Testing Earned Schedule Forecasting Reliability

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Abstract. Project duration forecasting using Earned Schedule (ES) has been affirmed to be better than other Earned Value Management based methods. Even so, the results from a study, employing simulation techniques, indicated there were conditions in which ES performed poorly. These results have created skepticism as to the reliability of ES forecasting. A recent paper examined the simulation study, concluding through deduction that ES forecasting is considerably better than portrayed. Researchers were challenged to examine this conclusion, by applying simulation methods. This paper uses real data for the examination, providing a compelling argument for the reliability of ES duration forecasting.

Background

Those of you who have submitted articles to the *CrossTalk* review process know that the critique and suggestions made consistently lead to a much improved article. Sometimes it doesn't feel like it, but it is nevertheless true. The most significant suggestion to my initial submission of this article was it needed more material on Earned Schedule (ES). The critical thought was readers would have to perform research of other articles and, possibly, books to gain much from the article as it was proposed. After brief reflection, I realized the reviewers were correct.

My anticipation in preparing the article was that only those familiar with Earned Value Management (EVM) and ES would be readers, and, thus, descriptions of these management methods was unnecessary. In taking this approach, I limited the usefulness and value of what I had to say. With the inclusion of foundational material, it is logical that reader interest is widely expanded.

However, with the addition of the descriptions, the article is constructed somewhat unconventionally. There is *background*, including the EVM and ES descriptions, followed then by the *introduction*. Having the fundamentals in-place, the *introduction* prepares the reader for the article's objective.

Earned Value Management

EVM is a management method succinctly depicted in figure 1. The method uses three measures: actual cost (AC), planned value (PV), and earned value (EV). PV is created from the cost estimates made for each task comprising the project. Using the schedule for the tasks, PV is accumulated at periodic time increments, concluding at budget at completion (BAC). This time-phased accrual of PV is commonly termed the performance measurement baseline (PMB); i.e., planned expenditure of the project budget. AC, of course, is the actual project cost accrued at the various status points, while EV is the accomplishment summed over the project tasks. EV for each task is measured in relation to its estimated PV; at task completion, the task EV will equal its PV, and at project completion the totals for EV and PV are equal to BAC.

The vertical dashed line in figure 1 represents a point in time when the project manager (PM) assesses performance of the project. From the three measures described, the performance indicators are derived:

Cost Variance: $CV = EV - AC$
Schedule Variance: $SV = EV - PV$

Cost Performance Index: $CPI = EV / AC$
Schedule Performance Index: $SPI = EV / PV$

When the difference for the variance formulas is positive, the project is doing well, and when it is negative further analysis is warranted. The indexes are indicators of performance efficiency. When their value is greater than 1.0 the project is doing well, while less than 1.0 indicates the need for improvement.

The indicators for cost are reliable and converge to the actual result at completion of the project. For example, if the project completed at more than its BAC by $1000, the computed CV would equal minus $1000. As well, if the project BAC equals $1000 and at completion AC is equal to $2000, CPI would equal 0.5; i.e., the cost performance efficiency for the project is 50 percent (a very poor value).

The ability to compute CPI facilitates the capability to forecast the final cost for a project. The most used formula is

IEAC = BAC / CPI

where IEAC is the Independent Estimate at Completion.

Just as the indicators for cost always converge to the actual result, the forecast does, as well.

To this point, the discussion is fairly straightforward. However, there is a problem: the EVM schedule indicators do not exhibit reliable behavior. They do not converge to the actual result and during execution for late performing projects the indicators do not accurately portray performance. This characteristic for late performance has been observed as early as when the project is 50 percent complete. The reason this occurs is the measures needed for the schedule indicators, EV and PV, are constrained to the value BAC. Because of this failure mode, EVM is not considered to be a useful method for evaluating project schedule performance.

Earned Schedule

ES resolves the problem with the EVM schedule indicators, and does so without requiring additional data. The fundamental concept of ES is shown in figure 2. As the description reads, "The idea is to determine the time at which the EV accrued should have occurred." The time duration associated with the point on the PMB where PV is equal to EV is Earned Schedule; that is, the point in time where the EV should been accomplished. For the EV accrued, ES provides a measure of how much has been earned of the planned duration (PD) of the project.

ES is computed from the simple formula:

ES = C + I

C is determined by comparing EV to the periodic values for PV, i.e., PV_n. C is the largest value of n satisfying the condition, EV ≥ PV_n. I is an interpolation over one period of the PMB, using the equation:

$$I = (EV - PV_C) / (PV_{C+1} - PV_C)$$

Having ES, the time based schedule indicators are formed, Schedule Variance (time) and Schedule Performance Index (time), abbreviated as SV(t) and SPI(t), respectively. The indicators are computed by applying the following formulas:

SV(t) = ES − AT
SPI(t) = ES / AT

where AT is the actual time, i.e. the duration from the start of the project to the time (status point) at which EV is measured.

These time-based schedule indicators perform reliably for both late and early performing projects, thereby supplementing and improving EVM. Furthermore, the time-based indicators always converge to the actual result at project conclusion, as do the EVM cost indicators.

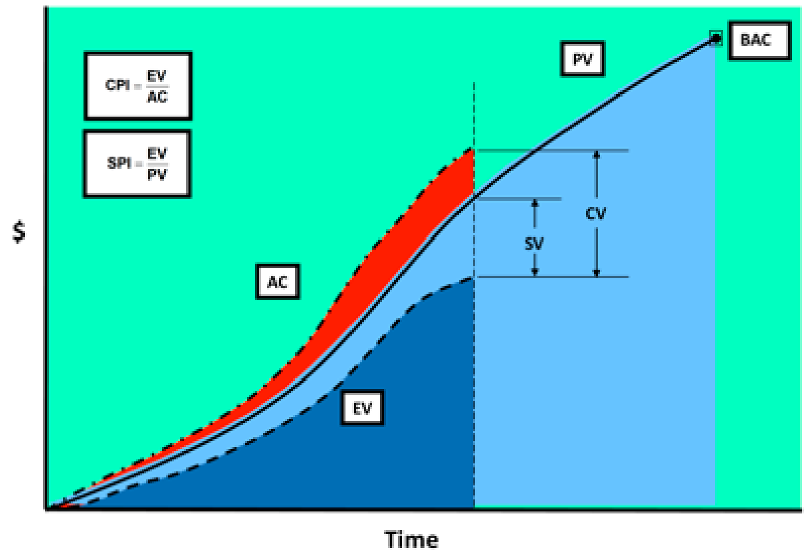

Figure 1. Earned Value Management

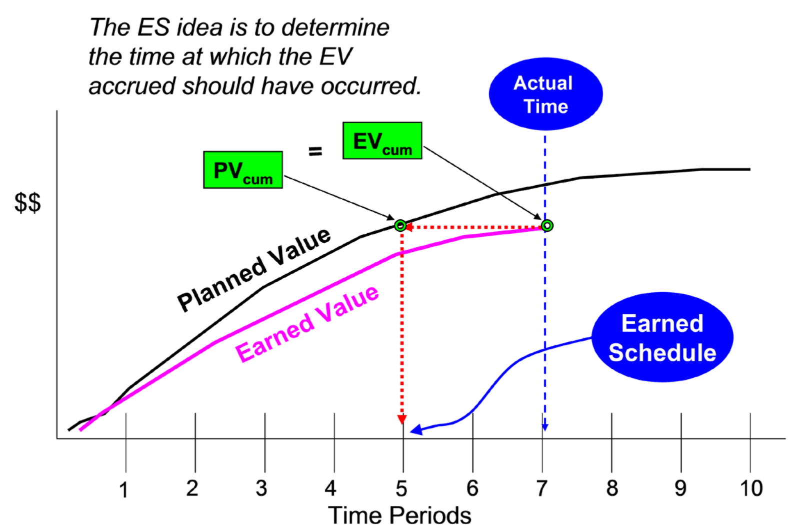

Figure 2. Earned Schedule Concept

In similar fashion, the SPI(t) indicator has made forecasting project duration possible from EVM performance data, using the simple formula [1]:

IEAC(t) = PD / SPI(t)

where IEAC(t) is Independent Estimate at Completion (time-based).

Similar to EVM forecasting, the ES forecast of project duration always converges to the actual result.

Introduction

A research study of project duration forecasting was made several years ago, employing simulation methods applied to created schedules having several variable characteristics [4]. The overall result from the study was that forecasts using

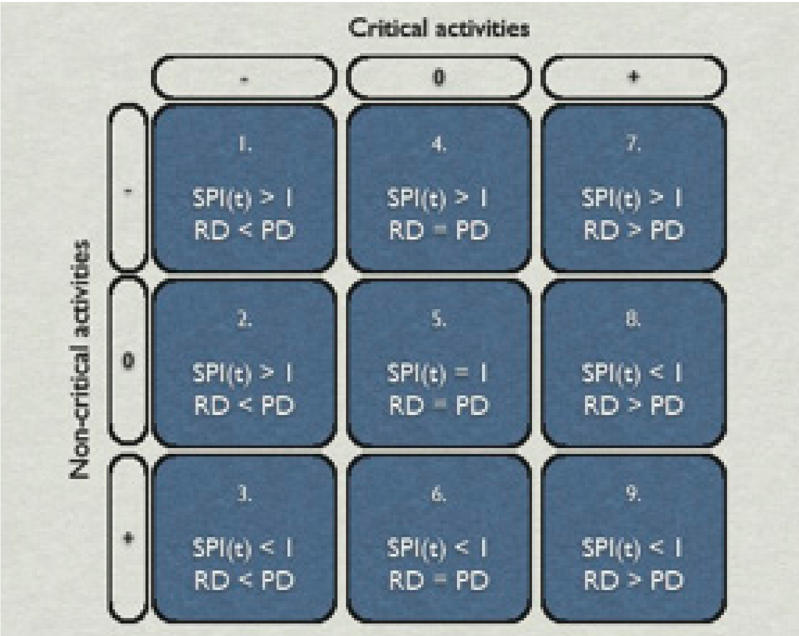

Figure 3. Schedule Performance Scenarios

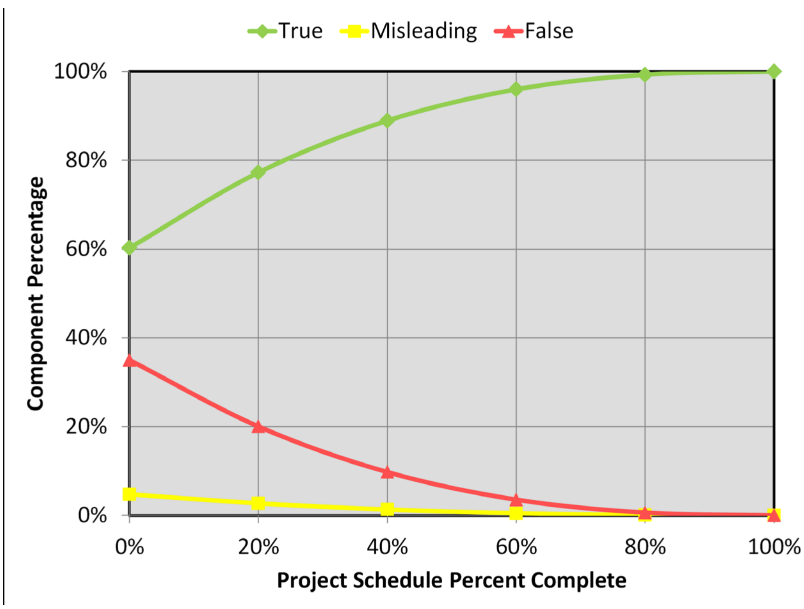

Figure 4. ES Forecasting Reliability Theory

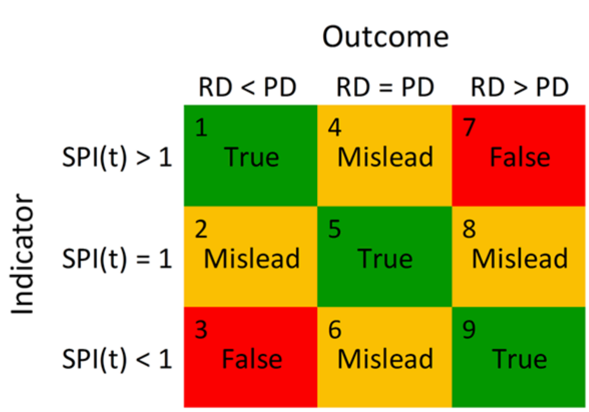

Figure 5. Indicator vs Outcome Scenarios

Earned Schedule (ES), on average, are better than other Earned Value Management (EVM) based methods. However, in certain instances the ES forecast was not.

The scenarios examined in the 2007 study are depicted in figure 3. The scenario model indicates nine possible outcomes. These outcomes are grouped into three categories: *true*, *misleading*, and *false*. True outcomes are associated with reliable forecasts, whereas the misleading and false categories indicate unreliable ES duration forecasting.

The three groupings are more fully explained as follows:[1]

The true scenarios (1, 2, 5, 8, 9)[2] have the characteristic that the relationship of the real or final project duration (RD) to the planned duration (PD) can be inferred from the schedule performance efficiency indicator, SPI(t).[3] Using scenario 1 for example, SPI(t) is greater than 1 (indicating good performance), while RD is less than PD (as one would expect from the indicator); i.e., the indicator is consistent with the duration result.

The misleading scenarios (4, 6) are characterized by the critical activities being completed as planned, while the non-critical activities are not.[4] The RD equals PD; however, SPI(t) is either greater or less than 1. Thus, the indicator is inconsistent with the duration outcome.

The false scenarios (3, 7) occur for two circumstances: 1) When non-critical activity performance is good and critical performance is poor, or 2) When critical activity performance is good and non-critical is poor. For these scenarios, the indicator, SPI(t), infers an outcome in opposition to the actual duration.

As indicated by the model only five of the nine possible outcomes are true (SPI(t) consistent with the final duration). Thus, a negative perception is created as to the reliability of ES forecasting.

A recent paper [2] examined the reliability question. Because of the convergence characteristic of ES forecasting, it was hypothesized that the misleading and false scenario indications resolve to consistency between SPI(t) and RD as the project progresses to conclusion. The evolution of scenario categories was illustrated in the paper by figure 4. As the project progresses, true scenarios increase, while misleading and false scenarios decrease. Thus, ES forecasting is theorized to become increasingly reliable as the project proceeds to completion.

In the final comments of the 2014 paper, a challenge was made to researchers to test the hypothesis that misleading and false scenarios migrate to true with project progress. For the proposed testing, the performance scenarios are categorized as shown in figure 5. The definitions of the categories are similar to those described for figure 3:

The true scenarios (1, 5, 9)[6] are characterized by SPI(t) being consistent with the relationship of RD to PD.

The misleading scenarios (2, 4, 6, 8) are identified when SPI(t) is inconsistent with RD, but are not regarded as false.

The false scenarios (3, 7) are determined when SPI(t) infers an early finish, while RD is greater than PD, or when it infers a late finish and RD is less than PD.

It is to be noted that the scenarios do not include the distinctions of critical and non-critical activities. They are unnecessary for the testing. The object is to determine the consistency of SPI(t) with the actual duration of the project, thereby providing evidence of ES forecasting reliability.

The research challenge was made intending for the hypothesis to be tested using simulation methods. The advantage of employing simulation is a large data sample can be created for the evaluation. This paper, however, performs the evaluation using data from sixteen real projects.

The motivation for this study is to provide information to managers, thereby enhancing their endeavor to effectively guide projects to successful completion. In this regard, the reliability of project duration forecasting is considered essential. The objective of this paper is to establish, at minimum, an initial understanding of ES forecasting reliability and provide confidence in its application should the testing yield positive results.

Description of Project Data

A total of sixteen projects is included in the study. Twelve (1 through 12) are from one source with four (13 through 16) from another. The output of the twelve projects is high technology products. The remaining four projects are typed as information technology (IT).

The primary data characteristic is the projects have not undergone any re-planning. This enables evaluation of the forecasting results without having undue outside influence. All sixteen projects performed from beginning to completion without baseline changes.

Table 1 illustrates the schedule performance of the projects in the data set. The twelve high technology projects are measured in monthly periods whereas the four IT projects are measured weekly. Two projects completed early, three as scheduled, and the remaining eleven delivered later than planned.

Method of Evaluation

For each project status point, the SPI(t) value and the relationship of RD to PD is used to classify the performance to one of the nine scenarios of figure 5. The scenario identification is then grouped to one of the three categories (true, misleading, or false) and associated with the schedule percent complete.[7] The tabulations of the categories are then assembled into ten percent increments of project completion. The results from all sixteen projects are then summed to form a composite. The composite results are normalized to percentages for each 10 percent increment, as shown in Table 2.

The process described is then re-evaluated taking into account quality of the forecast. Each misleading or false determination is examined for closeness of the forecast to the final duration. When the forecast is within 10 percent of RD, the determination is reassigned to true. It is reasonable to say that a forecast within 10 percent of the actual project duration is neither misleading nor false.

The assessment of whether ES forecasting is more reliable than previously portrayed in the literature is made from graphical analysis. The hypothesis that SPI(t) resolves to consistency with RD is credible, when it is demonstrated that the true percentage increases to 100 while the misleading and false components decrease to zero, as the project progresses to completion. Forecasting is considered reliable when the value from the linear fit of True% is approximately 60 percent at 25 percent schedule completion.

Schedule Performance								
Project	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Planned Duration	21m	32m	36m	43m	24m	50m	46m	29m
Actual Duration	24m	38m	43m	47m	24m	59m	54m	30m
Project	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Planned Duration	45m	44m	17m	50m	81w	25w	25w	19w
Actual Duration	55m	50m	23m	50m	83w	25w	22w	13w
Legend: m = month w = week								

Table 1. Schedule Performance

Pct Gp	@ 00	>5<=15	>15<=25	>25<=35	>35<=45	>45<=55	>55<=65	>65<=75	>75<=85	>85<=95	@100
Graph	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
True%	33.3%	72.7%	80.3%	86.1%	72.3%	72.5%	73.8%	92.3%	95.3%	100.0%	100.0%
Mislead%	44.4%	13.6%	11.8%	6.9%	10.6%	13.7%	18.5%	4.6%	4.7%	0.0%	0.0%
False%	22.2%	13.6%	7.9%	6.9%	17.0%	13.7%	7.7%	3.1%	0.0%	0.0%	0.0%

Table 2. Normalized Composite Results

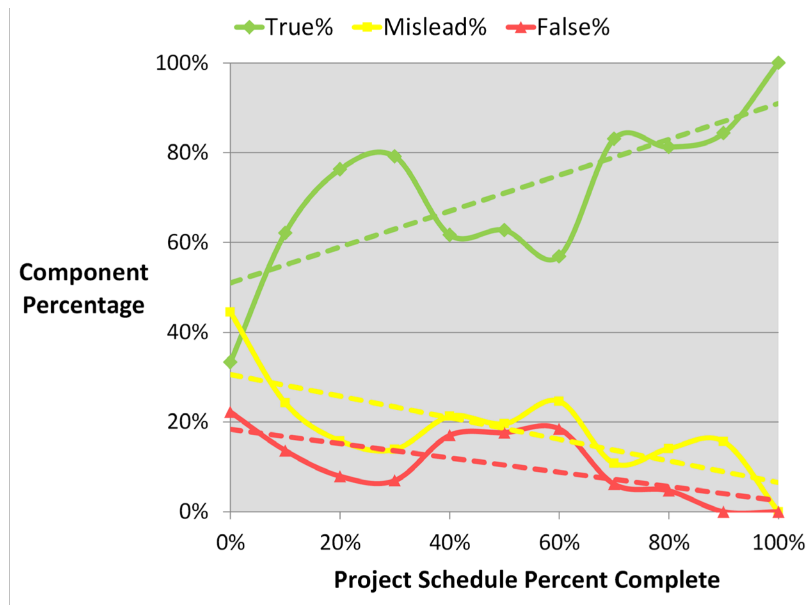

Figure 6. Composite Graph

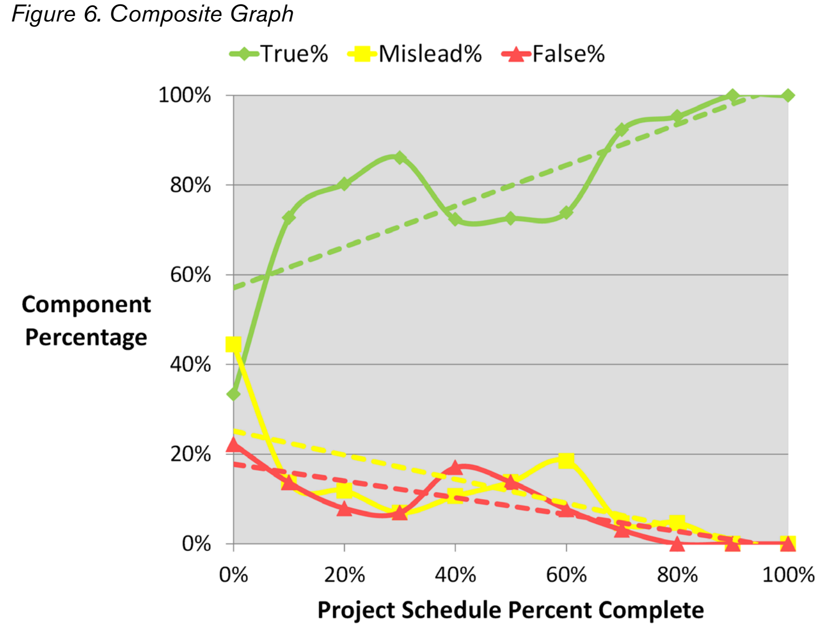

Figure 7. Composite Graph with 10% Margin

Analysis of Results

Two graphs depict the results. Figure 6 indicates results using the scenarios from figure 5. The scenario evaluation, depicted in figure 7, includes the reassigned category determinations from applying the 10 percent margin forecasting variance. Each graph begins at zero percent completion using the percentage of scenarios aligned to each performance component. For example, three scenarios align with true; thus, the initial point for True% is 33.3 percent.

Figure 6 depicts the trends of the forecast components. The compiled results clearly show the percentage of the true component increasing with project progress, while the unreliable components, misleading and false, simultaneously are decreasing. The graphs conclude with the true component at 100 percent and, consequently, the misleading and false components at zero percent.

For figure 7, as stated earlier, the True% includes the reassigned false and misleading results. The graph strongly indicates the convergence characteristic of ES forecasting. With the inclusion of the 10 percent margin, the true component approaches 100 percent much sooner. And overall, the misleading and false components are significantly smaller throughout.

Viewing the plot of True% from figures 6 and 7, the impact of including the 10 percent forecasting margin can be made. From figure 6, ES forecasting is approximately 60 percent reliable at 25 percent schedule completion, and 80 percent reliable at approximately 75 percent complete, reasonably good numbers. However, when the 10 percent margin is considered, figure 7 shows ES forecasting to be 60 percent reliable at approximately 5 percent complete, and 80 percent reliable at about 50 percent complete. These numbers are impressive, indicating ES forecasting for this set of data is good to excellent for 95 percent of the project duration.

Summary and Conclusion

Recently it was theorized that ES forecasting is considerably more reliable than how it has been portrayed previously in the literature. The essence of the theory is that due to the convergence characteristic of ES forecasting, the reliability of the forecasts must increase as the project progresses toward completion.

To test the theory, sixteen projects of real data were used. The performance values for SPI(t) and RD were categorized into the nine scenarios of figure 5 and subsequently grouped for each project into tabulations of true, misleading, and false components at ten percent progress increments. Subsequently, the project tabulations were summed to create a composite for evaluation.

The evaluation was made graphically. For the set of data tested, figures 6 and 7 clearly demonstrate that ES forecasting reliability increases with project progress. The true, or reliable, component increases while the unreliable components, misleading and false, decrease. It was also shown that when the ten percent forecasting margin was considered, the values for the True% component increased significantly. Overall, with the margin included, ES forecasting was assessed as good to excellent for 95 percent of the project duration.

Although more testing would be welcomed, it is reasonable from the results of this study to conclude that project managers employing EVM can have confidence in the forecasts made using ES.

NOTES

1. The true, misleading, and false grouping explanations are taken from [2].
2. The numbers in parenthesis for the groupings refer to the nine numbered cells of figure 3.
3. The relationship inference is obtained from the forecasting equation, IEAC(t) = PD / SPI(t).
4. The terms critical and non-critical refer to activities in relation to the schedule critical path.
5. Figure 3 is from the presentation [3].
6. The numbers in parenthesis for the groupings refer to the nine numbered cells of figure 5.
7. Schedule percent complete is equal to ES divided by PD, multiplied by 100.

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ABOUT THE AUTHOR

Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base. He has over 35 years of experience in the development, maintenance, and management of software for automated testing of avionics. During his tenure, the division achieved several software process improvement milestones, including the coveted SEI/IEEE award for Software Process Achievement. Mr. Lipke has published several articles and presented at conferences, internationally, on the benefits of software process improvement and the application of earned value management and statistical methods to software projects. He is the creator of the technique *Earned Schedule*, which extracts schedule information from earned value data. Mr. Lipke is a graduate of the USA DoD course for Program Managers. He is a professional engineer with a master's degree in physics, and is a member of the physics honor society, Sigma Pi Sigma (ΣΠΣ). Lipke achieved distinguished academic honors with the selection to Phi Kappa Phi (ΦΚΦ). During 2007 Mr. Lipke received the PMI Metrics Specific Interest Group Scholar Award. Also in 2007, he received the PMI Eric Jenett Award for Project Management Excellence for his leadership role and contribution to project management resulting from his creation of the Earned Schedule method. Mr. Lipke was selected for the 2010 Who's Who in the World. At the 2013 EVM Europe Conference, he received an award in recognition of the creation of Earned Schedule and its influence on project management, EVM, and schedule performance research. Most recently, the College of Performance Management awarded Mr. Lipke the Driessnack Distinguished Service Award, their highest honor.