EVM.05

Earned Value Management - Why Am I Being Forced to Do It?

Ursula Kuehn, EVP

To many, earned value management seems to be a recent requirement, but the technique has been around for a long time. The original techniques were conceived back in the early 1960s during the Minuteman Missile Development Program, back when most of the other, currently used, project management techniques were developed. But why, you may ask, if it hasn't caught on for all of those years, is it being forced on me now?

The answer: If implemented properly, it really works!

Any project plan is similar to a flight plan that the pilot of an airplane must submit before the flight. The pilot charts a course that points to the destination of the flight. If you ask a pilot how often he or she is exactly on the flight plan they will likely tell you that they are on the plan at take-off and at landing, and then they might happen to fly through it. Yet, they all seem to be able to fly to their destination with very few problems.

If the plane is not exactly on the flight plan, the pilot can usually steer the plane back. If not, the charts are brought out to develop a new flight plan. Hovering close to the flight plan is what allows the plane to reach its destination.

In project management, it's not being exactly on the baseline of the plan that counts - it's that you can steer the project team back toward the baseline. Using the tools and techniques of earned value management allows the project team to identify "control areas" around the baseline (like flight control lanes for a pilot) both on the positive side and on the negative side that the project status should stay in to be successful.

Borrowing from Quentin Fleming's selection of the top ten criteria? of the 32 criteria required to be ANSI/EIA-748-A compliant that he believes will get any project to be using earned value management techniques, let's see how it works.

STEP 1—DEFINE THE PROJECT SCOPE VIA A WORK BREAKDOWN STRUCTURE

To define the scope of the project's deliverable, decisions must be made about whether or not a deliverable or service will meet the customer's need and still fit within their budget. These decisions should be based on the answers to such questions as:

- Does the customer need it?
- Does the customer want it?
- Will it benefit the customer to have it?
- Can the customer afford it?
- Do other stakeholders need or want it?
- Will it benefit other stakeholders?
- Will it enable the project to be executed more efficiently?

The answers to these and other fundamental questions allow the project manager to truly focus this decision-making process regarding "what" is in the scope of the project on true objectives.

The most important tool of this process is the deliverable-oriented work breakdown structure (WBS). The decomposition of the scope is what forms the deliverable-oriented WBS into an architectural breakdown of that product or service.

The central focus of a deliverable-oriented WBS is the overall deliverable of the project. For example, if you are constructing a building, then the top block of the WBS would be the building. If you are developing software, then the top block would be the major function the software will perform for the customer. My favorite example is building a pond in my yard, where my top block would be "Ursula's pond." I would have to develop a business case of sorts to justify why I need a pond. I certainly would have to manage the pond. I know I'll have to design the pond and test the pond, but the rest of my sub-deliverables are going to be the major parts of the pond.

To start my decomposition, I would need to perform a requirements analysis. This is a process in itself where the project as a whole and each part of the project are scrutinized to make sure that they meet the need of the customer or stakeholder and, also, that the part fits into the budget. This analysis is like "peeling an onion." Through the analysis, the parts of the scope are identified. Then through a structured tool of documenting this decomposition of the scope (the WBS), the requirements analysis can be focused down the structure to each individual part.

Let's see how the WBS can help me plan my pond. Let's say that I would like to complete the entire pond in a weekend. If I were to use a task-oriented WBS, i.e., breaking down the project into the tasks of design the pond, build the pond, and test the pond, I can almost guarantee that I will not be able to complete the project in a weekend. It is very difficult to identify all the work - that is, anything that might take time - of the project using this type of WBS. If I don't identify all the work that might take time, I will not be able to plan for it in my schedule and by the time it becomes obvious to me that that additional work will need to be done, it will be too late.

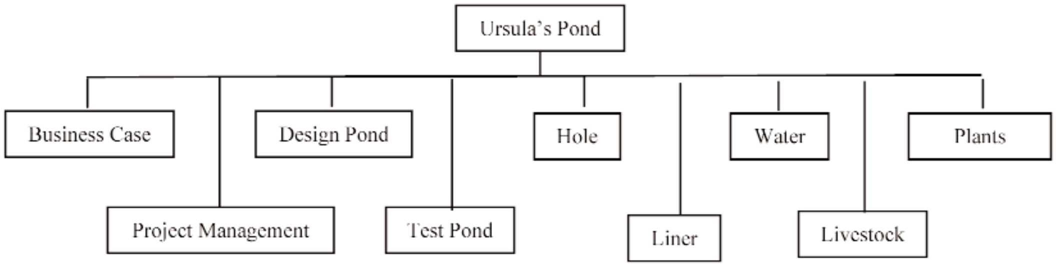

Figure 1—High-Level Breakdown of Ursula's Pond

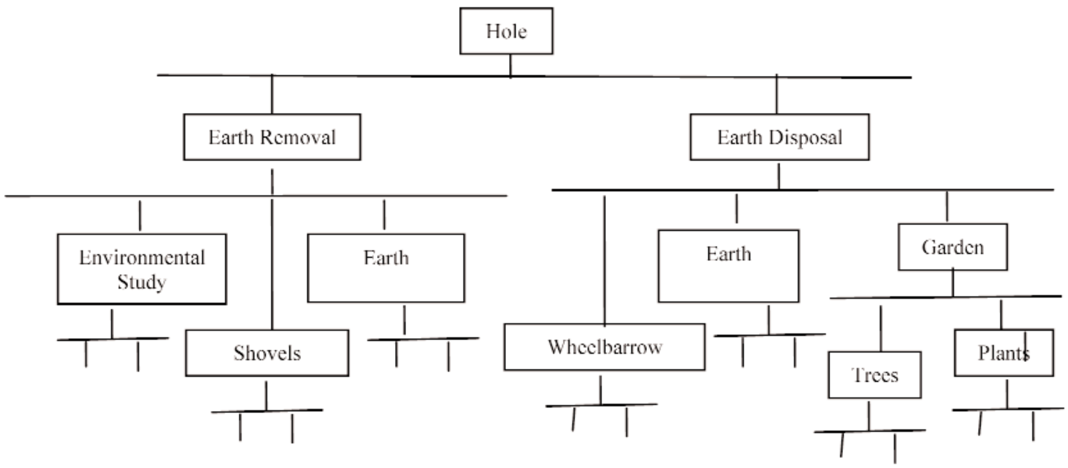

Figure 2—WBS of Hole

By doing a requirements analysis, I can identify the major parts of the pond, such as a hole to place the pond in, a liner, and water. Note that if a requirement for this project was to not break the ground surface, then the basic major parts of the WBS might be a plastic tub and water. The output of what is determined by my requirements analysis is the input to my deliverable breakdown, which in turn allows me to decide what goes into the scope of the project and what does not.

For this example, let's say that the basic requirements of my pond are a hole, a liner, and water, plus some livestock and some attractive plants. Our structure might look like the top-level structure shown in figure 1.

There could have been several more major parts to my pond, like a stone border, a water treatment, or external landscaping. There also could be many logistical deliverables that relate to the pond as a whole, such as training (possibly broken down into operation and maintenance), equipment needed to maintain the pond, user documentation, supplies, etc. These decisions are made based on the requirements and the budget.

The requirements analysis can now be focused on each of the individual major parts of the project. Let's take "hole" as an example. What is required to have a hole? The basic two functions that need to take place are to remove earth from the ground and to dispose of the earth. We could look at each of these functions as a sub-project in itself: "remove earth" and "dispose of earth."

Performing a requirements analysis on the sub-project "earth removal" might include a requirement to study the geological drawings of the area where the earth is to be removed. This study would further define whether a backhoe or just shovels will be needed, or maybe even dynamite, depending on the matter to be removed. In other words, this study is part of the requirements analysis but might never been identified as work that would take time if we had not analyzed this part of the WBS. This geological study may also identify other required deliverables, like an environmental study.

A study to locate any utility lines, as well as many other time-consuming activities, might need to be performed before any earth is removed from the ground. But that is the whole point of the WBS - it is the tool that helps identify anything that might take time in the project, and since that time usually translates into money, it helps determine if we really can afford to do the project within our budget.

"Earth disposal" might be another sub-project. For example, a decision may be to use the earth taken out of the ground to build a garden in another part of the yard. This sub-project would require its own breakdown of major parts.

Let's take a look, in figure 2, at what the WBS of the hole might look like.

Notice that the lines under sub-deliverable "hole" and the two sub-projects extend further than what we've identified.
That's because work packages, in this example those actions that need to be undertaken to remove the earth or dispose of the earth, have yet to be added to our WBS. Work packages are the lowest level of any branch of the WBS where resources will be assigned responsibility. Let's take a look at what types of actions or work packages can be identified so far in our structure.

The pond, as a whole, will need to be designed. This design of the pond will probably be a drawing of what the entire pond should look like once it is completed. The drawing should show each of the major parts of the pond that we decide will be part of the scope. Keep in mind that this work package can be broken down further into individual tasks, such as conducting a site survey, developing a drawing, and having the drawing reviewed and approved by the customer. You could almost say that this is a project in itself.

The pond will need to be tested. Maybe this will involve nothing more than an inspection that will take too small an amount of time to track on the project, but it will take time nonetheless. In other projects, a test might be further broken down into such work packages as developing a test plan, identifying various test scenarios, performing the tests, writing the test reports, etc., each of which could be broken down further.

Now let's take a look at the hole for the pond. The hole will need it own design. This design is different from the pond design because the hole needs a drawing that shows how long it should be, how wide it should be, how deep it should be, and where the shelves to hold those plants that need water but do not like being at the bottom of the pond ("bog plants" needed for filtration) should be constructed. A test will have to be conducted to make sure the hole will hold the plants properly. This test will take time and that time needs to be included in the project plan, especially if you want the project completed over a limited period of time, like a weekend.

The method for removing the earth has to be determined. An environmental assessment may need to be performed before any earth is removed. Do we need to buy a shovel, rent a backhoe, acquire some dynamite? If we build a garden with the removed earth, then the garden will need to be designed, and so on.

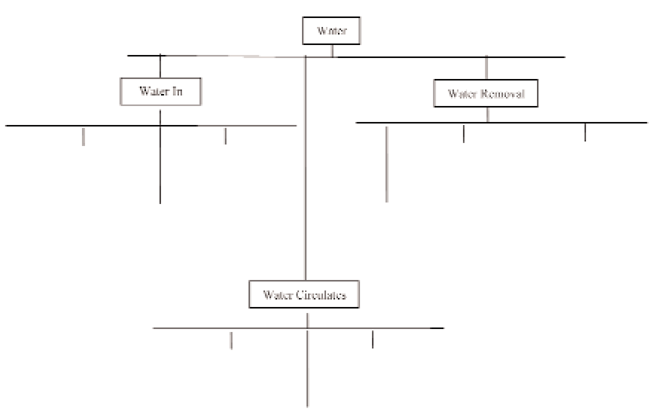

Figure 3—Breakdown of Water Sub-Deliverable

Now let's look at the sub-deliverable "water." The following three major functions have to take place to have water in the pond (which are very similar to any project that must deliver an information system, often referred to as an information technology, or IT, project).

- water has to get into the pond (input of information);
- water has to circulate (processing and storage of information); and
- at times water has to be drained from the pond (distribution of information), as displayed in figure 3.

Each of these can functions can be a sub-project. For example, "water in" could mean an entire plumbing system that pumps water from a water source to the pond. Often a landscape artist who specializes in ponds will contract this out to someone who specializes in plumbing systems. The details of this plumbing system should be broken down by someone who is familiar with all the requirements of this kind of system.

Water circulating would require a pump, which in turn requires electricity, which might be another sub-project where a certified electrician might be needed to run a new electrical line from the power source of the house to the area of the pond for the pump to plug or tap into. A water treatment or waterfall that might be one of the major components of the pond would need to interface with this pump via a hose or tubing that would have to be purchased. This water treatment may require a more powerful pump. Filters for the pump will be required. In other words, the circulation of water is a project in itself.

Water draining might also require an environmental study, depending on how and where the water is to be drained. An actual drain might need to be buried, which would change the requirements of the sub-project for earth removal.

Again, the work of each of these identified sub-projects and components takes effort that will cost money and will take time. Accordingly, decisions about whether or not to include these sub-projects and components in the scope of the project need to be made before any of this work can be planned. I'm not sure who first said it, but you can't plan what you don't know. The WBS is the tool that helps us figure it all out - or at least as much of it as we can.

STEP —DETERMINE WHO WILL PERFORM THE WORK AND WHAT IT MIGHT COST

For our example, let's say our resources and materials choices are as displayed in figure-4 and after the requirements analysis, WBS, and these estimates are identified, the roll-up is as shown in figure 5. Now let's say the customer's budget is $1,500. As you can see, the plan is already over-budget. Either the budget must be raised to afford all of this scope or the parts of the pond must be eliminated or acquired at a lower cost.

This balance of scope to budget must take place before the work identification is complete. If we were to go forward without balancing the scope, the earned value analysis will do nothing more than show us that we are over-budget at some point in time during the project. The balance of the "triple constraint," i.e., the scope to the budget to the time, is crucial for earned value management to be properly implemented.

STEP 3—PLAN AND SCHEDULE THE DEFINED WORK FOR THE AGREED UPON SCOPE

Once we know the work that will produce the agreed upon scope, we must now schedule that work using the standard scheduling techniques?.

Project Team Members	Charge Rates
Supervisor	$75/hour
Designer	$50/hour
Buyer	$35/hour
Tester	$35/hour
Skilled Laborer	$25/hour
Unskilled Labor	$15/hour

Work Estimates	
Major Design	1 hour
Minor Design	1/2 hour
Any Buy	1 hour
Fill Pond	3 hours
Major Test	1 hour
Minor Test/Inspect	1/2 hour
Minor Installs	10 minutes
Install Liner	30 minutes
Install Border	6 hours
Build Waterfall	2 hours
Dig Hole	4 hours

Materials Costs:	
Plants:	
Oxygenating grasses	$4.00/bunch
Bog Plants:	
Cattails	$10.95/plant
Irises	$23.95/plant
Papyrus	$26.95/plant
Floating Plants:	
Lotus	$67.95/plant
Waterlillies	$46.95/plant
Water Hyacinth	$12.95/plant
Fish:	
Shabunkins	$8.95/fish
Koi	$22.95/fish
Snails	$5.00/12 snails
Liners:	
Hard Molded Liner	$125.95
Soft Liner	$72.95
Water Test Kit	$15.95
Pumps:	
Heavy Duty Pump	$87.95
Regular Pump	$56.95
Rock:	
Round River Rock	$298/pallet
Flat River Rock	$376/pallet
Flagstone	$496/pallet

Figure 4—Resource and Material Estimates

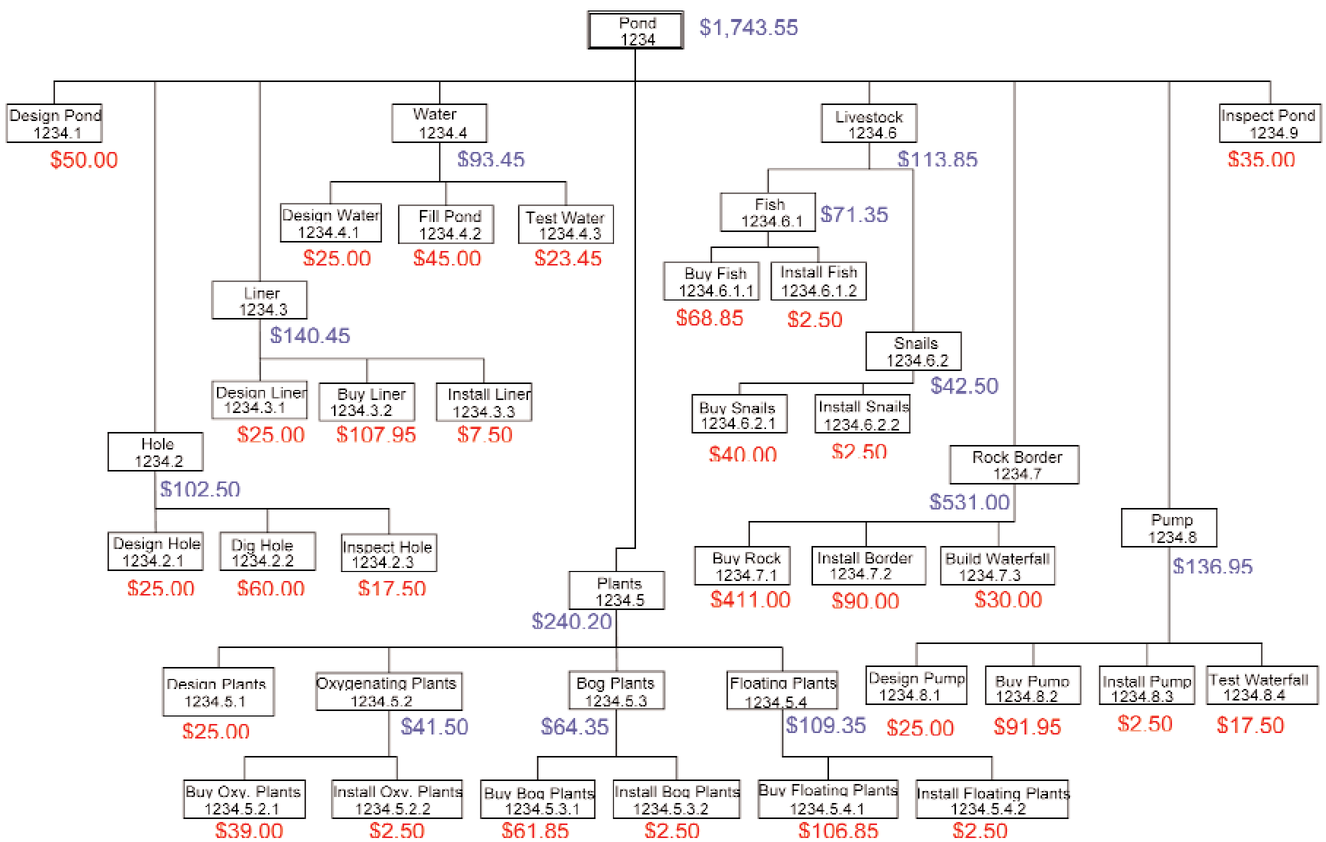

Figure 5—Estimated Costs Rolled Up the WBS

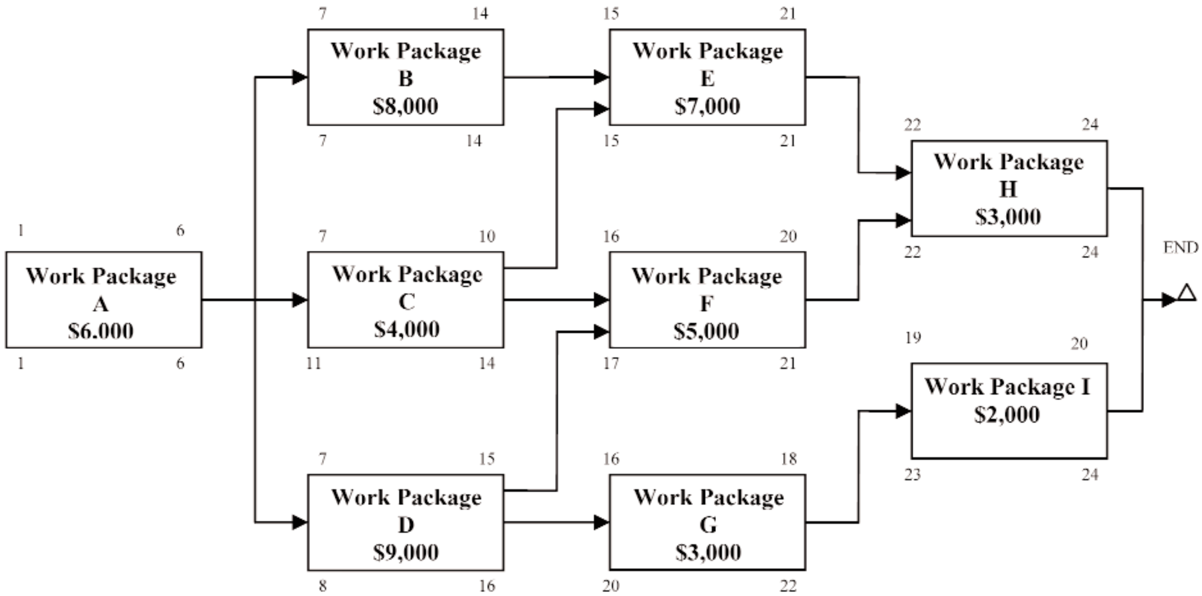

Figure 6—Budget Allocated to the Work Packages

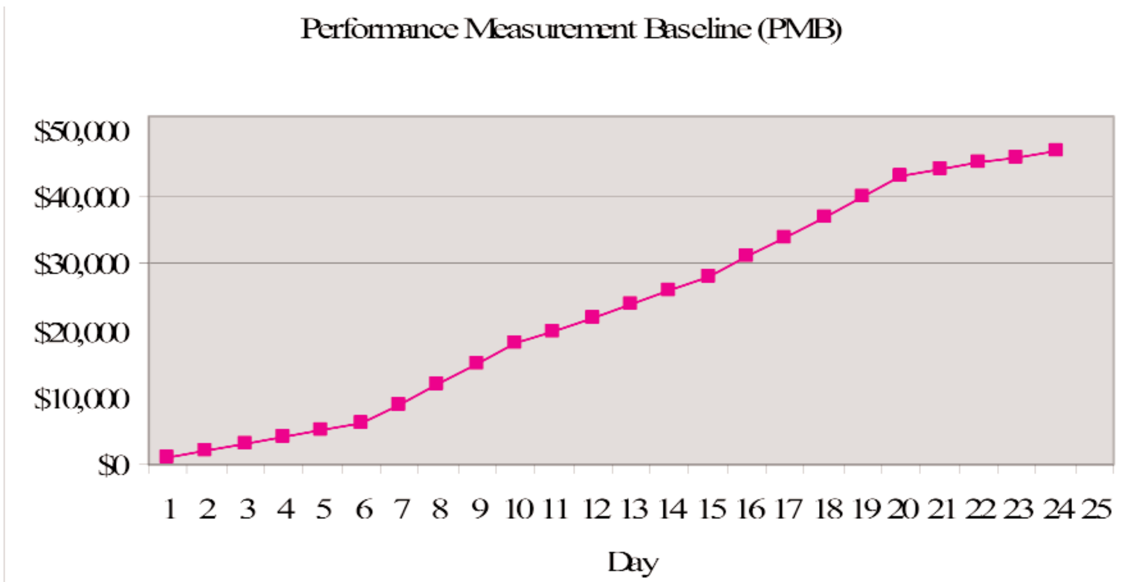

Figure 7—The Performance Measurement Baseline

STEP 4—DETERMINE POINTS OF MANAGEMENT CONTROL

The level of the WBS above the work packages is commonly referred to as the control account. In our example shown in figure 5, we form control accounts at the hole, at the liner, at the water, at each of the plants, etc. This would allow us to collect planned, earned, and actual data that can be analyzed to determine where problems are "cropping up" and to do something about the problem before it erodes the project as a whole.

STEP 5—AUTHORIZE BUDGETS FOR THE BASELINED PLAN

Once we have agreement on the scope, the estimates of the costs, and the scheduling of our plan, i.e., a balanced triple constraint, we lock the costs and time estimates in, and turn them into budgets for each work package. This is where the term "budgeted cost of work" starts. Figure 6 shows the budgeted work in a precedence diagram.

Now that the budgets are allocated and the schedule is baselined, what is called a performance measurement baseline (our flight plan) can be developed, figure 7, by graphing what we plan to spend over time.

As can been seen in our example, the performance measurement baseline (PMB) is an accumulation of the individual budgets of each work package over time. The final data point on the PMB chart is the cumulative sum of the budgets of all the work packages in the project. This data point is called the budget at completion (BAC) and will be a data point that we will use in our earned value analysis.

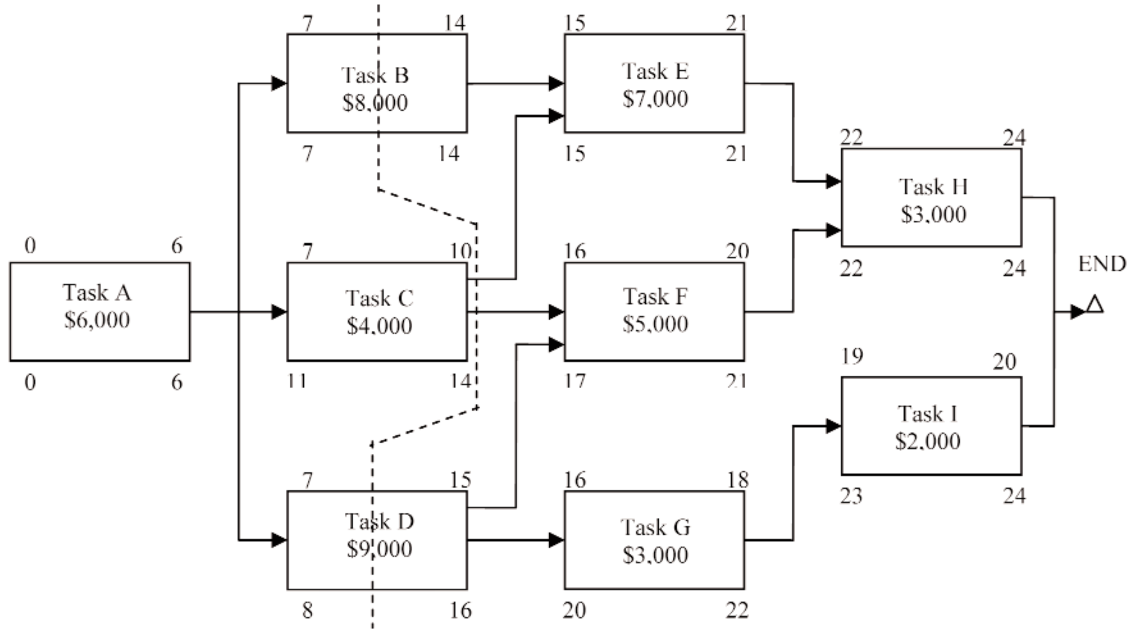

Figure 8—Baseline Schedule Showing Status Dat

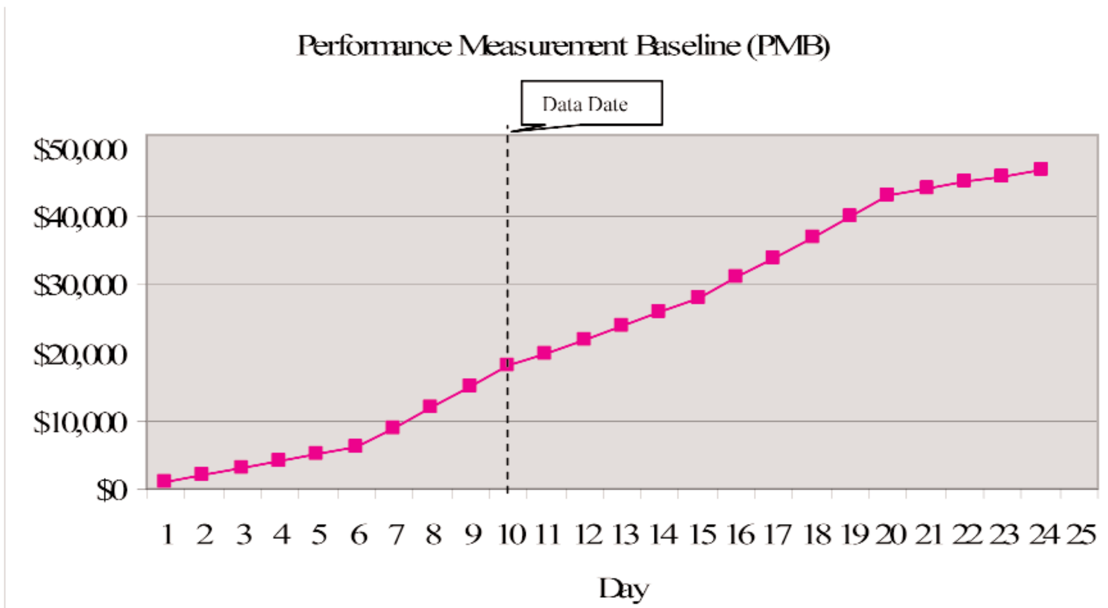

Figure 9—PMB with Planned Value as of Day 10 Displayed

STEP 6—DEFINE METRICS TO MEASURE PERFORMANCE OF WORK WITHIN EACH CONTROL POINT

Essentially, calculating earned value of each work package is a simple multiplication of the percent complete of the work package, times the budget that we allocated for that work package. To determine that percent complete we need to pre-determine how we will measure the work package. The most common techniques are the following:

- effort/(effort + remaining);
- physical percentage complete;
- weighted milestones or inchstones; and
- 50/50 rule, 20/80 rule, 0/100 rule.

An example of effort/(effort + remaining) is when we originally thought a work package would take us 80 hours worth of work and we allocated budget based on that estimate. The team working on the work package have expended 40 hours and they estimate that they will need another 60 hours to complete it. That means our percent complete will be 40/100 or 40 percent complete.

Physical percentage complete is based on a physical deliverable and what percent complete that deliverable exhibits. In order to not be subjective, this type of measurement usually requires identification of physical metrics that can be counted, such as lines of code, components installed, etc.

When physical metrics can not be determined, another method is to break the work package into lower level milestones or inchstones and identify a weighted percent complete for

Task	Total Task Budget	Planned Value (PV) As of Day 10
A	$6,000.00	$6,000.00
B	$8,000.00	$4,000.00
C	$4,000.00	$4,000.00
D	$9,000.00	$4,000.00
Project	**BAC = $47,000.00**	**$18,000.00**

Table 1—Sample Calculation of Planned Value as of Day 10

each, the total of which would equal 100 percent for the entire work package.

When there is no metric available, a decision can be made to use a "rule" that designates the work package as 50 percent complete at the time of actual start and the work package stays at 50 percent complete until an actual finish is recognized, at which time the remaining 50 percent is granted for a total of 100 percent of the work package – the 50/50 rule. The 20/80 rule grants 20 percent at the actual start with the remaining 80 percent granted at the actual finish of the work package. The 0/100 rule grants nothing until the work package is 100 percent complete.

STEP 7—RECORD ACTUAL COSTS OF THE WORK

Recording actual costs for each work package, or even at the control account level, is the challenge of an earned value management system. To many the idea of recording time or costs at the lower levels of the WBS equates to "bean counting." In order for this criteria to be accomplished each team member must enter their time on a timesheet, which is foreign and even intrusive to many people. This stems from the lack of understanding of the value of completing this task on a regular basis. This is where the "leadership" ability of the project manager is called upon.

The actual cost (AC) is also known as the actual cost of work performed (ACWP.)

STEP 8—MEASURE PERFORMANCE AND DETERMINE PROJECT PERFORMANCE

Like the flight plan, the baseline sets up a guidance system for the project. The baseline aids in directing the project execution to the ultimate goal of accomplishing all the work on time and within budget. Just as for the pilot, the idea is not to be precisely on the baseline, but to be able to hover around the baseline. To do this, we need to know where the baseline is.

The planned value (PV), also known as the budgeted cost of work scheduled (BCWS), is the point on the baseline where the line representing the date that status will be reported intersects the baseline. This line is often referred to as a data date or status date. The PV (BCWS) represents the portion of the budget we expected to spend as of the status date if all work is accomplished exactly as we planned. Figure 8 shows how the PV is determined for day 10 using our previous baseline example.

Task A is planned to be completed by day 10, so all of Task A's budget will be in the PV. Task B is planned to be 50 percent complete by day 10, so 50 percent of Task B's budget will be in the PV. Task C is planned to be completed by day 10, so all of Task C's budget will be in the PV. Finally, Task D is planned to have four days of its nine-day duration completed by day 10, so 4/9 of Task D's budget will be in the PV. Table 1 shows the PV for this project as of day 10.

The project PV can also be displayed using the PMB, as shown in figure 9.

Remember, the basic formula for calculating the earned value (EV), also known as the budgeted cost of work performed (BCWP) is:

Table 2 demonstrates earned value data for our example.

To perform earned value analysis, we need to have collected PV, AC, and EV, plus BAC (Figure 10 shows the cumulative data graphed on the PMB.)

Variances are simple calculations that tell us whether the project is ahead or behind schedule by calculating the schedule variance (SV) and whether the project is showing signs of going over or under budget by calculating the cost variance (CV). The formulas for these two variance indicators are:

Task	Total Task Budget	Planned Value (PV) As of Day 10	% Comp	Earned Value (EV) As of Day 10
A	$6,000.00	$6,000.00	100%	$6,000.00
B	$8,000.00	$4,000.00	25%	$2,000.00
C	$4,000.00	$4,000.00	75%	$3,000.00
D	$9,000.00	$4,000.00	50%	$4,500.00
Project	**BAC = $47,000.00**	**$18,000.00**		**$15,500.00**

Table 2—Sample Calculation of Earned Value as of Day 10

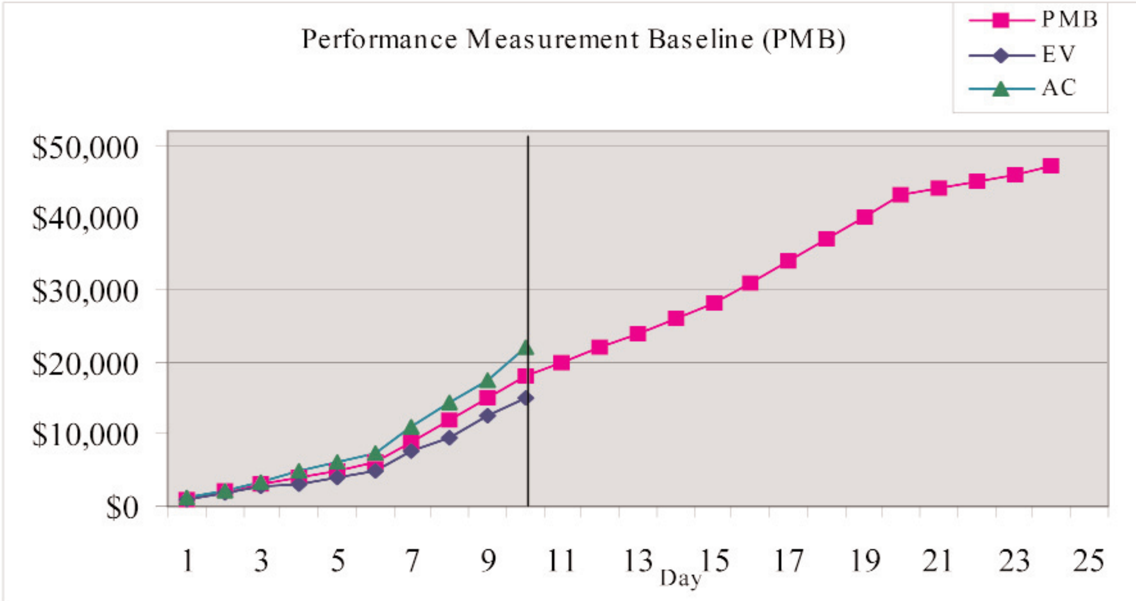

Figure 10—PMB with Earned Value Analysis Data as of Day 10 Displayed

SV = EV - PV

CV = EV - AC

In both calculations a positive or negative result equates to the status shown in table 3.

	Positive	Negative
SV	Ahead of schedule	Behind schedule
CV	Under budget	Over budget

Table 3—Variance Status Results

Figure 11 shows how the variances can be identified using the PMB.

While variances are nice to know, they are not useful for comparing the performance of one project to another, nor can they be used to isolate issues within a project, since they are not relative to the size of what's being analyzed. For a relative indication of performance we would want to calculate the performance indexes.

The performance indexes calculate performance relative to a unit, such as a dollar or an hour of effort. Here we calculate the schedule performance index (SPI) to determine the performance for every dollar (or whatever unit of currency or effort is being used in the analysis) scheduled to be spent according to the baselined plan. The cost performance index (CPI) tells us the performance for every dollar that has been spent at this time in the project. The formulas for these indexes are:

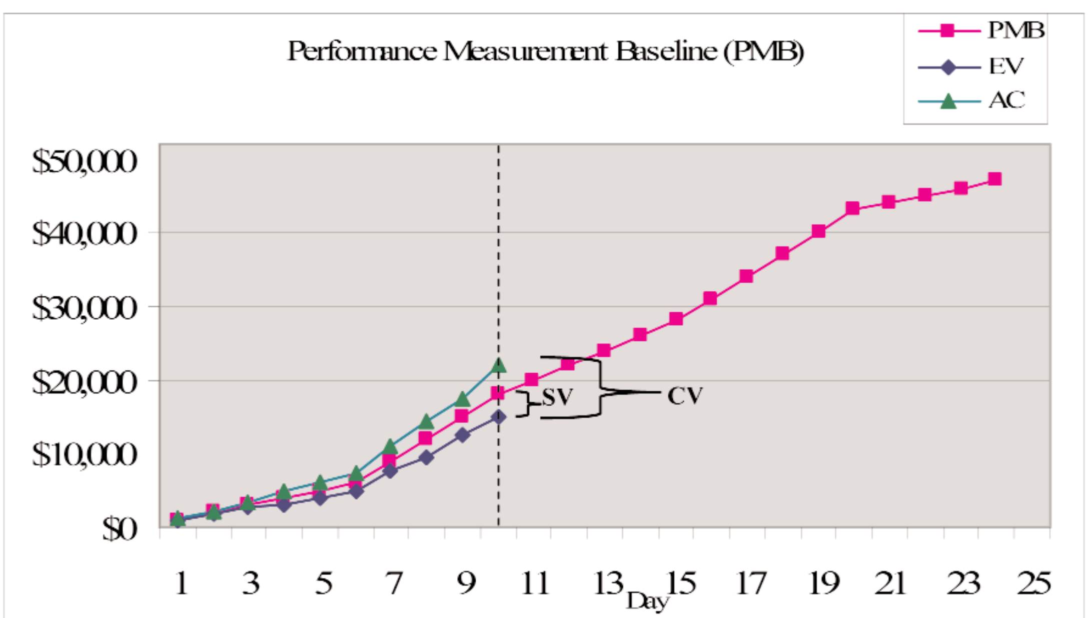

Figure 11—PMB Showing Earned Value Analysis Variance

$$SPI = \frac{EV}{PV}$$

$$CPI = \frac{EV}{AC}$$

Let's look at an example:

PV = \$45,000
EV = \$35,000
AC = \$40,000
SV = -\$10,000
CV = -\$5,000
SPI = 0.78
CPI = 0.86

The SV and the CV, both negative, tell us that the project is behind schedule and over budget. The SPI tells us that for every dollar we planned to spend on this project, we are getting 78 cents worth of performance. The CPI is telling us that for every dollar we have spent so far on this project, we are getting 86 cents worth of performance. If our tolerance is +10 percent, we would expect either performance indicator to be between 0.90 and 1.10 to be in control. Since neither is within the thresholds of our control area, we can say our project is out of control, both in terms of schedule and cost.

Let's look at a similar example:

PV = \$145,000
EV = \$135,000
AC = \$140,000
SV = -\$10,000
CV = -\$5,000
SPI = 0.93
CPI = 0.96

The SV and the CV are exactly the same as in the previous example and only tell us that the project is behind schedule and over budget. The SPI tells us that for every dollar we planned to spend on this project, we are getting 93 cents worth of performance. The CPI is telling us that for every dollar we have spent so far on this project, we are getting 96 cents worth of performance. With a tolerance of +10 figure, both are within the thresholds of our control area, so we can say this project is in control both in terms of schedule and cost.

Thus, the performance indicators are relative to the size of the project and produce much more useful information than the variances alone. Because they are relative to size we can use the performance indexes and the WBS to isolate problems at the control accounts of the project, before the project is out of control and formulate actions proactively to resolve these problems. As shown in Figure 12, the project is doing quite well with a performance index of 0.98, which is well within a +10 percent tolerance. However, if we look at the control accounts, we see Plants has a performance index of 0.87, which is outside our +10 percent tolerance and indicates a problem in that area.

Relevance-to-size indicators also lend themselves very well to being charted individually over time. Figure 13 shows the SPI and CPI charted over time using "stoplight" type colors of green when things are going very well; yellow, when the problem resolution should start to be considered; and red, when the project

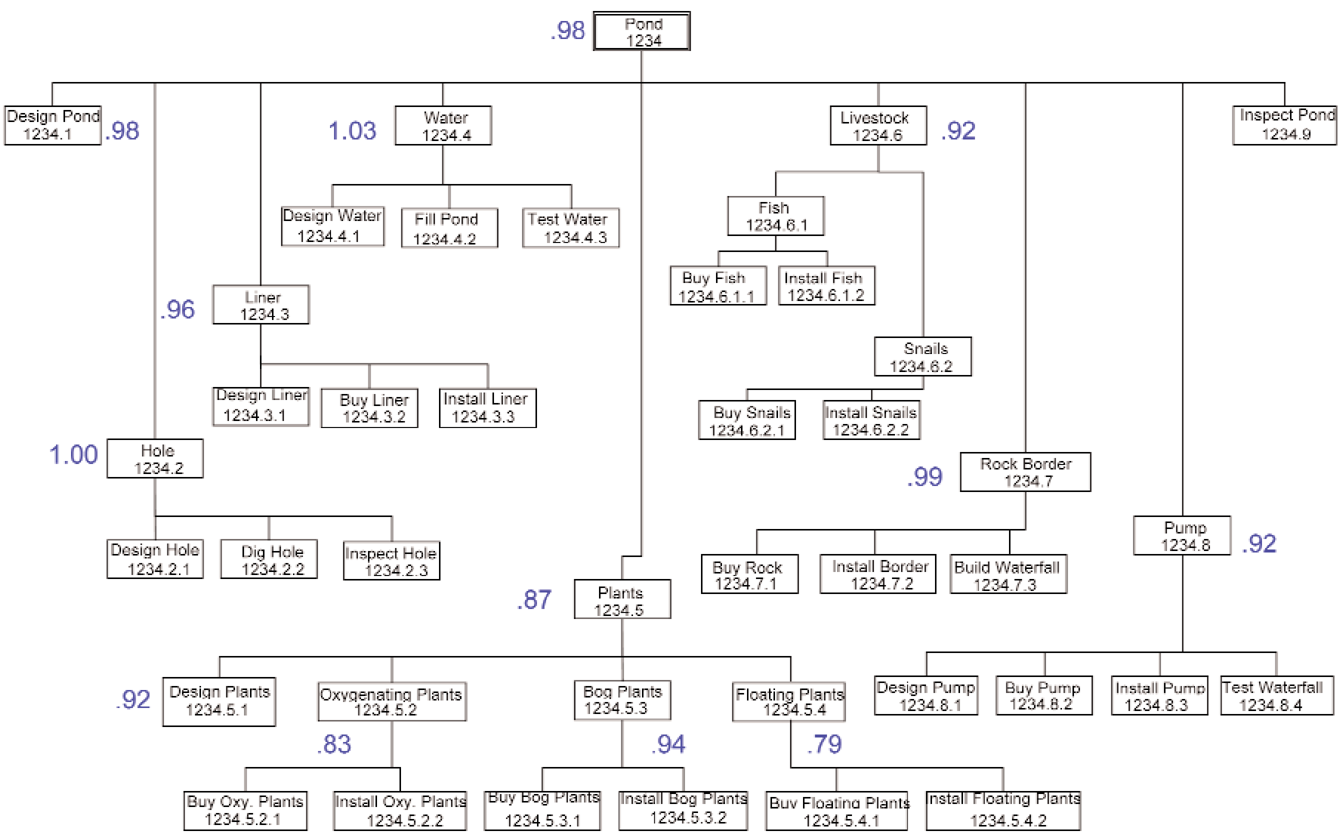

Figure 12—Using Performance Indicators With the WBS

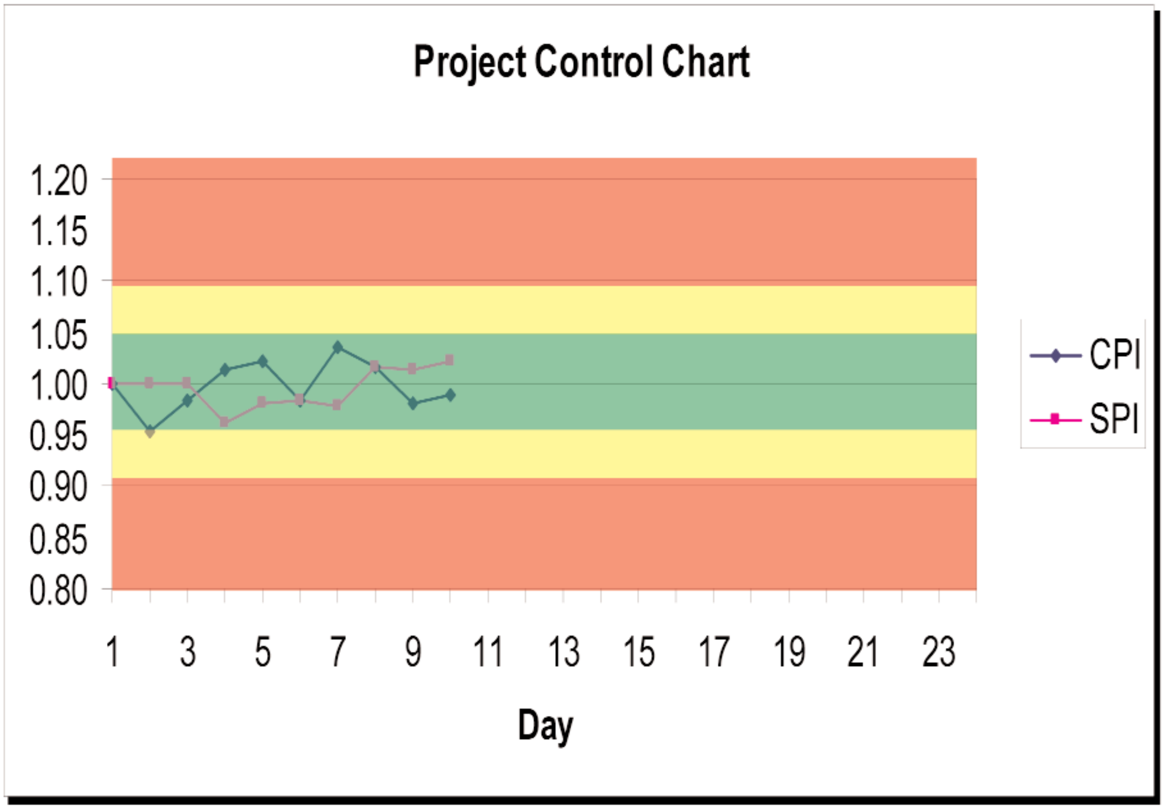

Figure 13—Performance Indicators Charted Over Time

or control account is out of control and actions need to be put in place to gain control.

STEP 9—FORECAST FUTURE PERFORMANCE

Just like the pilot of a plane, a project manager must monitor the resources needed for the future of the project. The second category of earned value analysis formulas helps us do just that.

The earned value analysis formula for predicting what the total project costs could be if things do not change is called the estimate at completion (EAC). The following are two formulas (of a multitude available) for various analytical situations:

- A simple way:

$$EAC = \frac{BAC}{CPI}$$

- A more complex way:

$$EAC = AC + \frac{BAC-EV}{CPI*SPI}$$

Using our sample data:

PV = \$45,000
EV = \$35,000
AC = \$40,000
SV = -\$10,000
CV = -\$5,000
SPI = 0.78
CPI = 0.86
BAC = \$100,000

Our EAC using both formulas would be:

$$EAC_{Simple} = \$100{,}000/0.86 = \$116{,}279$$
$$\begin{aligned} EAC_{Complex} &= \$40{,}000 + (\$100{,}000 - \$35{,}000)/0.86*0.78 \\ &= \$40{,}000 + \$65{,}000/0.67 \\ &= \$40{,}000 + \$97{,}015 \\ &= \$137{,}015 \end{aligned}$$

Keep in mind that all this forecasting analysis is still trying to predict the future and should always be qualified with the caveat "if things do not change."

A calculation of how much money or effort might be needed to complete the project, if things do not change, is known as the estimate to complete (ETC):

$$ETC = EAC-AC$$

For our sample using the complex EAC:

$$ETC = \$137{,}015 - \$40{,}000 = \$97{,}015$$

In this example we might need almost as much as our original budget to complete the rest of the work of the project.

Another simple calculation that will tell us if the project is likely to overrun or underrun the budget if things do not change is the variance at completion (VAC):

$$VAC - BAC-EAC$$

With our sample data:

VAC = \$100,000 - \$137,015 = -\$37,015

Again, if the VAC is negative, the project could go over budget.

The to-complete-performance-index (TCPI) is calculated by taking the money, or effort hours, remaining and dividing it by the work remaining:

$$TCPI = \frac{BAC - EV}{BAC - AC}$$

For our sample data:

TCPI = (\$100,000 - \$40,000)/(\$100,000 - \$35,000)
= \$65,000/\$60,000 = 1.08

This represents the amount of performance needed, from the data date forward, to complete the project for the budget that was baselined.

Step 10—Manage Changes to the Agreed Upon Baseline

One of the primary steps in controlling the cost and schedule during execution of the project is to establish a certain discipline on the project baseline, i.e., the baseline never changes unless a formal change management process has taken place. This does not mean that the work packages of the baselined scope cannot be replanned and rescheduled; however, many circumstances that cannot be controlled by any project manager can cause the project to be out of control. If the reality of the cost or schedule status of the project happens to be out of the control area of the baseline, then it is not this reality that is incorrect. The original plan that is represented by the baseline is incorrect and therefore may need to be changed.

The change management process should incorporate the following types of activities:

- An agreement of by both the customer and the project team on the level of change management control required.
- A form documenting that the change (e.g., a change request form).
- A team to analyze the change.
- A governing board.
- An agreed amount of budget and time for all approved changes. And,
- A rebaselining of the approved replan.

The baseline is the guidance system that makes the integrated process of earned value management work.

So Why Should We Do It?

Because earned value management is just basic good project management.

Ursula Kuehn, EVP
UQN and Associates
1515 Richie Lane
Annapolis, Maryland, 21401, US
Phone: +1.443.822.7400
Email: ursula@uqnandassociates