	23.1%
SCI6	17	17.0%	20.1%
SCIcum	10	14.3%	19.0%
CPI6 x SPIcum	11	14.9%	18.8%
Composite	4	12.4%	18.0%
Rayleigh (Lin Reg)	22	193.2%	456.3%
Rayleigh (T-G Reg)	26	352.7%	1323.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	280.7%	996.0%

TY Results for Fixed Price Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	4	9.5%	9.8%
CPI6	3	8.8%	10.1%
CPIcum	4	8.8%	10.5%
SPI3	16	12.4%	12.1%
SPI6	12	10.8%	11.0%
SPIcum	6	9.3%	10.6%
SCI3	18	13.4%	13.0%
SCI6	14	11.2%	11.4%
SCIcum	9	9.6%	10.8%
CPI6 x SPIcum	11	9.8%	11.0%
Composite	4	8.8%	10.5%
Rayleigh (Lin Reg)	23	358.8%	1662.5%
Rayleigh (T-G Reg)	23	403.4%	1249.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	20	42.1%	68.3%

TY Results for Fixed Price Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	12	6.0%	5.0%
CPI6	8	5.6%	4.2%
CPIcum	3	5.1%	3.4%
SPI3	6	5.1%	4.2%
SPI6	4	4.9%	3.9%
SPIcum	4	5.1%	3.7%
SCI3	14	6.3%	6.8%
SCI6	8	5.4%	4.5%
SCIcum	5	5.4%	3.7%
CPI6 x SPIcum	11	6.0%	4.6%
Composite	3	5.1%	3.4%
Rayleigh (Lin Reg)	18	293.7%	1996.2%
Rayleigh (T-G Reg)	20	935.1%	11015.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	16	9.9%	21.3%

Results for Fixed Price Contracts Using Inflation Adjusted Data

CY95 Results for All Fixed Price Data			
	Score	MAPE	SDAPE
CPI3	10	12.4%	20.5%
CPI6	5	11.0%	14.8%
CPIcum	5	10.9%	14.9%
SPI3	20	15.7%	27.2%
SPI6	10	13.2%	18.5%
SPIcum	12	12.9%	21.1%
SCI3	22	21.0%	107.7%
SCI6	17	14.5%	21.7%
SCIcum	17	13.8%	22.2%
CPI6 x SPIcum	12	13.7%	19.7%
Composite	2	10.6%	14.4%
Rayleigh (Lin Reg)	25	159.3%	439.9%
Rayleigh (T-G Reg)	28	294.5%	2295.8%
Rayleigh MMAE	25	227.3%	418.3%
Beta	30	97240.0%	2829658.4%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI3 CPI6
>50% - 75%	CPI6
>75% - 100%	CPIcum Composite

CY95 Results for Fixed Price Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	11	21.9%	32.5%
CPI6	6	19.2%	19.9%
CPIcum	4	18.9%	19.3%
SPI3	21	28.8%	43.8%
SPI6	9	23.6%	26.3%
SPIcum	14	24.0%	32.7%
SCI3	24	44.7%	200.6%
SCI6	18	27.7%	32.8%
SCIcum	18	27.1%	34.2%
CPI6 x SPIcum	13	26.5%	29.2%
Composite	2	17.6%	18.5%
Rayleigh (Lin Reg)	25	108.7%	61.9%
Rayleigh (T-G Reg)	17	96.8%	26.5%
Rayleigh MMAE	28	378.9%	639.5%
Beta	30	357209.9%	5424614.9%

CY95 Results for Fixed Price Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	3	12.5%	17.6%
CPI6	3	11.8%	17.8%
CPIcum	5	11.8%	18.4%
SPI3	17	18.1%	20.4%
SPI6	14	16.4%	20.2%
SPIcum	9	14.5%	19.2%
SCI3	20	20.3%	23.8%
SCI6	17	16.9%	20.7%
SCIcum	10	14.3%	19.6%
CPI6 x SPIcum	11	14.9%	19.5%
Composite	4	11.8%	18.3%
Rayleigh (Lin Reg)	22	165.9%	222.6%
Rayleigh (T-G Reg)	24	198.7%	368.6%
Rayleigh MMAE	27	328.9%	433.5%
Beta	27	293.4%	1011.3%

CY95 Results for Fixed Price Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	4	9.4%	9.8%
CPI6	3	8.9%	10.2%
CPIcum	6	9.1%	10.6%
SPI3	16	12.2%	11.7%
SPI6	12	10.7%	11.0%
SPIcum	8	9.7%	10.5%
SCI3	18	12.5%	12.6%
SCI6	14	10.8%	11.5%
SCIcum	9	9.6%	10.8%
CPI6 x SPIcum	11	9.7%	11.0%
Composite	6	9.1%	10.6%
Rayleigh (Lin Reg)	24	186.5%	558.9%
Rayleigh (T-G Reg)	24	205.1%	389.7%
Rayleigh MMAE	24	205.5%	357.4%
Beta	20	42.6%	68.9%

CY95 Results for Fixed Price Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	14	6.1%	5.8%
CPI6	10	5.9%	5.2%
CPIcum	3	5.3%	4.4%
SPI3	7	5.4%	5.2%
SPI6	4	5.2%	4.6%
SPIcum	4	5.3%	4.5%
SCI3	16	6.2%	7.4%
SCI6	10	5.7%	5.3%
SCIcum	6	5.5%	4.5%
CPI6 x SPIcum	14	6.2%	5.4%
Composite	3	5.3%	4.4%
Rayleigh (Lin Reg)	22	171.7%	575.5%
Rayleigh (T-G Reg)	24	482.4%	3645.3%
Rayleigh MMAE	20	99.0%	163.6%
Beta	18	9.6%	21.1%

Results for Mixed Type Contracts Using Non-Inflation Adjusted Data

TY Results for All Mixed Data			
	Score	MAPE	SDAPE
CPI3	16	13.9%	5.9%
CPI6	16	14.1%	5.5%
CPIcum	15	14.4%	4.4%
SPI3	6	12.1%	3.8%
SPI6	5	12.3%	3.6%
SPIcum	5	12.5%	3.1%
SCI3	12	11.7%	6.5%
SCI6	11	12.1%	5.6%
SCIcum	8	12.6%	3.7%
CPI6 x SPIcum	10	12.3%	4.8%
Composite	12	14.0%	3.9%
Rayleigh (Lin Reg)	26	296.6%	773.2%
Rayleigh (T-G Reg)	22	88.8%	98.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	155.3%	445.6%

Best Performing Method(s)

Overall	SPI6 SPIcum
0% - 25%	SPIcum
>25% - 50%	CPI6 x SPIcum
>50% - 75%	SPI3
>75% - 100%	SCI6

TY Results for Mixed Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	17	17.1%	4.8%
CPI6	16	17.5%	4.2%
CPIcum	11	16.5%	3.3%
SPI3	9	9.4%	4.8%
SPI6	9	10.1%	4.5%
SPIcum	5	9.2%	3.8%
SCI3	16	12.0%	9.1%
SCI6	17	13.2%	7.2%
SCIcum	12	11.3%	5.6%
CPI6 x SPIcum	15	12.4%	6.5%
Composite	11	15.2%	3.4%
Rayleigh (Lin Reg)	24	120.9%	23.4%
Rayleigh (T-G Reg)	14	132.1%	0.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	627.0%	870.2%

TY Results for Mixed Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	15	16.7%	3.3%
CPI6	11	16.3%	1.1%
CPIcum	13	17.6%	0.9%
SPI3	12	15.1%	3.0%
SPI6	9	14.3%	2.6%
SPIcum	6	14.1%	0.9%
SCI3	13	14.8%	4.3%
SCI6	7	13.5%	2.6%
SCIcum	6	14.8%	0.4%
CPI6 x SPIcum	5	13.3%	1.1%
Composite	11	17.0%	0.6%
Rayleigh (Lin Reg)	24	1070.0%	1443.0%
Rayleigh (T-G Reg)	22	184.2%	150.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	20	23.9%	12.3%

TY Results for Mixed Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	17	13.6%	7.9%
CPI6	16	14.2%	7.5%
CPIcum	14	14.4%	5.0%
SPI3	7	13.5%	3.6%
SPI6	9	14.3%	3.5%
SPIcum	11	15.1%	1.9%
SCI3	15	12.2%	8.5%
SCI6	16	13.6%	7.8%
SCIcum	12	14.4%	3.8%
CPI6 x SPIcum	15	14.3%	6.4%
Composite	14	14.5%	4.4%
Rayleigh (Lin Reg)	10	10.8%	7.0%
Rayleigh (T-G Reg)	25	44.3%	31.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	10	13.1%	6.1%

TY Results for Mixed Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	16	8.3%	2.8%
CPI6	12	8.2%	1.9%
CPIcum	12	9.0%	0.8%
SPI3	11	9.7%	0.5%
SPI6	11	9.8%	0.4%
SPIcum	13	10.7%	0.5%
SCI3	11	7.6%	2.1%
SCI6	9	7.8%	1.5%
SCIcum	11	9.4%	0.6%
CPI6 x SPIcum	13	8.5%	1.6%
Composite	12	9.4%	0.7%
Rayleigh (Lin Reg)	24	21.3%	5.6%
Rayleigh (T-G Reg)	26	38.3%	49.3%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	11	4.9%	2.3%

Results for Mixed Type Contracts Using Inflation Adjusted Data

CY95 Results for All Mixed Data			
	Score	MAPE	SDAPE
CPI3	14	11.6%	7.3%
CPI6	14	11.8%	7.1%
CPIcum	13	12.1%	6.2%
SPI3	4	9.8%	5.8%
SPI6	5	10.0%	5.8%
SPIcum	5	10.1%	5.5%
SCI3	10	9.7%	7.7%
SCI6	11	10.1%	7.2%
SCIcum	7	10.4%	5.8%
CPI6 x SPIcum	9	10.1%	6.6%
Composite	10	11.7%	6.0%
Rayleigh (Lin Reg)	26	761.1%	2286.9%
Rayleigh (T-G Reg)	20	73.1%	76.5%
Rayleigh MMAE	24	141.5%	369.7%
Beta	22	125.5%	337.8%

Best Performing Method(s)

Overall	SPI3
0% - 25%	SPI3 SPIcum
>25% - 50%	CPI6 x SPIcum
>50% - 75%	Rayleigh (Lin Reg)
>75% - 100%	SCI6

CY95 Results for Mixed Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	17	12.9%	5.2%
CPI6	19	13.4%	5.6%
CPIcum	13	12.3%	4.8%
SPI3	4	5.7%	4.1%
SPI6	8	6.4%	4.9%
SPIcum	4	5.5%	4.4%
SCI3	17	8.4%	8.2%
SCI6	18	9.6%	7.4%
SCIcum	13	7.6%	5.8%
CPI6 x SPIcum	16	8.8%	6.7%
Composite	14	10.9%	5.0%
Rayleigh (Lin Reg)	25	127.0%	31.5%
Rayleigh (T-G Reg)	14	140.9%	0.0%
Rayleigh MMAE	30	731.0%	811.7%
Beta	28	504.5%	635.7%

CY95 Results for Mixed Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	19	15.9%	4.9%
CPI6	11	15.5%	2.3%
CPIcum	12	16.9%	1.5%
SPI3	14	14.3%	4.2%
SPI6	12	13.5%	4.3%
SPIcum	8	13.4%	2.7%
SCI3	16	14.0%	6.1%
SCI6	11	12.7%	4.5%
SCIcum	10	14.1%	2.4%
CPI6 x SPIcum	7	12.6%	3.2%
Composite	12	16.2%	1.6%
Rayleigh (Lin Reg)	30	2932.6%	4395.6%
Rayleigh (T-G Reg)	28	135.3%	108.3%
Rayleigh MMAE	26	45.7%	64.0%
Beta	24	21.6%	19.2%

CY95 Results for Mixed Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	17	13.4%	9.5%
CPI6	16	13.9%	9.2%
CPIcum	16	14.1%	6.9%
SPI3	9	13.4%	5.6%
SPI6	11	14.1%	5.5%
SPIcum	13	14.8%	4.1%
SCI3	17	12.2%	9.9%
SCI6	16	13.4%	9.4%
SCIcum	14	14.2%	5.7%
CPI6 x SPIcum	16	14.0%	8.1%
Composite	17	14.3%	6.4%
Rayleigh (Lin Reg)	2	7.3%	1.5%
Rayleigh (T-G Reg)	26	38.0%	38.0%
Rayleigh MMAE	8	8.2%	6.0%
Beta	14	10.0%	9.4%

CY95 Results for Mixed Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	13	3.6%	2.2%
CPI6	11	3.6%	1.5%
CPIcum	10	4.2%	0.7%
SPI3	9	4.7%	0.2%
SPI6	11	4.8%	0.3%
SPIcum	13	5.3%	0.5%
SCI3	10	3.2%	1.8%
SCI6	8	3.3%	1.3%
SCIcum	11	4.5%	0.6%
CPI6 x SPIcum	11	3.8%	1.4%
Composite	10	4.4%	0.6%
Rayleigh (Lin Reg)	23	17.4%	5.3%
Rayleigh (T-G Reg)	27	35.1%	51.1%
Rayleigh MMAE	25	22.0%	10.1%
Beta	18	4.5%	2.3%

Results for Army Contracts Using Non-Inflation Adjusted Data

TY Results for All Army Data	Score	MAPE	SDAPE
CPI3	9	12.4%	12.8%
CPI6	4	11.0%	11.6%
CPIcum	6	11.4%	11.9%
SPI3	19	14.8%	20.7%
SPI6	9	12.0%	14.0%
SPIcum	14	12.7%	19.8%
SCI3	22	17.8%	23.8%
SCI6	15	13.1%	16.2%
SCIcum	19	13.6%	21.2%
CPI6 x SPIcum	13	13.0%	16.1%
Composite	2	10.8%	10.9%
Rayleigh (Lin Reg)	24	147.8%	359.6%
Rayleigh (T-G Reg)	26	193.5%	587.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	1055.5%	6544.0%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI6
>50% - 75%	CPI6
>75% - 100%	CPIcum SPI6 Composite

TY Results for Army Data 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	8	22.2%	16.4%
CPI6	5	21.1%	15.7%
CPIcum	5	21.7%	15.1%
SPI3	17	26.9%	32.0%
SPI6	10	22.5%	20.1%
SPIcum	15	23.9%	32.8%
SCI3	22	32.1%	34.6%
SCI6	14	25.8%	23.8%
SCIcum	20	27.5%	34.3%
CPI6 x SPIcum	14	24.8%	25.2%
Composite	2	19.5%	13.7%
Rayleigh (Lin Reg)	24	111.3%	46.4%
Rayleigh (T-G Reg)	26	140.7%	187.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	28	2638.6%	10306.1%

TY Results for Army Data >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	7	13.1%	10.8%
CPI6	2	12.8%	10.0%
CPIcum	5	12.9%	10.4%
SPI3	15	17.6%	12.7%
SPI6	12	17.1%	12.2%
SPIcum	8	15.4%	10.4%
SCI3	18	20.3%	15.3%
SCI6	15	17.7%	12.4%
SCIcum	9	15.2%	12.2%
CPI6 x SPIcum	12	16.1%	12.4%
Composite	3	12.8%	10.2%
Rayleigh (Lin Reg)	22	221.6%	598.7%
Rayleigh (T-G Reg)	20	159.1%	301.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	1783.4%	8422.2%

TY Results for Army Data >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	12	9.2%	6.8%
CPI6	2	8.0%	5.3%
CPIcum	5	8.1%	5.6%
SPI3	18	10.8%	8.6%
SPI6	14	9.6%	7.6%
SPIcum	9	9.0%	6.0%
SCI3	21	12.5%	12.0%
SCI6	18	9.7%	9.1%
SCIcum	9	8.7%	6.6%
CPI6 x SPIcum	15	9.6%	7.7%
Composite	5	8.2%	5.5%
Rayleigh (Lin Reg)	25	190.0%	416.7%
Rayleigh (T-G Reg)	27	245.0%	578.2%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	23	52.7%	61.3%

TY Results for Army Data >75% to 100% Complete	Score	MAPE	SDAPE
CPI3	14	5.9%	6.1%
CPI6	12	5.4%	5.8%
CPIcum	3	4.6%	3.9%
SPI3	10	5.0%	5.7%
SPI6	3	4.3%	4.2%
SPIcum	7	4.9%	4.3%
SCI3	18	6.6%	10.8%
SCI6	7	4.7%	5.5%
SCIcum	7	5.0%	4.2%
CPI6 x SPIcum	16	6.0%	6.2%
Composite	3	4.6%	3.9%
Rayleigh (Lin Reg)	22	110.0%	249.2%
Rayleigh (T-G Reg)	24	205.2%	776.5%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	20	11.9%	25.0%

Results for Army Contracts Using Inflation Adjusted Data

CY95 Results for All Army Data			
	Score	MAPE	SDAPE
CPI3	8	11.8%	11.9%
CPI6	4	10.8%	10.7%
CPIcum	6	11.1%	11.1%
SPI3	19	15.5%	24.0%
SPI6	10	12.7%	15.4%
SPIcum	14	13.5%	23.1%
SCI3	22	18.2%	26.8%
SCI6	14	13.8%	18.0%
SCIcum	19	14.5%	24.8%
CPI6 x SPIcum	14	13.7%	18.1%
Composite	2	10.6%	10.0%
Rayleigh (Lin Reg)	24	145.2%	445.8%
Rayleigh (T-G Reg)	28	514.5%	4307.0%
Rayleigh MMAE	26	326.4%	674.0%
Beta	30	2143.4%	15882.0%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI6 Composite
>50% - 75%	CPI6
>75% - 100%	SPIcum Composite

CY95 Results for Army Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	8	18.9%	16.8%
CPI6	5	17.8%	16.0%
CPIcum	5	18.3%	15.6%
SPI3	17	26.9%	39.6%
SPI6	10	22.3%	24.6%
SPIcum	15	24.2%	40.1%
SCI3	22	33.1%	42.2%
SCI6	14	26.1%	29.1%
SCIcum	20	28.2%	42.1%
CPI6 x SPIcum	14	25.0%	30.8%
Composite	2	16.4%	13.7%
Rayleigh (Lin Reg)	25	111.0%	55.9%
Rayleigh (T-G Reg)	25	112.0%	45.1%
Rayleigh MMAE	28	618.9%	986.6%
Beta	30	5873.7%	28227.0%

CY95 Results for Army Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	7	12.5%	10.0%
CPI6	3	12.2%	9.2%
CPIcum	4	12.1%	9.9%
SPI3	17	17.3%	13.3%
SPI6	13	16.7%	12.6%
SPIcum	9	15.0%	10.7%
SCI3	20	20.4%	16.1%
SCI6	16	17.8%	12.8%
SCIcum	11	15.2%	12.6%
CPI6 x SPIcum	14	16.3%	13.0%
Composite	3	12.1%	9.7%
Rayleigh (Lin Reg)	22	208.0%	582.3%
Rayleigh (T-G Reg)	24	271.2%	820.7%
Rayleigh MMAE	26	505.7%	913.4%
Beta	28	2874.0%	12212.5%

CY95 Results for Army Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	6	9.1%	6.0%
CPI6	2	8.3%	5.5%
CPIcum	4	8.7%	5.7%
SPI3	16	11.5%	7.7%
SPI6	13	10.1%	7.4%
SPIcum	9	9.6%	6.1%
SCI3	19	11.9%	10.6%
SCI6	15	9.7%	8.7%
SCIcum	8	9.1%	6.7%
CPI6 x SPIcum	11	9.5%	7.6%
Composite	4	8.7%	5.7%
Rayleigh (Lin Reg)	23	128.0%	154.9%
Rayleigh (T-G Reg)	27	839.9%	5574.0%
Rayleigh MMAE	25	292.6%	456.4%
Beta	21	49.6%	58.3%

CY95 Results for Army Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	11	7.1%	6.2%
CPI6	12	7.2%	6.2%
CPIcum	5	6.4%	5.3%
SPI3	9	6.7%	6.1%
SPI6	5	6.1%	5.4%
SPIcum	4	6.6%	5.1%
SCI3	13	7.2%	7.4%
SCI6	7	6.4%	6.1%
SCIcum	7	6.7%	5.3%
CPI6 x SPIcum	13	7.5%	6.2%
Composite	4	6.4%	5.2%
Rayleigh (Lin Reg)	20	142.0%	578.4%
Rayleigh (T-G Reg)	22	627.7%	5339.4%
Rayleigh MMAE	18	101.8%	111.4%
Beta	16	11.4%	24.5%

Results for Air Force Contracts Using Non-Inflation Adjusted Data

TY Results for All Air Force Data	Score	MAPE	SDAPE
CPI3	17	13.3%	24.5%
CPI6	5	11.8%	16.8%
CPIcum	4	11.8%	16.7%
SPI3	19	14.2%	27.4%
SPI6	11	12.4%	18.6%
SPIcum	7	12.2%	17.7%
SCI3	21	20.6%	141.6%
SCI6	15	13.0%	21.7%
SCIcum	9	12.3%	18.0%
CPI6 x SPIcum	13	12.6%	18.9%
Composite	2	11.6%	16.6%
Rayleigh (Lin Reg)	23	193.1%	849.8%
Rayleigh (T-G Reg)	25	817.7%	8895.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	27	142149.1%	3183770.8%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI6
>50% - 75%	CPI6
>75% - 100%	CPIcum

TY Results for Air Force Data 0% to 25% Complete	Score	MAPE	SDAPE
CPI3	15	26.5%	43.0%
CPI6	6	23.2%	23.5%
CPIcum	4	22.4%	22.3%
SPI3	18	28.0%	49.0%
SPI6	10	24.3%	27.9%
SPIcum	7	23.2%	24.4%
SCI3	22	53.5%	294.0%
SCI6	15	27.4%	36.7%
SCIcum	9	24.3%	25.0%
CPI6 x SPIcum	12	25.9%	28.7%
Composite	2	21.6%	22.2%
Rayleigh (Lin Reg)	23	114.1%	78.0%
Rayleigh (T-G Reg)	21	101.7%	49.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	26	639821.2%	6754639.4%

TY Results for Air Force Data >25% to 50% Complete	Score	MAPE	SDAPE
CPI3	7	15.6%	21.1%
CPI6	3	14.5%	21.3%
CPIcum	7	15.2%	21.7%
SPI3	11	17.5%	21.3%
SPI6	15	16.5%	22.2%
SPIcum	15	15.9%	22.4%
SCI3	20	18.7%	22.7%
SCI6	12	15.9%	21.9%
SCIcum	14	15.4%	22.5%
CPI6 x SPIcum	9	15.1%	22.0%
Composite	6	15.0%	21.8%
Rayleigh (Lin Reg)	22	256.2%	611.5%
Rayleigh (T-G Reg)	26	545.3%	1700.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	24	395.4%	1247.6%

TY Results for Air Force Data >50% to 75% Complete	Score	MAPE	SDAPE
CPI3	6	10.7%	11.3%
CPI6	3	10.3%	12.0%
CPIcum	8	10.4%	12.5%
SPI3	14	12.0%	12.6%
SPI6	10	10.8%	12.3%
SPIcum	9	10.6%	12.4%
SCI3	10	12.4%	12.0%
SCI6	7	10.7%	12.0%
SCIcum	10	10.6%	12.5%
CPI6 x SPIcum	6	10.5%	12.1%
Composite	9	10.5%	12.5%
Rayleigh (Lin Reg)	20	320.8%	1601.3%
Rayleigh (T-G Reg)	20	524.6%	1551.6%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	17	64.9%	110.2%

TY Results for Air Force Data >75% to 100% Complete	Score	MAPE	SDAPE
CPI3	14	5.5%	4.6%
CPI6	10	5.3%	4.0%
CPIcum	3	4.9%	3.4%
SPI3	8	5.1%	3.7%
SPI6	5	4.8%	3.7%
SPIcum	6	4.9%	3.7%
SCI3	16	5.8%	5.5%
SCI6	11	5.3%	4.1%
SCIcum	6	5.0%	3.6%
CPI6 x SPIcum	13	5.5%	4.2%
Composite	4	4.9%	3.5%
Rayleigh (Lin Reg)	20	124.1%	479.7%
Rayleigh (T-G Reg)	22	1331.7%	13603.8%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	18	17.3%	73.8%

Results for Air Force Contracts Using Inflation Adjusted Data

CY95 Results for All Air Force Data			
	Score	MAPE	SDAPE
CPI3	17	13.8%	24.4%
CPI6	6	12.4%	17.0%
CPIcum	4	12.1%	16.6%
SPI3	19	14.8%	27.6%
SPI6	12	13.1%	19.0%
SPIcum	8	12.8%	18.0%
SCI3	21	20.9%	137.1%
SCI6	16	13.8%	22.0%
SCIcum	10	13.0%	18.3%
CPI6 x SPIcum	14	13.4%	19.4%
Composite	2	12.0%	16.5%
Rayleigh (Lin Reg)	27	358.7%	4511.4%
Rayleigh (T-G Reg)	23	190.8%	381.7%
Rayleigh MMAE	25	228.8%	441.9%
Beta	29	161491.9%	3644375.1%

Best Performing Method(s)

Overall	Composite
0% - 25%	Composite
>25% - 50%	CPI3 CPI6
>50% - 75%	CPI3 CPI6
>75% - 100%	SPI3

CY95 Results for Air Force Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	16	25.3%	42.7%
CPI6	6	21.6%	23.3%
CPIcum	4	20.3%	22.0%
SPI3	19	27.9%	49.6%
SPI6	12	23.9%	29.2%
SPIcum	8	22.4%	25.4%
SCI3	23	52.6%	284.4%
SCI6	16	26.9%	37.3%
SCIcum	10	23.5%	25.9%
CPI6 x SPIcum	14	25.3%	29.7%
Composite	2	19.9%	21.9%
Rayleigh (Lin Reg)	24	118.3%	89.6%
Rayleigh (T-G Reg)	22	100.7%	36.0%
Rayleigh MMAE	27	548.2%	736.5%
Beta	29	726897.4%	7732256.3%

CY95 Results for Air Force Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	4	14.5%	21.5%
CPI6	4	13.4%	21.9%
CPIcum	6	14.1%	22.4%
SPI3	10	16.9%	21.8%
SPI6	13	15.9%	22.8%
SPIcum	13	15.3%	23.1%
SCI3	16	17.9%	23.1%
SCI6	10	15.2%	22.5%
SCIcum	11	14.8%	23.1%
CPI6 x SPIcum	8	14.5%	22.5%
Composite	6	14.1%	22.4%
Rayleigh (Lin Reg)	24	1192.6%	9633.1%
Rayleigh (T-G Reg)	18	228.7%	367.9%
Rayleigh MMAE	20	355.5%	479.0%
Beta	22	413.6%	1265.0%

CY95 Results for Air Force Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	3	10.7%	11.4%
CPI6	3	10.6%	12.1%
CPIcum	8	10.8%	12.5%
SPI3	13	12.1%	12.6%
SPI6	9	11.2%	12.2%
SPIcum	8	11.1%	12.2%
SCI3	9	12.1%	12.1%
SCI6	5	10.8%	12.1%
SCIcum	8	10.8%	12.5%
CPI6 x SPIcum	4	10.6%	12.2%
Composite	8	10.9%	12.4%
Rayleigh (Lin Reg)	19	142.8%	476.7%
Rayleigh (T-G Reg)	20	183.8%	365.0%
Rayleigh MMAE	18	166.6%	275.4%
Beta	15	64.7%	109.3%

CY95 Results for Air Force Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	12	7.9%	7.6%
CPI6	15	8.2%	8.5%
CPIcum	6	7.2%	6.6%
SPI3	2	6.9%	6.4%
SPI6	6	7.1%	6.7%
SPIcum	3	7.1%	6.4%
SCI3	13	7.7%	8.6%
SCI6	12	7.8%	8.2%
SCIcum	7	7.3%	6.6%
CPI6 x SPIcum	17	8.3%	8.6%
Composite	5	7.2%	6.5%
Rayleigh (Lin Reg)	23	121.8%	394.4%
Rayleigh (T-G Reg)	25	200.3%	444.7%
Rayleigh MMAE	20	70.7%	162.9%
Beta	20	33.9%	195.9%

Results for Navy Contracts Using Non-Inflation Adjusted Data

TY Results for All Navy Data

	Score	MAPE	SDAPE
CPI3	10	12.6%	15.7%
CPI6	2	11.2%	13.8%
CPIcum	6	11.5%	15.0%
SPI3	18	15.3%	17.5%
SPI6	12	13.2%	15.3%
SPIcum	9	12.7%	15.2%
SCI3	20	17.6%	21.5%
SCI6	16	14.5%	16.7%
SCIcum	13	12.9%	16.0%
CPI6 x SPIcum	9	13.2%	14.9%
Composite	3	11.2%	14.5%
Rayleigh (Lin Reg)	24	294.7%	2075.5%
Rayleigh (T-G Reg)	22	141.3%	233.7%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	26	5197.9%	61154.0%

Best Performing Method(s)

Overall	CPI6
0% - 25%	CPI6
>25% - 50%	CPI6 CPIcum SPIcum SCIcum Composite
>50% - 75%	CPIcum
>75% - 100%	SPIcum Composite

TY Results for Navy Data 0% to 25% Complete

	Score	MAPE	SDAPE
CPI3	14	23.0%	21.5%
CPI6	3	20.3%	18.0%
CPIcum	10	21.7%	19.5%
SPI3	18	27.1%	20.3%
SPI6	7	23.5%	17.7%
SPIcum	9	23.4%	18.9%
SCI3	22	33.1%	25.5%
SCI6	14	26.5%	19.0%
SCIcum	16	25.1%	20.6%
CPI6 x SPIcum	10	25.3%	18.0%
Composite	5	20.8%	18.6%
Rayleigh (Lin Reg)	16	93.6%	18.6%
Rayleigh (T-G Reg)	18	93.2%	19.1%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	26	18032.6%	115070.1%

TY Results for Navy Data >25% to 50% Complete

	Score	MAPE	SDAPE
CPI3	7	15.9%	16.5%
CPI6	6	15.7%	16.5%
CPIcum	6	14.2%	17.2%
SPI3	17	21.7%	20.1%
SPI6	13	20.1%	18.7%
SPIcum	6	17.5%	16.2%
SCI3	19	23.1%	24.5%
SCI6	15	21.5%	19.9%
SCIcum	6	15.3%	16.8%
CPI6 x SPIcum	8	18.1%	16.3%
Composite	6	14.2%	17.2%
Rayleigh (Lin Reg)	21	89.1%	48.9%
Rayleigh (T-G Reg)	23	89.3%	61.2%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	25	751.5%	3163.3%

TY Results for Navy Data >50% to 75% Complete

	Score	MAPE	SDAPE
CPI3	11	7.3%	6.3%
CPI6	7	6.1%	6.0%
CPIcum	2	5.5%	5.1%
SPI3	18	10.4%	9.9%
SPI6	14	8.8%	7.8%
SPIcum	8	6.4%	6.0%
SCI3	20	11.1%	11.8%
SCI6	16	9.5%	8.9%
SCIcum	7	6.4%	5.6%
CPI6 x SPIcum	11	7.0%	7.1%
Composite	4	5.6%	5.2%
Rayleigh (Lin Reg)	26	396.2%	1763.5%
Rayleigh (T-G Reg)	24	232.4%	409.9%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	22	15.6%	17.3%

TY Results for Navy Data >75% to 100% Complete

	Score	MAPE	SDAPE
CPI3	15	5.2%	4.2%
CPI6	11	4.9%	3.6%
CPIcum	5	4.5%	3.0%
SPI3	9	4.4%	4.0%
SPI6	6	4.1%	3.7%
SPIcum	4	4.3%	3.2%
SCI3	18	5.4%	5.8%
SCI6	13	4.6%	4.7%
SCIcum	9	4.8%	3.3%
CPI6 x SPIcum	14	5.2%	4.0%
Composite	4	4.4%	3.0%
Rayleigh (Lin Reg)	23	500.0%	3262.2%
Rayleigh (T-G Reg)	21	142.1%	195.0%
Rayleigh MMAE	N/A	0.0%	0.0%
Beta	16	4.8%	8.3%

Results for Navy Contracts Using Inflation Adjusted Data

CY95 Results for All Navy Data			
	Score	MAPE	SDAPE
CPI3	11	13.0%	16.5%
CPI6	3	11.4%	13.5%
CPIcum	5	11.4%	14.2%
SPI3	18	15.4%	17.4%
SPI6	10	13.3%	15.3%
SPIcum	7	12.9%	15.0%
SCI3	20	18.2%	23.2%
SCI6	16	15.0%	17.3%
SCIcum	12	13.4%	16.0%
CPI6 x SPIcum	12	13.9%	15.3%
Composite	3	10.9%	13.6%
Rayleigh (Lin Reg)	24	143.9%	549.0%
Rayleigh (T-G Reg)	26	241.3%	854.9%
Rayleigh MMAE	22	139.3%	248.9%
Beta	28	2777.5%	29718.4%

Best Performing Method(s)

Overall	CPI6 Composite
0% - 25%	Composite
>25% - 50%	CPI3 CPI6
>50% - 75%	CPIcum
>75% - 100%	SPI6

CY95 Results for Navy Data 0% to 25% Complete			
	Score	MAPE	SDAPE
CPI3	14	21.9%	22.8%
CPI6	3	18.4%	17.4%
CPIcum	6	19.7%	18.2%
SPI3	17	26.9%	20.8%
SPI6	10	22.6%	18.3%
SPIcum	11	22.2%	19.3%
SCI3	23	34.1%	29.2%
SCI6	18	26.3%	21.2%
SCIcum	15	24.6%	21.0%
CPI6 x SPIcum	13	25.0%	19.2%
Composite	2	18.1%	17.4%
Rayleigh (Lin Reg)	24	95.4%	24.6%
Rayleigh (T-G Reg)	14	94.3%	18.0%
Rayleigh MMAE	27	199.8%	337.2%
Beta	29	9336.4%	55809.1%

CY95 Results for Navy Data >25% to 50% Complete			
	Score	MAPE	SDAPE
CPI3	6	15.8%	16.4%
CPI6	6	15.3%	16.6%
CPIcum	8	13.4%	17.3%
SPI3	19	21.0%	20.6%
SPI6	16	19.3%	19.2%
SPIcum	11	16.5%	16.8%
SCI3	22	23.0%	25.3%
SCI6	19	21.5%	20.4%
SCIcum	8	15.5%	16.7%
CPI6 x SPIcum	9	18.5%	16.5%
Composite	8	13.5%	17.2%
Rayleigh (Lin Reg)	24	92.9%	64.3%
Rayleigh (T-G Reg)	26	98.7%	110.1%
Rayleigh MMAE	28	193.5%	336.1%
Beta	30	807.2%	3342.3%

CY95 Results for Navy Data >50% to 75% Complete			
	Score	MAPE	SDAPE
CPI3	11	6.8%	6.0%
CPI6	7	6.0%	5.9%
CPIcum	2	5.5%	5.2%
SPI3	18	9.5%	8.9%
SPI6	14	7.9%	7.6%
SPIcum	7	6.5%	5.7%
SCI3	20	9.6%	11.1%
SCI6	16	8.4%	8.8%
SCIcum	5	6.0%	5.5%
CPI6 x SPIcum	11	6.6%	6.7%
Composite	3	5.5%	5.3%
Rayleigh (Lin Reg)	26	211.5%	674.2%
Rayleigh (T-G Reg)	28	336.2%	851.6%
Rayleigh MMAE	24	109.3%	101.3%
Beta	22	16.9%	19.9%

CY95 Results for Navy Data >75% to 100% Complete			
	Score	MAPE	SDAPE
CPI3	20	7.6%	9.5%
CPI6	14	7.1%	7.0%
CPIcum	8	6.5%	5.6%
SPI3	5	6.1%	5.3%
SPI6	3	5.9%	5.1%
SPIcum	6	6.4%	5.3%
SCI3	20	7.4%	9.6%
SCI6	12	6.8%	6.8%
SCIcum	10	6.7%	5.8%
CPI6 x SPIcum	16	7.3%	7.1%
Composite	8	6.5%	5.6%
Rayleigh (Lin Reg)	25	168.7%	775.8%
Rayleigh (T-G Reg)	27	343.2%	1226.1%
Rayleigh MMAE	23	83.6%	145.0%
Beta	9	4.5%	8.3%

Bibliography

Abernathy, Thomas S. An Application of the Rayleigh Distribution to Contract Cost Data. Masters thesis. Naval Post Graduate School, Monterey CA, September 1984 (AD-A151551).

Air Force Materiel Command. Financial Management Guide to Analysis of Contractor Cost Data. AFMC Pamphlet 65-501. Wright-Patterson AFB OH: HQ AFMC, 4 April 1994.

Armstrong, J. Scott and Fred Callopy. "Error Measures for Generalizing About Forecasting Methods: Empirical Comparisons," International Journal of Forecasting, 8: 69-80 (1992).

Biery, Frederick P. "The Accuracy of Military Cost and Schedule Forecasts," The Journal of Cost Analysis, 3: 13-23 (Spring 1986).

Bright, Harold R. and Truman W. Howard, III. Weapon System Cost Control: Forecasting Contract Completion Costs, TR-FC-81-1. Comptroller/Cost Analysis Division, US Army Missile Command, Redstone Arsenal AL, September 1981.

Christensen, David S. "An Analysis of Cost Overruns on Defense Acquisition Contracts," Project Management Journal, 24: 43-48 (September 1993).

Christensen, Maj David S. and Capt Scott R. Heise. "Cost Performance Index Stability," National Contract Management Journal, 25: 7-15 (1993).

Christensen, David S., Richard C. Antolini, and John W. McKinney. "A Review of Estimate at Completion Research," in Cost Estimating and Analysis: Balancing Technology and Declining Budgets. Ed. Thomas R. Gulledge and others. New York: Springer-Verlag, 1992.

Cost Management Systems, Inc. Performance Analyzer User's Manual for Version 4.0. Vienna VA, June 1994.

Covach, John, Joseph J. Haydon, and Richard O. Riether. A Study to Determine Indicators and Methods to Compute Estimate at Completion (EAC). Contract N00600-79-D-0957. Virginia: ManTech International Corporation, 30 June 1981.

Department of the Air Force. Acquisition Management Policies and Procedures. AF Supplement 1/DoDI 5000.2. Washington DC: HQ USAF, February 1993.

Department of Defense. Defense Acquisition Management Policies. DoD Instruction 5000.2. Washington DC: GPO, 23 February 1991.

Devore, Jay L. Probability and Statistics for Engineering and the Sciences (Third Edition). Pacific Grove CA: Brooks/Cole Publishing Company, 1991.

Drezner, Jeffrey A., J. M. Jarvaise, R. W. Hess, P. G. Hough, and D. Norton. An Analysis of Weapon System Cost Growth. Contract F49620-91-C-0003. Santa Monica CA: The RAND Corporation, 1993.

Fleming, Quentin W. Cost Schedule Control Systems Criteria: The Management Guide to C/SCSC (Revised Edition). Chicago: Probus Publishing Company, 1992.

Gallagher, Mark A. and David A. Lee. "Final-Cost Estimates for Research and Development Programs Conditioned on Realized Costs." Unpublished paper. Office of the Secretary of Defense, Program Analysis and Evaluation, Washington DC. 7 July 1995.

Gates, William R. "Department of Defense Procurement Policy Reform: An Evolutionary Perspective." The Journal of Cost Analysis, 8: 1-32 (Fall 1989).

Heydinger, Gerard N. "Space and Missile Systems Organization Cost Performance Forecasting Study." Unpublished report. Cost Analysis Division, Los Angeles CA, June 1977.

Hoaglin, David C., Frederick Mosteller, and John W. Tukey. Understanding Robust and Exploratory Data Analysis. New York: John Wiley and Sons, Inc., 1983.

Jones, L. R. "Management of Budgetary Decline in the Department of Defense in Response to the End of the Cold War." Armed Forces and Society, 19: 479-509 (Summer 1993).

Knepp, Richard E. and Michael E. Stroble. Development of Standardized S Curves for the Evaluation of Major Department of Defense Purchases. Masters thesis, AFIT/GCA/LAS/93S-7. School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1993 (AD-A273963).

Land, Capt Thomas J. and Capt Edward L. Preston. A Comparative Analysis of Two Cost Performance Forecasting Models: The Automated Financial Analysis Program, Electronic Systems Division, November 1976, Versus a Cost Performance Forecasting Concept and Model, Aeronautical Systems Division, November 1974. Masters thesis, LSSR 23-80. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, June 1980 (AD-A087500).

Makridakis, Spyros and Steven C. Wheelwright. Forecasting Methods and Applications. New York: John Wiley & Sons, 1978.

Maybeck, P.S. Stochastic Models, Estimation, and Control: Volume 2. New York: Academic Press, Inc., 1982.

McKinney, John W. Estimate-At-Completion Research–A Review and Evaluation. Masters thesis, AFIT/GCA/LSY/91S-6. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1991 (AD-A243926).

Microsoft® Excel. Version 5.0, IBM, 1.44M, disk. Computer software. Microsoft® Corporation, Redmond WA, 1993.

Morrison, David C. "Deep-Sixing the A-12," Government Executive: 30-35 (March 1991).

Morrocco, John D. "Congressional Support Eroding for C-17 Program," Aviation Week and Space Technology, 138: 30-31 (15 March 1993).

Nahmias, Steven. Production and Operations Analysis (Second Edition). Burr Ridge IL: Richard D. Irwin, Inc., 1993.

Norden, Peter V. "Useful Tools for Project Management," in Software Cost Estimating and Life-Cycle Control: Getting the Software Numbers. Ed. Lawrence H. Putnam. New York: Institute of Electrical and Electronics Engineers, Inc., 1980.

Riedel, Mark A. and Jamie L. Chance. "Estimates at Completion (EAC): A Guide to Their Calculation and Application for Aircraft, Avionics, and Engine Programs." Unpublished report. Aeronautical Systems Division, Wright-Patterson AFB OH, August 1989.

Terry, Mark F. and Capt Mary M. Vanderburgh. An Analysis of Estimate at Completion Models Utilizing the Defense Acquisition Executive Summary Database. Masters thesis, AFIT/GCA/LAS/93S-9. School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1993 (AD-A275914).

Watkins, Harry, III. An Application of Rayleigh Curve Theory to Contract Cost Estimation and Control. Masters thesis. Naval Post Graduate School, Monterey CA, March 1982 (AD-A118213).

Whitlock, Richard D. "Estimates at Completion Using Beta Curves," Journal of Parametrics, 2: 15-18 (Fall 1982).

Vita

Capt Todd D. Nystrom was born on 19 July 1965 in Minot, North Dakota. He graduated from AFCENT High School in Brunssum, Netherlands in 1983 and entered undergraduate studies at Michigan State University in East Lansing, Michigan. He graduated with a Bachelor of Science degree in Electrical Engineering and was commissioned through the Reserve Officer Training Corps in June 1987. His first assignment was at Eglin AFB as an Electronic Warfare Test Engineer. His second assignment was to the Joint Tactical Systems Program Office, also at Eglin AFB. While in the Program Office he served as a Project Manager, Executive Officer to the System Program Director, and Program Manager for Test Assets on a major defense acquisition program. In May 1994 he entered the School of Logistics and Acquisition Management, Air Force Institute of Technology.

Permanent Address: 49607 Deer Run Drive
Shelby Twp, MI 48513

REPORT DOCUMENTATION PAGE

OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1995

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
A COMPARATIVE STUDY OF LINEAR AND NONLINEAR ESTIMATE AT COMPLETION METHODS

5. FUNDING NUMBERS

6. AUTHOR(S)
Todd D. Nystrom, Captain, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology,
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GSM/LAS/95S-5

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Wayne Abba
OUSD(A&T) API/PM
3020 Defense Pentagon, Room 3E1025
Washington DC 20301-3020

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Controlling costs in the acquisition of new defense systems is a major challenge in today's environment of declining budgets and rapidly changing technology. One of the challenges faced by program managers and cost analysts is selecting the most appropriate Estimate at Completion (EAC) method for their program. This study compares the performance of the popular index-based EAC methods with several newer nonlinear regression-based EAC methods to determine whether the complex nonlinear methods perform better than the simpler index-based methods. In addition, the sensitivity of the results to stage of contract completion, system type, program phase, contract type, Department of Defense service component, and inflation effects are also investigated.

Eighty-eight contracts were examined in this study and it was found that overall the index-based EAC methods performed significantly better than the nonlinear regression-based methods as measured by two criteria, the accuracy and stability of the EACs. In addition, the tip performing method overall was determined to be the index-based method using the Composite Index ($0.2SPI_{cum}+0.8CPI_{cum}$). The best performing method was, however, sensitive to all of the factors investigated in the sensitivity analysis.

14. SUBJECT TERMS
Estimate at Completion, Cost/Schedule Control Systems Criteria, Cost Estimating, Rayleigh Distribution, Beta Distribution, Multiple Model Adaptive Estimation

15. NUMBER OF PAGES
194

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL