

# RISK ANALYSIS and COST MANAGEMENT (RACM)

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*A Cost/Schedule Management Approach*

using

**STATISTICAL COST CONTROL (SCC)**

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# **RISK ANALYSIS and COST MANAGEMENT (RACM) *A Cost/Schedule Management Approach* using STATISTICAL COST CONTROL (SCC)**

## **1.0 INTRODUCTION**

In an effort to better understand the processes that are usually used in forecasting program costs and managing budgets, a three year study was initiated in 1992. The study concluded that there are cost forecasting and management deficiencies which are resulting in unnecessarily high costs. These deficiencies are:

- When forecasting program costs, program management often use the practice of "arithmetically" summing instead of "statistically" summing<sup>(1)</sup> the cost elements of a Work Breakdown Structure (WBS).<sup>(2)</sup>
- Money allocated is money spent (MAIMS) and consequently, underruns are not available to fund overruns. This is amplified by the following:
  - The allocation of budgets is not consistent with statistically expected results.
  - Subtle "hidden" incentives in present day management styles become cost disincentives.
- The Earned Value Management System (EVMS) discipline is incorrectly applied.
- The incorrect application of Cost Estimating Relationships (CERs). E.g. assuming that the results of past programs represent a symmetrical distribution and a 50% Probability of Successfully meeting all program requirements without exceeding the budget (Ps).
- The use of methods and models which do not provide management with adequate insight and are not developed in consonance with management.
- The use of Monte Carlo techniques which inhibit a thorough analysis and a "what-if" capability. Monte Carlo may also introduce a random sampling error; particularly with small sample sizes.<sup>(3)</sup>
- The Acquisition Processes used by the government and contractors is not a level playing field.

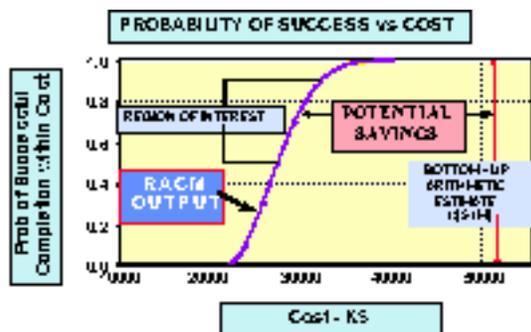


Figure 1.0

The impacts on costs and the reasoning behind these conclusions are discussed in detail in Section 3.0. However, an optimal solution is a set of incentives which motivate all levels<sup>(1)</sup> of management to produce the best product at the lowest cost in consonance with approaches such as SCC and the RACM process.

In response to these findings, a process has been developed to correct or minimize each of these deficiencies in order to improve the probability of completing the program within the costs allocated. This process is called Risk Analysis and Cost Management (RACM) using Statistical Cost Control (SCC) methods. By using SCC, the Program Manager can take advantage of the expected distributions about each cost element and improve the outcome. In most cases this will result in significant cost savings. Figure 1 is an example of the potential savings which can be realized by using SCC in a RACM process.

Using a process which addresses these concerns has become increasingly important for two reasons; funding is limited and competition is serious. Stephen R. Hardis, chief executive of \$7 billion Eaton Corp., estimates that his company pays as much as 4 percent more each year for labor and materials but can raise prices only by less than 1 percent. To stay in business, *the company is forced to continue driving down its overall costs* through new technologies and management methods. "We have to absorb inflation," says Hardis." Few options for reducing costs are left. Management must seek new methods for understanding the costs associated with their product or program. RACM addresses the problems identified above and provides the following *unique* capabilities:

- The "most likely" cost for each account or element in the accounting structure is provided - with visibility into each major assumption.
- A suggested distribution of the budget is provided which will assist in achieving the lowest cost.
- A cost management tool which is integrated with the Government's "earned value" approach.

(1) "Statistical summing" is the term used in this paper for "creating the probability density function for a sum of random variables."

(2) "Work Breakdown Structure (WBS)" is used interchangeably with "Cost Account." Structure.

(3) For reasons to be explained later, the statistical summing is developed on RACM using an analytical approach and not a Monte Carlo approach.<sup>2.0</sup>

## APPLICABILITY

The RACM process is applicable for *any projections of cost which have any uncertainty associated with the estimating and managing processes*. The appropriateness of the process increases as the number of separate sources of uncertainty associated with a project increases. For example: the forecasting and managing of development programs, new production programs, and civil engineering tasks; determining the probability of success associated with a new business; and

## 3.0 RACM's SOLUTIONS TO DIFFICULTIES WITH CURRENT PRACTICES

Most of the cost increases from existing deficiencies noted in the introduction will require changes to existing cost forecasting, government acquisition methods, and program management methods. It should be noted that statistics best

represents the expected outcome of an event. Therefore, using statistics to allow program management to forecast and manage a program would more nearly provide the results sought. For example, program management does not know the quality of personnel they will be able to obtain. The only type of program where the changes suggested in the following paragraphs would not result in significant savings are very repetitive program such as the manufacturing of aspirin tablets by a manufacturer who has been in the business for some time. In such a program, the unknowns are minimal. The discussions of deficiencies and their solutions, as delineated in the following paragraphs, are directed to those programs which have relatively large unknowns.

## 3.1 Simple Arithmetic Summing instead of Statistical Summing

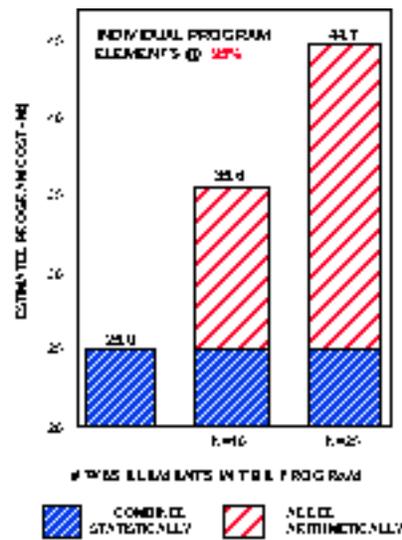


Figure 3.1a

Simple Arithmetic Summing is the practice of "arithmetically" summing (using single point estimates) instead of "statistically" summing the cost elements of a Work Breakdown Structure (WBS). This is usually characterized by the "bottom-up" approach, which is commonly used to forecast costs. It involves a simple arithmetic summing of single point estimates instead of creating the probability function for the sum of random variables.

The major assumption underlying current bottom-up estimating method is that arithmetically summing WBS cost elements results in a program cost which has a  $P_s$  that is reasonable. This is not the case. The tasks within the program should be characterized by a statistical distribution of potential values rather than a point estimate. For this reason, the bottom-up approach yields an increasing confidence for the total program cost with an attendant *increase in total costs*. In most cases this is crucial.

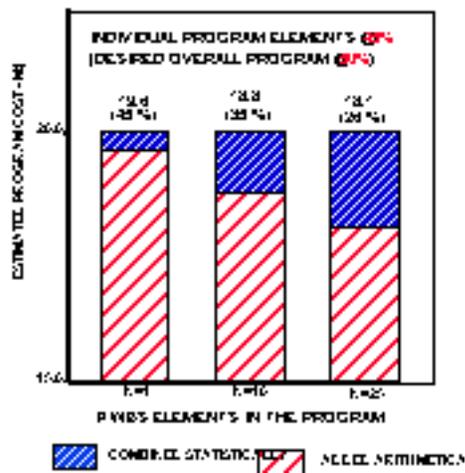


Figure 3.1b

Figure 3.1a is an example of what can happen if all elements in a WBS are estimated at a 95% Ps and then added arithmetically as single point estimates. The error will continue to compound with the number of WBS elements being used. If the program consists of one element, it does not create an error if the distribution is normal. However, with 25 elements, this example shows almost a doubling of the costs and an increase in the program's Ps to beyond 999 out of 1000. If this is often the case, why don't most programs finish with an underrun? The overruns are usually caused by some of the subsequent reasons discussed below. It is primarily due to not creating a situation where underruns are available to fund overruns.

Figure 3.1b is the other side of the coin. It is an example of the problem which can be encountered if the estimations are too aggressive. With a 45% Ps for each element instead of 50% Ps, a program cost estimate would be at a Ps of 26% with just 25 elements in the WBS. This most likely lead to an overrun or, worse, a program failure.

These examples illustrate the necessity of estimating the distribution of costs associated with each cost account or element in the WBS. This is actually a simpler task than trying to make a single point estimate, i.e. estimate the exact cost of each element, and results in a better understanding of the cost elements in the program.

(1) All levels of management must include the lowest level that can control the budget. E.g. a design engineer.

## 3.2 Budget Allocation Policies

The specification and application of management reserves are business policies which can have a dramatic effect on the final outcome of any program. RACM provides management with a technique to: (a) determine the size of the program's reserve, and (b) suggest how the remaining funding should be allocated among the program tasks, so that the project can be completed at a reasonable risk level.

Once budget is allocated it is difficult to retract. For example, once personnel have been hired, removing the personnel is fraught with problems. At best, there is a delay which will result in unnecessary expenditures. And, the more money that is available, the more will be spent, regardless of the need. A recent program by Indiana University showed that if a large quantity of anything is available, the more that the holders of the money or product act in a predictable way. In this particular study, different families were given economy size products of soap, toothpaste, etc. The savings which they should have realized disappeared because each family with the "economy" sizes, used more each time.

Therefore, it is best to provide only that budget which will give the "expected" result. Usually the 50% Ps point. Allocating less would seem advisable, however, allocating less than 50% can cause program difficulties also; e.g. insufficient hiring, etc.

## 3.2.1 Effects of Budget Allocation

If the allocation of budgets is not consistent with statistically expected results, the model is no longer valid and the budget allocation policies will inadvertently cause increased costs and overruns.

This result is due to the "budget received is budget spent" or "money allocated is money spent" syndromes. All of this is unintentional on the part of government and contractor personnel. They are usually unaware of these additional costs.

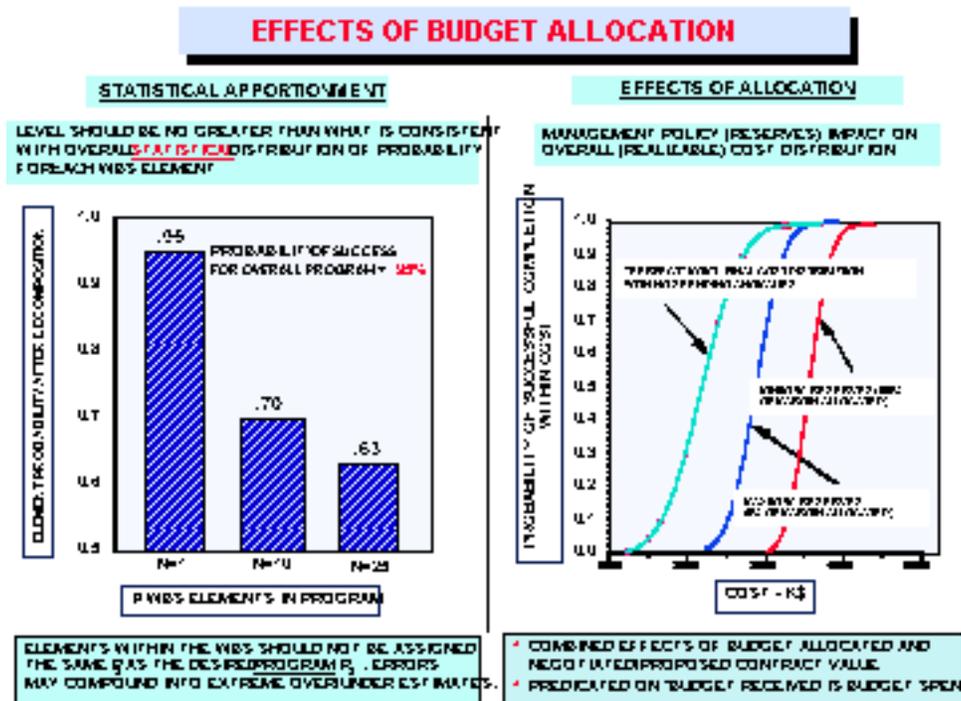


Figure 3.2a

Elements within the WBS should not be allocated with the same probability of success ( $P_s$ ) as the desired overall program's  $P_s$ . This can only be accomplished if the distribution about each element in the WBS is truly normal and the  $P_s$  used in arithmetically summing each element in the WBS is equal to a 50%  $P_s$ . In reality this situation does not occur. The distribution about each element in the WBS is not symmetrical and identifying the 50% probability of success point is impractical. Most distributions will be skewed because the element manager will normally use all budget allocated in order to provide the best product and to maintain a cadre of knowledgeable personnel.

Figure 3.2a shows the effects of budget allocation and the proposed contract value on the program's  $P_s$ . As illustrated in the figure, there can be substantial changes to the cost of a program depending on the type of management reserve policy invoked.

The left side of the figure illustrates that the greater the number of elements involved in the budget allocation, the lower the  $P_s$  needs to be for each element if the overall probability for the program is to be realized. The  $P_s$  for each element in a large program will eventually approach 50%  $P_s$ . This is the expected value and is a reasonable value to use initially for distributing budget to all elements.

The right side of Figure 3.2a illustrates the effect on the program's  $P_s$  with various reserve levels. The first line of the three lines shown is the expected result of managing a program where management had the ability to know when a task is complete and can immediately remove the personnel involved in that part of the program from further involvement or cost

to the program. An example of this would be the construction of a house. Accomplishments are evident and the personnel involved are usually dedicated to a single discipline.

In most DOD programs, however, these factors are not present. For this reason, a more conservative approach must be taken. The middle line of the three lines represents the allocation of a minimum budget. Minimum in this case is an allocation of the "expected" value. This is reasonable and provides the best possibility of meeting the program's cost goals. The third line illustrates the difference that maintaining no reserves has on the expected cost. In this example it is quite consequential. This radical shift to the right is caused by the inability of management to recover budget which has been allocated in order to properly fund the anticipated overruns with anticipated underruns.

## 3.2.2 Budget Allocation Methods

BUDGET ALLOCATION								
BUDGET ALLOCATION FOR 98% $P_s$ BID LEVEL & MAXIMUM MNGMNT RESERVE POLICY								
WBS ELEMENT	BID				ALLOCATED			
	TOTAL	LABOR	%-LBR	$P_s$	TOTAL	LABOR	%-LBR	$P_s$
MISSILE								
PROPULSION	4,385	1,327	3,058	T4	3,285	1,325	1,960	5U
GSC	3,043	501	2,542	T4	2,015	318	1,697	5U
USEF	778	824	152	T4	833	512	321	5U
PROGRAM MGMT	3,254	3,213	18	T4	2,025	2,019	12	5U
SYSTEMS ENGRG	4,349	4,331	18	T4	3,280	3,245	15	5U
TRAINING	192	823	33	T4	538	515	11	5U
SUPPORT EQUIP	1,037	300	197	T4	197	833	42	5U
INITIAL SPARES	872	487	235	T4	479	404	85	5U
ETC.	xxx	xxx	xxx	xx	xxx	xxx	xxx	xx
<b>TOTAL (WBS)</b>	<b>\$30,995K</b>	<b>\$22,762</b>	<b>\$8,133</b>		<b>\$21,661K</b>	<b>\$16,220</b>	<b>\$5,441</b>	
<b>RESERVE</b>	<b>\$4,327K (Non WBS Element \$)</b>				<b>\$13,562K (Management Reserves)</b>			
<b>PROGRAM</b>	<b>\$35,222K (From Final Curve)</b>							
<b>OVERALL PROB. SUCCESS</b>	<b>98%</b>							

Figure 3.2b

It is important to allocate the budget equitably and at a reasonable level. What is a reasonable level? It is the statistically identified "most likely" value? In figure 3.2 b the WBS or list of cost accounts is shown on the left hand side. The two major columns to the right of the WBS show what the  $P_s$  is for each element or cost account in the WBS. In this example, the middle set of columns represents the  $P_s$  for each element at a 98% overall program  $P_s$ , i.e. the bid level.

The budget which should be allocated to each cost account manager is shown in the "allocated" column for both labor and non-labor. It should be noted that all accounts are allocated an *equal*  $P_s$ . This allows the proper consideration for the uncertainty about each element and therefore maximizes the overall  $P_s$ . Under this scenario, each account manager is provided the "expected" budget. Variations, with explanation, must be allowed during the conduct of the program. In other words, underruns and overruns should be allowed to offset each other.

Why is this important? Because, whatever funds are allocated will, in most cases, be spent. "Money allocated is money spent." (MAIMS)

## 3.3 The Effects of "Hidden" and Contractual Incentives

The incentive structure which exists on most programs are subtle incentives which are incorporated into present day management styles. They are the unwritten incentives. That is:

1. The inability and reluctance to off-load competent personnel from the program.
2. The need to spend the budget provided or "it will not be available next year."
3. The need by the program personnel such as design engineers to provide the most reliable product for the money provided.

For example, design engineers will continue to develop their design as long as they are funded. Why? Because they are evaluated on how their design works during testing and after delivery. This is a much larger incentive to them than under running or over running the budget. If the engineers were to under run the budget and have a failure during development tests, they would be considered a failure. If, however, they overran the budget but had a successful test, they would usually be considered a success.

Why are these "hidden" incentives contributing to overruns? Because each task or cost account in a WBS has uncertainties associated with it. These uncertainties are potential underruns or overruns. If these potentials are not allowed to occur, only the overruns will occur with no offsetting underruns. This phenomenon can have a very consequential effect, especially in large, multi-tasked programs.

The obvious solution is to change the incentives. However, this is usually not practical. For this reason, it is necessary to develop the tools to recognize the potential savings and to guide program management to these goals. That is, determine the potential variations in each task and manage accordingly. This capability is what makes SCC and the RACM process unique.

Written incentives include cost, schedule, and performance incentives. However, performance incentives have, in the past, often been large enough to outweigh the cost and schedule incentives. The most subtle incentive that relates to the use of a good risk management process is the misuse of the EVMS intent. It was intended as a management tool. However, it is often used to provide an absolute budget line from which there can be no variance, i.e. no under-runs or overruns are allowed.

As stated in "Punished by Rewards" by Alfie Kohn 1993 "Not only are incentive systems and pay-for performance plans pervasive in U.S. companies, but there exists a deep and rarely questioned commitment to the belief that offering people rewards will cause them to do a better job. The evidence, however, suggests that extrinsic motivations in the workplace are not only ineffective but often positively counterproductive. The most familiar reasons proposed to explain this failure deal with relatively minor issues that apply only to specific incentive programs. But several other reasons strike at the heart of the assumptions about motivation that underlie all such programs. It is simply unfair that employees are held responsible for what are, in reality, systemic factors that are beyond their control."

The unwritten and misused incentives should be examined. This can be partially accomplished by *changing the culture* in several ways. (1) Understanding the "expected" and "most likely" outcome in a program's cost and schedule structure. (2) Use EVMS as a tool to manage the program in conjunction with the RACM process. (3) Provide incentives and recognition at the level where costs can best be controlled, i.e. design engineers, integrated product development teams, etc.. (4) Allow companies to make large profits if they meet all cost, schedule, and performance goals. (5) Include, as part of the cost analysis, how companies will be able to maintain a basic cadre without having them "sit" on the program being proposed. The "basic" cadre, the cadre required during the course of the program, should be identified in the first estimate.

## 3.4 Incorrect Application of the Earned Value Management System

All uncertainties must be identified and considered in developing a cost model for the program and they must be considered during the conduct of the program. Meeting this goal requires the additional use of a tool which will allow an understanding of how the program is progressing. This is the EVMS method of cost management developed by the government. Under EVMS a reasonable baseline stability is sought against which performance is measured, i.e. it is a methodology for monitoring and comparing progress against program plans. Performance measurement as defined by the EVMS system can be used to update RACM as a refinement of EACs.

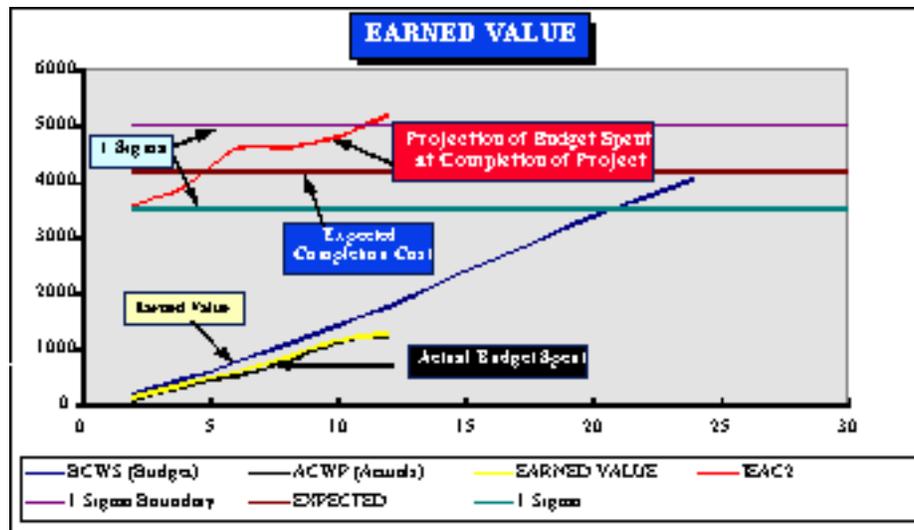


Figure 3.4

For example, managers are usually given a budget and told to stay within budget. If they do a perfect job of staying within budget they are, inadvertently, either contributing to the overrun of the program or to an inadequate completion of the task. This has often been the interpretation used in applying the EVMS (previously called CSCSC) discipline. Any variation, either above or below the expected expenditure, is treated as a variation which must be explained. Too often this is responsible for a manager "staying on the line" just because that is what is expected. This then becomes another "hidden" incentive to overrun.

An approach to accomplishing this is illustrated in figure 3.4. In this example each WBS element or cost account is analyzed for both labor and non-labor. The budget is plotted at the "expected completion cost," i.e. 50% Ps for a symmetric distribution. About this plot, two boundaries are plotted. In this example, two 1 sigma lines are shown as the boundaries. These boundaries are then monitored against a projection of budget spent at completion which is developed from the results of an EVMS evaluation. The program could be evaluated periodically, e.g. after each 10% of the total span and no variance reports or corrective action would be required until the boundaries were crossed. However, in the example shown, some action earlier would probably be prudent since the "trend" is to exceed the upper 1 sigma line.

This approach to performance analysis and prediction is a necessary adjunct to the usual approach of monitoring only the cost and schedule by comparing the dollars budgeted to actual dollars expended and the scheduled events to actual events which have occurred. This earned value approach is necessary in order to assure that the effort being expended is accomplishing the goals of the program. For example, if the projected budget has been expended after 10% of the schedule has been completed, the program may or may not be in trouble. Only by considering the work accomplished for the dollars expended, can management be assured of a thorough understanding of the status of the program.

Government studies <sup>(1)</sup> indicate that when a contract is more than 15% complete, you can't recover. i.e.

- Overrun at completion will not be less than overrun incurred to-date
- Percent overrun at completion will be greater than percent overrun incurred to-date.

Based on an analysis<sup>(2)</sup> of 64 completed contracts; "the overruns at completion predicted by the contractor and by the government program office were unrealistically optimistic. From as early as the 10 percent completion point through the end of the contracts, the predicted final overruns were less than the current overruns reported on the contracts. Although the estimates supported by the government program offices were less optimistic than the contractors' estimates, neither was found to be realistic."

"From the United States Government's perspective, which must allocate resources between competing products, the performance measurement concept has provided a good method to obtain an accurate assessment of the cost and schedule status of their procurements, on a monthly basis, and it has improved their ability to ascertain the true final costs."

The key term used in the EVMS method for measuring contract performance is "earned value." This method combined with the RACM process can provide a more accurate analysis for: Budgeted Cost for Work Scheduled (BCWS), Actual Cost of Work Performed (ACWP), etc., by analyzing each within the framework of RACM

Not only should this be more accurate but it should result in fewer variance reports and will provide the program management the ability to determine their risks and how to best make adjustments to the budget plan.

## 3.5 Inadequacy of Historical Data and Cost Estimating Relationships (CERs)

CERs often assume that the results of past programs represent a symmetrical distribution and a 50% Ps. However, historical data *should* be used whether explicitly as in parametric models or implicitly as in a model developed from engineering experience. Both rely on what has been done before. However, any historically based model should be used with caution. The factors that incorrectly influence the data are discussed in the introduction. Two of the most consequential factors are:

1. Improper allocation of resources (money allocated is money spent)
2. Acceptance by the contractor of changes beyond the scope of the contract without adjustments.

CERs are based on historical data and the relationships that were apparent on those programs. These relationships are usually adjusted for each program that they represent. While historical data is necessary in trying to predict the future, any use of the data must be dissected, examined, and only then can it be reassembled for use in a model and, as pointed out before, there is a more efficient method of allocating money which will greatly reduce costs.

The impact of accepting changes beyond the scope of the contract creates a false cost baseline. Any future analysis for use in cost forecasting would develop CERs which would assume a product as originally specified without the benefit of knowing what additional tasks are represented by the costs.

## 3.6 Visibility of the Process (Assumptions and Inputs) is Critical.

There are many methods and models being used which do not provide management with adequate insight. Because they are not developed in consonance with management and are often used to record the results of "blackboard bogies.," they are not performing their intended use. "Blackboard bogies" result from program management being asked to rely on cost forecasting models without being provided the insight to the factors used in the final assessment.

The RACM process requires management, design engineers, manufacturing engineers, logistics engineers, planners, cost modelers, and other program personnel to work closely together. Furthermore, each discipline involved can see the results of their inputs. This eliminates much of the misunderstanding often associated with cost forecasting. This approach will result in a better understood forecast which will ultimately save time and be more accurate.

The factors which should be separately considered in any cost forecasting method can be divided into two basic categories, (1) those factors affecting each cost account or WBS element, and (2) those factors which are global in nature. The effect of global factors must be assessed on the total program only. Listed below are those factors which have been identified as the major factors influencing the cost of a program.

(1) Wayne Abba, Office of the Under Secretary of Defense. (Acquisition & Technology - Performance Management)

(2) Dr. David Christensen in the 1994 Winter issue of the Acquisition Review Quarterly

As such, they should be separately analyzed. Some examples of these factors are listed below and illustrated in Figure 3.6. It is an example of the type of visibility management should have concerning the effect of each major assumption.

### 1. Examples of Factors affecting each WBS element

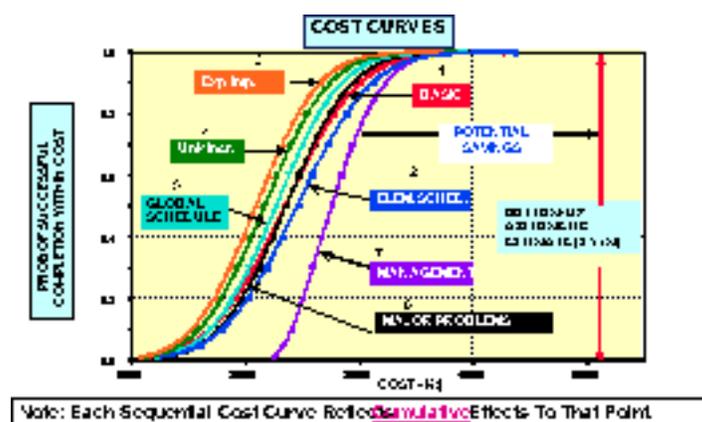


Figure 3.6

- Performance requirements (Establishes the basic estimate for each element in the WBS)
- Structure of the contract. Is it fixed fee, incentive, firm fixed price, etc.? This affects the distribution about the estimate.

- Schedule uncertainties that are identifiable with specific elements of the WBS.
- Improvements contemplated.
- Changes in future parameters which can be anticipated now. e.g. labor rates.
- Correlation between elements

## 2. Examples of Global Factors Affecting All Elements

- Global schedule uncertainties affecting all of the elements in the WBS. e.g. a flight failure requiring scheduling of another test.
- Potential major design problems discovered during operational tests.
- Management Policies such as the allocation of resources.
- Major changes in business climate and redirection of effort.

## 3.7 RACM's Analytical Approach Instead of Monte Carlo

The use of Monte Carlo techniques inhibit a thorough analysis and a "what-if" capability. Monte Carlo may also introduce a random sampling error; particularly with small sample sizes.

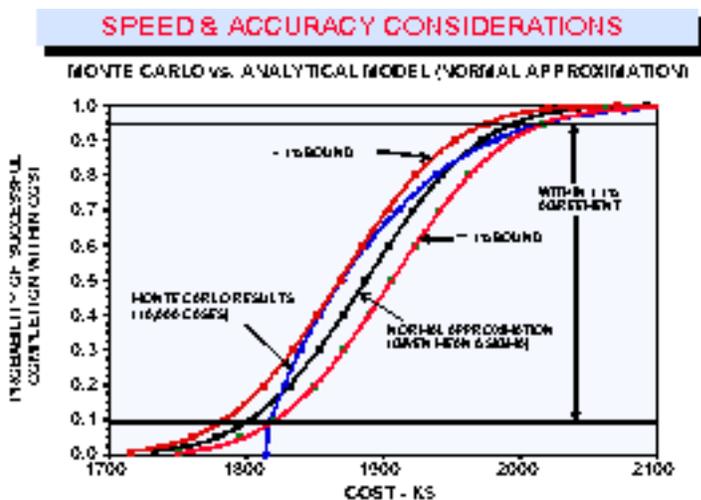
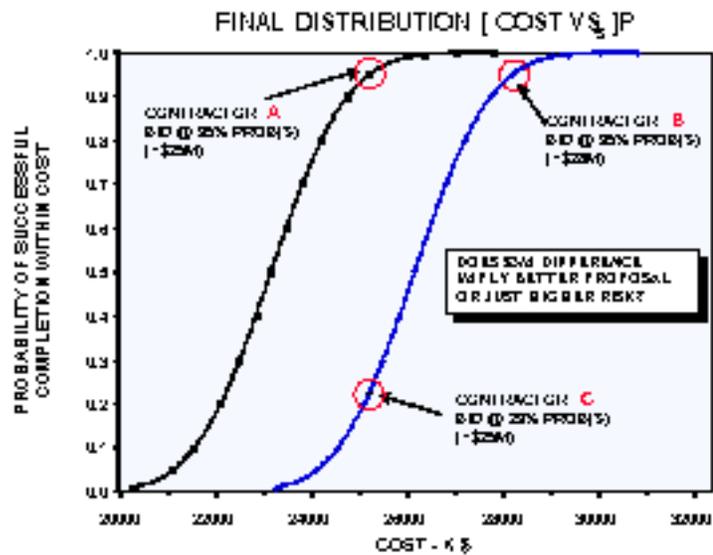


Figure 3.7

For these reasons, the RACM process uses the analytical approach instead of the Monte Carlo approach which is used in most cost forecasting models. An analysis of the two methods shows the results of RACM's analytical method to be consistent with Monte Carlo. Accuracy is a function of the parameters used to define the function. For the comparison shown in figure 3.7, the same parameters were used for the Monte Carlo and RACM methods. These two approaches provided results that are within 1% of each other and, in the range of anticipated use (50% Ps to 95% Ps), the agreement is even greater.

However, because the RACM model is able to provide an analysis in a matter of seconds more analysis can be done. The same analysis on Monte Carlo models take an hour or more. Speed is essential for one very good reason. An understanding of any model's forecast requires many "runs" of the model using different inputs. This allows management to better understand what elements in the WBS should be watched and examined further. If each analysis takes an hour or more, there will not be enough time to make all of the runs necessary for a full understanding of the program risks.

## 3.8 The Acquisition Processes used by the government and contractors is not a level playing field.



### CONSIDERATIONS

- CONTRACTOR'S PROPRIETARY DATA MUST BE PROTECTED
- REQUIRES A GENERALLY ACCEPTED METHODOLOGY

The example shown in figure 3.8 illustrates the need for a better method of evaluating contractors and subcontractors. They are missing one very important evaluation term; the "probability of success."

In this example there are three contractors who have bid. Without the additional information, Ps, provided, the award would probably go to Contractor A or Contractor C. If there are only two contractors, B and C, the award would probably go to Contractor C.

However, if the Ps information is available to the customer, the award will probably go to Contractor A. This assumes that all other factors in the granting of the award are equal.

If the playing field is to be leveled, all contractors must submit to the customer the same type of information. That is, they would all be required to follow selected guidelines. There are many precedents for this approach. The contractors would not necessarily be required to submit the results of the Ps but would be required to provide the inputs. However, the model to be used by the customer in the evaluation would be made known to the contractors.

## 4.0 SUGGESTED CHANGES

There are several changes which should be made to the present methods of doing business if these concerns are to be alleviated. They are:

- Use a statistical model which will:
  - provide the most likely cost for each account or element in the WBS
  - provide management visibility into each major assumption
  - provide a suggested equitable distribution of the budget which is consistent with the program goals.
  - Provide a cost management tool that is consistent and a compliment to the EVMS. Eliminate "staying on the line."
  - Level the playing field in the selection process.
- Develop incentives which will apply to all levels of personnel that can influence the cost of the product. These must be sufficiently large to overcome the "hidden incentives"

## 5.0 BACKGROUND AND STATUS

# 5.1 PHASE I - Examination of the Process

The standard methods of developing cost estimates and managing budgets were first questioned<sup>(1)</sup> in response to the growing concern that costs of many programs had increased significantly over the past 20 years. Most of the increases could not be attributed to inflation or other known factors which normally increase costs. The first explanation was that each element or cost account in the WBS was being "padded." If this were true (and sometimes it is), the "padding" should have eliminated the many overruns that were occurring. They didn't.

The next assumption was that the overruns were caused by those responsible for forecasting costs, i.e. they were not recognizing, in advance, all of the costs which were to be encountered. This may account for the over runs but would not account for the significantly increased costs. The third assumption was an excessive number of changes being incorporated which were beyond the original scope of the contract and outside the original specifications. This establishes a false cost baseline for future programs.

Because these explanations were not adequate in explaining the increase in costs, a study was initiated to develop a model which considered each step in the forecasting and managing of a program, especially the human element. The most important finding was the effect that "hidden" incentives have on the final cost of a program. These incentives are not the usual cost incentives or performance incentives written into a contract or made part of the standard operating procedure. These are the "hidden" incentives that govern the conduct of the personnel performing the tasks.

# 5.2 PHASE II- Implementation

Once these findings were documented, the implementation phase began. Because the results were quite different from those obtained from standard off-the-shelf models, an independent analysis was initiated<sup>(2)</sup> at Santa Clara University<sup>(3)</sup> for: (1) verification of the underlying mathematics and, (2) a literature search for similar models. The results of this review were positive.

In addition to independent reviews and because of the implications this new approach would have on the Government's acquisition programs, discussions with OSD's Acquisition Management were initiated. The contact was Mr. Wayne Abba.<sup>(4)</sup> After reviewing the material, he requested a series of presentations to those eventual users in the Government's Defense Industry in order to get their opinion. These presentations were subsequently made to the following organizations:

- Cost Analysis Improvement Group (CAIG)
- Acquisition Reform

- Economic Security
- Research and Engineering
- BMDO - Program Office
- USAF Cost Analysis
- US Army Cost Analysis
- Aeronautical Systems Center
- AFSC (ESD)
- US Navy Cost Analysis
- NAVAIR-ASW
- Fleet Ballistic Missile Program (FBM)
- IDA - Institute for Defense Analyses

All organizations involved provided OSD with a positive feedback. Meetings were then held internally at OSD's Acquisition and Performance Management office. Their conclusion was that the process was new and unique and that no major concerns had been surfaced. This conclusion resulted in the funding of a study by OSD which was contracted with the Institute for Defense Analyses (IDA)<sup>(5)</sup>. They were to conduct a two phase study. Phase I was to verify, once again, the mathematical (statistical) concepts and the uniqueness of the concept. This was completed with positive results. Phase II was to actually use the process in a controlled environment. IDA has chosen Boeing as an evaluator.

In addition, presentations were made to non-government organizations with equally positive results. These presentations included the following:

- Northwestern University
- Penn. State
- Santa Clara University
- Massachusetts Institute of Technology
- SCEA - Society of Cost Estimating and Analysis
- PMA and NSIA - 6th Annual International Conference

At the present time, the process is being used to varying degrees at Lockheed Martin as a forecasting tool and on some non-government programs.

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(1) Original study and initial modeling accomplished by Creaghe Gordon, George Rosenthal, and Jim Garofalo. Subsequent modeling and examination accomplished by Creaghe Gordon, Ron Welch, Ed Henderson, Dr. Feinstein, and Doug Johnson

(2) Mike Laden, Executive Vice President, Lockheed Missiles and Space (Missile Systems Division)

(3) Professor Charles D Feinstein, Ph.D. (Santa Clara University)

(4) Wayne Abba, Office of the Under Secretary of Defense. (Acquisition & Technology - Performance Management) and Gary Christle - Director

(5) IDA (Matt Goldberg, Ph.D. and Chuck Weber, Ph.D.)