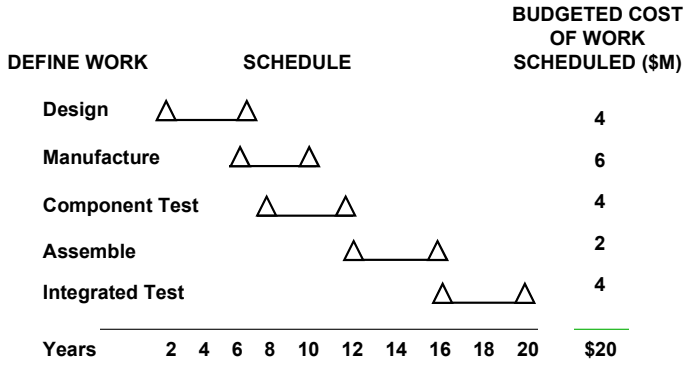
IF THE PHARAOH HAD ONLY USED AN EARNED VALUE SYSTEM IN BUILDING THE PYRAMIDS

Lieutenant Colonel William J. Neimann, USAF (Ret.)

The developer of the great pyramid of Egypt might be looked upon as the father of program management. He had one of the first programs in recorded history that required a great deal of integration and coordination (i.e. program management). He did not, however, have the relatively new concept of "earned value" to assist in the management of this ambitious program. An "earned value" concept is the heart of all defense contractor management information systems, which comply with DoD Instruction 5000.2 concerning the earned value management control system (EVMCS). But let's go back nearly 5,000 years to the construction of the pyramids to see if "earned value" would have been of any utility in managing that program.

Figure 1. THE PROGRAM PLAN



Let's assume we are all members of the pharaoh's air force and work in a program management office. We are competing for resources with the Icarus, Pegasus, and Sphinx programs, so we must manage our technical, schedule, and cost performance with the highest of skills. Let's further assume that our office has been given a PMD (Pharaoh's Management Directive) for implementation of the pharaoh's dream. He wants to build a tomb to keep out the barbarians, last forever, etc. We have been given 20 years and a budget of $22 million ($ is the symbol for shekel) to accomplish the task. The pharaoh also wants us to report the status of the program to him on a quarterly basis using the PAR (Pharaoh's Acquisition Report) format.

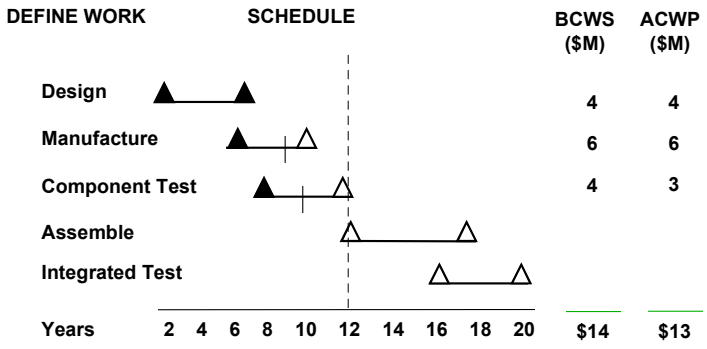
Now that we have our marching orders, what's the first thing we should do? As a military organization, experience would tell us that we need to lay out a plan. Let's approach the plan using the requirements and available resources. To convert the pharaoh's requirements into brick and mortar, we need to break down the work into its component tasks and distribute the responsibilities within the office. We could break down the work into either product-oriented or functionally oriented categories. For our own purposes, let's break the work down into the functional categories shown in Figure 1. We could, of course, discuss whether this is the correct functional breakdown, but for our purposes, let's assume this breakdown of the work is adequate.

What next? We must look at the resources available for the completion of the program. One of those resources is time. In conjunction with the individuals responsible for each functional area, we determine the amount of time required for each task and the interrelationships of the tasks. Figure 1 shows the agreed-to times for accomplishing the individual tasks and the overall program. We have not shown the interrelationship of the tasks on our chart.

Lastly, for our plan to be complete, we must determine the expected cost of each work task. Since we are still in the planning stage, the cost we are referring to is budgeted cost. But cost of what? The answer is; of course, cost of the work we have just scheduled, or budgeted cost of work scheduled (BCWS). Cost in our definition will include both direct and indirect costs, but not profit or fee. For the design task we have to budget for wages of the astrologers, alchemists, and engineers, as well as any material required in this task. We also have to budget for other direct charges (ODC) that may occur (i.e. abacus time, or travel to headquarters at Cairo). Finally, we must include an es-

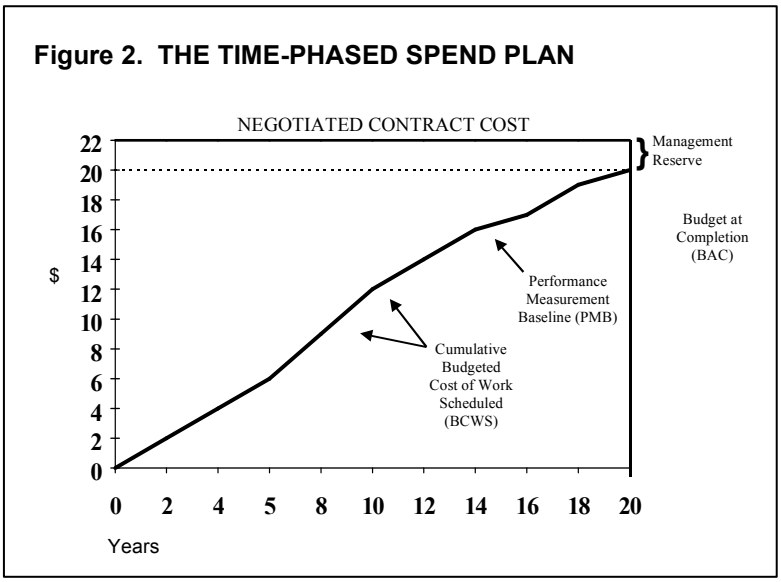
timate of the overhead (indirect) charges, which will be incurred. When all of these anticipated costs are added up, we see that Budgeted Cost for the Work Scheduled (BCWS) in the design task is $4 million. The manufacturing task is beyond our in-house capability and we plan to subcontract this to the Phoenicians, who are known to be shrewd negotiators, so we budget this task at $6 million. For the component test, we will need to get the astrologers, alchemists, and abacus operators' back together, and this is estimated to cost us $4 million. For the assembly task, we intend to use slave labor, so the cost is relatively low at $2 million. For the last task of integrated test, we expect the cost to be $4 million. Note that when all the costs of all the tasks are added, the total is $20 million, leaving $2 million in management reserve which the prudent program manager is setting aside for future problems (i.e. those infamous unk-unks).

Figure 3. CURRENT STATUS



In summary, we know the pharaoh likes to see a chart depicting shekels ($) on the ordinate and time on the abscissa. This will result in a spend plan showing planned use of shekels over time. Taking the total amount of shekels expected to be expended over time, and then adding them cumulatively, results in a line in Figure 2 called the performance measurement baseline (PMB). This baseline is the result of adding together the BCWS for all tasks to be accomplished over certain time periods in the program. Management reserve (MR) is the difference between the total allocated budget and the budget at completion (BAC) of the performance measurement baseline (PMB). Clearly, management reserve lies outside of the PMB.

Figure 2. THE TIME-PHASED SPEND PLAN



We now have laid out our basic program plan, and after developing several of the areas in a little more depth, we are ready to take our plan to the pharaoh for his approval. Let's assume the pharaoh is satisfied with our plan and gives us the program go-ahead, while reminding us to report program progress on a quarterly basis.

Twelve years have now passed since program initiation. Like most programs we have had some success and some failures. It is now time to prepare another of our quarterly PAR reports to the pharaoh. What can we include in our reports? Let's look at our current status (Figure 3) and determine what we can tell the boss.

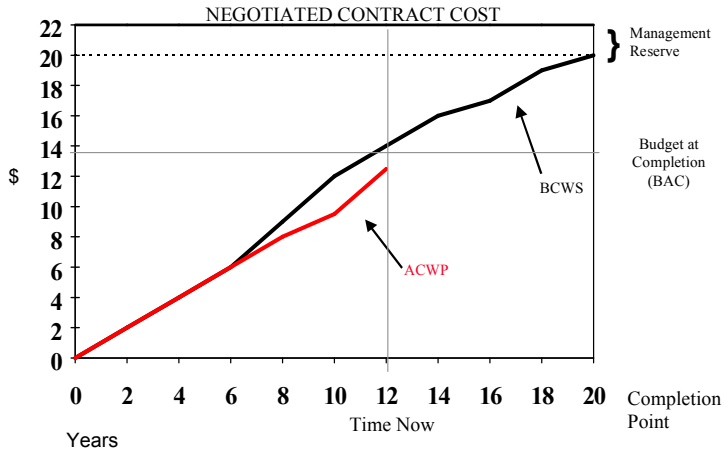
In our discussion with the manager of the design task, we found that he started his task on time and completed it on time by year 4. We know he had planned to spend $4 million to do the task. We can also now collect some actual cost data. Using the bill of material, labor hours, and overhead rates, we can calculate the total amount of money actually spent to accomplish the design task. We find that $4 million is the actual cost of work performed (ACWP). So far, so good. We spent exactly what we had projected to accomplish the design task.

Our discussion with the manager of the manufacturing task reveals that we are having a problem with our subcontractor, the Phoenicians. They are getting behind on their deliveries, and we only have 667 of the 1,000 granite cubes needed for the program. We had planned to spend (BCWS) $6 million for this task and we have already spent (ACWP) $6 million. The task is only two-thirds complete.

The component test area consists of two tests: a wind tunnel test and an environmental chamber test. Both tests are of equal cost. We have completed the environmental test, but have been out-prioritized by the Sphinx program for the use of the wind tunnel and unable to do the second test. We planned to spend $4 million for the component test task and have spent $3 million so far. The test effort is only one-half complete.

Let's again turn our attention to the spend plan (Figure 4), but let's include an indication of current status. We are at "time now" in year 12 and we had planned to spend (BCWS) a total of $14 million by this time. We may also plot the actual cost of the work that was performed (ACWP), which totals $13 million. We could have determined ACWP in previous reporting periods and plotted these points. These points also define a line, which is an analog representation of the ACWP over time.

Figure 4. CURRENT STATUS IMPOSED ON THE SPEND PLAN



What could we tell the pharaoh from this information? By examining the current status chart we can determine that:

- we have spent less than we planned to spend at this point in time (planned to spend $14 million, actually spent $13 million);
- we still have $2 million in management reserve;
- we have spent 65 percent of the money ($\frac{ACWP\$13million}{BAC\$20million}$);

and,

- we have done less work than we planned. We can tell this from looking at the schedule.

The last time we briefed the pharaoh, he asked some difficult questions. For example:

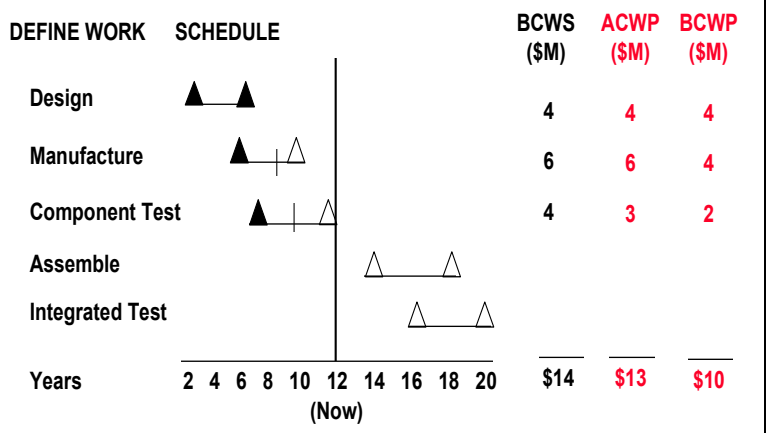
- For the work that has been performed, are we overrunning cost or underrunning? How much?

- What percent of the work has been accomplished?

- Do we have enough money? What is our estimate at completion?

Getting the answer to the above questions is very difficult given the current arrangement of the data. What do we get when we compare planned cost with actual cost? We find only that we have spent $1 million less than intended. This information is useful, but only from a *funding* viewpoint. It would be *incorrect* to state that from a performance viewpoint we have a cost variance of -$1 million. What we need is a measure of performance that takes into account what really has been accomplished. We could measure this accomplishment or work performed in terms of budgeted cost. This measurement of work performed is designated as "earned value" in C/SCSC terminology. The budgeted cost of work (BCWP) is a measurement of work accomplished in terms of the cost budget for that work and is the heart of a good cost performance reporting system. Figure 5 shows the earned value for calculation for the example. If we now subtract the actual cost of the work performed from the budgeted cost of work performed, we get a measurement, in $, of the difference between planned cost and actual cost, *for the same amount of work performed*. Likewise, if we subtract the BCWS from the BCWP, we see in $ the difference between the work scheduled and the work performed. Note that this $ difference represents accomplishment of more or less work than originally planned. No consideration is given to the interrelationship of the tasks, so the ability to meet a particular milestone cannot be determined from this calculation. Said another way; there is no critical path consideration in the determination of schedule variance. Therefore, schedule variance is only a measure of how much more or less work has been accomplished than originally planned *not* a complete measure of progress toward a completion date.

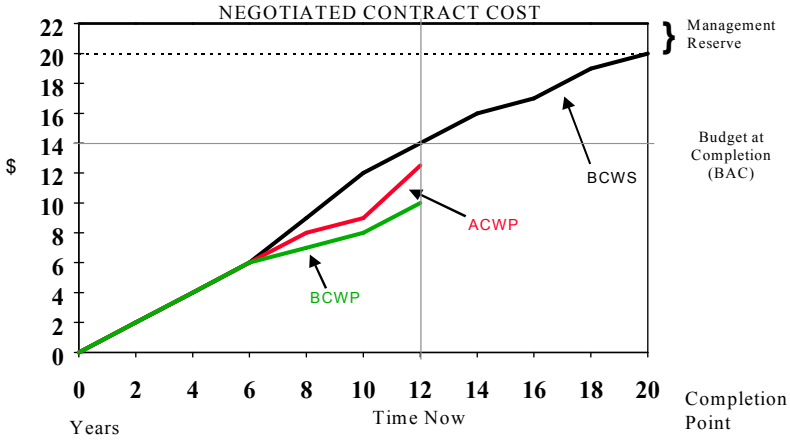
Figure 5. CURRENT STATUS



If "earned value" or BCWP is the key to good performance measurement, how is it calculated? Basically, BCWP is a measurement of the work performed compared to the original plan. For example, in the design task the budgeted cost for the task was $4 million. All work has been performed, so a value of $4 million work of work has been "earned". BCWP for this task is $4 million. Note that the calculation of BCWP is completely independent of the actual cost of the work. In the manufacturing task, we have performed two-thirds of the total budgeted work of $6 million. Therefore, BCWP for this task is $4 million. Likewise, we have performed half of the component test task that was budgeted at $4 million. Therefore, BCWP for this task is $2 million. If we add the BCWP for the tasks, we can see that the BCWP for the program *at time now* is $10 million. This means we can take "credit" for, or we have actually completed $10 million of the originally budgeted work.

The BCWP term is then plotted on the spend plan as shown in Figure 6. We are now in a better position to answer some of the pharaoh's questions. As far as determining current over/underrun is concerned, we simply subtract the ACWP ($13 million) from the BCWP ($10 million) and find we have an unfavorable variance of -$3 million or an overrun to date of $3 million. We have scheduled to perform $14 million worth of work (BCWS) but has performed (BCWP) only $10 million worth. We have therefore performed $4 million less work than planned, and are $4 million behind schedule. Remember this work may or may not be on the critical path, so we must look at the schedule to determine progress toward the completion date.

Figure 6. CURRENT STATUS IMPOSED ON THE SPEND PLAN



The percent complete may be calculated by dividing the work performed by the budget at completion (BAC). Therefore, 10/20 or 50 percent of the work has been accomplished. Remember, from an earlier calculation that 65 percent of the money has been spent (ACWP).

We are now ready to answer the pharaoh's last question. There are many different methods used to reach an estimate at completion (EAC). We could take the actual cost incurred to date (ACWP) and do a complete bottoms-up estimate for the remaining work. This is a time-consuming and costly process. We could use a "management estimate" of the remaining work. This tends to be very subjective and open to management optimism. We could make the assumption that in our work to date, we have established a certain cost *efficiency,* which will continue to program completion. We can develop such a "cost-efficiency index" by dividing the budgeted cost of work performed (BCWP/ACWP). In our example, this is 10/13 or .77. The cost efficiency index for the first half of the work accomplished is .77. If we assume that this efficiency will continue to completion, we divide the BAC by the efficiency index (20/.77), and determine the EAC to be $26 million. Said another way; we have accomplished 50 percent of the work at a cost of $13 million. Therefore, when the program is 100 percent complete, the cost is projected to be $26 million.

This estimate at completion is $4 million greater than currently authorized. What do we do? First, we must recognize the limitations of our estimate, but it indicates that it's time to reevaluate the direction of the program. Perhaps we should consider descoping our effort, perhaps building the pyramid out of 800 blocks rather than 1,000,

or canceling one of the tests. If this descoping were not feasible, another alternative would be to look around for additional funds. Whatever we do, we must remember that the pharaoh doesn't like surprises and we must inform him as early as possible when we think we may have a funding problem. Earned value (BCWP) helps in finding those problems much earlier in the program life when a wide variety of alternatives are viable.

The purpose of this example is to point out the utility of the "earned value" method and to introduce some terms used in cost performance measurement. Many of the concepts, such as determination of BCWP, were only touched upon and will be further developed in further articles. The next article in this series will discuss preparing the environmental impact statement for the Pegasus project.