All budgets must be traceable through the budget "log," which includes:

• Distributed budget

• Management reserve

• Undistributed budget

• Contract changes

Management reserve is the dollar amount established by the project office to budget for all categories of unforeseen problems and contingencies resulting in out-of-scope work to the performers. Management reserve should be used for tasks or dollars, such as rate changes, and not to cover up bad planning estimates or budget overruns. When a significant change occurs in the rate structure, the total performance budget should be adjusted.

In addition to the "normal" performance budget and the management reserve budget, there also exists the following:

• Undistributed budget, which is that budget associated with contract changes where time constraints prevent the necessary planning to incorporate the change into the performance budget. (This effort may be time-constrained.)

• Unallocated budget, which represents a logical grouping of contract tasks that have not yet been identified and/or authorized.

15.5— Variance and Earned Value

A variance is defined as any schedule, technical performance, or cost deviation from a specific plan. Variances are used by all levels of management to verify the budgeting system and the scheduling system. The budgeting and scheduling system variance must be compared together because:

• The cost variance compares deviations only from the budget and does not provide a measure of comparison between work scheduled and work accomplished.

• The scheduling variance provides a comparison between planned and actual performance but does not include costs.

There are two primary methods of measurement:

• *Measurable efforts:* discrete increments of work with a definable schedule for accomplishment, whose completion produces tangible results.

• *Level of effort:* work that does not lend itself to subdivision into discrete scheduled increments of work, such as project support and project control.

Variances are used on both types of measurement.

In order to calculate variances we must define the three basic variances for budgeting and actual costs for work scheduled and performed. Archibald defines these variables:[3]

• Budgeted cost for work scheduled (BCWS) is the budgeted amount of cost for work scheduled to be accomplished plus the amount or level of effort or apportioned effort scheduled to be accomplished in a given time period.

• Budget cost for work performed (BCWP) is the budgeted amount of cost for completed work, plus budgeted for level of effort or apportioned effort activity completed within a given time period. This is sometimes referred to as "earned value."

• Actual cost for work performed (ACWP) is the amount reported as actually expended in completing the work accomplished within a given time period.

These costs can then be applied to any level of the work breakdown structure (i.e., program, project, task, subtask, work package) for work that is completed, in-program, or anticipated. Using these definitions, the following variance definitions are obtained:

• Cost variance (CV) calculation:

$$CV = BCWP - ACWP$$

A negative variance indicates a cost-overrun condition.

• Schedule variance (SV) calculation:

$$SV = BCWP - BCWS$$

A negative variance indicates a behind-schedule condition.

In the analysis of both cost and schedule, costs are used as the lowest common denominator. In other words, the schedule variance is given as a function of cost. To alleviate this problem, the variances are usually converted to percentages:

$$\text{Cost variance \% (CVP)} = \frac{CV}{BCWP}$$

$$\text{Schedule variance \% (SVP)} = \frac{SV}{BCWS}$$

The schedule variance may be represented by hours, days, weeks, or even dollars.

[3] Russell D. Archibald, *Managing High-Technology Programs and Projects* (New York: John Wiley & Sons, 1976), p. 176.

As an example, consider a project that is scheduled to spend $100K for each of the first four weeks of the project. The actual expenditures at the end of week four are $325K. Therefore, BCWS = $400K and ACWP = $325K. From these two parameters alone, there are several possible explanations as to project status. However, if BCWP is now known, say $300K, then the project is behind schedule and overrunning costs.

Variances are almost always identified as critical items and are reported to all organizational levels. Critical variances are established for each level of the organization in accordance with management policies.

Not all companies have a uniform methodology for variance thresholds. Permitted variances may be dependent on such factors as:

• Life-cycle phase

• Length of life-cycle phase

• Length of project

• Type of estimate

• Accuracy of estimate

Variance controls may be different from program to program. Table 15–2 identifies sample variance criteria for program X.

For many programs and projects, variances are permitted to change over the duration of the program. For strict manufacturing programs (product management), variances may be fixed over the program time span using criteria as in Table 15–2. For programs that include research and development, larger deviations may be permitted during the earlier phases than during the later phases. Figure 15–11 shows time-phased cost variances for a program requiring research and development, qualification, and production phases. Since the risk should decrease as time goes on, the variance boundaries are reduced. Figure 15–12 shows that the variance envelope in such a case may be dependent on the type of estimate.

By using both cost and schedule variance, we can develop an integrated cost/schedule reporting system that provides the basis for variance analysis by

TABLE 15–2. VARIANCE CONTROL FOR PROGRAM X

Organizational Level	**Variance Thresholds***
Section	Variances greater than $750 that exceed 25% of costs
Section	Variances greater than $2500 that exceed 10% of costs
Section	Variances greater than $20,000
Department	Variances greater than $2000 that exceed 25% of costs
Department	Variances greater than $7500 that exceed 10% of costs
Department	Variances greater than $40,000
Division	Variances greater than $10,000 that exceed 10% of costs

*Thresholds are usually tighter within company reporting system than required external to government. Thresholds for external reporting are usually adjusted during various phases of program (% lower at end).

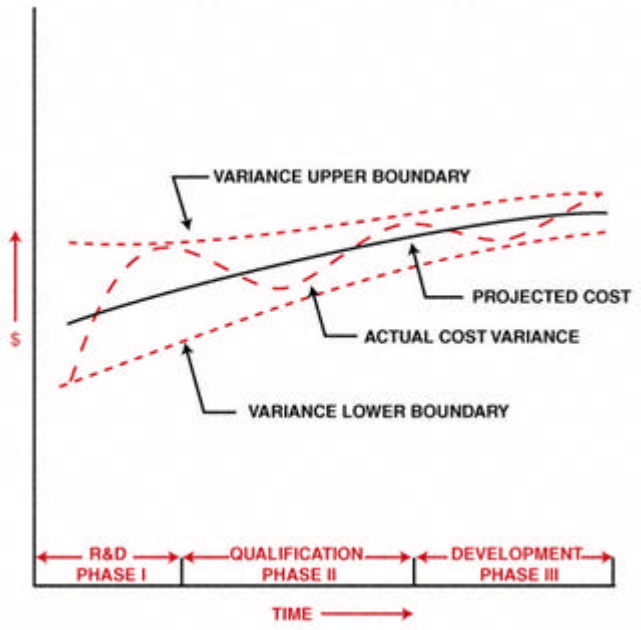

Figure 15–11.
Project variance projection.

measuring cost performance in relation to work accomplished. This system ensures that both cost budgeting and performance scheduling are constructed on the same database.

In addition to calculating the cost and schedule variances in terms of dollars or percentages, we also want to know how efficiently the work has been accomplished. The formulas used to calculate the performance efficiency as a percentage of BCWP are:

$$\text{Cost performance index (CPI)} = \frac{\text{BCWP}}{\text{ACWP}}$$

$$\text{Schedule performance index (SPI)} = \frac{\text{BCWP}}{\text{BCWS}}$$

If CPI = 1.0, we have perfect performance. If CPI > 1.0, we have exceptional performance. If CPI < 1.0, we have poor performance. The same analysis can be applied to the SPI.

LIFE CYCLE PHASE	MANPOWER REQUIRED	$ REQUIRED	TIME DURATION	TYPE OF ESTIMATE	ACCURACY	PERMITTEI VARIANCE
MAIN	16,000 HRS.	1,285,600	6 MOS	HISTORY	±5%	±2%

Figure 15–12.
Methodology to variance.

The cost and schedule performance index is most often used for trend analysis as shown in Figure 15–13. Companies use either three-month, four-month, or six-month moving averages to predict trends. The usefulness of trend analysis is to take corrective action to alleviate unfavorable trends by having an early warning system. Unfortunately, effective use of trend analysis may be restricted to long-term projects because of the time needed to correct the situation.

Figure 15–14 shows an integrated cost/schedule system. The figure identifies a performance slippage to date. This might not be a bad situation if the costs are proportionately underrun. However, from the upper portion of Figure 15–14, we find that costs are overrun (in comparison to budget costs), thus adding to the severity of the situation.

Also shown in Figure 15–14 is the management reserve. This is identified as the difference between the contracted cost for projected performance to date and the budgeted cost. Management reserves are the contingency funds established by

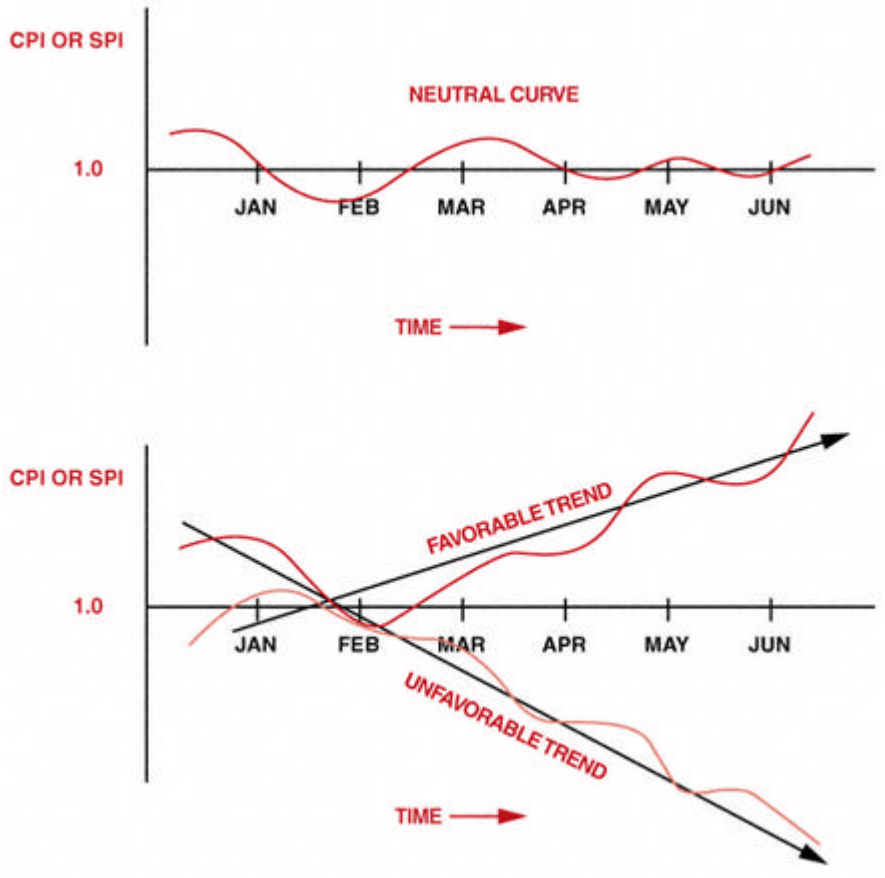

Figure 15–13.
The performance index.

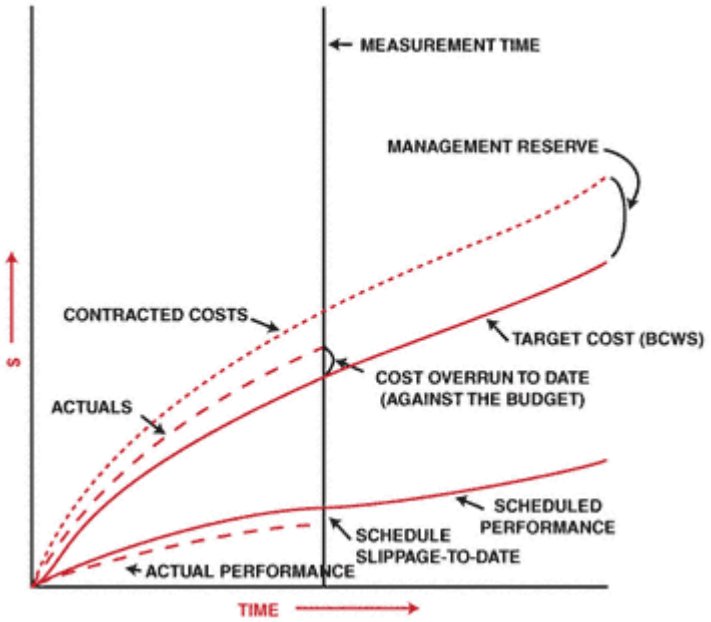

Figure 15–14.
Integrated cost/schedule system.

the program manager to counteract unavoidable delays that can affect the project's critical path. Management reserves cover unforeseen events *within* a defined project scope that experience has shown are likely to occur. Management reserves are not used for unlikely major force events or changes in scope. These changes are funded separately, perhaps through management-established contingency funds. Actually, there is a difference between management reserves (which come from project budgets) and contingency funds (which come from external sources) although most people do not differentiate. It is a natural tendency for a functional manager (and some project managers) to substantially inflate estimates to protect the particular organization and provide a certain amount of cushion. Furthermore, if the inflated budget is approved, managers will undoubtedly use all of the allocated funds, including reserves. According to Parkinson:[4]

- The work at hand expands to fill the time available.
- Expenditures rise to meet budget.

Managers must identify all such reserves for contingency plans, in time, cost, and performance (i.e., PERT slack time).

[4] C. N. Parkinson, *Parkinson's Law* (Boston: Houghton Mifflin, 1957).

The line indicated as actual cost in Figure 15–14 shows a cost overrun compared to the budget. However, costs are still within the contractual requirement if we consider the management reserve. Therefore, things may not be as bad as they seem.

Government subcontractors are required to have a government-approved cost/schedule control system. The information requirements that must be demonstrated by such a system include:

• Budgeted cost for work scheduled (BCWS)

• Budgeted cost for work performed (BCWP)

• Actual cost for work performed (ACWP)

• Estimated cost at completion

• Budgeted cost at completion

• Cost and schedule variances/explanations

• Traceability

The last two items imply that standardized policies and procedures should exist for reporting and controlling variances.

When permitted variances are exceeded, cost account variance analysis reports, as shown in Figure 15–15, are required. Signature approval of these reports may be required by:

• The functional employees responsible for the work

• The functional managers responsible for the work

• The cost accountant and/or the assistant project manager for cost control

• The project manager, work breakdown structure element manager, or someone with signature authority from the project office.

For variance analysis, the goal of the cost account manager (whether project officer or functional employee) is to take action that will correct the problem within the original budget or justify a new estimate.

• Five questions must be addressed during variance analysis:

• What is the problem causing the variance?

• What is the impact on time, cost, and performance?

• What is the impact on other efforts, if any?

• What corrective action is planned or under way?

• What are the expected results of the corrective action?

One of the key parameters used in variance analysis is the "earned value" concept, which is the same as BCWP. Earned value (or whatever other name might be used in the literature) is a forecasting variable used to predict whether the project will finish over or under the budget. As an example, on June 1, the budget showed that 800 hours should have been expended for a given task. However,

only 600 hours appeared on the labor report. Therefore, the performance is (800/600) × 100, or 133 percent, and the task is underrunning in per-

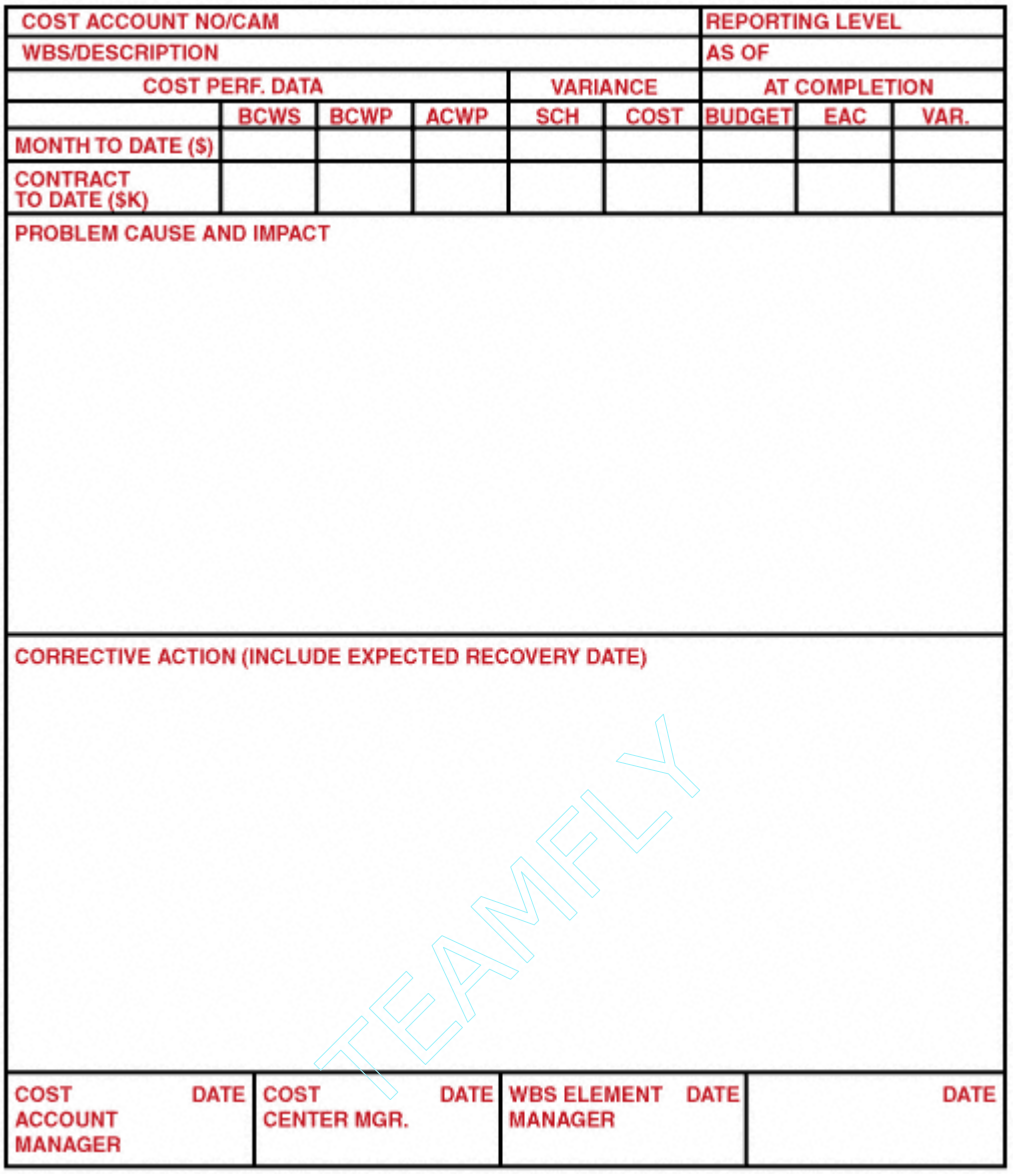

Figure 15–15.
Cost account variance analysis report.

formance. If the actual hours were 1,000, the performance would be 80 percent, and an overrun would be occurring.

The difficulty in performing variance analysis is the calculation of BCWP because one must predict the percent complete. To eliminate this problem, many companies use standard dollar expenditures for the project, regardless of percent complete. For example, we could say that 10 percent of the costs are to be "booked" for each 10 percent of the time interval. Another technique, and perhaps the most common, is the 50/50 rule:

> Half of the budget for each element is recorded at the time that the work is scheduled to begin, and the other half at the time that the work is scheduled to be completed. For a project with a large number of elements, the amount of distortion from such a procedure is minimal. (Figures 15–16 and 15–17 illustrate this technique.)

One advantage of using the 50/50 rule is that it eliminates the necessity for the continuous determination of the percent complete. However, if percent com-

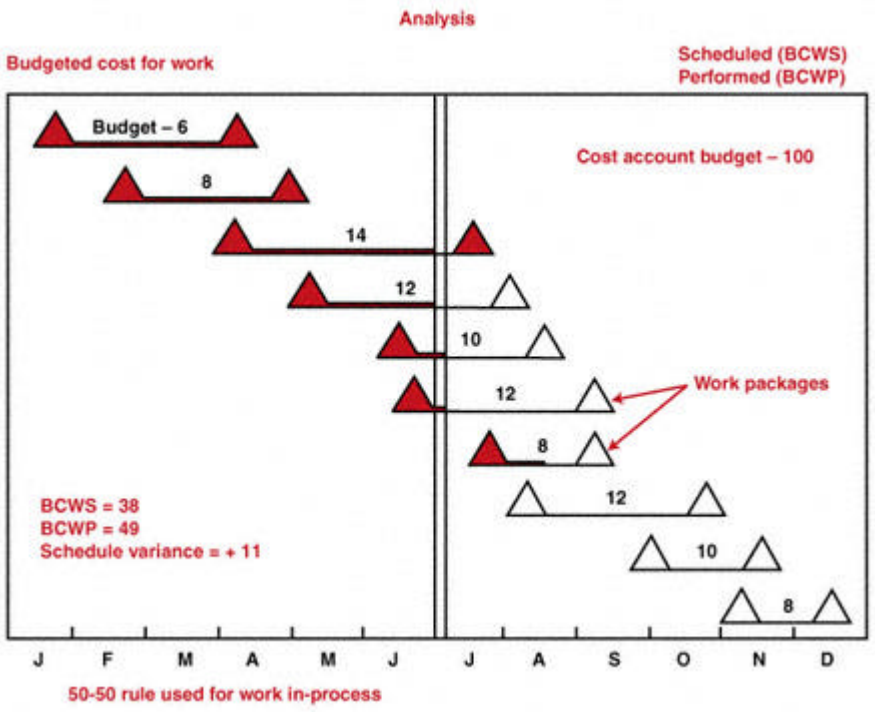

Figure 15–16.
Analysis showing use of 50/50 rule.

plete can be determined, then percent complete can be plotted against time expended, as shown in Figure 15–18.

There are techniques available other than the 50/50 rule:[5]

• 0/100—Usually limited to work packages (activities) of small duration (i.e., less than one month). No value is earned until the activity is complete.

• Milestone—This is used for long work packages with associated interim milestones, or a functional group of activities with a milestone established at identified control points. Value is earned when the milestone is completed. In these cases, a budget is assigned to the milestone rather than the work packages.

• Percent complete—Usually invoked for long-duration work packages (i.e., three months or more) where milestones cannot be identified. The value earned would be the reported percent of the budget.

[5] These techniques, in addition to the 50/50 method for determining work in progress, are available in software packages. The reader might wish to contact AGS Management Systems, 800 First Avenue, King of Prussia, PA 19406.

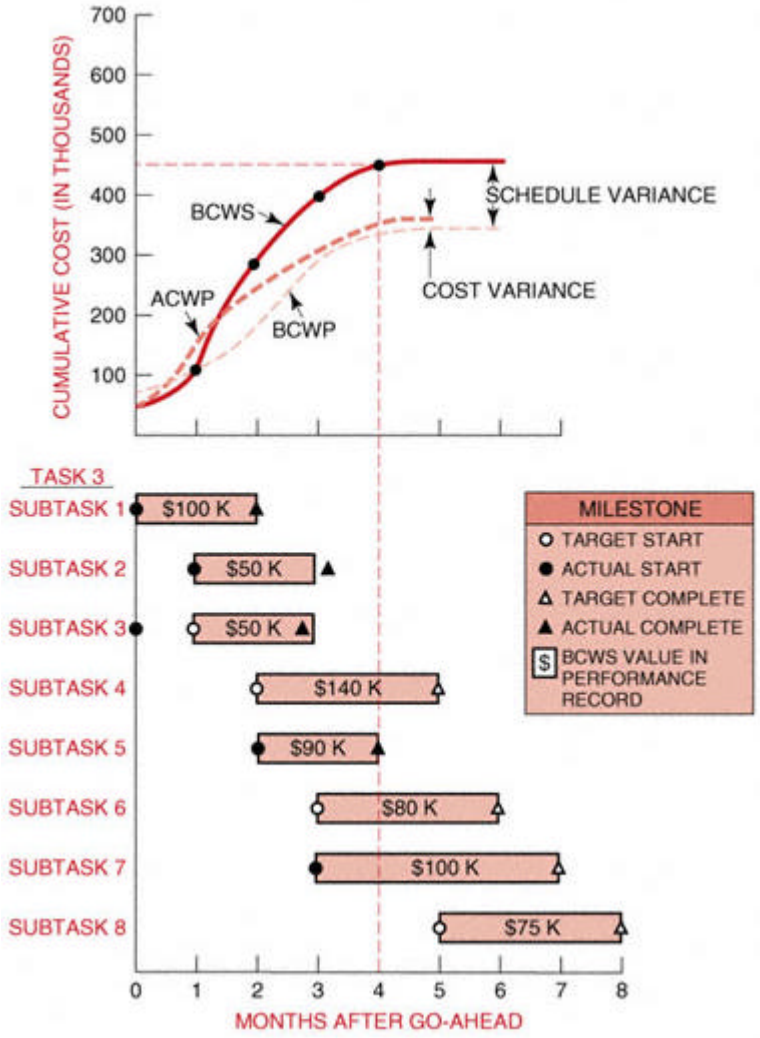

Figure 15–17.
Project Z, task 3 cost data (contractual).

• Equivalent units—Used for multiple similar-unit work packages, where earnings are on completed units, rather than labor.

• Cost formula (80/20)—A variation of percent complete for long-duration work packages.

• Level of effort—This method is based on the passage of time, often used for supervision and management work packages. The value earned is based on time expended over total scheduled time. It is measured in terms of resources consumed over a given period of time and does not result in a final product.

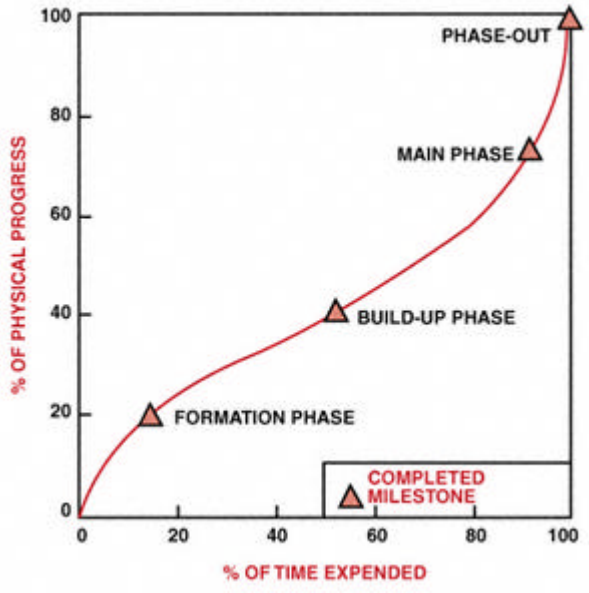

Figure 15–18.
Physical progress versus time expended.

• Apportioned effort—A rarely used technique, for special related work packages. As an example, a production work package might have an apportioned inspection work package of 20 percent. There are only a few applications of this technique. Many people will try to use this for super-vision, which is not a valid application. This technique is used for effort that is not readily divisible into short-span work packages but that is in proportion to some other measured effort.

Generally speaking, the concept of earned value may not be an effective control tool if used in the lower levels of the WBS. Task levels and above are normally worth the effort for the calculation of earned value. As an example, consider Figure 15–17, which shows the contractual cost data for task 3 of project Z, and Table 15–3, which shows the cost data status at the end of the fourth month. The following is a brief summary of the cost data for each subtask in task 3 at the end of the fourth month:

• Subtask 1: All contractual funds were budgeted. Cost/performance was on time as indicated by the milestone position. Subtask is complete.

• Subtask 2: All contractual funds were budgeted. A cost overrun of $5,000 was incurred, and milestone was completed later than expected. Subtask is completed.

• Subtask 3: Subtask is completed. Costs were underrun by $10,000, probably because of early start.

TABLE 15–3. PROJECT Z, TASK 3 COST DATA STATUS AT END OF FOURTH MONTH (COST IN THOUSANDS)

Subtasks	Status	BCWS	BCWP	ACWP
1	Completed	100	100	100
2	Completed	50	50	55
3	Completed	50	50	40
4	Not started	70	0	0
5	Completed	90	90	140
6	Not started	40	0	0
7	Started	50	50	25
8	Not started	—	—	—
Total		450	340	360

Note. The data assume a 50/50 ratio for planned and earned values of budget.

• Subtask 4: Work is behind schedule. Actually, work has not yet begun.

• Subtask 5: Work is completed on schedule, but with a $50,000 cost overrun.

• Subtask 6: Work has not yet started. Effort is behind schedule.

• Subtask 7: Work has begun and appears to be 25 percent complete.

• Subtask 8: Work has not yet started.

~~To complete our analysis of the status of a project, we must determine the budget at completion (BAC) and the estimate at completion (EAC)? Table 15–4 shows the parameters for variance analysis.~~

~~• The budget at completion is the sum of all budgets (BCWS) allocated to the project. This is often synonymous with the project baseline. This is what the total effort should cost.~~

~~• The estimate at completion identifies either the dollars or hours that represent a realistic appraisal of the work when performed. It is the sum of all direct and indirect costs to date plus the estimate of all authorized work remaining (EAC = cumulative actuals + the estimate-to-complete).~~

~~TABLE 15–4. THE PARAMETERS FOR VARIANCE ANALYSIS~~

~~Question~~	~~Answer~~	~~Acronym~~
~~How much work *should* be done?~~	~~Budgeted cost of work scheduled~~	~~BCWS~~
~~How much work *is* done?~~	~~Budgeted cost of work performed~~	~~BCWP~~
~~How much *did* the "is done" work cost?~~	~~Actual cost of work performed (actuals)~~	~~ACWP~~
~~What was the total job *supposed* to cost?~~	~~Budget at completion (total budget)~~	~~BAC~~
~~What do we *now* expect the total job to cost?~~	~~Estimate at completion or latest revised estimate~~	~~EAC LRE~~