

Comparing Methods of Measuring Progress, Earned Values & Estimated Cost at Completion

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Introduction

There is general agreement among shipbuilders that intelligent control over basic resources (engineering, manpower, material, facilities and time) will result in improved ship construction costs.

The task of estimating costs, planning and scheduling men and materials and then controlling these resources to maximize production output, while minimizing costs, can be a very difficult job. These efforts become more complex with the increase in the size of the shipyard organization and the scope of the yard operations. Modern-day shipbuilding poses no mean management challenge.

A very basic problem has been work progress visibility, or lack thereof. Without it, management must operate blindly. Cause and effect relationships become blurred in the midst of daily shipyard production problems and drain away the capacity to direct production effectively and economically. Knowing precisely, and in a timely manner, the exact status of men and material, a responsible management can rectify problems quickly before they become critical. Logical priorities can then be assigned to solving various impacted areas of production and ideally new techniques can be developed, simulated and evaluated to improve current yard production methods. These are the basic goals for what is called a shipbuilder's earned value system, or EVMS.

Simply put, EVMS is a tool that allows the shipbuilder to have visibility into technical, cost, and schedule progress on their contracts. It is a means for measuring progress, for measuring current cost and schedule variances from plan and for forecasting final costs and schedules at any point in time of the contract duration.

Most shipyards today have means for accounting and reporting work resources and schedules, but mostly employ manual methods to obtain EVM information. These methods often have difficulty producing complete, accurate and timely information. Other shipyards use EVM software products that are not fully integrated with the daily business transactions of the shipyard. Transcribing only summary information from the shipyard's operating systems can result in the EVM system not recognizing problems that are occurring down in the roots of operations. Also, making certain simplified assumptions for the EVM data can result in misleading conclusions.

The quality and timeliness of information determines its value and potential benefit. This applies to all of the EVM data described below (progress, earned value, etc.). If the EVM data is poor or even worse incorrect, then it may very well impact management's ability to make good decisions. This document describes the good, the bad, and the ugly of EVM data.

Earned Value Report Information

One of the core pieces of information necessary for a successful earned value management system is an accurate assessment of progress. Progress is the basis for measuring earned value (budgeted cost of work performed, or BCWP) and earned value is the basis for measuring cost and schedule variances. Without an accurate assessment of progress, the entire credibility of the earned value system is in jeopardy.

At any point in time over the course of a contract, when the actual cost of work performed, or ACWP, exceeds the planned earned value (BCWP), there is a cost problem that must be addressed. This variance indicates that current costs are being expended over budget and might indicate a problem that uncorrected could jeopardize the success of the project.

Of equal importance to progress and earned value is a forecast of final costs, the estimated costs at completion, or EAC. An EAC should be developed at regular time intervals through the course of a contract and compared with the total budget at completion, or BAC. When the EAC reports being greater than the BAC, or its trend appears to be increasing to a point later in time to exceed the BAC, contract management should begin in earnest to determine where problems are occurring and then initiate corrective actions.

Another important measure of progress is how it affects planned schedules. The accumulation of planned budgets over time is the budgeted cost of work scheduled, or BCWS. When the earned value, or BCWP, begins to lag the BCWS, the contract management should determine the source of the schedule problems and implement appropriate work around solutions.

How and when these EVM metrics are determined is critical in whether or not EVM reports are truly beneficial. Too often EVM systems are adopted simply because they are contract reporting requirements. As such, management may be less than willing to utilize EVM as an important management tool. Under these circumstances, the shipyard's efforts to develop realistic EVM reports will most likely be compromised. The first sign that EVM has not been fully implemented within the operations of an organization is when the EVM system is installed as a tertiary system practically disassociated from the primary business systems of the shipyard. Then, important EVM parameters, such as earned value and estimates at completion will be manually estimated, usually without reference to what is actually being performed in production.

Work Order Size & Schedule Duration

At the heart of a number of methods for measuring progress and estimating final costs at completion are work orders. They are the individual work tasks necessary to carry out the totality of the contract.

It is important that for a well-planned and scheduled project, work orders should be executed in their proper sequence unless problems arise and work-around plans need to be initiated. Doing work out of sequence can create problems down schedule with other work orders. It also can result in non-value added work if they must be interrupted and restarted later to finish.

Measuring progress for a very large project like building a ship can be a daunting and expensive exercise if done manually. A new construction project requiring one million labor hours can easily result in approximately 4,000 individual work orders. At any given point in time, a well planned and executed project may have 15%-20% of these work orders in process. Any more in process and either the risk of non-value added hours accumulated against the project or there is an increase in schedule risk due to too much work being done in parallel.

The size of work orders also is important. Too few with too long durations, and the ability to accurately measure their progress will be highly questionable. However, too many, and they can result in problems dealing with too many details especially with regard to time charging by employees.

For new construction, a good rule of thumb provides an approximate size for work orders to be 250-500 man-hours with schedule durations of about 2-3 weeks. However, level-of-effort (LOE), like support services, can be bigger in budget and longer in duration. Nevertheless, LOE work often becomes a cost problem due to their being so non-specific of work accomplished over time. SPAR's *PERCEPTION*¹ system provides a special type of work order for LOE called the time-phased work order. It breaks up the large scope of work into monthly budgeted sub-tasks that can be measured and reviewed monthly. Time charges are made against the total LOE work order, and the system determines which monthly sub-task to charge based on the date of the time charge.

Ship repair projects, on the other hand, more typically are of short schedules and are oriented around performing smaller tasks. For short order projects, progressing is less necessary than for longer term new construction projects.

¹ AKA Product Orient Design & Construction ("PODAC") Cost Model

Methods for Measuring Progress & Earned Value

There are many different methods for measuring progress of a contract. Popular choices include manual progress assessments of contract work orders; using various earned value rules, and other automated methods based on actual cost and schedule performance to planned work orders.

Progress can be measured in a number of different ways. Schedule progress is measured in terms of calendar time against a planned set of project schedules. Progress also can be measured in terms of materials fabricated or assembled and even by the amount of money spent. However, progress as developed for the earned value system more typically is based on labor hours.

Real Progress

Real progress can be tracked as actual labor hours against the final total labor hours expended on a project. This, however, requires knowing what the final total is. Therefore, real progress can only be estimated using the estimated hours at completion until the project is 100% finished.

$$\begin{aligned} \text{Real Progress} &= \text{Actual Hours} / \text{Total Actual Hours at Completion} \\ &= ACWP / EAC \end{aligned}$$

Planned Progress

Planned progress can be measured at any point in time over the course of a project when the labor hour budgets (work orders) have been time-phased. At any point in time, the cumulative schedule budget hours to that point in time is called the budgeted cost of work scheduled, or BCWS (Figure 1).

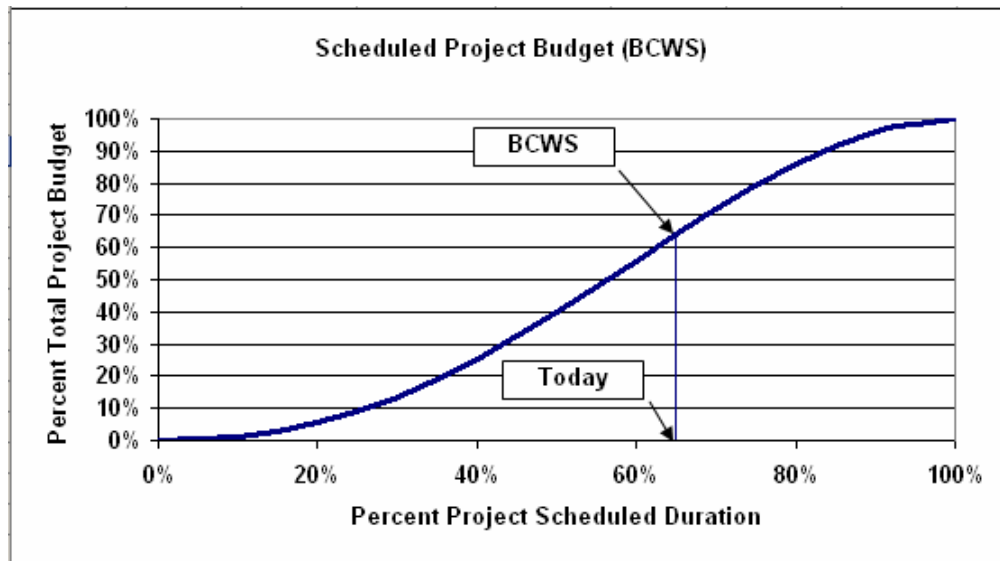


Figure 1: Time-Phasing Project Labor Hour Budgets

At the planned finished date for the project, the BCWS equals the total budget at completion, or BAC.

$$\text{Planned Progress} = \text{BCWS}/\text{BAC}$$

Manual Progress

Manually measuring 20% of these work orders requires 800 individual assessments each week. Another frequent problem is that there is always pressure to report good results. Manual progress assessments therefore can often be too optimistic such that early cost and schedule problems cannot be recognized even with earned value reporting methods.

There are two points in time when progress is most certainly known: a) when a work order has not yet been started and b) when a work order is completed. Sometimes the later status is not always correctly reported when subsequent reviews reveal that the work is not 100% complete and additional work is needed to really finish the job. Manual assessments can be largely subjective, and trying to get too accurate a progress figure can be a waste of valuable time. Simple figures of 10%, 20%, etc. should be sufficient.

The *PERCEPTION* system provides entries of manual progress estimates as well as it internally computed estimates described below.

Progress = Hours Spent/Budget Hours

Measuring progress as the ratio of hours spent to the total hour budget is acceptable, but only if the work is performed on-budget. But no one will know if the work order is on-budget until the work order is finished and a final tally of hours spent is compared with its budget. When work is running significantly over or under budget, the error in this assessment method will be significant. The over-run situation will leave an assessment of progress in a vacuum when the actual hours spent exceeds the budget. This means the earned value also is in a vacuum, and management cannot get a good picture of where costs and schedules are going until too late to initiate any remedies. And the under-run assessment will present an earned value that is less than it should be credited for the work being performed.

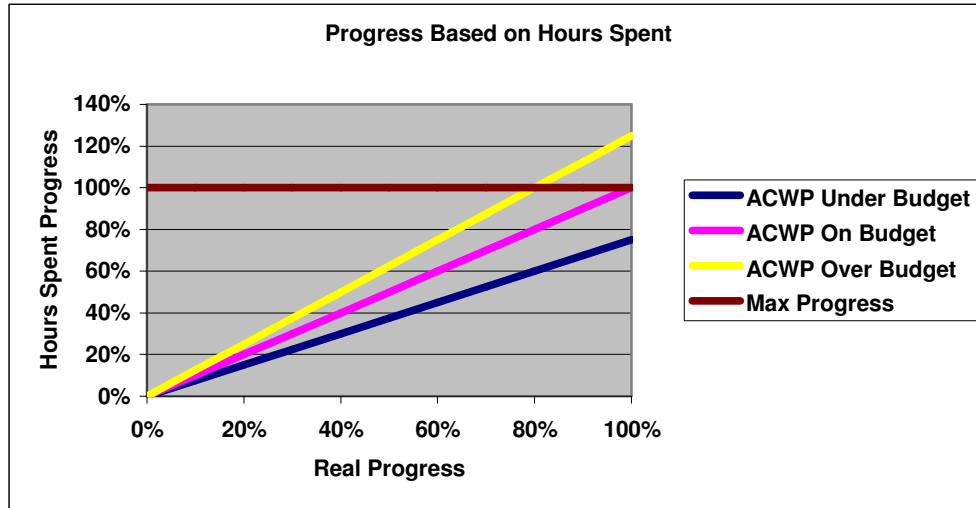


Figure 1: Drawbacks of Progress Based on Hours Spent

Figure 1 above illustrates the drawbacks of using hours spent as the basis for a progress assessment. In an over-run situation, this method will show better than budgeted progress until the entire budget has been spent. The reverse occurs for the under-run situation.

Pre-Formulated Earned Value Progress

Pre-formulated progress applies to methods for automating progress assessments. Popular methods are the 0/100 rule, 25/75 rule, 50/50 rule, the 80/20 rule and others. Except for the 0/100 rule, these methods assume an initial progress merely upon opening the work order, then assessing the final 100% upon the completion of the work order. Each rule places a different weight on either beginning a work order or finishing it. The benefit of this method of assessing progress is that it can be easily automated within an automated earned value management system. However, there are notable drawbacks.

Figure 2 below shows how various earned value rules would apply to one plan scenario. The plan is characterized by the distribution of its budget over time (budgeted cost of work performed, or BCWS), while the rule indicates how earned value will be determined at any given time. The rule applies to the work orders that are started or completed regardless of whether or not they in fact are executed according to the plan BCWS.

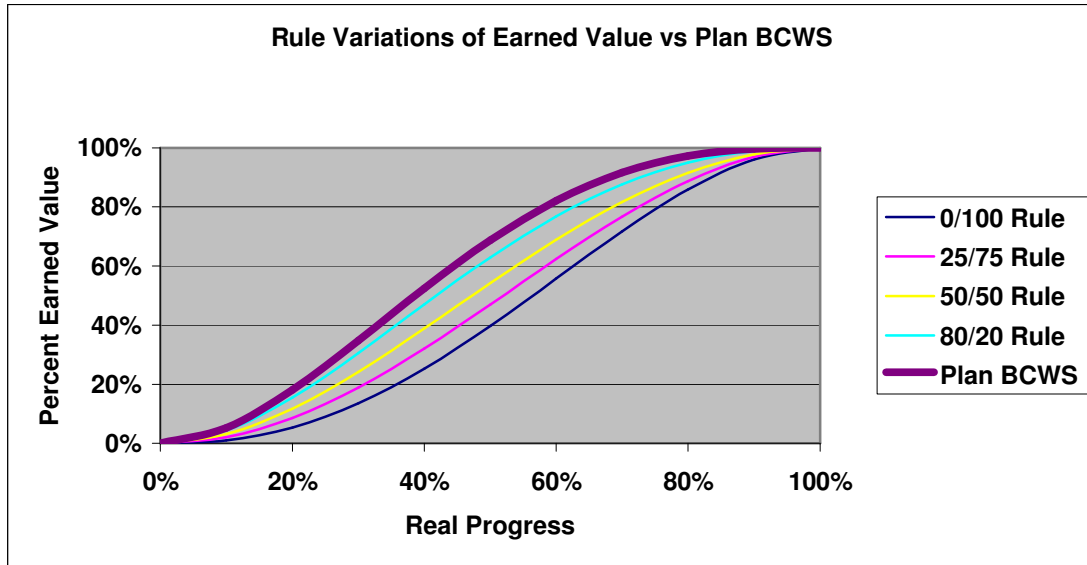


Figure 2: Applying Various Earned Value Rules to a Plan

The assumptions for earned values above are that the project is performing exactly as planned schedule-wise. This is rarely the case, however, as some work orders may be started either earlier or later than planned. Note that for this condition, the pre-formulated earned values will always be less than the actual earned values as the plan advances.

Under this plan there can be any number of scenarios for starting and completing work orders. Figure 3 below illustrates two separate curves under the plan BCWS: one shows the accumulated budgets of completed work orders; and the other shows the budgets of work in process. If the project remains on schedule, the difference between the completed budget curve and the planned BCWS curve represents the budgets of open, in-process work orders. The lower the amount of in-process work orders, the closer the curve of completed budgets approaches the total planned BCWS.

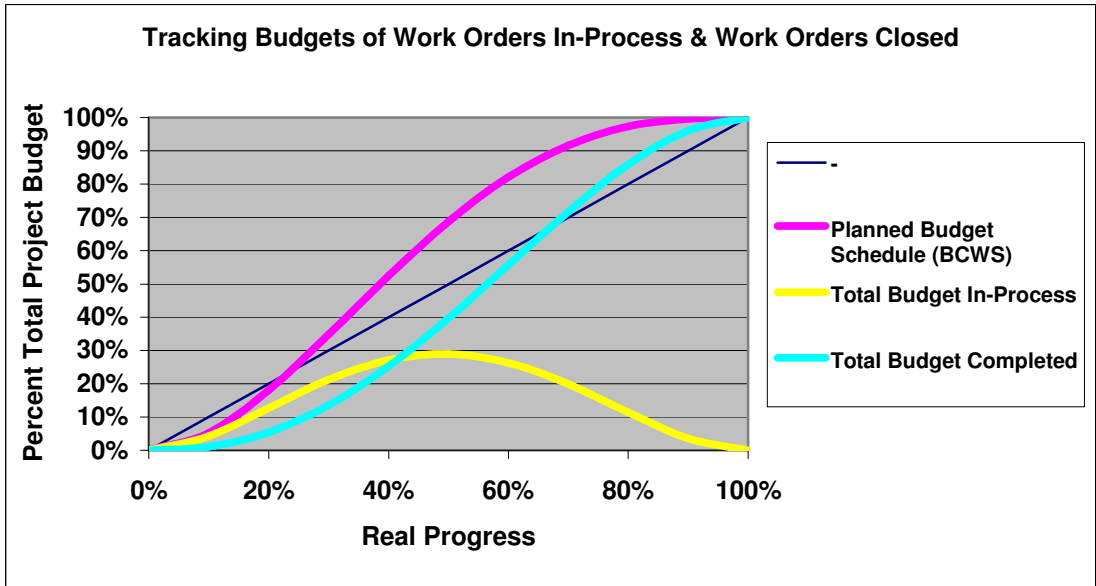


Figure 3: Tracking Budgets of Work Orders In-Process and Work Orders Completed (Closed)

But, what happens if the work orders are not performed according to plan. Figure 4 shows how more work orders are started earlier than planned. The in-process budgets now exceed the early portion of the planned BCWS.

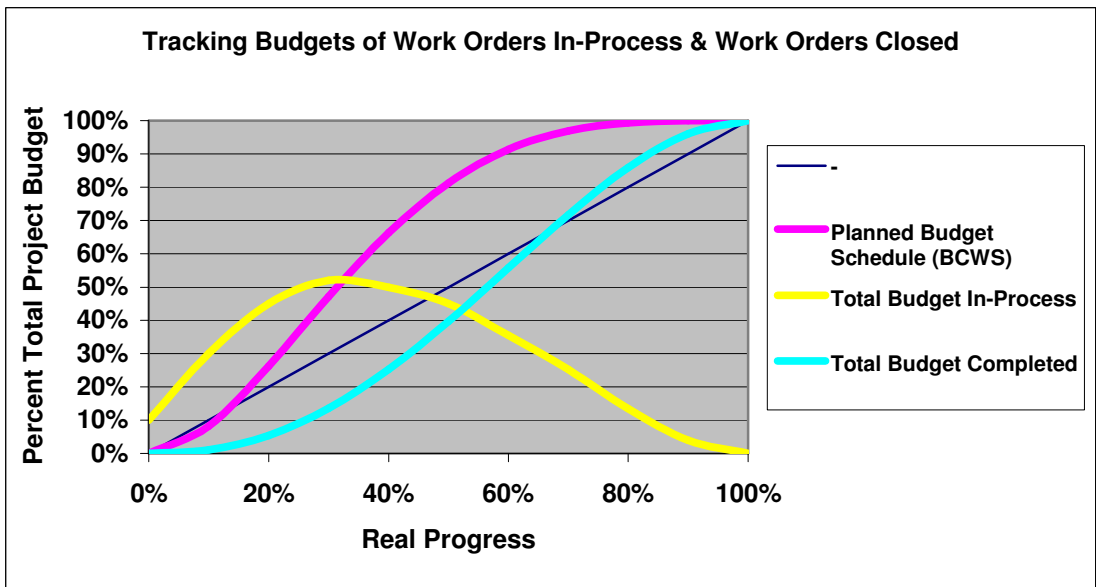


Figure 4: Starting Work Orders Earlier Than Planned.

Figure 5 shows the effect of these early starts will have under the various earned value rules.

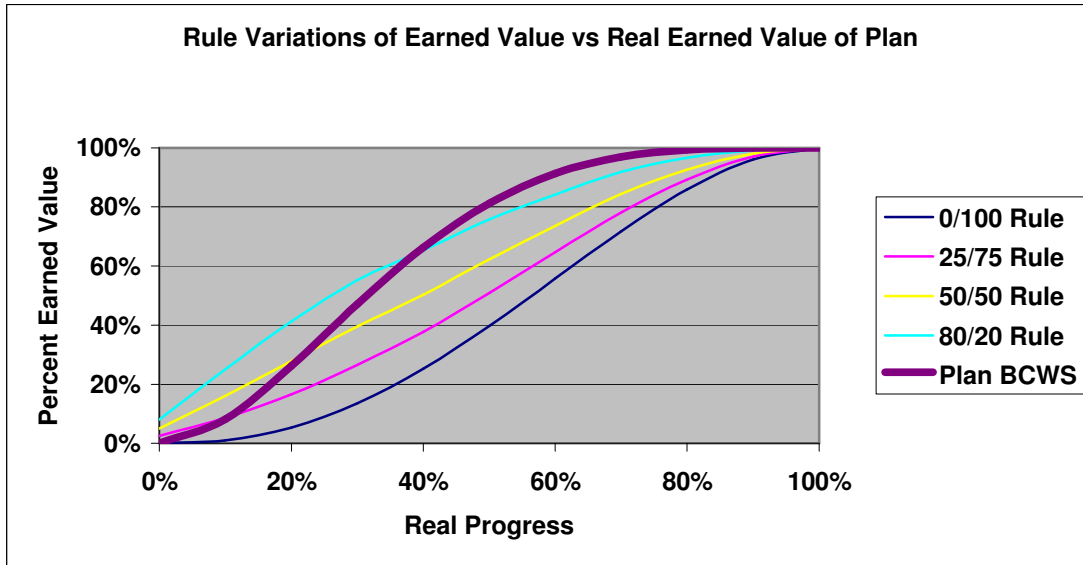


Figure 5: Applying Various Earned Value Rules to a Plan

Figure 5 shows that the earned value rules that place more weight on opening a work order can exhibit a positive schedule variance, while those rules with lower weights for starting may still indicate negative schedule variances. Unfortunately, the real schedule status can be blurred simply by the rule that is applied. These rules also can blur the real status of cost variances in the same way. Front loading the earned value with earlier starts can indicate a cost savings when there may very well be a cost problem. The more the weight is placed on the starting of a work order, the more the disguising of a true cost problem. This exemplifies how the selection of an earned value rule can be gamed for the early benefit of keeping cost and schedule problems under cover. Figure 6 illustrates examples of rule errors over the course of the planned schedule.

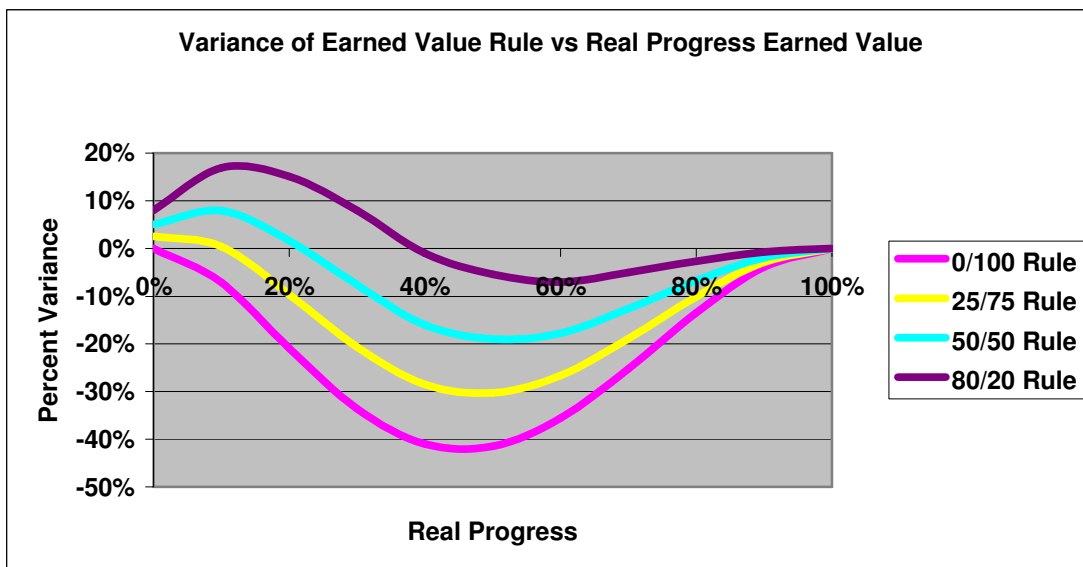


Figure 6: Range of Errors Introduced from Earned Value Rules

The accuracy of an earned value rule will depend on the length of time to start and finish a work order. The longer the planned work order duration, the less accurate will be the pre-formulated earned value, regardless of the rule applied. Figure 7 shows an example of earned values computed over time for work orders of relatively long durations. Figure 8 shows the very same schedule of the work effort, but the effort has been broken up into much smaller work orders of smaller schedule direction.

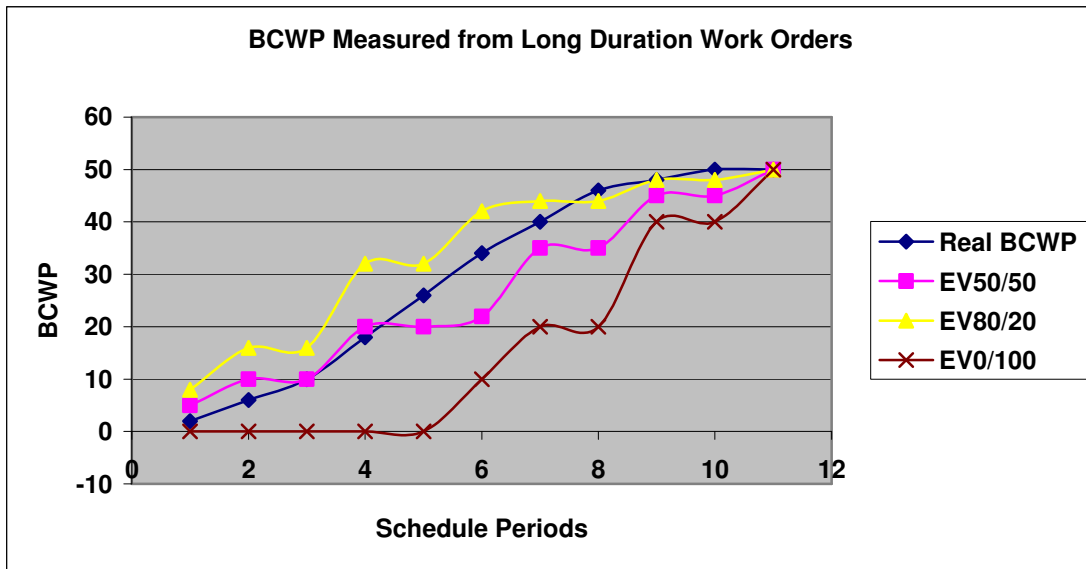


Figure 7: Measuring Earned Value by Pre-Formulated Rule with Long duration Work Orders

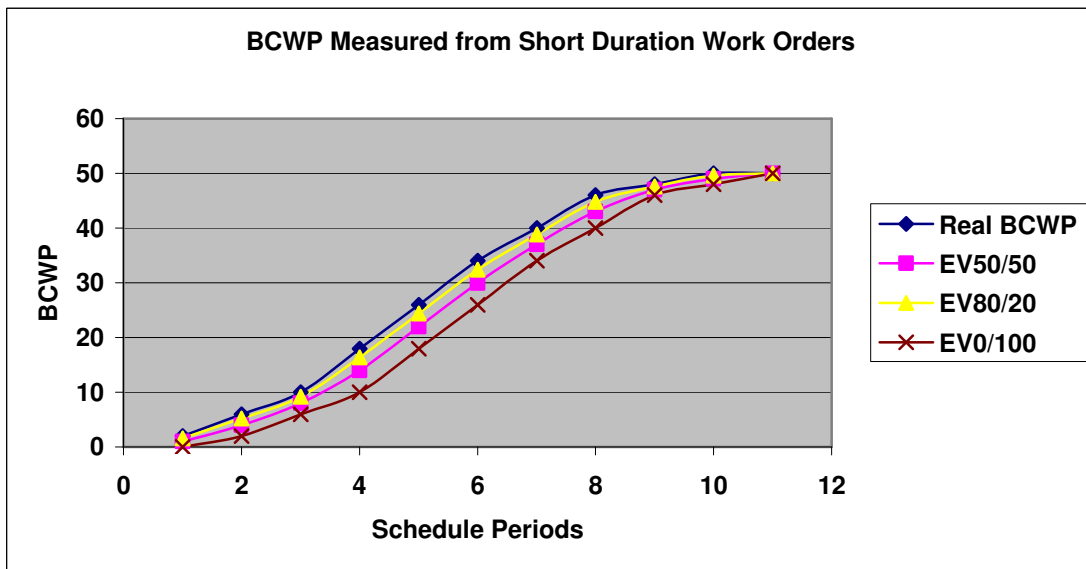


Figure 8: Measuring Earned Value by Pre-Formulated Rule with Short duration Work Orders

SPAR Progress

SPAR's *PERCEPTION* will accept manual progress entries and it also has the capability to measure work progress at any summary level of a project (SWBS, PWBS, COA work center, and production trade) automatically. The basis for these measurements is the labor hour budget performance of work orders.

Under most circumstances, *PERCEPTION* computes progress with the following formula:

$$P = 100 \times (ACWP/EAC),$$

Where,

- "P" is the progress.
- "ACWP" is its total accumulated labor hours charged to date (actual cost of work performed), not including rework, which contributes to no progress.
- "EAC" is the current forecast total labor hours at completion.

There are numerous special conditions that require *PERCEPTION* to make adjustments that are not apparent in this brief discussion.

Using this simple formula, computing progress is simple if the ACWP and EAC are known. ACWP is not a problem as it is available directly from time charges. The EAC, however, is not so easily determined. The following describes the general method used by *PERCEPTION* to compute the EAC.

As described below in the discussions determining EAC, SPAR's progress is almost automatic and requires very little manual effort. Work orders automatically begin progressing when time charges against them are entered into the system. When production foreman report back to the system that work orders are complete, the system determines the EAC and calculates the progress by the formula above. As described below, SPAR's EAC is computed based on the budget performance of completed work orders. The greater the extent of budget over-run, the system assesses a slower rate of progress for labor hours expended. The greater the extent of budget under-run, the system assesses a faster rate of progress for labor hours expended.

Methods for Determining EAC

There are many different methods for developing EACs. Some are good and provide realistic estimates that reflect the contract's actual cost performance. Other methods are not so good and can even indicate cost conditions that are 100% at odds with actual cost performance.

EAC Based on Manual Estimate

A manually determined EAC is perhaps the least accurate and reliable EAC. Basically, it is based on very simplistic assumptions and almost always tends to be very optimistic. When a contract is being reviewed for an EAC, manual estimates will most likely be so subjective that the project will always be reported as on budget and on schedule, even if there are cost and schedule problems behind the scenes. Unfortunately, this is an approach that does not recognize, at least early enough, that there are problems and that good responsible decisions need to be made to initiate appropriate remedies before the problems reach crisis proportions.

EAC Based on Manual Progress

An EAC based on a manual progress assessment can be equally unreliable if the progress is made entirely at a high level of the WBS.

On the other hand, if the progress at the higher level is the result of rolling up manual progress assessments at the lowest level (the work orders), and if the work orders are of reasonably short duration as described above, then this method for determining EAC can be quite good. However, the problem remains that manually progressing work orders is an expensive exercise for large projects and often are not kept fully updated in time for a full development of an EAC:

$$EAC = ACWP/Manual\ Progress$$

EAC Based on Pre-Formulated Earned Value Rule

An EAC developed using various earned value rules can be far from the mark depending on what rule is used and how well work orders are opened according to the planned schedules. Work orders opened too early merely to gain earned value will erroneously develop a low EAC, while work orders left open too long and failing to gain their final earned value credits will result in an EAC that may be too high.

The EAC calculation for the earned value rules are as follows:

$$\begin{aligned} \text{Earned Value} &= \text{Rule Based BCWP} \\ \text{Progress} &= \text{BCWP/BAC} \\ EAC &= \text{ACWP/Progress} \end{aligned}$$

EAC Based on Performance Index

A performance index is a ratio that indicates current cost, schedule, or combination variance.

$$CPI = \text{Cost Performance Index} = BCWP/ACWP$$

$$SPI = \text{Schedule Performance Index} = BCWP/BCWS$$

$$TCPI = \text{Combined Cost \& Schedule Performance Index} = (BAC-BCWP)/(EAC-ACWP)$$

An EAC developed from a performance index is calculated as follows and applies the index to estimated remaining work (BAC-BCWP):

$$EAC = ACWP + (BAC-BCWP)/Index$$

This EAC is dependent upon the value of earned value, BCWP. If the BCWP is unrealistic, the resulting EAC also will be unrealistic.

SPAR's EAC

The *PERCEPTION* method for forecasting final labor hours (EAC) is to apply some measure of known budget performance to remaining work. For example, if work orders are overrunning on an average of 15%, it might be reasonable to assume that the final cost also is likely to be an overrun as well. The problem however is to determine how much and in what area of the work breakdown structure (WBS).

It is perhaps not reasonable to expect that after only a few early work orders over-runs that the entire project should be forecast to suffer exactly the same degree of overrun at the finish². While this eventually may be indeed the case, no one typically wishes to predict such dire consequences when there still remain considerable opportunities to turn things around. We all tend to be eternal optimists, and if we must deviate from plan in order to rescue a problematic project, we will do so and often times are successful. However, the secret for success lies in having sufficient resources to effectively implement corrective action and, perhaps more importantly, have enough time to allow these actions be productive.

On the other hand, if not much work remains, and the project suffers from this 15% overrun, then the final outcome is likely to be closer to a 15% overrun than not. There is not enough time left in the project to turn things around.

From the above discussion, facts (known work order performance) need to be balanced in some way with an acceptable method for predicting what is not yet factually known (performance of remaining work). This is exactly the approach taken by *PERCEPTION* in its calculations of final estimated costs at completion:

² Some well recognized EVM systems do make this global assessment for EAC when a manual assessment is not provided.

NOTE: At early stages of the project, the system heavily discounts early budget variances (excess start-up time, etc.), as *PERCEPTION* tries to apply current overrun or under-run performance to a final forecast figure. As progress advances, however, the discounting process becomes less significant. When all the work orders have been completed, *PERCEPTION* applies the full values of variances for the final figure.

In practical terms, this method of forecasting moderates early indications of cost variances and assumes considerable credibility of remaining work budgets. As more work is completed, the system begins to swing the emphasis away from remaining no-variance budgets and more towards an increasingly greater acceptance of the current cost variance.

PERCEPTION Budget Variance Forecasting Factors

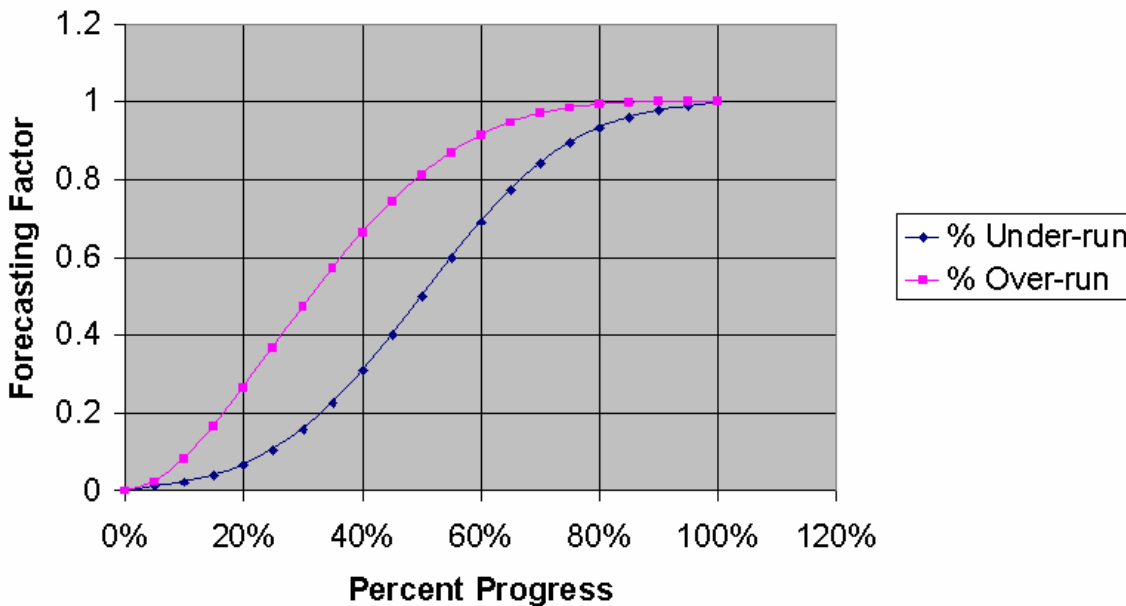


Figure 9: PERCEPTION Forecasting Factors

PERCEPTION employs different methods for different situations. The system places more emphasis on over-runs than it does on under-runs in its final cost forecasting calculations. The reason for this is to catch management's attention early about problems, but to not allow management to get too optimistic, and perhaps complacent, about early savings.

Figure 9 illustrates the factors developed by *PERCEPTION* to apply to current budget variances (over-runs and under-runs). These factors start off very small at early stages of progress. As progress advances, the factors increase until at 100 percent progress, they equal 1.0. The general

formula for how the system applies the factor to compute the forecast cost at completion is given as follows:

$$EAC = BAC + Factor \times [Variance_{closed\ w/os} + Adjustments_{in-progress\ w/os}]$$

Where EAC is the forecast estimate at completion and BAC is the total budget (at completion). Variance_{closed w/os} is the sum of budget variances from closed work orders, and Adjustments_{in-progress w/os} are system-applied adjustments for variances of in-progress work.

Because of its discounting of early budget variances, *PERCEPTION* forecasts should be considered conservative. But because variance trends are noted early by the system, management has more time to correct serious production problems before they reach crisis proportions.

As work progresses, *PERCEPTION* may exhibit some fluctuations in the final cost projections. Usually these fluctuations are moderate and the final cost forecasts do not change dramatically as the progress advances. Unless all work progresses at the same rate of performance, these fluctuations are inevitable and normal. In fact, what may seem to be an inherent drawback to *PERCEPTION* is really an advantage. *PERCEPTION* must be sensitive enough to respond to changes that may be imposed by management upon work performance, yet remain stable without introducing wild changes in forecasts week to week. *PERCEPTION* has a long reputation for producing accurate, stable, yet responsive forecasts, and this has enhanced the system's high level of confidence by users.

Fluctuations will occur under the following circumstances:

- Work patterns within the given collection of work orders may change for better or for worse, such that the average budget variances become smaller or larger as additional work orders are completed. Use of the variance factoring approach for the forecasting calculation will moderate initial large variances, and some smoothing of successive projections then should occur as work progresses.
- Labor incorrectly or belatedly charged (i.e., hours after close) to complete work orders will always increase final cost projections. These additional labor hours will alter the system's earlier measured budget variances of what was previously considered completed work. These new labor charges will cause forecasts of the remaining work to be projected at higher figures. If labor is incorrectly charged to the wrong work order, projections will rise unless the incorrect work orders are generally performing better than the correct ones. Obviously, this situation requires corrections to the database, and management needs to intervene to make certain incorrect charging does not continue. *PERCEPTION* provides a variety of time charge validations, and transaction reporting is available at the time charge level of detail.
- If a group of un-started or incomplete work orders are suddenly closed, the final cost projection will take a sudden drop-down to the current total of accumulated labor hours.

The size of the drop depends upon the amount of the budget unused and upon how well (or badly) the work orders had been performing just prior to the closing.

- Rework work orders do not contribute to progress in the project. Therefore, rework time charges will increase the forecast final cost without any benefit of gaining any earned value from the budget. If rework work orders are planned with budgets, these budgets are not included in the earned value calculations, but they are included in the EAC computations for remaining work.

Forecasting with Rework

Normally, *PERCEPTION* treats work orders as having the basic ability to advance progress. The maximum amount of progress that a work order can contribute to overall progress is the ratio of the work order budget to the total budget for the given level of the WBS.

PERCEPTION, however, has features for accommodating rework, and the system assumes that rework is cost incurred outside the normal work budget and contributes nothing to progress. Rework can be charged against a normal work order, and the system segregates rework charges from normal charges.

A work order also may be specifically identified as a rework work order, whereupon the system assumes that all charges made against the rework work order are totally rework charges.

PERCEPTION includes rework charges with normal charges when reporting the actual cost of work performed (ACWP). However, when computing the estimated cost at completion (EAC), the system processes rework separately from normal work performance to budget.

The system performs the following in its calculation of EAC:

- a) For normal work orders, the system computes EAC according to the procedure outlined above. Completed work orders provide the statistical basis for the system's factored application of over-runs and under-runs to the EAC. The system assumes that any WBS budget not yet assigned to open and/or closed work orders will be affected to some degree by the current work order budget performance.
- b) If rework is charged against a normal work order with budget, the rework charges are simply added to the EAC computed from the normal work order performance EAC forecast procedure. The system assumes that the budget applies only for normal work, not for any rework charges.
- c) If rework is charged against a rework work order that has its own budget, that budget is treated by the system as a rework budget only. The performance of rework charges against rework budgets are processed for a rework EAC that is added to the normal work order performance EAC forecasts.

WBS level budgets should be only for normal work, and should not include any effort identified for rework. The WBS level budget may be equal to or more than the sum of normal work order budgets. If the WBS level budget is greater than the sum of normal work order budgets, the

system will always assume that planning has not yet been completed, but remaining work orders eventually will be added to the project. This remaining portion of WBS budget will be included in the EAC calculations and will be influenced by actual work order budget performance information.

Forecasting All Levels of Project WBS

PERCEPTION develops forecasts of final costs at project summary WBS levels higher than the work orders (Figure 10).

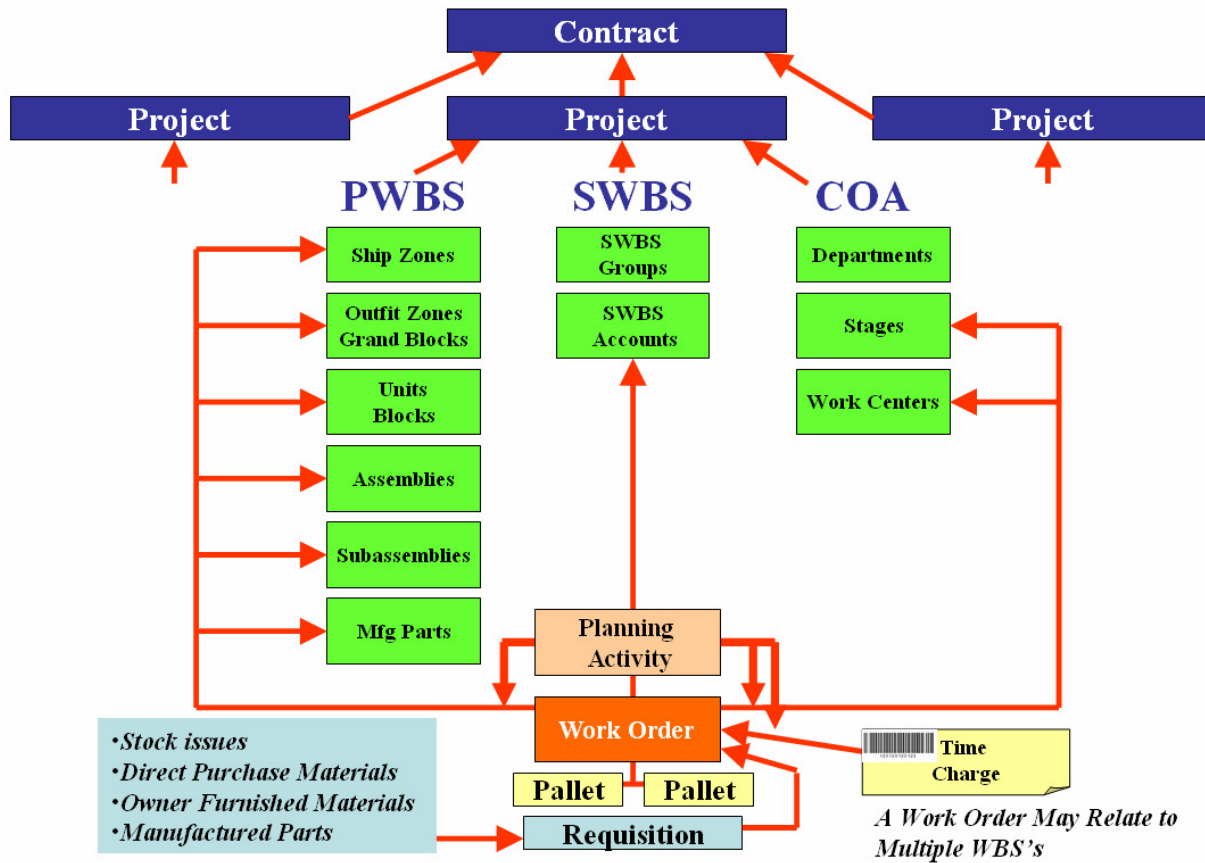


Figure 10: PERCEPTION's Multiple WBS Options

Forecasts are generated for the following summary levels as defined for the project by the user:

- Total contract
- Total project
- SWBS (Systems Work Breakdown Structure) cost groups & cost accounts
- All defined levels of the PWBS (Product Work Breakdown Structure)
- All defined levels of the company COA (Functional Organization)
- The project work centers
- The production trades

The point of view for which a forecast is made determines what work orders are used for the analysis. A forecast for a SWBS cost account will cause the system to select only the work orders that are defined for that account. A forecast for a level of the PWBS will cause the system to select only the work orders defined for that PWBS level.

One could expect that the total forecasts for all WBS accounts should equal the total forecasts for the PWBS and for the COA. However, this is not likely to be exactly the case, because the sets of forecasting factors developed by the system for each point of view can be very different. What this really means is that there are some points of view that should be regarded as better than others for forecasting purposes.

A good forecast may imply that there is some consistency in the way work has been executed. Some points of view contain work that is more consistent and these will have forecasts that are better than others.

If the SWBS defines engineered systems, such as ship systems, each system will include work from various different production processes, from fabrication, assembly and perhaps even testing. If the cost variance from fabrication proves to be a problem, but assembly work has stayed on budget, the early forecasts of the SWBS account will be somewhat negative for assembly, only because the forecasting method uses fabrication performance to predict the performance of the assembly work.

Later, when assembly work gets under way, its improved performance will begin to moderate the negative effects of the earlier fabrication work.

Forecasting for the PWBS also is likely to exhibit some differences in the type of work being executed. Therefore, PWBS forecasts can have similar inconsistencies as for SWBS accounts.

From the point of view of COA work center performance, fabrication forecasts are developed independently from those for assembly work. Each work center is evaluated not just on the basis of one SWBS system account, but for all work orders of other accounts being worked on by that work center. Poor fabrication performance for any given account now will be used as a measure of performance for all other fabrication work orders. Since one might assume that the work orders for a given work center describe more or less the same kind of work to be done, this consistency should yield better total cost forecasts as work for the project is executed and completed.

The following are the various forecast reports and their expected level of forecast accuracy (they all will agree when the contract is 100% finish!):

- Work center forecasts are based upon work orders that are more or less of the same work processes. This consistency should produce the most accurate total cost variance forecast.
- Trade forecasts are based upon work order trade performance. Since trades generally do similar work tasks, the forecasts should be fairly accurate. However, since trades actually do different manufacturing processes (for example, pipe fitters cut pipe, bend

pipe, assemble on-unit, assemble on-board and test systems), this variety may lead to some measure of inconsistency in performance and yield less accurate total trade forecasts.

- SWBS accounts that represent engineered systems are based upon work orders that are defined for the various production processes required by fabricating and building them. Account forecasts can suffer consistency problems that are perhaps even greater than those for the trade forecasts. If accounts define systems that are generally to be built by a specific trade (for example, wash down system by pipe fitters), the account forecasts should not be any worse than what one would expect from a trade forecast. However, if an account includes work for multiple trades and involving a divergence of different production processes, the forecasts may not be so reliable.
- The SWBS cost group forecast is merely the summation of SWBS account forecasts defined under that group. The group forecast, therefore, is dependent upon the quality of the individual account forecasts. However, if a poor quality account forecast is relatively small compared to other accounts in the group, the group forecast is not likely to be compromised too much.
- The PWBS lower level forecasts, like for assemblies, are based upon work orders defined to manufacture and build the defined interim products. Here, there is some consistency of work, although there are several very different production processes involved. Forecasts may therefore not be quite so good.

The PWBS higher level forecasts, like for ship zones, are probably the least accurate, since these include work across a wide range of engineered systems (SWBS accounts), trades, work centers (processes), and units (including outfit modules, if used). Zone forecasts are not a summation of unit forecasts.

SPAR's Trend EAC

The SPAR Trend EAC is described in the *PERCEPTION WORK-PAC* User Manual and attempts to smooth out short term changes in the EAC by extrapolating out beyond the current reporting period to what may be the expected EAC when the project is finally 100% complete. The trend uses a weighting formula of period EACs, placing more weight on the more recent EACs for the project. This method can be subject to fluctuations at the early stages, but the closer actual progress approaches 100%, the more stable and accurate the Trend EAC will be.

Comparing EAC Methods

The following describes the use of various methods for developing EACs for an actual contract that began over-running work orders fairly consistently over time, ending with a 12% over-run. Shipyard management used SPAR's reported EAC and both SPAR's progress and their own manual progress assessments throughout the course of the contract.

Figure 11 shows tracking of several EAC methods as a percentage of BAC for the actual contract, including SPAR's automated EAC described above. The various methods begin to settle down after about 30% progress. However, some methods continue to provide false indications of performance.

As might be expected, the 0/100 earned value rule is by far the most pessimistic. Initially, even though charges are made on open work orders, no earned value is recorded using this rule until the work orders are finished and closed. No earned value equates to no progress gained, and charges expended without progress translates to very high EACs. Unfortunately, this general condition continues predicting a much greater cost over-run condition than any of the other methods until almost 90 percent total progress has been achieved.

The most optimistic EAC is derived by the 80/20 earned value rule. It accepts a large amount of earned value; hence progress, just upon opening work orders. Big progress with little expenditure translates into a very low and unrealistic EAC. This method recognizes the actual over-run but only after about 80% total progress has been achieved. Figure 12 shows this more clearly. The 80% progress mark is much too late for initiating an effective change in course to benefit the final cost. Has the shipyard management made decisions based on the 80/20 rule, they could well have not kept as tight reins on production and the final costs could have been much higher.

The SPAR EAC began indicating an over-run problem from about 40% total progress. Even at the early stages of the contract, the SPAR EAC is relatively quite stable. It uses any current measured cost variance as part of its calculation.

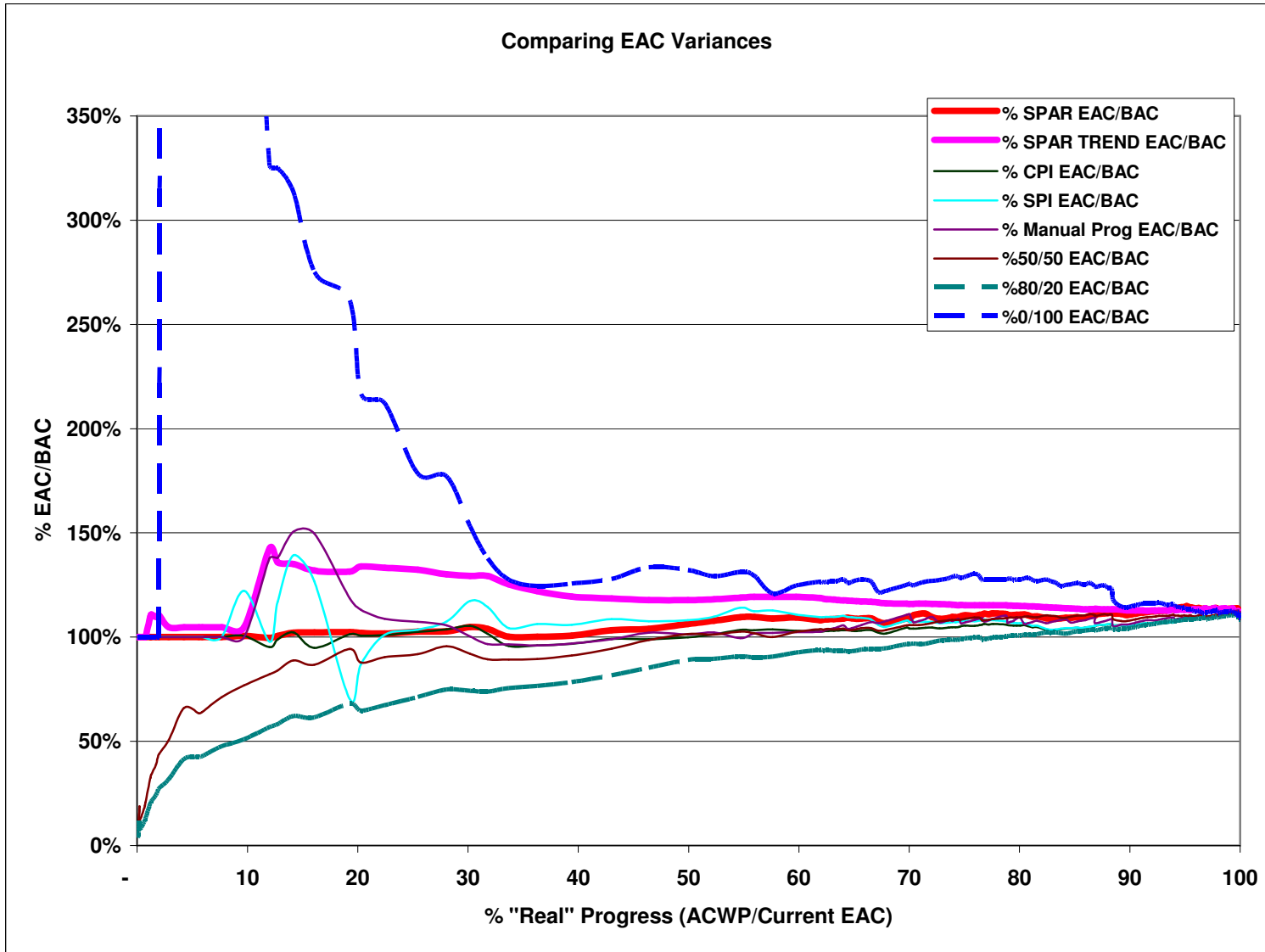


Figure 11: Comparing EAC Methods

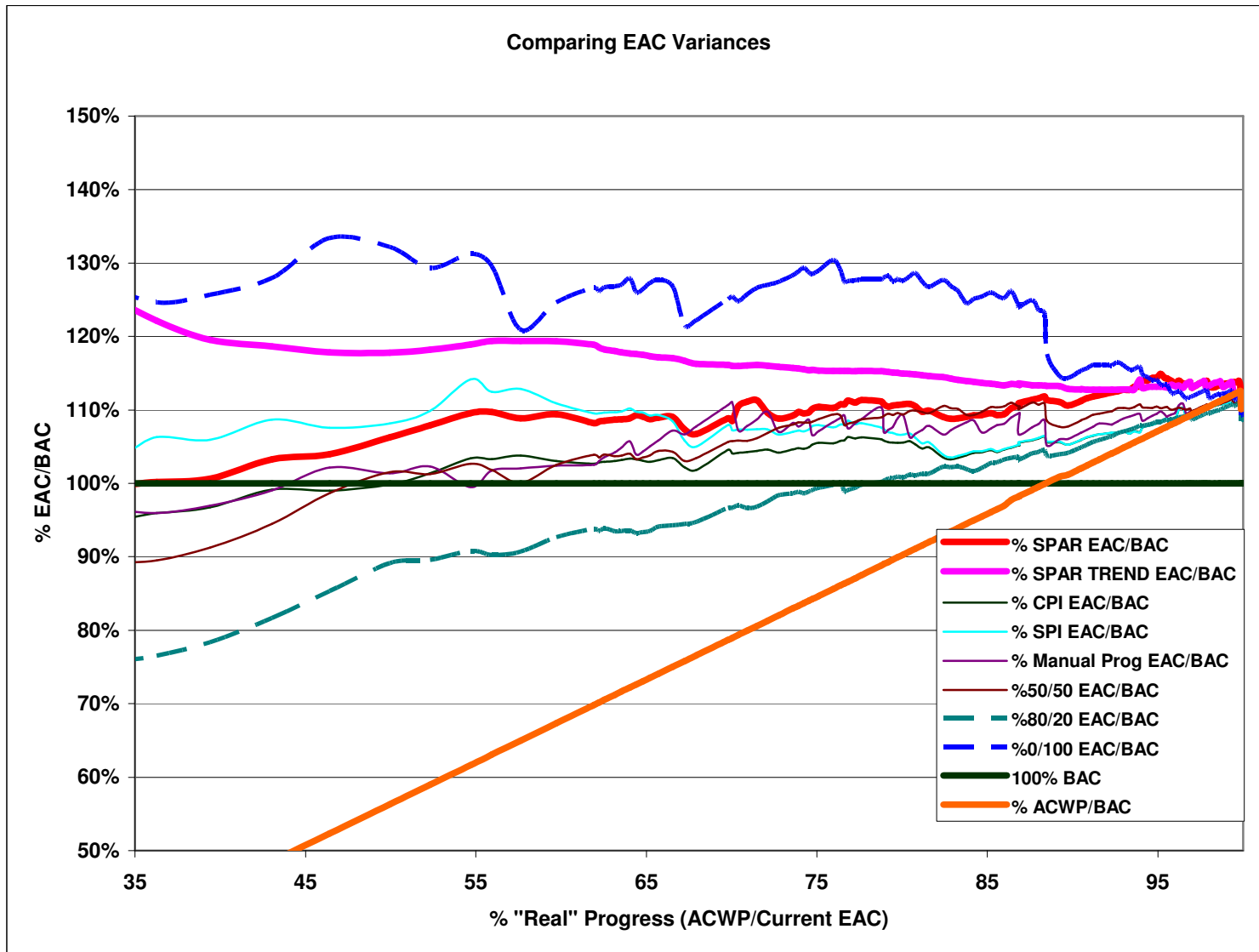


Figure 12: Comparing EAC Methods

Comparing Progress Measurement Methods

Figure 13 shows the tracking of progress using a variety of different progressing methods as described earlier above. Each method is compared to what may be considered the real progress. The SPAR progress and the manual progress track fairly closely. The SPAR progress method is somewhat optimistic due to the assumption that any over-runs can be minimized if recognized early.

The hours spent progress, as discussed above, is not a good method simply because it cannot accommodate either and cost over-run or under-run.

Figure 14 compares four basic methods for determining progress over the course of this same project. The *PERCEPTION* progress tracks well with the manual progress.

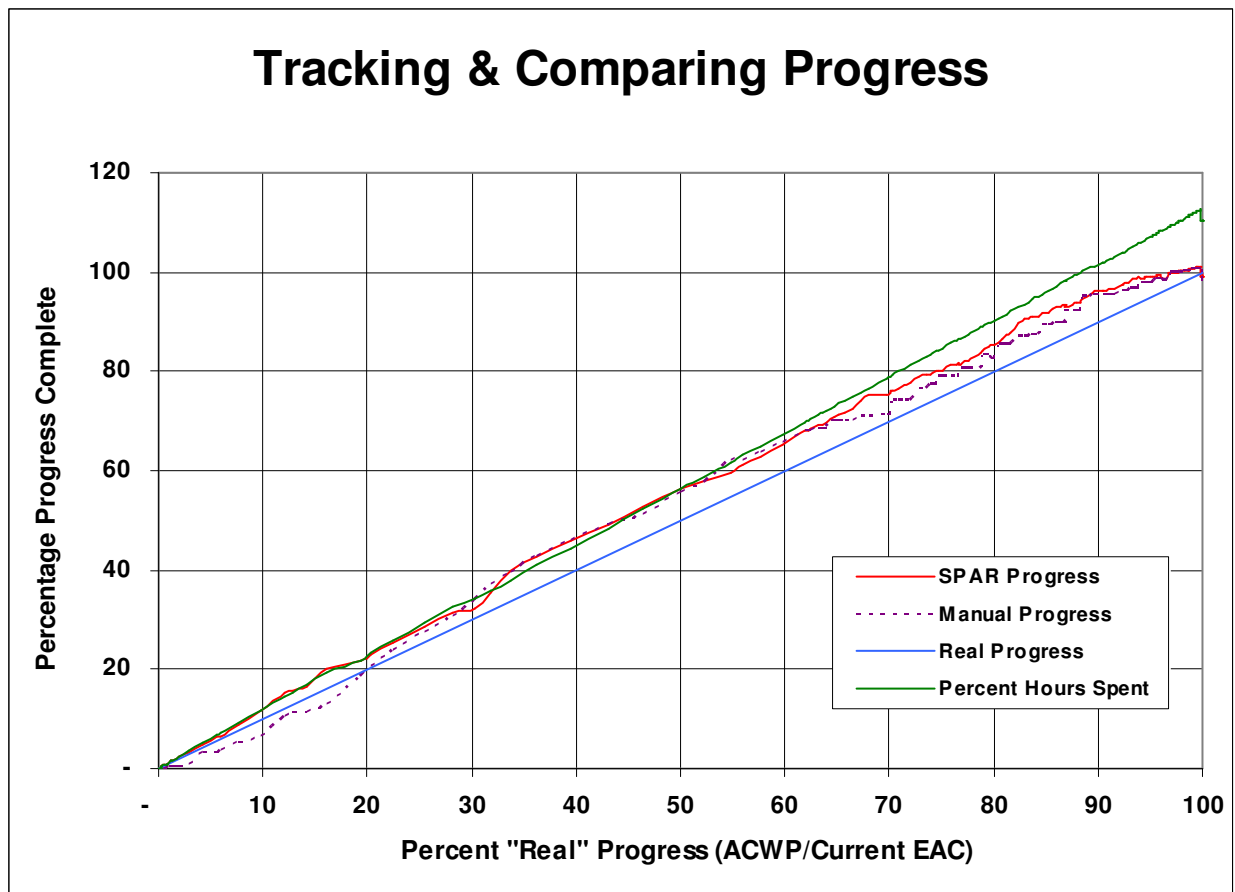


Figure 13: Comparing Different Methods for Determining Progress

Figure 14 expands upon Figure 13 to include methods using different earned value rules. These methods show considerable discrepancies for the rules that are either heavily weighted at the start of work orders (progress too optimistic) or heavily weighted at the completions of work

orders (progress too pessimistic). Methods that are too optimistic will disguise cost and schedule problems. Methods that are too pessimistic, of course, will accentuate these problems.

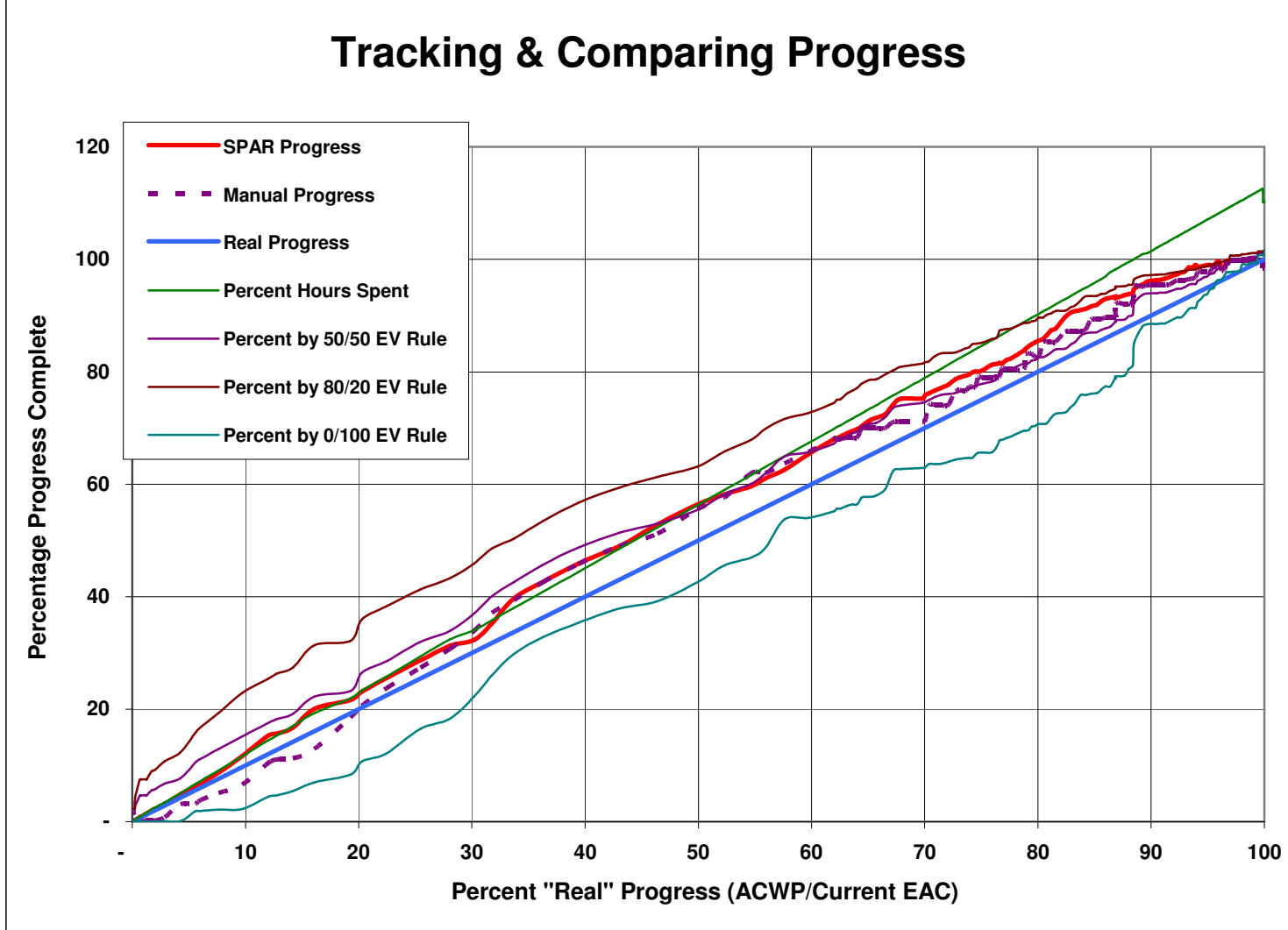


Figure 14: Comparing Various Progressing Methods

Glossary

ACWP

Actual Cost of Work Performed: costs (labor and material) actually incurred and apportioned or distributed in accomplishing the work performed within a given time period.

BAC

Budget At Completion: same as Budget.

BCWP

Budgeted Cost of Work Performed: the sum of budgets for completed work packages and completed portions of open work packages, plus the appropriate portion of the budgets for level of effort. For material, BCWP is the sum of the budgeted costs planned for the relevant time period's actual proportion of overall expenditure.

BCWS

Budgeted Cost of Work Scheduled: the sum of the budgets for completed work packages and completed portions of open work packages, plus the appropriate portion of the budgets for level of effort of work scheduled to be accomplished for the relevant time period. For material, BCWS is the sum of the budgets scheduled for the relevant time period.

COA

The Chart of Accounts, or COA, identifies the shipyard as a functional organization. The organization may be broken down to levels that identify the individual workshops, stages of construction, and manufacturing and assembly processes. The COA is one of several types of project work breakdown structures, or WBS.

The purpose of the COA is to provide a basis for collecting project data and for generating performance reports of the shipyard organization.

Contract

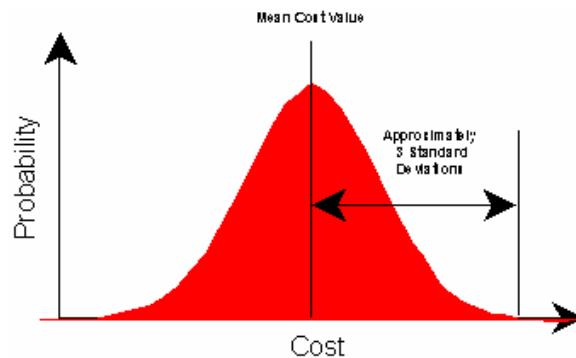
A contract describes an overall scope of work to be performed. One or more projects may be developed under a contract. Cost and schedules can be summarized across projects within a contract.



Cost Risk

Cost Risk is the degree of cost uncertainty within an area of a project. It can be measured simply by relating the cost estimate against potential minimum and maximum cost values. Cost Risk can be impacted by Schedule Risk, Technical Risk, Performance Risk and Economic Risk. A statistical analysis may provide an additional measure of risk by estimating the probability that the actual return cost will equal the cost estimate in question. Refer to Risk Management, Schedule Risk, Technical Risk, Performance Risk and Economic Risk.

The Minimum and Maximum risk values are calculated by the system when a Cost Estimate Rollup is performed and can be viewed on any of the Estimate WBS level records.



Cost Variance

The difference between the actual cost and the budget planned to accomplish what the actual cost accomplished. Cost variance is the difference between BCWP and ACWP. At any point in time it shows whether the work actually performed has cost more or less than that budgeted.

EAC

Estimate-At-Completion is an estimate of the final costs when all work is completed. *PERCEPTION* develops an automated labor and material EAC (hours and cost) based upon work performance to budgets.

Earned Value

Earned Value is the portion of the total budget earned or accomplished from the costs actually expended.

Interim Product

Standard Manufactured Items (Interim Products) are those components and assemblies that can exploit the cost savings benefits from zone outfit or bulk manufacturing methods.

IPT

Interim Product Team is an optional level of the COA hierarchy. It is an organization structure of multiple skills and expertise engaged in planning and managing the labor and material requirements for manufacturing an interim product, such as an outfitted hull block.

Management Reserve

Management Reserve is a portion of a bid estimate that is withheld and not allocated as production budget to cover contingencies, and unplanned production costs. Reserves may also be withheld to provide cost incentives for production to enable cost performance to be lower than what was estimated.

Performance Risk

Performance Risk is the degree of uncertainty that the engineering, manufacturing and management resources can perform for the estimated cost and schedule. It can be measured simply by estimating a possible spread of costs under a best and worst case scenario. A statistical analysis may provide an additional measure of Performance Risk by estimating the probability that the actual cost will equal that of the estimate in question. Refer to Cost Risk.

Progress

Progress is a measure work accomplishment. *PERCEPTION* measures progress essentially as the percent of earned value to the total budget. The system adjusts the earned value over the course of the project's execution based upon the project's actual cost performance to its budgets.

PERCEPTION also tracks a manual progress that is rolled up from work orders.

Project

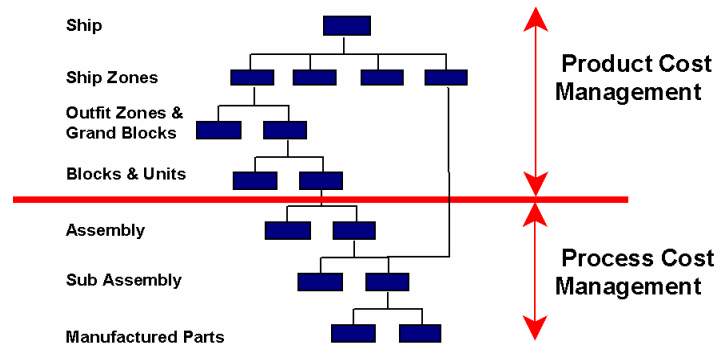
A project defines the major work and cost elements to be estimated. Each project must have a work breakdown structure to summarize costs at various levels, from the detail cost items up to the overall project. Each project may have a product work breakdown structure against which cost items may be catalogued for summary purposes.

Projects usually are developed for each ship to be built or ship to be repaired. Each project may be all-inclusive with respect to work requirements such as design, construction and management support costs. However, additional projects may be developed for class design work that applies across all ships (i.e., projects) of the contract. Separate projects also may be developed for other non-construction contract requirements, such as training programs, operational cost estimating, etc.

PWBS

Product Work Breakdown Structure is a hierarchical list of interim products. Once any complex product, such as a ship, has been designed, planning efforts need to be applied toward maximizing production efficiencies. This effort entails organizing work and

resources that promote productivity and eliminate non-value added costs. The concept of group technology, for example, supports this objective and enables engineered systems, as defined by a system Work Breakdown Structure (SWBS), to be broken down into definable interim products. These products can exploit significant cost and schedule savings because they enable the work to be performed under more convenient and more easily performed work conditions.



The elements comprising the PWBS are the contract, project, zone, outfit zone/grand block, unit/block, assembly, sub assembly, and manufactured parts.

The Generic PWBS (GPWBS) is an attempt to standardize the definition of the PWBS across the shipbuilding industry. Such a standard benefits the Navy by enabling a common basis for comparing ship designs and build strategies and evaluating their costs. Project estimate cost items may be mapped to the GPWBS, and GPWBS reports are available on the system. The GPWBS is limited to Ship Zone, Work Type and Stage of Construction.

Schedule Risk

Schedule Risk is the degree of schedule uncertainty within an area of a project. It can be measured simply by relating the schedule estimate against potential minimum and maximum schedules. A statistical analysis may provide an additional measure of risk by estimating the probability that the actual schedule will equal the schedule estimate in question. Costs typically have some dependency upon schedule. For example, schedule directly impacts overhead costs and effects cost escalation (Economic Risk). Schedule also can have a direct impact upon the cost to perform the work (Performance Risk) and affect the available resources and technical information. Schedule can have an effect upon Technical Risk and upon contractual items such as penalties and incentives. Refer to Cost Risk.

Schedule Variance

The difference in both time and cost between what was planned to be accomplished and what was actually accomplished. Schedule variance is the difference between BCWP and BCWS. At any point in time it represents, in terms of cost, the difference between work actually performed (accomplished) and work scheduled.

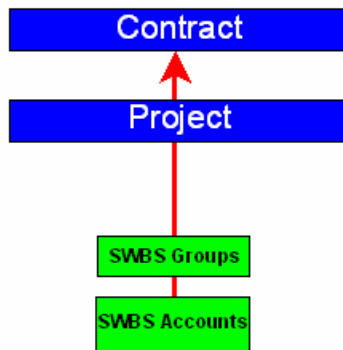
Stage of Construction

Stage of Construction is the division of the manufacturing and assembly process by sequence.

SWBS

System Work Breakdown Structure, or SWBS, is a means for identifying work components of a project. SWBS is one of several types of project work breakdown structures, or WBS. Normally, the SWBS is oriented around engineered systems that make up the ship as a deliverable product. SWBS may also be applied to ship repair projects.

Since each project requires its own SWBS, each project can have a different SWBS. For ship repair and non-construction projects, the SWBS can be tailored to suit specific contract job orders. The hierarchies that comprise the SWBS are the contract, project, SWBS groups and SWBS accounts that are cataloged under the SWBS groups.



Technical Risk

Technical Risk is the degree of uncertainty that a technology required for the project can be developed and implemented within estimated costs (and schedule). It can be measured simply by estimating the costs for best and worst case scenarios, including possible need to pursue alternate technologies. A statistical analysis may provide an additional measure of Technical Risk by estimating the probability that the actual cost and schedule for the technology will equal those of the estimates in question. Refer to Cost Risk.

WBS

Most projects are identified by the major components that comprise the project. These components may be the major items to be designed or manufactured, or the particular services to be rendered. These components are the basis for the project System Work Breakdown Structure (SWBS), the Product Work Breakdown Structure (PWBS) and the Code of Accounts (COA).

Work Center

A company department or stage of construction, which is assigned specific responsibility, and resources needed to perform work. Work centers may also be assigned to subcontractors.

Work Order

A work order is a distinct and definable unit of work that can be started and completed without significant interruption under the direction of a single work center.

PERCEPTION manages 3 types of work orders:

- Discrete work orders that can be identified to a single level of the project WBS (such as SWBS).
- Distributed work orders that can be identified across any number of levels of a project WBS, such as multiple SWBS accounts and/or multiple PWBS elements.
- Time-phased work orders that can manage level-of-effort support efforts. Time-phased work orders operate with monthly budgeted sub-tasks.