COST RESEARCH REPORT

NO. 117

A COST PERFORMANCE FORECASTING CONCEPT AND MODEL

NOVEMBER 1974

COST ANALYSIS DIVISION
COMPTROLLER
AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AFB, OHIO

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This report identifies and illustrates the principles of a new and potentially valuable cost forecasting method. It is the objective of the technique to forecast Estimates At Completion (EACs) each month, utilizing data available in the Cost Performance Reports (CPRs). A single sample was used as a uniform data base for comparing the consequences of various methods. These methods are the linear extrapolation of percent cumulative cost variance and unconstrained and constrained regression analysis applied to an exponential relationship. The

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) sample data, computed data, computational procedures, and resource references are contained in the report to permit reproduction of similar results. The report shows that the constrained regression method applied to an exponential relationship offers the forecaster an improved method of final cost forecasting and introduces the use of measured subjectivity as a management input.

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A COST PERFORMANCE FORECASTING CONCEPT AND MODEL

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NOVEMBER 1974

COST ANALYSIS DIVISION

COMPTROLLER

AERONAUTICAL SYSTEMS DIVISION

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A

FOREWORD

This report presents a new cost forecasting method developing independent estimates at completion (EACs) by utilizing data available in the Cost Performance Reports (CPRs).

The fact that many tools and data sources are used for cost forecasting suggests that forecasting inherently contains some degree of subjectivity. This model provides the analyst with a method for including subjective adjustment based on prior experience when developing an EAC. Evaluation of any method requires that it be repeatedly tested under realistic conditions. Although the Aeronautical Systems Division is in the process of accumulating a large body of test data that can be useful in implementing and improving this method, time limitations dictate that the principles of its operation be described to the financial analysis community as an initial step in its evolutionary development.

The author expresses his appreciation to many individuals, Program Offices, and the Comptroller at ASD for their cooperation and encouragement in pursuit of this research task, particularly, Mr. Douglas Tussing (a former member of the B-1 office) and Mr. John Grace of the Computer Science Center (4950/ADDP).

ABSTRACT

This report identifies and illustrates the principles of a new and potentially valuable cost forecasting method. It is the objective of the technique to forecast Estimates At Completion (EACs) each month, utilizing data available in the Cost Performance Reports (CPRs).

A single sample was used as a uniform data base for comparing the consequences of various methods. These methods are the linear extrapolation of percent cumulative cost variance and unconstrained and constrained regression analysis applied to an exponential relationship. The sample data, computed data, computational procedures, and resource references are contained in the report to permit reproduction of similar results.

The report shows that the constrained regression method applied to an exponential relationship offers the forecaster an improved method of final cost forecasting and introduces the use of measured subjectivity as a management input.

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1.0 INTRODUCTION:

The primary objective of any forecasting method is to predict the true outcome of an event. Predicting a true outcome is more often a desired goal rather than an achievement. However, such a goal serves as a motivating force for stimulating the creative aspirations of many analysts.

This report describes and compares three EAC forecasting methods on the basis of the data contained in the Cost Performance Reports (CPRs) and within the scope of the Cost/Schedule Control Systems Criteria. Although the CPR contains data that reflects the consequences of many influences, it is a measure of past performance. In contrast, forecasting deals with future time periods and their corresponding influences. Each of the methods treat the CPR data in different ways in order to account for the influences in future time periods.

It is not the intent of this report to evaluate the data contents of the CPR other than to utilize certain of the elements within the report. The description of the data base, forecasting methods, assumptions, and graphical illustrations of the EAC forecasts are contained in the body of the report. The source data and computed results are contained in the Appendix for reference.

2.0 THE DATA BASE:

Although a variety of R&D program results are available for analysis and would have contributed to a more complete presentation, limited resources precluded their inclusion in this report. The more important priority was the need to communicate the principles of a new method. Therefore, a single sample of CPR data was chosen as the data base for comparing various methods. Table 1 and part of Table 2 in the Appendix contains the transcribed data sample of a completed program. Table 1 includes the monthly cumulative values of Actual Cost of Work Performed (ACWP), Budgeted Cost of Work Performed (BCWP), and Budget At Completion (BAC). The contractors monthly Estimate at Completion (EAC) was recorded in Table 2 to permit a direct comparison with the EACs computed from the three methods described in this report.

The sample was selected on the following basis.

a. The program was completed. This prerequisite was believed necessary in order to insure that all the ACWPs were included in the sample even though it was observed that BCWP had summed to BAC prior to the last submittal of the CPR.

b. Some engineering changes occurred during the life of the program. It is typical rather than the exception to expect engineering changes.

c. A modest increment of additional work was added to the program. Modest additions of new work is reasonable to expect in R&D programs in order to take advantage of technological improvements and adjust for changing requirements, especially if the program is planned for several years.

d. The program was effected by cost escalation. Many programs that extend for several years have experienced the effects of cost escalation.

There was no attempt to pre-select the sample on the basis that it could prove or disprove any method. The solutions associated with this sample were not available to the author at the time of sample selection.

3.0 DESCRIPTION AND COMPARISON OF METHODS:

3.1 COMPARISON FRAMEWORK

A comparison of three independent methods of forecasting is described and illustrated in this report. The three methods are identified as the "Cumulative Current Percent Cost Variance", the "Unconstrained Exponential", and the "Constrained Exponential", respectively. The monthly EAC dollar forecasts for each method are graphically related to each month of the 60 month program in Figures 1 and 4. In addition, the % completion $\left(\frac{\text{Cum.BCWP}}{\text{BAC}}\right)$ is superimposed on the linear monthly scales so that each forecast may be examined with respect to time.

It is also noted that:

The monthly BAC is included in the same manner as the forecasted EACs. The monthly BAC may be viewed as another EAC method since it is related to a contractual definition of program cost.

The final ACWP, which is obtained after the last CPR publication, is the reference point for judging the relative merits of the forecasting methods for each monthly forecast.

Table 2, in the Appendix, contains a summary of all the data used in the comparison of EAC methods. Due to the volume of data being compared, the description of the methods and their comparisons are divided into two parts for ease of discussion.

In the first part (paragraph 3.2), EACs generated by applying the "Cum. Current % Cost Variance Method" are described and compared to the results obtained by the "Unconstrained Exponential Method" and illustrated in Figure 1. In the second part (paragraph 3.3), EACs generated by applying the "Constrained Exponential Method" are described and added to the illustration of the first part (Figure 1) so that all three methods may be examined simultaneously in Figure 4.

3.2 COMPARISON OF TWO EAC METHODS:

3.2.1 DESCRIPTION OF THE CUM. CURRENT % COST VARIANCE METHOD:

This method of computing an EAC is based upon the assumption that in each month the computed cumulative % cost variance $(\frac{BCWP-ACWP}{BCWP} \times 100)$ may be linearly extrapolated to the end of the program as a measure of the final outcome. It assumes that an increment of ACWP dollars (overrun or underrun) at the end of the program applied to the current BAC entirely depends upon the current status reported in the CPR without regard to its proximity to the end point. Identical results may be obtained by applying the Cumulative Performance Index (CPI = BCWP/ACWP) to the BAC using the relationship, EAC = BAC/CPI. This relationship is further illustrated in the AFSC Guide for use of Contractor - Reported Cost Data, dated 1 July 1972.

Monthly forecasts of EAC were generated by this method in chronological sequence without regard to the data in previous or subsequent CPRs. Table 3 in the Appendix highlights the monthly cumulative % cost variances and the resulting EACs throughout the entire program. Figure 1 contains a graphical view of the monthly EACs in dollars on the ordinate against the combined scale of % completion and number of months. Superimposed on Figure 1 are the monthly BACs and the horizontal trace line representing the Final ACWP. In addition, the results obtained from the method described in paragraph 3.2.2 were included for comparison purposes.

COMPARISON OF TWO EAC METHODS

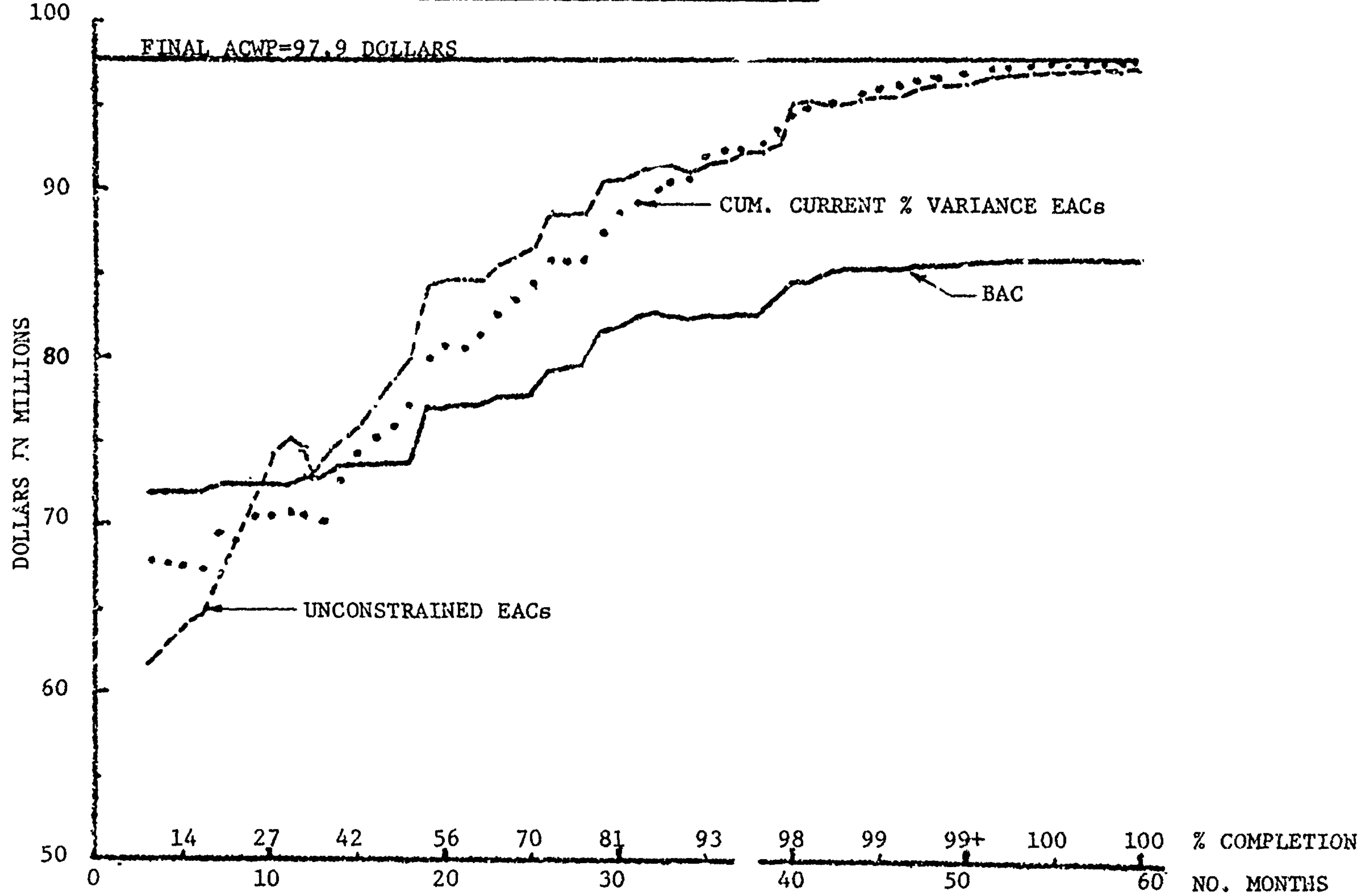


FIGURE 1

3.2.2 DESCRIPTION OF THE UNCONSTRAINED EXPONENTIAL METHOD:

3.2.2.1 GENERAL CONSIDERATIONS

This method makes use of a least squares regression analysis technique for developing trend characteristics. It assumes that the identification of a reasonable trend relationship of an ongoing activity will set the pace for future activity. Once established and defined it may permit extrapolating to the ultimate outcome.

This approach inherently requires a balanced treatment in the areas of data, selection of behavioral relationships and a realistic rationale. The research accomplished to date examine the type of data variables contained in this sample data, (ACWP, BCWP & BAC). It is noted that Budgeted Cost of Work Scheduled (BCWS) has been omitted. Although it was observed that the continuous presence of schedule variance could impact the final ACWP it was believed that:

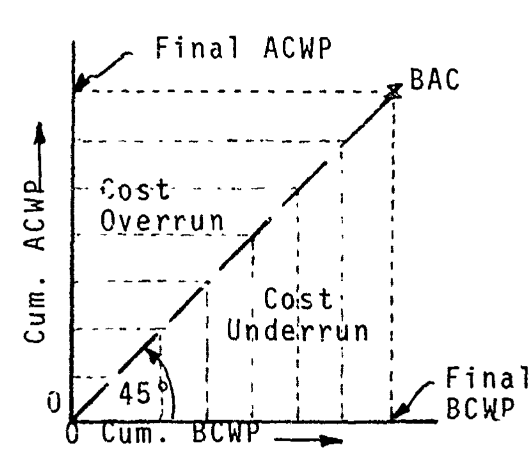
a. The treatment of schedule variance required a more subtle and sophisticated examination than was feasible within the scope and resources of this research project.

b. The selection of a reasonable behavioral relationship between ACWP and BCWP may be sufficient to account for the impact that BCWS has on EAC without the added completity of another variable.

3.2.2.2 GROUND RULES AND ASSUMPTIONS

It is the ideal cost objective of any defined program that the preplanned budget will be achieved. Before action is taken to implement the plan, it is assumed that work has not been performed; hence, ACWP and BCWP are both equal to zero since they are both measures of work performance. After initial action is taken to implement the plan, the output of human, physical, and financial resources are periodically measured in terms of the original plan at various levels of data aggregation and classification. Although the ideal objective (Final ACWP = Final BCWP = BAC) represents the end point of the total effort, it would be ideal if cum. ACWP would equal cum. BCWP at each measurement period. Sketch #1 illustrates this arrangement. It is observed that a series of equal and increasing values of ACWP & BCWP produce an extended 45° straight line that starts at the origin and ends at the BAC. Above the line represents the area of cost overrun and below the line the area of cost underrun. If the ACWPs

SKETCH #1

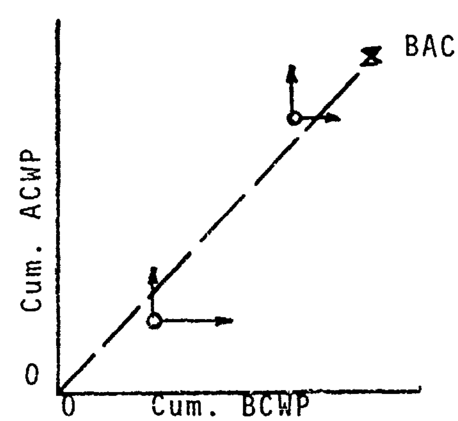


and BCWPs from each CPR in a given program were to locate on the 45° line, it would evolve a breakeven line that culminates at the BAC and results in a series of zero current cost variances. However, a variety of reasons can cause differences between the dollar values of ACWPs and BCWPs. Therefore, as the system for producing output may be viewed as an ongoing or continuous process, the actual relationship between ACWP and BCWP may not appear continuous or linear with each passing CPR. The realization of a series of zero variances under actual conditions should not be expected.

In a reporting system that is related to controlled work performance, it is anticipated that the performance trend may have a rational and continuous relationship. From a trend of view the following observations are made:

As work is being performed and new work added between reporting periods, an increment of BCWP (equal to or greater than zero) and an increment of ACWP (equal to or greater than zero) should appear in the subsequent CPR (see sketch #2). Each new

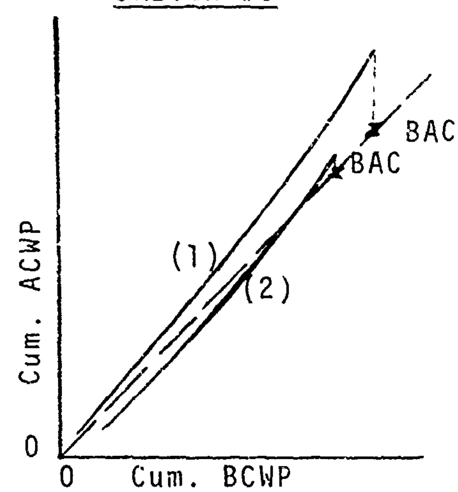
SKETCH #2



increment contributes to the new cum. totals as the process is repeated. The earlier disparity between cum. ACWP and cum. BCWP is reduced as the work packages keep flowing through the productivity process and approaches completion.

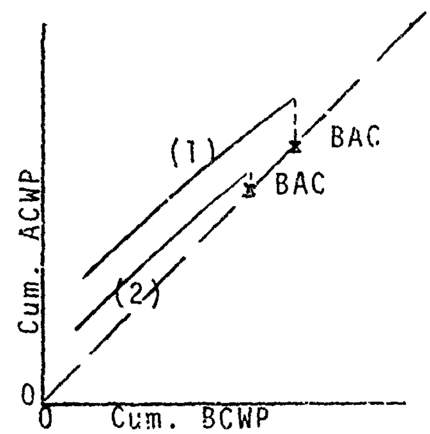
The ability to discern any trend characteristics between cum. ACWP and cum. BCWP requires that many samples of historical CPR data be examined and compared. Unfortunately, the large amount of data that was examined could not be included in this report. The R&D data samples included cases from Level 1, 2 & 3 of the Work Breakdown Structure (WBS) and several functional data samples. They encompassed aircraft, missile and electronic systems. Although samples were different in technology, dollar amount, element type, contractor, and cost outcome, these large differences narrowed considerable when viewed in terms of their overall growth trends. Sketch #3 illustrates the predominant behavior of different samples. It is observed that the two curves (1) & (2) appear near parallel even though their outcomes are different. It is noted that an overrun outcome is not a prerequisite for

SKETCH #3



this shape curve. It is possible that another curve containing larger amounts of earlier underrun cost variances could produce a breakeven or underrun result at the BAC and still retain a near parallel trend characteristic. A minority of samples portrayed a slightly different long term trend characteristic. Sketch #4 illustrates two different samples in which high initial cost overruns are gradually reduced as the program nears completion. Again it is noted that curves, (1) & (2) appear near parallel.

SKETCH #4



Although the above sketches were slightly exaggerated for illustration purposes, the smooth curves representing the data examples were developed by utilizing a non linear least squares technique and the assumed relationship, $y = b_1 . x^{b_2}$. This relationship was selected for its desirable properties described below:

a. In most samples observed a straight line relationship between cum. ACWPs & BCWPs did not represent the long term growth relationship. Therefore, a curve linear form was considered more realistic.

b. This curve linear form can be compared easily to the ideal case (the breakeven line). For example, in the form $y = b_1.x^{b2}$, it may be observed that when b_1 and b_2 are both equal to one, y equals x, and the result is a 45° straight line that passes through the origin. When b_2 is greater than one, it suggests that y has a tendency to grow faster than x which produces a growth curve that is accelerating. Conversely, when b_2 is smaller than one, it suggests that y has a tendency to grow slower than x which produces a growth curve that is decelerating.

c. This relationship is familiar to the financial analysis community and would be easy to handle by the user. Although there are other potentially useful curve linear growth relationships that deserve study, they are more complex in their mathematical form and generally contain more than two parameters. The additional parameters could compound the complexity.

d. The parameters (b_1 & b_2) are non-dimensional and they represent the growth characteristics of a sample rather than a dollar value.

In summary, if a large family of completed program samples are similar in their characteristics and $y = b_1.xb_2$ is a reasonable behavioral relationship then:

a. One may use the relationship to extrapolate an EAC after each CPR is submitted throughout the program life.

b. It is reasonable to expect that the computed parameters b_1 & b_2 would reflect these similarities. For example, the variety of samples examined illustrated that the range of the extreme values of the exponent (b_2) was narrow (1.18 - .97), and the majority of cases between 1.10 and 1.0. The possible use of this quantitative information is illustrated in paragraph 3.3.

3.2.2.3 UNCONSTRAINED PROCEDURE

The unconstrained exponential method contained in this report extrapolates an EAC after each CPR submittal. It presumes that the least squares technique, in conjunction with the cumulative ACWPs & BCWPs from each CPR available to date, the current BAC, and the behavioral relationship $y = b_1 \cdot x^{b_2}$, would generate a smooth curve representing the cost trend of the program. The process is accomplished in two basic steps described in paragraph 3.5.

The single sample defined in paragraph 2.0 is used to illustrate the process and application of the computer program. Table 4 in the Appendix contains a summary of results of this method including the value of the parameters (b_1 & b_2) for each month of the 60 month period. Table 5 and Figure 2 in the Appendix contains the sample computational and graphical displays of the computer program at the end of the 60th month. Figure 1 contains a graphical view of the monthly EACs in dollars on the ordinate against the combined scale of % completion and number of months.

3.2.2.4 THE COMPARISON OF TWO METHODS

When examining the variety of curves illustrated on Figure 1, the reader is reminded that the total illustration exists only after the last CPR is made available. At any intermediate position, the right hand portions of the various curves do not exist since they depend upon subsequent CPRs. In addition, the horizontal solid line representing the final reported ACWP (97.9 dollars) exists only after the last CPR is delivered. The following observations are made:

a. In each of the first 14 months of the program the data sample exhibited a continuing cumulative cost underrun. During this period the Cum. Current % Cost Variance Method forecasted a series of EACs consistently lower than the relatively uniform BACs. Considering the fact that in 14 months the program is approximately 40% complete, an optimistic view of this series suggests a potential cost savings at the end of the program; conversely, a pessimistic view suggests a potential breakeven at program completion. The Unconstrained Exponential Method generated underrun EACs' up to the 9th month. From the 9th through the 14th montns these EACs exceeded the BACs even though cum current variance was showing underrun. This occurred because the amount of underrun in the 7th month was significantly reduced and subsequently maintained for two more months at a new but lower underrun level. Essentially, the Unconstrained Exponential Method draws attention to the trend of all the past cum. current cost variances and shapes the curve accordingly.

After the 14th month the BAC was periodically adjusted for the reasons stated in paragraph 2.0 until it leveled at about 45 months and 99% completion. During this period of time, to approximately 93% completion, the Unconstrained Exponential Method EACs had a large and clear lead over the Cum. Current Method EACs as they both attempted to target in on the Final ACWP. Between 93% and 98% completion the two methods generated near equal results. After 98% completion, the Cum. Current Variance Method had a small but clear lead over the Unconstrained Exponential Method which persisted to completion.

To select one method over another requires that a selection criteria be defined. A simple selection criterion was defined as the method which generates EACs that are closest to the final ACWP during the earlier stages of the program, and the Unconstrained Method proves best after the 7th month. This criteria offers the most direct comparison of the two methods used in their entirety without the benefit of additional information that may have been available to the SPO management.

3.3 COMPARISON OF THREE EAC METHODS

3.3.1 DESCRIPTION OF THE CONSTRAINED EXPONENTIAL METHOD

The notion of "Constrained" and "Unconstrained" is described as follows:

The Unconstrained Method described in paragraph 3.2.2 solves for the parameters (b_1 & b_2) without the benefit or intelligence of other information dealing with growth characteristics. The parameters derived from a few early samples are inadequate "estimates" of the parameters that will be obtained after the entire population becomes available. The quality of the parameters may be readily examined in Table 4 by observing the change in the parameters as each CPR is added to the sequence. As a consequence, caution is advised when attempting to use them for extrapolation purposes during the early stages of the program.

The Constrained Method is an attempt to overcome the deficiency of small samples by superimposing an intelligence source that is available from completed programs. Selection of an intelligence source introduces a high degree of subjectivity since there are few identical contractual situations. However, it is reasoned that if the data associated with the subjectivity can be quantified, the range of results narrow, and the process is realistic, the credibility of its use as a forecasting method is improved and under the control of the user.

In paragraph 3.2.2.2 it was stated that many diverse and completed samples produced sets of sets of parameters in which the range of extremes of the exponent (b_2) was narrow. This phenomenon suggest the possibility that the quantitative values of the historical (b_2)s may be used as the subjective device for superimposing a single value or family of reasonable values on an ongoing program in which the sample size is small. In effect, the user is attempting to reduce the error in the parameters of small samples by placing the sample in a historical context. This "constrains" the model under the guidance of the manager. A simple demonstration is used to illustrate the effects of the constrained method on forecasting EAC.

3.3.2 CONSTRAINING PROCEDURE

It is observed that in Table 4 the final exponent for the given sample = 1.1175. There is no way of knowing the precise value of a final exponent until the last CPR is available. However, if a body of historical parameters for similar and completed programs suggest a range of reasonable values or a particular value, those values could be used as a constraining influence on the early stages of the new program. For demonstration purposes the above value is used to constrain the solution as each CPR is submitted in sequence for the given sample.

The same computer program referred to in paragraph 3.2.2.3 performs a similar two step process. In performing the process for the Constrained Method the user inputs the value of the selected parameter (b_2 = 1.1175), and the computer solves for the remaining parameter (b_1) and the EACs for each month.

Table 6 in the Appendix contains a summary of results of this method including the values of the parameters for each month.

Figure 3 in the Appendix graphically illustrates the monthly behavior of b_1 and b_2 for the Unconstrained and Constrained Solution Methods. It is observed that a reasonable estimate of a parameter (b_2 = 1.1175) produces a near uniform values for b_1. This phenomenon may offer additional insight into behavior and deserves further study.

3.3.3 THE COMPARISON OF THREE METHODS

Figure 4 contains all the information in Figure 1 plus the results of the Constrained Method. It is observed that the EACs generated by the Constrained Exponential Method are considerably higher than those obtained by the other methods, and are consistently closer to the final ACWP through approximately 93% of program completion. From 93% to 98% completion all three methods are about equal in results. Beyond 98% completion the Cum. Current Variance Method retains a small but clear lead over the remaining methods.

If the same selection criterion defined in paragraph 3.2.2.4 is used, the Constrained Exponential Method would be preferred over the Unconstrained Exponential and Cum. Current % Cost Variance Methods. As a practical matter, the close proximity of the program to completion at approximately 98% suggests that the Cum. Current Variance Method should reflect the final position since the remaining distance is minimal. Figure 4 illustrates this reality.

COMPARISON OF THREE EAC METHODS

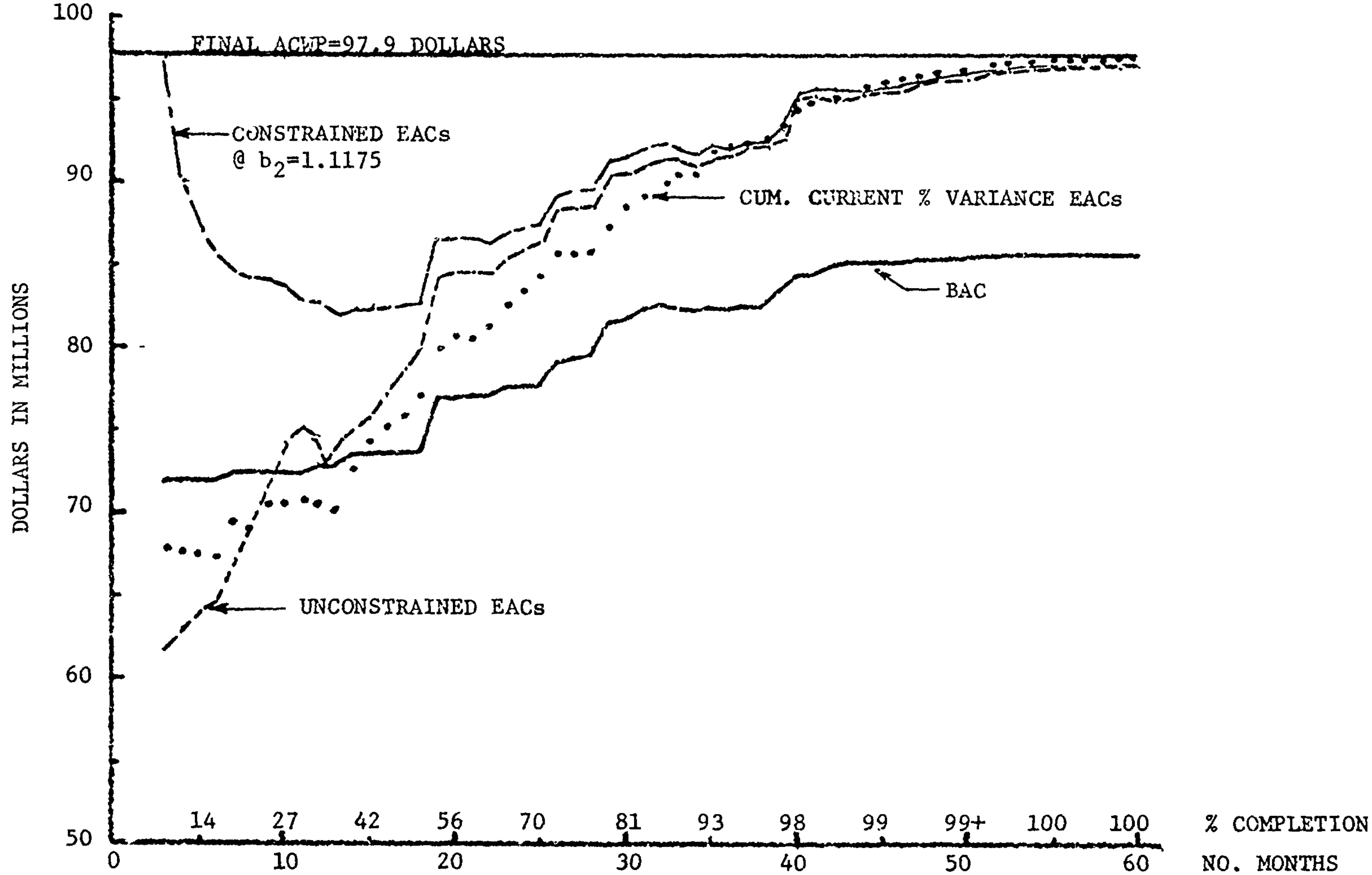


FIGURE 4

3.4 COMPARISON OF CONSTRAINED & CONTRACTORS EAC

Frequently, an observer is interested in a comparison between the Constrained Exponential Method and the Contractors reported EACs. For examination purposes this comparison is illustrated in Figure 5. It is observed that the Constrained Exponential Method significantly leads the Contractor EAC through approximately 90% completion. Beyond that point the Constrained Exponential Method lags the Contractor EAC by approximately 2 million dollars in each succeeding month. After 99.5% completion the Contractor EACs exceeded the Final reported ACWP.

COMPARISON OF CONSTRAINED & CONTRACTORS EACs

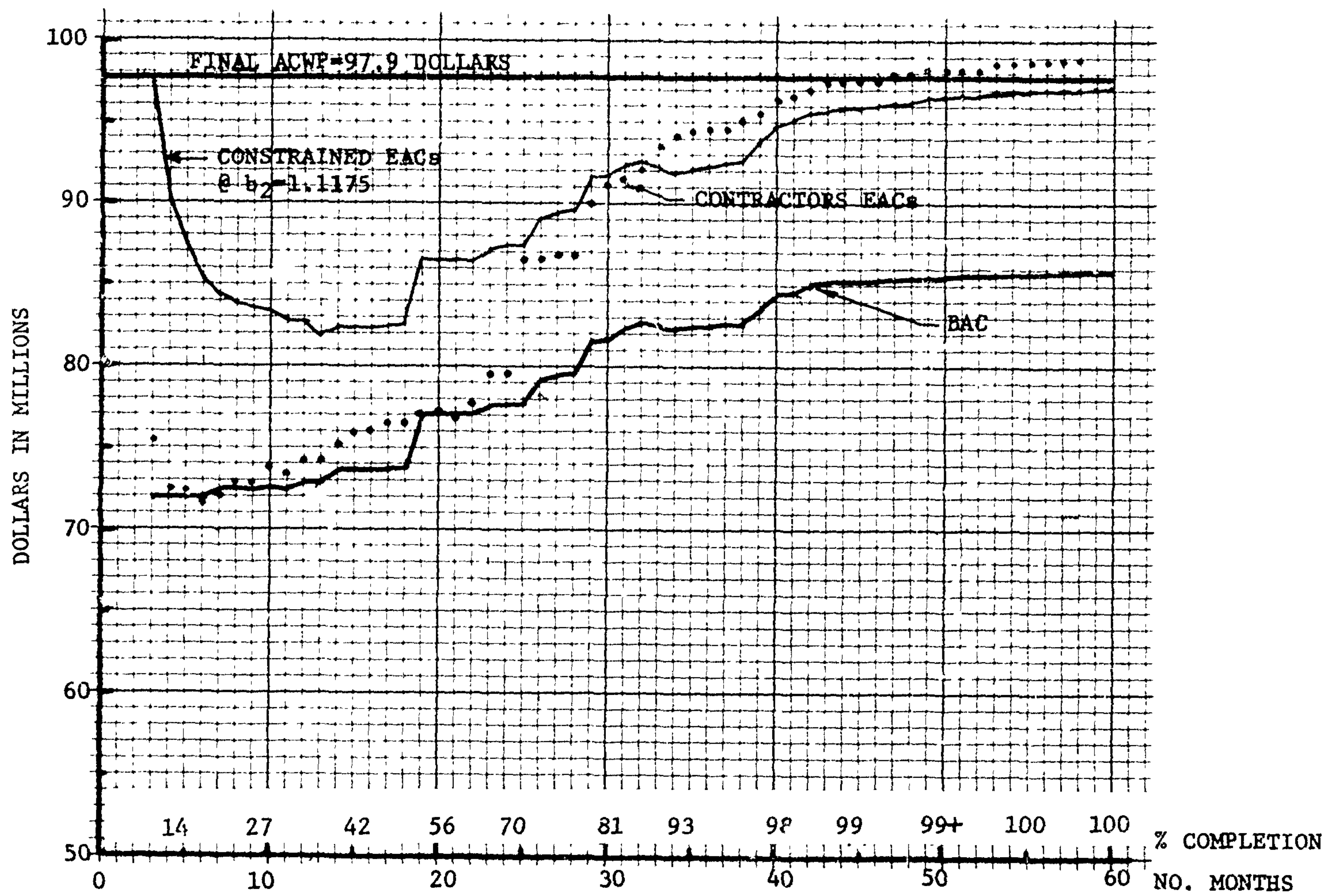


FIGURE 5

3.5 COMPUTER PROGRAM AND OUTPUT DISPLAYS

An overview of the computational process is described as follows:

STEP 1: Given the sample (each monthly cummed values of ACWP and BCWP to date) and the function $ACWP = b_1 \circ BCWP^{b2}$, the least squares technique computes the values of b_1 & b_2.

STEP 2: Given the computed values of b_1 & b_2 from Step 1, the current value of BAC, the function final $ACWP = EAC = b_1 \circ BAC^{b2}$, the value of EAC is computed.

STEPS 1 & 2: Steps 1 & 2 are repeated with the arrival of each subsequent CPR which generates a series of monthly EACs.

The process described in the above steps was programmed at ASD on the CDC 6600 System in Fortran Extended, SCOPE 3.4. The mass of manual computations involved in the process would preclude the timely acquisition and evaluation of results by financial and program analysts. The computer program produces results in less than a day and can be implemented by anyone with a minimum knowledge of Fortran and statistics. Description of the programs versitility and input instructions are beyond the scope of this report. However, it is noted that the program provides three types of output, namely:

a. A display of all input data and output computations for each sample. Each sample is limited to 125 data points. A maximum of 50 samples per computer pass was provided.

b. A graphical display for each sample containing the input data, the computed curve and the breakeven line.

c. A summary total display which accumulates and totals the pertinent status data and forecasted results for all samples contained in the computer pass.

3.6 CONCLUSIONS

The report shows that the constrained regression method applied to an exponential relationship offers the forecaster an improved method of final cost forecasting and introduces the use of measured subjectivity as a management input. The maximum potential of this procedure requires that the CPR data from many historical programs be collected, and b_1's and b_2's processed and made available to users in program offices.

Small and large program offices may apply this procedure for developing long range forecasts and take advantage of local computer facilities. In small offices with limited resources, this procedure may serve as one of the few methods that may be available for developing forecasts. In large offices, it may serve as one of many independent forecasting methods for comparative analysis.

It is believed that the constrained method can be improved by the acquisition and testing of additional CPR data from all types of Department of Defense programs. For example, it may be possible to generate confidence limits with each forecast if a large volume of historical data is available. If the procedure warrants further sophistication, program simulation techniques could be examined and applied.

Other factors such as schedule variance could be considered and tested for their impact on the final forecast. Different growth relationships and their constraining procedures could be tested if the added complexity is justified. In addition, the use of different relationships could be tested at discrete milestones or phases of historical programs for application on ongoing programs.

APPENDIX

TABLE 1

SOURCE DATA

COST PERFORMANCE REPORT

WBS LEVEL 1

CUMULATIVE DOLLARS IN THOUSANDS

MONTH NUMBER	ACWP	BCWP	BAC	MONTH NUMBER	ACWP	BCWP	BAC
1 *	1263.00	1263.00	71901.00	31	74508.00	68728.00	82241.00
2 *	3213.00	3377.00	71901.00	32	78408.00	71982.00	82618.00
3 *	5163.00	5491.00	71901.00	33	81105.00	73763.00	82329.00
4 *	7113.00	7605.00	71901.00	34	82978.00	75073.00	82081.00
5 *	9063.00	9719.00	71901.00	35	85641.00	76730.00	82270.00
6	11013.00	11834.00	71901.00	36	87636.00	77965.00	82295.00
7 *	12963.00	13730.00	72055.00	37	88919.00	79275.00	82399.00
8	14913.00	15627.00	72208.00	38	90428.00	80299.00	82491.00
9	16893.00	17280.00	72208.00	39	91134.00	81087.00	83496.00
10 *	19205.00	19624.00	72239.00	40	92096.00	82399.00	84275.00
11	21616.00	21967.00	72147.00	41	93247.00	82970.00	84538.00
12	23837.00	24593.00	72799.00	42	93877.00	83552.00	84972.00
13	25715.00	26726.00	72813.00	43	94719.00	83976.00	85089.00
14	28738.00	29091.00	73439.00	44	95228.00	84230.00	85126.00
15	31108.00	30917.00	73538.00	45	95555.00	84452.00	85058.00
16	33310.00	32775.00	73538.00	46	95895.00	84696.00	85123.00
17	36132.00	35007.00	73602.00	47	96213.00	84939.00	85295.00
18	38958.00	37237.00	73659.00	48	96453.00	84997.00	85295.00
19	41836.00	40336.00	76950.00	49	96486.00	85104.00	85461.00
20	45355.00	43253.00	76950.00	50	96565.00	85269.00	85539.00
21	47965.00	45935.00	77050.00	51	96787.00	85551.00	85686.00
22	50893.00	48323.00	77050.00	52	96896.00	85670.00	85686.00
23	53904.00	50606.00	77598.00	53	97219.00	85738.00	85777.00
24	56293.00	52586.00	77801.00	54	97513.00	85758.00	85778.00
25	59001.00	54448.00	77802.00	55	97581.00	85778.00	85778.00
26	62021.00	57141.00	79054.00	56	97611.00	85778.00	85778 00
27	64208.00	59469.00	79353.00	57	97864.00	85778.00	85778.00
28	66501.00	61863.00	79823.00	58	97882.00	85778.00	85778.00
29	68682.00	64169.00	81507.00	59 *	97885.00	85778.00	85778.00
30	71573.00	66289.00	81789.00	60	97887.00	85778.00	85778.00

*CPRs in these months were not available, therefore data were approximated.

TABLE 2

MONTHLY ESTIMATES AT COMPLETION (EACs)

SUMMARY

DOLLARS IN MILLIONS

MONTH	% COMPLETION	BAC	CONTRACTORS EAC	EAC METHODS: CONSTRAINED $EAC=b_1 \cdot BAC^{b_2}, b_2=1.1175$	EAC METHODS: UNCONSTRAINED $EAC=b_1 \cdot BAC^{b_2}$	% CURRENT VARIANCE
3	7.64	71.9	75.3	97.7	61.6	67.6
4	10.58	71.9	72.3	90.0	63.1	67.2
5	13.52	71.9	72.3	87.4	64.0	67.0
6	16.46	71.9	71.9	85.3	64.6	66.9
7	19.05	72.1	72.0	84.4	67.2	69.6
8	21.64	72.2	72.9	83.9	69.6	68.9
9	23.93	72.2	72.9	83.8	73.1	70.6
10	27.17	72.2	73.9	83.4	74.6	70.7
11	30.45	72.1	73.3	82.9	75.2	70.9
12	33.78	72.8	74.1	82.8	74.3	70.6
13	36.70	72.8	74.1	81.9	72.9	70.0
14	39.61	73.4	75.2	82.3	74.3	72.5
15	42.04	73.5	75.9	82.3	75.9	74.0
16	44.57	73.5	76.0	82.3	77.1	75.0
17	47.56	73.6	76.4	82.5	78.6	76.0
18	50.55	73.7	76.4	82.7	80.1	77.1
19	52.42	77.0	77.0	86.7	84.2	80.0
20	56.21	77.0	77.0	86.6	84.5	80.7
21	59.62	77.1	76.8	86.6	84.5	80.5
22	62.72	77.1	77.8	86.4	84.5	81.2
23	65.21	77.6	79.6	87.1	85.4	82.7
24	67.59	77.8	79.6	87.3	85.9	83.3
25	69.98	77.8	86.5	87.4	86.4	84.3
26	72.28	79.1	86.5	89.0	88.2	85.9
27	74.94	79.4	86.9	89.3	88.4	85.7
28	77.50	79.8	86.9	89.7	88.7	85.8

TABLE 2 (cont.)

MONTH	% COMPLETION	BAC	CONTRACTORS EAC	EAC METHODS: CONSTRAINED $EAC=b_1 \cdot BAC^{b_2}, b_2=1.1175$	EAC METHODS: UNCONSTRAINED $EAC=b_1 \cdot BAC^{b_2}$	EAC METHODS: % CURRENT VARIANCE
29	78.73	81.5	90.0	91.6	90.4	87.2
30	81.05	81.8	91.1	91.8	90.5	88.3
31	83.57	82.2	91.6	92.2	91.0	89.1
32	87.13	82.6	92.0	92.6	91.3	90.0
33	89.60	82.3	93.7	92.2	91.1	90.5
34	91.46	82.1	94.1	91.8	90.9	90.7
35	93.27	82.3	94.4	92.1	91.4	91.9
36	94.74	82.3	94.4	92.2	91.6	92.5
37	96.21	82.4	94.4	92.4	91.9	92.4
38	97.34	82.5	95.1	92.6	92.2	92.9
39	97.11	83.5	95.6	93.8	93.5	93.8
40	97.77	84.3	96.3	94.8	94.5	94.2
41	98.15	84.5	96.6	95.1	94.8	94.1
42	98.33	85.0	97.0	95.7	95.4	95.5
43	98.69	85.1	97.7	95.8	95.6	96.0
44	98.95	85.1	97.7	95.9	95.7	96.2
45	99.29	85.1	97.7	95.9	95.7	96.3
46	99.50	85.1	97.8	96.0	95.8	96.4
47	99.58	85.3	98.0	96.2	96.1	96.6
48	99.65	85.3	98.0	96.2	96.1	96.8
49	99.58	85.5	98.1	96.5	96.4	96.9
50	99.68	85.5	98.1	96.6	96.5	96.8
51	99.84	85.7	98.1	96.8	96.7	97.0
52	99.98	85.7	98.1	96.8	96.7	96.9
53	99.95	85.8	98.6	96.9	96.8	97.3
54	99.98	85.8	98.6	96.9	96.9	97.6
55	100.0	85.8	98.6	97.0	96.9	97.6
56	100.0	85.8	98.6	97.0	96.9	97.6
57	100.0	85.8	98.8	97.0	97.0	97.9
58	100.0	85.8	98.8	97.0	97.0	97.9
59	100.0	85.8		97.1	97.1	97.9
60	100.0	85.8		97.1	97.1	97.9

TABLE 3

MONTHLY ESTIMATES AT COMPLETION (EACs)

FINAL % COST VARIANCE = CUM. CURRENT % COST VARIANCE

DOLLARS IN MILLIONS

MONTH	BAC	CUM. CURRENT % COST VARIANCE	EAC	MONTH	BAC	CUM. CURRENT % COST VARIANCE	EAC
3	71.9	+ 5.97	67.6	31	82.2	- 8.41	89.1
4	71.9	+ 6.47	67.2	32	82.6	- 8.93	90.0
5	71.9	+ 6.75	67.0	33	82.3	- 9.95	90.5
6	71.9	+ 6.94	66.9	34	82.1	-10.53	90.7
7	72.1	+ 5.59	69.6	35	82.3	-11.61	91.9
8	72.2	+ 4.57	68.9	36	82.3	-12.40	92.5
9	72.2	+ 2.24	70.6	37	82.4	-12.17	92.4
10	72.2	+ 2.14	70.7	38	82.5	-12.61	92.9
11	72.1	+ 1.60	70.9	39	83.5	-12.39	93.8
12	72.8	+ 3.07	70.6	40	84.3	-11.77	94.2
13	72.8	+ 3.78	70.0	41	84.5	-12.39	94.1
14	73.4	+ 1.21	72.5	42	85.0	-12.36	95.5
15	73.5	- .62	74.0	43	85.1	-12.79	96.0
16	73.5	- 1.63	75.0	44	85.1	-13.06	96.2
17	73.6	- 3.21	76.0	45	85.1	-13.15	96.3
18	73.7	- 4.62	77.1	46	85.1	-13.22	96.4
19	77.0	- 3.72	80.0	47	85.3	-13.28	96.6
20	77.0	- 4.86	80.7	48	85.3	-13.48	96.8
21	77.1	- 4.42	80.5	49	85.5	-13.37	96.9
22	77.1	- 5.32	81.2	50	85.5	-13.25	96.8
23	77.6	- 6.52	82.7	51	85.7	-13.13	97.0
24	77.8	- 7.05	83.3	52	85.7	-13.10	96.9
25	77.8	- 8.36	84.3	53	85.8	-13.39	97.3
26	79.1	- 8.54	85.9	54	85.8	-13.71	97.6
27	79.4	- 7.97	85.7	55	85.8	-13.76	97.6
28	79.8	- 7.50	85.8	56	85.8	-13.79	97.6
29	81.5	- 7.03	87.2	57	85.8	-14.09	97.9
30	81.8	- 7.97	88.3	58	85.8	-14.11	97.9
				59	85.8	-14.11	97.9
				60	85.8	-14.12	97.9

TABLE 4

MONTHLY ESTIMATES AT COMPLETION (EACs)

UNCONSTRAINED LEAST SQUARES SOLUTIONS

$$EAC = b_1 \cdot BAC^{b_2}$$

DOLLARS IN MILLIONS

MONTH	EAC	PARAMETERS b_1	b_2	MONTH	EAC	PARAMETERS b_1	b_2
3	61.6	1.2804	.9640	32	91.3	.4110	1.0874
4	63.1	1.1949	.9724	33	91.1	.4056	1.0886
5	64.0	1.1421	.9777	34	90.9	.3976	1.0905
6	64.6	1.1074	.9813	35	91.4	.3833	1.0939
7	67.2	.9624	.9971	36	91.6	.3673	1.0979
8	69.6	.8393	1.0123	37	91.9	.3580	1.1003
9	73.1	.6755	1.0361	38	92.2	.3485	1.1029
10	74.6	.6157	1.0462	39	93.5	.3431	1.1043
11	75.2	.5869	1.0513	40	94.5	.3435	1.1042
12	74.3	.6576	1.0392	41	94.8	.3408	1.1050
13	72.9	.7382	1.0271	42	95.4	.3391	1.1054
14	74.3	.6904	1.0341	43	95.6	.3357	1.1064
15	75.9	.6125	1.0465	44	95.7	.3319	1.1074
16	77.1	.5494	1.0576	45	95.7	.3284	1.1084
17	78.6	.4825	1.0708	46	95.8	.3253	1.1093
18	80.1	.4228	1.0842	47	96.1	.3224	1.1101
19	84.2	.4149	1.0861	48	96.1	.3193	1.1110
20	84.5	.3999	1.0898	49	96.4	.3170	1.1117
21	84.5	.4084	1.0877	50	96.5	.3154	1.1122
22	84.5	.4067	1.0881	51	96.7	.3145	1.1124
23	85.4	.3936	1.0913	52	96.7	.3137	1.1127
24	85.9	.3827	1.0941	53	96.8	.3123	1.1131
25	86.4	.3633	1.0991	54	96.9	.3102	1.1137
26	88.2	.3529	1.1020	55	96.9	.3082	1.1143
27	88.4	.3569	1.1009	56	96.9	.3063	1.1149
28	88.7	.3704	1.0973	57	97.0	.3039	1.1156
29	90.4	.3909	1.0921	58	97.0	.3017	1.1163
30	90.5	.4000	1.0899	59	97.1	.2997	1.1169
31	91.0	.4064	1.0884	60	97.1	.2979	1.1175

TABLE 5
SAMPLE COMPUTER OUTPUT
COST PERFORMANCE FORECASTING MODEL-C/SCSC

(Company Name) ROTE

TOTAL SYSTEM LEVEL: 1 TOTAL COST(000)LESS GA,PROFIT (System Name)

FUNCTION: F=B(1)*X(I,1)**B(2)

CONSTRAINED PARAMETER(S): NONE
PARAMETERS: .29791 1.11751
STANDARD ERROR: 576.33256

****

PROJ. ACWP	FINAL BCWP INITIAL	FINAL BCWP CURRENT	PROJ. CUM. VARIANCE	PROJ. PERCENT CUM. VARIANCE	PERCENT COMPLETION INITIAL	PERCENT COMPLETION CURRENT	NUMBER
97091.52	71901.00	85778.00	-11313.52	-13.19	119.30	100.00	60

****

OBS. ACWP	OBS. BCWP	CUM. VAR.	PERCENT CUM. VAR.	DATE	PROJ. ACWP	PROJ. CUM. VAR.	PROJ. PERCENT CUM. VARIANCE
1263.00	1263.00	0.00	0.00		870.83	392.17	31.05
3213.00	3377.00	164.00	4.86		2613.67	763.33	22.60
5163.00	5491.00	328.00	5.97		4499.67	991.33	18.05
7113.00	7605.00	492.00	6.47		6475.16	1129.84	14.86
9063.00	9719.00	656.00	6.75		8517.07	1201.93	12.37
11013.00	11834.00	821.00	6.94		10613.26	1220.74	10.32
12963.00	13730.00	767.00	5.59		12530.59	1199.41	8.74
14913.00	15627.00	714.00	4.57		14480.43	1146.57	7.34
16893.00	17280.00	387.00	2.24		16202.46	1077.54	6.24
19205.00	19624.00	419.00	2.14		18677.41	946.59	4.82
21616.00	21967.00	351.00	1.60		21186.34	780.66	3.55
23837.00	24593.00	756.00	3.07		24035.85	557.15	2.27
25716.00	26726.00	1010.00	3.78		26377.08	348.92	1.31
28738.00	29091.00	353.00	1.21		28998.71	92.29	.32
31108.00	30917.00	-191.00	-.62		31040.18	-123.18	-.40
33310.00	32775.00	-535.00	-1.63		33132.03	-357.03	-1.09
36132.00	35007.00	-1125.00	-3.21		35663.37	-656.37	-1.87
38958.00	37237.00	-1721.00	-4.62		38211.48	-974.48	-2.62
41836.00	40336.00	-1500.00	-3.72		41782.24	-1446.24	-3.59
45355.00	43253.00	-2102.00	-4.86		45172.96	-1919.96	-4.44
47965.00	45935.00	-2030.00	-4.42		48314.36	-2379.36	-5.18
50893.00	48323.00	-2570.00	-5.32		51129.66	-2806.66	-5.81
53904.00	50605.00	-3299.00	-6.52		53835.32	-3230.32	-6.38
56293.00	52586.00	-3707.00	-7.05		56195.78	-3609.78	-6.86
59001.00	54448.00	-4553.00	-8.36		58424.00	-3976.00	-7.30
62021.00	57141.00	-4880.00	-8.54		61662.47	-4521.47	-7.91
64208.00	59469.00	-4739.00	-7.97		64476.54	-5007.54	-8.42
66501.00	61863.00	-4638.00	-7.50		67383.91	-5520.91	-8.92
68682.00	64169.00	-4513.00	-7.03		70196.96	-6027.96	-9.39
71573.00	66289.00	-5284.00	-7.97		72793.61	-6504.61	-9.81
74508.00	68728.00	-5780.00	-8.41		75793.08	-7065.08	-10.28
78408.00	71982.00	-6426.00	-8.93		79814.27	-7632.27	-10.88
81105.00	73763.00	-7342.00	-9.95		82024.31	-8261.31	-11.20

TABLE 5 (CONTINUED)

OBS. ACWP	OBS. BCWP	CUM. VAR.	PERCENT CUM. VAR.	DATE	PROJ. ACWP	PROJ. CUM. VAR.	PROJ. PERCENT CUM. VAR.
82978.00	75073.00	-7905.00	-10.53		83653.89	-8580.89	-11.43
85641.00	75730.00	-8911.00	-11.61		85719.92	-8989.92	-11.72
87636.00	77965.00	-9671.00	-12.40		87263.20	-9298.20	-11.93
88919.00	79275.00	-9644.00	-12.17		88903.34	-9628.34	-12.15
90428.00	80299.00	-10129.00	-12.61		90187.63	-9888.63	-12.31
91134.00	81087.00	-10047.00	-12.39		91177.24	-10090.24	-12.44
92096.00	82399.00	-9697.00	-11.77		92827.42	-10428.42	-12.66
93247.00	82970.00	-10277.00	-12.39		93546.57	-10576.57	-12.75
93877.00	83552.00	-10325.00	-12.36		94280.17	-10728.17	-12.84
94719.00	83976.00	-10743.00	-12.79		94814.99	-10838.99	-12.91
95228.00	84230.00	-10998.00	-13.06		95135.53	-10905.53	-12.95
95555.00	84452.00	-11103.00	-13.15		95415.78	-10963.78	-12.98
95895.00	84696.00	-11199.00	-13.22		95723.91	-11027.91	-13.02
96218.00	84939.00	-11279.00	-13.28		96030.87	-11091.87	-13.06
96453.00	84997.00	-11456.00	-13.48		96104.16	-11107.16	-13.07
96486.00	85104.00	-11382.00	-13.37		96239.37	-11135.37	-13.08
96565.00	85269.00	-11296.00	-13.25		96447.91	-11178.91	-13.11
96787.00	85551.00	-11236.00	-13.13		96804.43	-11253.43	-13.15
96896.00	85670.00	-11226.00	-13.10		96954.92	-11284.92	-13.17
97219.00	85738.00	-11481.00	-13.39		97040.92	-11302.92	-13.18
97513.00	85758.00	-11755.00	-13.71		97066.22	-11308.22	-13.19
97581.00	85778.00	-11803.00	-13.76		97091.52	-11313.52	-13.19
97611.00	85778.00	-11833.00	-13.79		97091.52	-11313.52	-13.19
97864.00	85778.00	-12086.00	-14.09		97091.52	-11313.52	-13.19
97882.00	85778.00	-12104.00	-14.11		97091.52	-11313.52	-13.19
97885.00	85778.00	-12107.00	-14.11		97091.52	-11313.52	-13.19
97887.00	85778.00	-12109.00	-14.12		97091.52	-11313.52	-13.19

SAMPLE COMPUTER OUTPUT

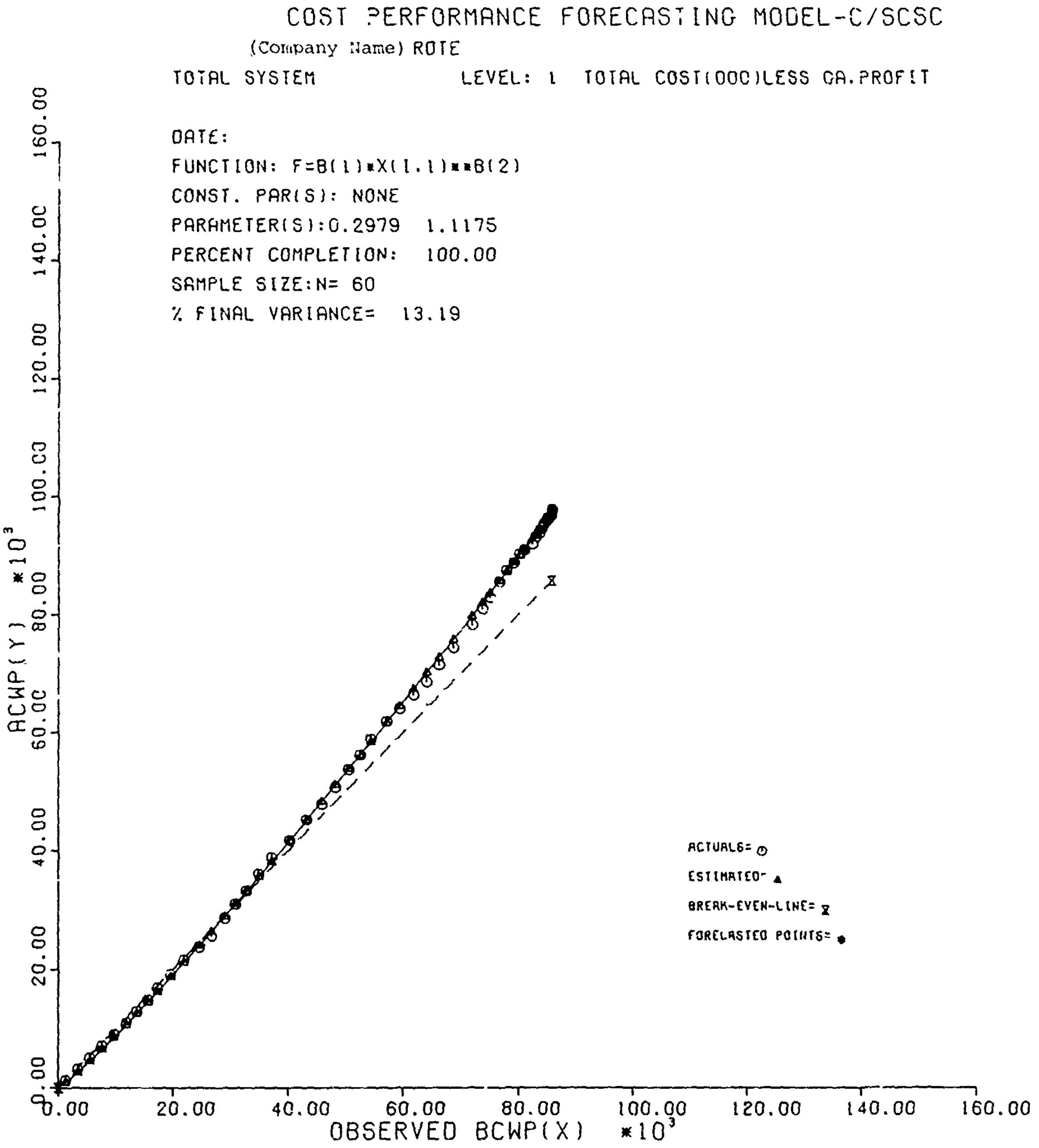


FIGURE 2

TABLE 6

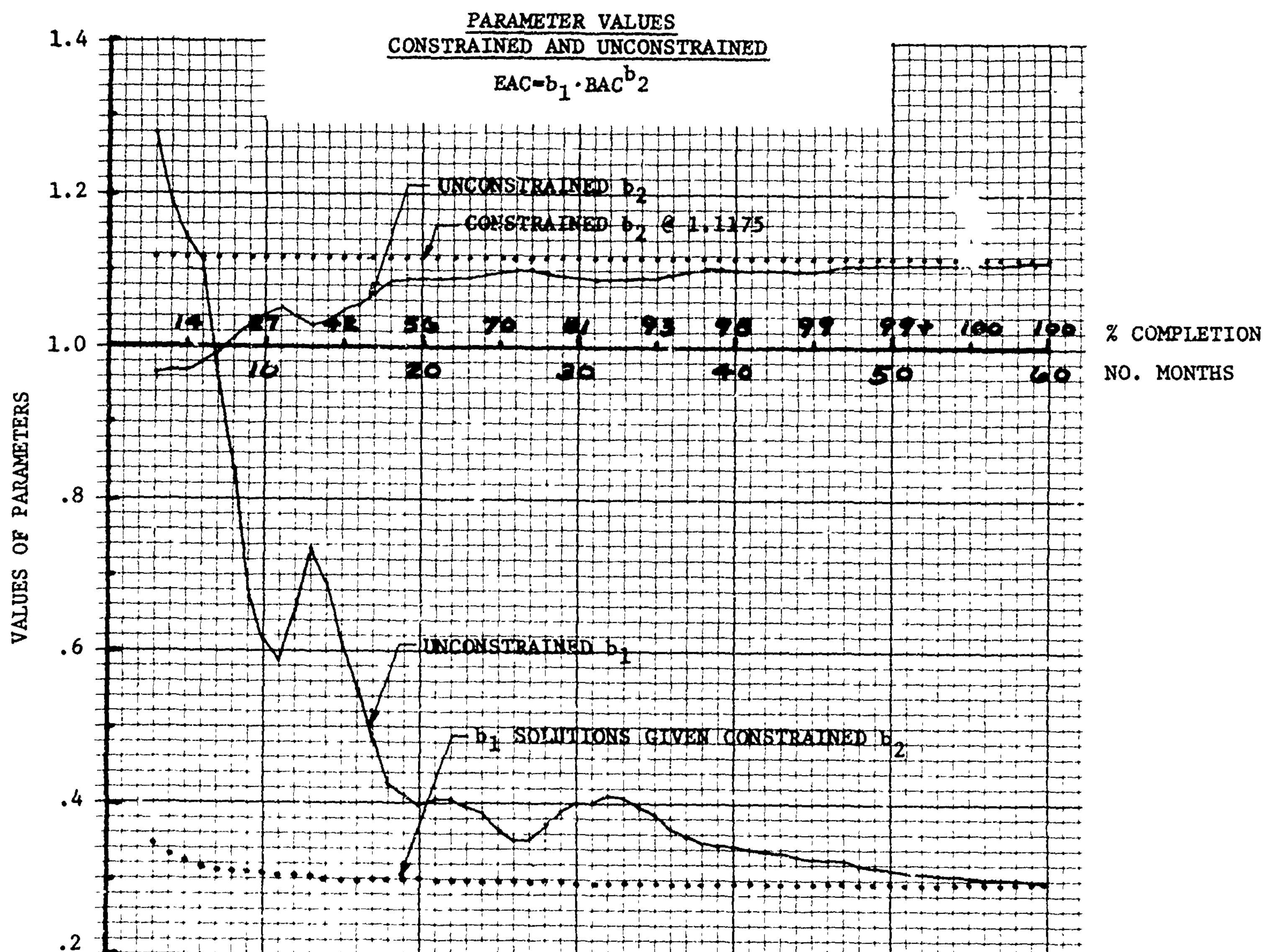
MONTHLY ESTIMATES AT COMPLETION (EACs)

CONSTRAINED LEAST SQUARES SOLUTIONS

$EAC = b_1 \cdot BAC^{b_2}$, ASSUMED $b_2 = 1.1175$

DOLLARS IN MILLIONS

MONTH	EAC	PARAMETERS b_1	b_2	MONTH	EAC	PARAMETERS b_1	b_2
3	97.7	.3502	1.1175	32	92.6	.2962	1.1175
4	90.0	.3364	"	33	92.2	.2960	"
5	87.4	.3265	"	34	91.8	.2960	"
6	85.3	.3188	"	35	92.1	.2961	"
7	84.4	.3147	"	36	92.2	.2964	"
8	83.9	.3120	"	37	92.4	.2965	"
9	83.8	.3116	"	38	92.6	.2966	"
10	83.4	.3101	"	39	93.8	.2967	"
11	82.9	.3084	"	40	94.8	.2966	"
12	82.8	.3051	"	41	95.1	.2967	"
13	81.9	.3016	"	42	95.7	.2967	"
14	82.3	.3002	"	43	95.8	.2967	"
15	82.3	.2999	"	44	95.9	.2968	"
16	82.3	.2998	"	45	95.9	.2969	"
17	82.5	.3001	"	46	96.0	.2970	"
18	82.7	.3007	"	47	96.2	.2970	"
19	86.7	.3003	"	48	96.2	.2971	"
20	86.6	.3001	"	49	96.5	.2972	"
21	86.6	.2994	"	50	96.6	.2972	"
22	86.4	.2990	"	51	96.8	.2973	"
23	87.1	.2989	"	52	96.8	.2973	"
24	87.3	.2988	"	53	96.9	.2973	"
25	87.4	.2991	"	54	96.9	.2974	"
26	89.0	.2991	"	55	97.0	.2975	"
27	89.3	.2988	"	56	97.0	.2975	"
28	89.7	.2983	"	57	97.0	.2976	"
29	91.6	.2975	"	58	97.0	.2977	"
30	91.8	.2970	"	59	97.1	.2978	"
31	92.2	.2966	"	60	97.1	.2979	"



PARAMETER VALUES
CONSTRAINED AND UNCONSTRAINED
EAC=b1·BACb2
UNCONSTRAINED b2
CONSTRAINED b2 @ 1.1175
UNCONSTRAINED b1
b1 SOLUTIONS GIVEN CONSTRAINED b2
VALUES OF PARAMETERS
1.4
1.2
1.0
.8
.6
.4
.2
14
27
42
56
70
81
93
98
99
99+
100
100
% COMPLETION
10
20
30
40
50
60
NO. MONTHS

FIGURE 3