AN ANALYSIS OF COST OVERRUNS ON DEFENSE ACQUISITION CONTRACTS[1]

INTRODUCTION

Donald J. Yockey, the former Under Secretary of Defense for Acquisition, has called for more realism in the defense acquisition process [19:35]. More specifically, he has called for more realistic cost estimates. The hope is that more realistic estimates will help surface problems in enough time to resolve them.

Based on a review of over 500 contracts, the Office of the Under Secretary of Defense for Acquisition (OUSD(A)) has observed that once a contract is 15 percent complete it is highly unlikely to recover from a cost overrun [1]. Despite this important observation, contractor and governmental personnel often claim that their programs are different.

This article examines the history of cost overruns reported on 64 completed defense contracts. Its purpose is to formally test the observation of (OUSD(A). Results confirm the observation at the 95 percent level of confidence (i.e., alpha = .05), and are generally insensitive to the contract type (price, cost), the contract phase (development, production), the type of weapon system (air ground, sea), and the armed force service (air force, army, navy) that managed the contract. After a review of terminology, concepts, and related research for those unfamiliar with the area, the methodology, results, and managerial implications are described.

BACKGROUND

Gansler reports that the average cost overrun on defense acquisition contracts is 40 percent [12:4]. Cost data on defense contracts are regularly reported on cost management reports prepared by defense contractors. These reports include the Cost Performance Report (CPR) and the Cost/Schedule Status Report. Department of Defense Instruction 5000.2 requires a CPR on all contracts judged significant enough for Cost/Schedule Control Systems Criteria (C/SCSC). Significant contracts are research, evaluation, test, and development contracts with estimated costs of $60 million or more, or procurement contracts with estimated costs of $250 million or more [11, p. 11B2]. Thus, a 40 percent cost overrun on a procurement contract that barely qualifies as significant is at least $100 million dollars.

The cost/schedule control systems criteria are not a system. Instead, they are minimal standards for contractors' internal management control systems. The purpose of the criteria is to foster reliable decision making by contractor and governmental personnel. One of the requirements is that data reported by the contractor be summarized from the same systems that the contractors use for internal management. These and other requirements help ensure that the data submitted to the government is useful for decision making.

Another requirement of the criteria is a disciplined budgeting system. A time-phased budget of all the authorized work on the contract, termed the "Performance Measurement Baseline," is developed by the contractor. The baseline is simply the summation of budgets assigned to elements of work on the contract. Because each element of work has a schedule, the budget for the work is said to be "time-phased."

The time-phased budgets assigned to work elements, termed the "Budgeted Cost of Work Scheduled," form the basis for earned value measurement and reporting. Earned value, also termed the "Budgeted Cost of Work Performed" (BCWP), is the same number as BCWS. The only difference is when they are recorded. BCWS is recorded when work is planned to be accomplished, and BCWP is recorded when work is actually accomplished. If work is accomplished at a time different that it is planned to be accomplished, then a schedule variance is identified. In a disciplined budgeting system, all significant variances are investigated in a timely manner.

A schedule variance often signals a cost variance. A cost variance is simply the difference between the budgeted cost of the work performed (BCWP) and the actual cost of the same work, termed "Actual Cost of Work

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Performed" (ACWP). As with the schedule variance, the criteria require a timely investigation and reporting of significant cost variances. The intent is that through the timely analysis of variances, problems will be corrected before they become serious.

Figures 1 and 2 illustrate the relationship between the three basic data elements just described. The performance measurement baseline is the cumulative expression of BCWS. Against this baseline, performance (BCWP) and actual cost (ACWP) are measured. Figure 1 illustrates the typical condition of defense contracts: over budget and behind schedule.

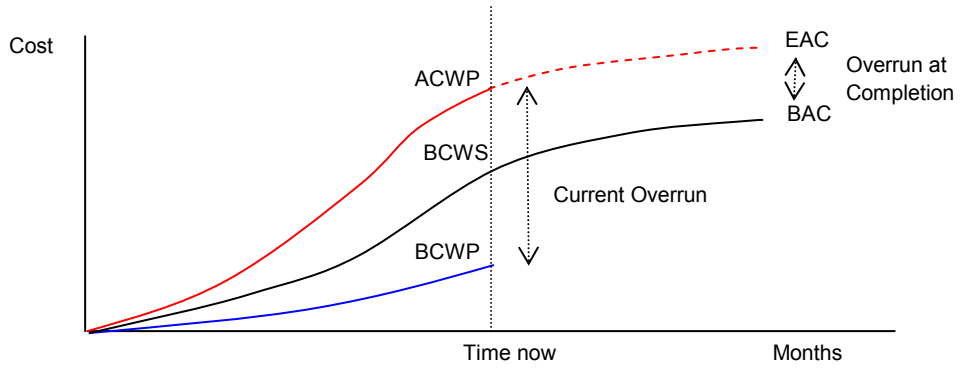

Figure 1. The Current Cost Overrun and the Overrun at Completion.

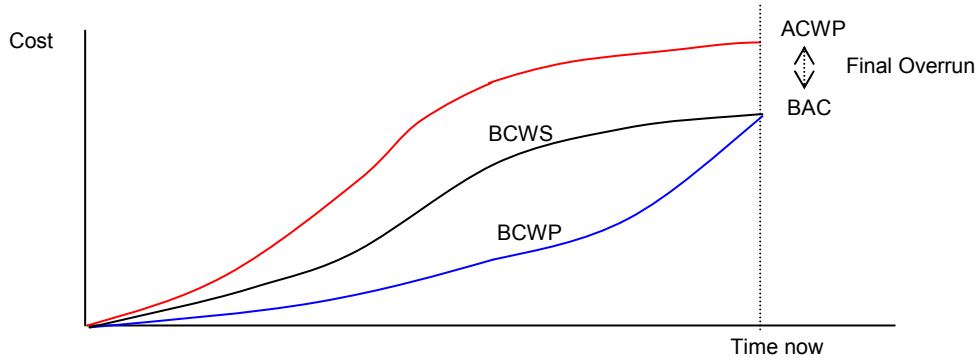

Figure 2. The Final Cost Overrun.

In this article the focus is on cost overruns. A cost overrun is an adverse cost variance. Figure 1 illustrates two kinds of cost overruns, termed the "current overrun" and the "overrun at completion." The current overrun is the adverse cost variance to date. The overrun at completion is the difference between the total budget for all work on the contract, termed the "Budget at Completion" (BAC) and the estimated final cost of the contract, termed the "Estimate at Completion" (EAC). Note that the overrun at completion is an estimate until the contract is completed. As shown in Figure 2, at the end of the contract BCWP equals BCWS, and the current overrun is the final overrun.

The estimate at completion is an important number and it is very controversial, largely because there is literally an infinite number of possible EAC formulas [7,10]. The criteria do not prescribe a particular formula or set of formulas; the choice is the contractor's. The only requirement is that the estimate be rational [9].

Because rational people can disagree, the government will usually evaluate the reasonableness of the contractor's estimate by computing a range of EACs. Unfortunately, there is little guidance on what constitutes a reasonable range. As a result, the projected overrun at completion supported by the government program office is

usually higher than the contractor's estimate. Because the government program office is necessarily an advocate of its program [17], its estimate may also be unrealistically optimistic.

One way to assess the reasonableness of the estimated overrun at completion is to compare it to the overrun date. If the overrun at completion is less than the overrun date, then the contractor or program office is optimistically projecting a cost recovery. Such was the case in the A-12 program.

In April of 1990 the A-12 was in full-scale development and was 37 percent complete [2]. The contractors' reported overrun at completion was $354 million. The overrun to date was $459 million [3]. Thus, the A-12 contractors were predicting a recovery of $105 million. Although this may seem optimistic, it is impossible to know for sure, because the A-12 was cancelled in January of 1991.

Is such optimism justified? More specifically, is it unrealistically optimistic for the predicted overrun at completion to be less than the overrun to date? Based on a review of cost overrun data on completed contracts, the answer is that such optimism is unrealistic with 95 percent confidence (alpha = .05).

WHAT PRIOR RESEARCH SAYS

There has been some research into this issue. Abba and Christle, senior analysts at the Office of the Under Secretary of Defense for Acquisition (OUSD(A)), have observed:

> *Given a contract is more than 15 percent complete, the [final] overrun at completion will not be less than the overrun to date, and the [final] percent overrun at completion will be greater than the percent overrun to date* [1].

This observation is based on a review of cost data on over 500 completed contracts. The analysts are quick to point out, however, that timely management attention to adverse cost variances can reverse them, especially early in the program. The problem has been a failure to use performance measurement data proactively.

The assertion of Abba and Christle is based on an informal review of over 500 completed contracts. The results of two empirical studies support the assertion [6, 13]. Both studies established that once a contract is 20 percent complete, the cumulative Cost Performance Index (CPI) does not change more than 10 percent; in fact, in most cases it only worsens. For example, in April 1990, the A-12 program was 37 percent complete and reported a CPI of 0.77. By September, the program was 47 percent complete and its CPI was 0.72.

As shown in Equation 1, the Cost Performance Index is a ratio of BCWP to ACWP.

$$CPI = BCWP / ACWP \quad [1]$$

A CPI that is less than 1 means that for every dollar spent, less than one dollar of work is accomplished. It follows that when the cumulative CPI is less than 1, the contract is experiencing a cost overrun. Because an unfavorable cumulative CPI only worsens, a contract is not likely to recover from a cost overrun. Therefore, if the predicted overrun at completion is less than the overrun to date, the contractor's estimated final cost of the contract (EAC) is unrealistically optimistic. This study further establishes these results by examining the cost overrun history on 64 completed contracts extracted from the Defense Acquisition Executive Summary (DAES) database.

METHODOLOGY

The DAES database has received summary data on completed contracts since 1977 [8]. Presently, data are summarized from Cost Performance Reports by government program offices and sent to OUSD(A) as quarterly DAES Reports [11]. The database is a fairly detailed source of information on the cost performance of the country's defense acquisition contracts. It is also reasonably accurate because most of the contracts in the database are C/SCSC-compliant.

For this study, a sample of 64 completed contracts was extracted from the database. Although the sample was purely judgmental, it is considered sufficiently rich to generalize to any C/SCSC-compliant defense contract. Table 1 summarizes final cost overrun data by various categories considered relevant to this study.

TABLE 1
FINAL COST OVERRUN ON 64 COMPLETED CONTRACTS

Contract Category	*Number*	*Overrun ($Millions)*			*Overrun (Percent)*		
		Avg	*Min*	*Max*	*Avg*	*Min*	*Max*
All	64	36	-3	493	18	-3	109
Army	28	21	-3	46	20	-3	46
Air Force	18	49	-2	407	19	-1	109
Navy	18	47	0	493	13	0	46
Air	43	45	-3	492	18	-3	109
Ground	13	23	7	42	21	5	45
Sea	8	12	0	36	12	0	38
Development	25	38	-2	407	21	-1	109
Production	39	35	-3	493	16	-3	46
Cost	23	41	-2	493	14	-1	46
Price	41	34	-3	407	20	-3	109

Based on the OUSD(A) assertion and the results of prior research, four hypotheses were tested (Table 2). For Hypothesis 1, the average final cost overrun in dollars (FCO$) exceeds the average cost overrun to date (CO$). Hypothesis 2 is the same, except the overruns are expressed in percentages. If these hypotheses are correct with statistical significance, then recoveries from cost overruns are improbable with a certain level of confidence. For this study, the hypotheses were tested at the 95 percent level of confidence (alpha =.05).

TABLE 2
HYPOTHESES

Hypothesis	*Interpretation*
H1: FCO$ >CO$	Recoveries from cost overruns ($) are improbable
H2: FCO% >CO%	Recoveries from cost overruns (%) are improbable
H3: $\beta\$ > 0$	Cost overruns ($) tend to increase
H4: $\beta\% > 0$	Cost overruns (%) tend to increase

Based on the results of prior research involving estimates at completion [7], it was expected that the results of the testing may be sensitive to the contract completion point and other factors specific to the contracts in the sample. Therefore, the hypotheses were systematically tested at nine contract completion points (10 to 90 percent at 10 percent increments) for various categories within the sample. The categories examined were the contract type (fixed price, cost), the contract phase (development, production), the generic type of weapon system (air, ground, sea), and the armed forces service that managed the contract (air force, army, navy).

The remaining hypotheses are related to the results of the referenced CPI stability studies which established that the cumulative CPI tends to worsen from the 20 percent completion point. Here, the hypothesis was that the average cost overrun tended to increase. To test this hypothesis, the average cost overrun (CO) was regressed against percent complete (x):

$$CO = \alpha + \beta x \qquad [2]$$

If the resulting slope coefficient (β) is positive with statistical significance, then the hypothesis is accepted, which means that cost overruns tend to increase. In Hypothesis 3, the average cost overrun was in dollars; in Hypothesis 4,

the average cost overrun was a percent. As with Hypotheses 1 and 2, Hypotheses 3 and 4 were tested on the entire sample.

Equations 3 and 4 define the current cost overrun and final cost overrun in dollars. Equations 5 and 6 define the overruns as percentages.

Current Overrun (CO$) = Cum ACWP – Cum BCWP [3]

Final Overrun (FO$) = Final ACWP – BAC [4]

Current Overrun Percent = 100 * (CO$/Cum BCWP) [5]

Final Overrun Percent = 100 * (FO$/BAC) [6]

The cost overruns were averaged for each category of the sample by dividing the number of contracts in that category into the total overrun for that category. The averaging was done at various stages of completion ranging from 10 to 100 percent complete, where percent complete was defined as follows:

Percent Complete = 100 * (Cum BCWP / BAC) [7]

Data entered earlier than the 10 percent completion point were not considered sufficiently reliable. It can take as long as one year from contract award for the contractor to demonstrate C/SCSC-compliance. Until then the data on the Cost Performance Report are suspect.

RESULTS

As shown in the remaining tables, the hypotheses were generally confirmed at the 95 percent level of confidence. Table 3 shows the results of testing Hypotheses 1 and 2 on the entire sample of 64 contracts. Recoveries from cost overruns expressed in either dollars or as a percentage are improbable, especially cost overruns experienced between the 10 to 70 percent completion points. Between these points the difference between the final cost overrun and the overrun to date was statistically significant at confidence levels well above 95 percent (alpha = .05). After the 70 percent completion the current overrun percent is necessarily much closer to the final overrun percent because monthly expenditures typically decrease as the work nears completion.

Hypotheses 1 and 2 were also generally confirmed for the categories of the sample examined. In short, *recoveries from cost overruns on defense contracts are highly improbable, regardless of the contract type, the contract phase, the type of weapon system, or the armed forces service that managed the contract.*

Table 4 shows the results of testing Hypotheses 3 and 4, and confirm that *cost overruns on defense contracts tend to increase.* The slope coefficients were greater than zero with statistical significance for the entire sample, and for each category of the sample that was examined.

MANAGERIAL IMPLICATIONS

These results show that recoveries from cost overruns on defense contracts are highly improbable, and that cost overruns tend to worsen as a defense contract proceeds to completion. This was found to be true regardless of the type of weapon system, or the armed forces service that managed the contract. The results are consistent with the results of related research involving the stability of the cost performance index, and confirm the observations of senior analysts at the Office of the Under Secretary of Defense for Acquisition.

TABLE 3
RECOVERY FROM COST OVERRUNS IN IMPROBABLY
(ALL CONTRACTS)

	Cost Overrun ($Millions)				*Cost Overrun (Percent)*			
PC	*CO*	*FO-CO*	*SD*	*t*	*CO*	*FO-CO*	*SD*	*t*
10	2.6	33.6	76.3	3.53	5.5	12.4	20.7	4.78
20	3.8	32.4	73.5	3.53	7.8	10.0	20.6	3.88
30	5.3	30.9	73.3	3.38	10.0	7.8	19.2	3.26
40	9.3	27.0	60.6	3.57	9.8	8.0	15.9	4.04
50	14.0	22.2	53.8	3.30	11.9	5.9	14.9	3.18
60	18.3	17.9	45.2	3.17	13.2	4.6	12.3	3.02
70	23.6	12.7	38.9	2.61	14.7	3.1	11.1	2.21
80	30.1	6.2	26.9	1.84	16.5	1.3	9.4	1.10
90	35.9	0.3	1.5	1.84	17.6	0.2	1.7	1.12
100	36.3	0.0	-	-	17.8	-	-	-

PC = Percent Complete, FO = Final Overrun, CO = Cost Overrun
SD = Standard Deviation
t = t statistic; $t_{a = .05, df = 63} = 1.645$

TABLE 4
COST OVERRUNS TEND TO INCREASE

Contract	*Cost Overrun ($Millions)*			*Cost Overrun (Percent)*		
Categories	*Slope (β)*	*SE*	*T*	*Slope (β)*	*SE*	*t*
All	0.325	0.020	16.13	0.198	0.009	22.09
Army	0.186	0.013	14.27	0.234	0.016	15.08
Air Force	0.417	0.034	12.11	0.180	0.005	36.11
Navy	0.459	0.021	21.38	0.159	0.013	12.20
Air	0.416	0.022	18.71	0.210	0.010	20.30
Ground	0.168	0.024	7.06	0.193	0.018	11.00
Sea	0.095	0.008	12.57	0.139	0.013	10.37
Development	0.318	0.024	13.37	0.232	0.008	29.12
Production	0.330	0.019	17.18	0.176	0.012	15.08
Cost	0.393	0.018	21.40	0.116	0.015	10.88
Price	0.287	0.022	12.93	0.215	0.006	34.48

SE = Standard error of the slope coefficient with the intercept zero
t = t statistic; $t_{a = .05, df = 8} = 1.895$

These results have clear managerial implications for the project manager: more realistic projections of the final costs are needed. When the projected overrun at completion is less than the overrun to date, the projected overrun at completion is too optimistic. Former Under-Secretary of Defense for Acquisition, Donald J. Yockey, commented on this issue:

> *We can't afford to understate, sit on, or cover up problems in any program – at any time – at any level. They must be brought forward. This includes not just "show stoppers" but also "show slowers." I can't stress this strongly enough* [19: 26].

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

Wayne Abba and Gary Christle, senior analysts at the Office of the Under Secretary of Defense for Acquisition, have commented that although recoveries from cost overruns are improbable, they are possible, especially if management pays proper attention to them. With proper attention, adverse variances have been reversed.

Proper attention requires a timely and disciplined analysis of variances as they are identified. It also requires a proper culture. A "shoot the messenger" culture was partly responsible for the delayed reporting of adverse information on the A-12 program [2]. Accordingly, senior management should make every effort to cultivate a healthy attitude regarding variance reporting. Managers are necessarily advocates of their projects. But this does not mean suppression or delaying the communication of adverse information about their projects to senior decision makers.

It is not known if recoveries from cost overruns on non-defense projects are also improbable. Perhaps additional research can explore this issue. Technical and political problems that contribute to cost overruns on defense projects may not be relevant to non-defense projects; however, the "shoot the messenger" culture involved in the A-12 program is certainly a potential problem in non-defense industries.

A related "cultural" factor that contributed to the cancellation of the A-12 was the natural optimism of senior management. In testimony before Congress, Navy Secretary of Defense Garrett characterized the senior managers involved in the A-12 program as "can do" people who did not admit to failure lightly [14]. Although optimism has its place, it can be dangerous when it blinds the manager to the truth.

Finally, social scientists have extensively documented many real-world examples of "escalation error" [15, 16]. In these examples, the decision maker is extremely reluctant to cancel an ongoing project or switch to an alternative, despite excessive overruns or other compelling evidence that the project has failed or that the alternative is superior to the present course of action. In some cases, the manager chooses to escalate commitment to the project by increasing the spending on the project. Researchers [15, 16] have attributed such behavior to psychological factors, such as a myopic "can do" attitude or a need to "save face." More recently, others have suggested that escalation error is caused by the manager's desire to protect his/her reputation in the managerial labor market [4]. Given the adverse economic consequences of cost overruns, additional research in this area is needed.

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