

# Applying Earned Schedule to Critical Path Analysis and More

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**Abstract.** *Earned Schedule is a fairly new method for analyzing schedule performance; it is a derived application of Earned Value Management (EVM) data. Created three years ago, the method has propagated to several countries and been used for various types of work spanning a large range of project sizes. During this period of infancy, a misperception may have emerged that ES is only applicable to the total project and thus is limited for schedule performance analysis. As has been shown in the article, “Connecting Earned Value to the Schedule,” ES can be used for much more. It facilitates the ability to identify constraints, impediments, and the possibility of rework at the task level [1]. This information is very useful for management purposes, but it does not provide performance indicators below the project level. This paper describes how ES can be applied to sub-levels of the project. Using this capability, the project manager can analyze schedule performance at virtually any level desired – control accounts, work packages, and critical path activities.*

During presentations about Earned Schedule (ES) I am sometimes asked, “Can Earned Schedule be used to analyze the critical path?” My response is always, “Certainly, simply treat the critical path as the project.” I notice then that the person doesn’t say anything else, but has the look of someone who didn’t have his question answered. This question is asked often enough ...with the same result ...that it is apparent a more complete response is needed. Hopefully this paper will satisfy all those who have voiced the question in the past, as well as those who are seeking a way to use ES as a “drill-down” tool.

In this paper, it is assumed the reader has good understanding of Earned Value Management (EVM) and that Earned Schedule is being used as one of the project management tools. Although it is likely the reader has a working knowledge of ES, a review of the concept, the time-based indicators and the forecasting calculation is needed to establish a common foundation for the remainder of the paper.

## **Earned Schedule**

The ES idea is simple: identify the time at which the amount of earned value (EV) accrued should have been earned [2]. By determining this time, time-based indicators can be formed to provide schedule variance and performance efficiency management information.

Figure 1, Earned Schedule Concept, illustrates how the ES measure is obtained. Projecting the cumulative EV onto the project management baseline (PMB), as shown by the diagram, determines where planned value (PV) equals the EV accrued. This intersection point identifies the time that amount of EV should have been earned in accordance with the schedule. The vertical line from the point on the PMB to the time axis determines the “earned” portion of the schedule. The duration from the beginning of the project to the intersection of the time axis is the amount of earned schedule (ES).

With ES determined, time based indicators can be created. It is now possible to compare where the project is time-wise with where it should be in accordance with the PMB. “Actual time,” denoted AT, is the duration at which the EV accrued is recorded. The time-based indicators are easily formulated from the two measures, ES and AT. Schedule Variance becomes  $SV(t) = ES - AT$ , and Schedule Performance Index is  $SPI(t) = ES / AT$ .

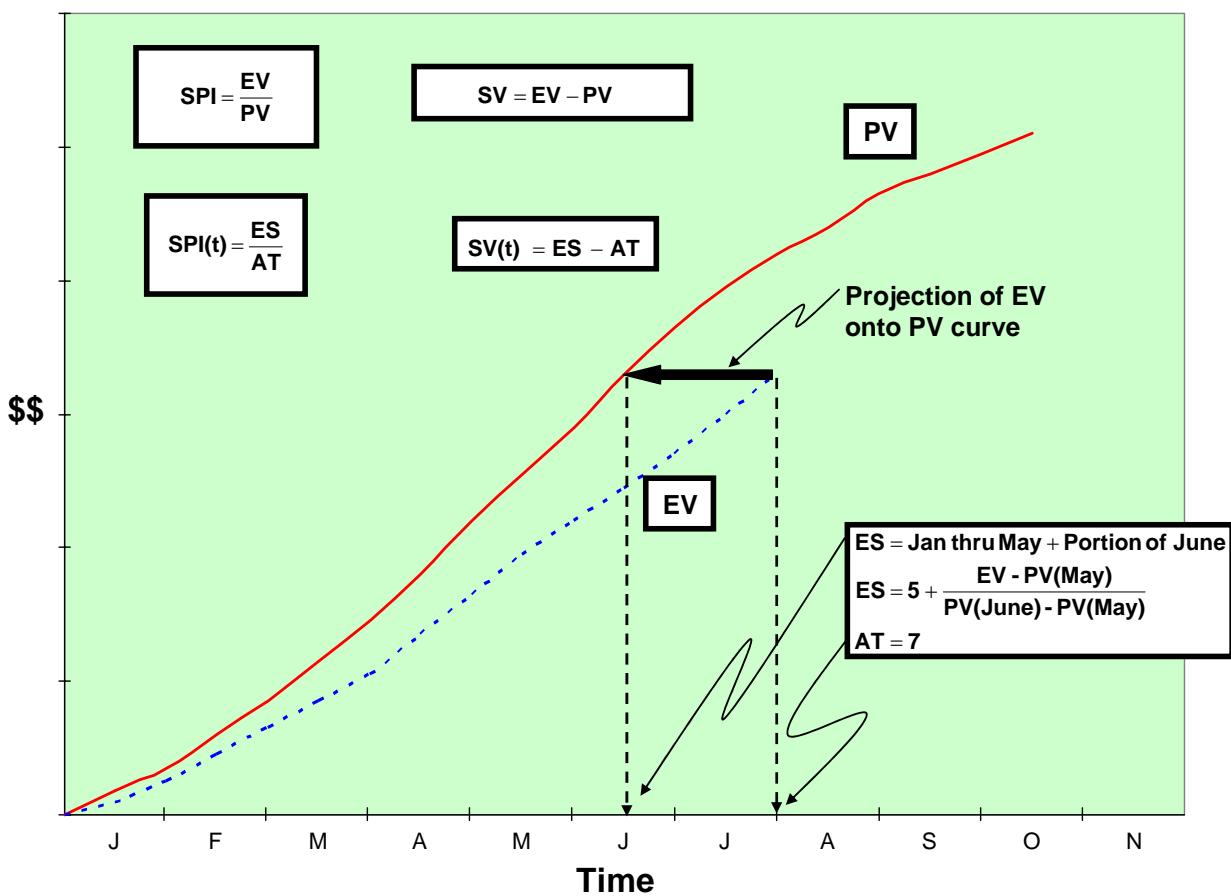


Figure 1. Earned Schedule Concept

The graphic and the box in the lower right of figure 1 portray how ES is calculated. While ES could be determined graphically as described previously, the concept becomes much more useful when facilitated as a calculation. As observed from the figure, all of the PV through May has been earned. However, only a portion of June has been completed with respect to the baseline. Thus the duration of the completed portion of the planned schedule is in excess of 5 months. The EV accrued appears at

the end of July, making actual time equal to 7 months. The method of calculation to determine the portion of June to credit to ES is a linear interpolation. The amount of EV extending past the cumulative PV for May divided by the incremental amount of PV planned for June determines the fraction of the June schedule that has been earned.

The creation of ES and the derivative time-based schedule performance efficiency, i.e. SPI(t), facilitates forecasting the duration of the project and its completion date. Two formulas are presently in use; one is termed the “short form” and the other the “long form.” The short form is  $IEAC(t) = PD / SPI(t)$ , where IEAC(t) is the Independent Estimate at Completion (time) and PD is the planned duration for the project [3]. The long form is not needed in the subsequent discussion and, consequently, is not stated.

### **Why the Question?**

In the previous discussion of the concept, it is established that the determination of ES requires the Project Management Baseline (PMB), and is a cumulative measure. It is the cumulative “earned” portion of the schedule. The cumulative nature of ES is, also, emphasized in the seminal paper, “Schedule is Different” [2]. And, the instructions for using the ES calculator also stress that the complete PMB of the project must be entered to expect correctly calculated results [4].

My conjecture is the emphasis of these statements could cause the misunderstanding that the method is only applicable to the total project. With the repeated overtures to use the project PMB along with the statements that ES is a cumulative measure, it is a reasonable deduction.

However, ES is not limited to only the total project. It is much more applicable. I intend to dispel the perception of the limitation and show how the ES method can be applied at any level of interest within a project, including work packages, control accounts, and critical path activities. In other words, the capability is available for “drill-down” schedule analysis by applying the ES method to the project EVM data.

### **What’s the Trick?**

To broaden the applicability of ES to detailed schedule performance analysis is not difficult. All that is required is to view the subject of the analysis as if it is the total project. This response is very similar to my answer, earlier in the paper, to the question concerning applying ES to analyze the critical path. *It should be*. But, just as it was for the persons who posed the question during my presentations, the answer is incomplete. Thus, the question becomes, “How do I make a portion of a project appear like a total project?”

To answer this question, let us view Table 1, Project Plan and Performance Measures by Task. The table depicts the time-phased plan, earned value (EV), and actual costs (AC) for each of ten tasks comprising the notional project. The time-phased plan, the performance baseline, is created from the planned value (PV) amounts. All amounts are in units of cost and are periodic, not to be understood as cumulative. The diamond symbol indicates the initiation of the task. At project completion, the sum of the periodic EV amounts for each task equals the sum of its PV quantities.

To construct the PMB, first sum the periodic PV amounts across all tasks by performance period (PP). Then, finalize the PMB by creating the cumulative quantities

by PP. This is accomplished by adding, successively, the periodic PV determined from the summing across tasks. For example, add the total periodic PV in period two to period one to obtain the cumulative PV for period two; then for period three add its periodic PV to the cumulative PV for period two. This process is repeated through period ten. The resultant cumulative values for periods one through ten is the PMB. This is the project performance baseline from which ES for the total project is determined.

Project Data														
Task Nr	Measure	●●● Performance Period ●●●												
		0	1	2	3	4	5	6	7	8	9	10	11	12
1	PV	♦	5	5	5									
	EV		♦	4	5	6								
	AC		♦	5	5	7								
2	PV			♦	10									
	EV				♦	7	3							
	AC				♦	10	5							
3	PV			♦	10	10	10							
	EV			♦	8	13	9							
	AC			♦	10	15	10							
4	PV				♦	5	5							
	EV			♦	3	4	3							
	AC			♦	5	5	5							
5	PV				♦	5	5	5						
	EV				♦	5	3	5	2					
	AC				♦	5	5	5	2					
6	PV					♦	5	5						
	EV						♦	6	4					
	AC						♦	5	5					
7	PV			♦	10	10	10	10	10					
	EV				♦	8	9	7	13	8	5			
	AC				♦	10	10	10	15	10	5			
8	PV						♦	5	10	5				
	EV							♦	12	8				
	AC							♦	15	12				
9	PV							♦	5	5	5			
	EV								♦	4	5	3	3	
	AC								♦	5	6	5	3	
10	PV								♦	5	5			
	EV									♦	10			
	AC									♦	14			

Table 1. Project Plan and Performance Measures by Task

To analyze tasks (work packages), control accounts or critical path a performance baseline must be created specific to the analysis area; i.e., if a cost account is to be analyzed, its comprising tasks must be segregated and grouped. Then the process for creating the project PMB is applied to this set of tasks to create a PMB for the cost account, PMB<sub>a</sub>. Having PMB<sub>a</sub> allows ES to be calculated specifically for the cost account. In turn, the determination of ES facilitates the calculations of SPI(t) and IEAC(t) for the specific evaluation of cost account performance.

### Critical Path Example

With the methods in place, the process for applying ES to critical path analysis can be described. As discussed in the previous section of the paper, segregate and group the critical path tasks, and create a PMB representing them, PMB<sub>c</sub>. For this example, the critical path for the notional project includes tasks one, four, eight, and ten (1-4-8-10). Table 2, Performance Baselines and Earned Value Measures, aggregates the data for both the total project and the critical path.

Measure		●●● Performance Period ●●●												
		0	1	2	3	4	5	6	7	8	9	10	11	12
Total Project	PVper	0	5	5	35	30	40	30	20	5	10	5	0	0
	PVcum	0	5	10	45	75	115	145	165	170	180	185	185	185
	EVper	0	0	4	16	43	27	18	31	16	9	15	3	3
	EVcum	0	0	4	20	63	90	108	139	155	164	179	182	185
	ACper	0	0	5	20	52	35	20	37	22	10	20	5	3
	ACcum	0	0	5	25	77	112	132	169	191	201	221	226	229
	PVper	0	5	5	5	5	5	5	10	5	5	5	0	0
	PVcum	0	5	10	15	20	25	30	40	45	50	55	55	55
	EVper	0	0	4	8	10	3	0	12	8	0	10	0	0
	EVcum	0	0	4	12	22	25	25	37	45	45	55	55	55
ACper	0	0	5	10	12	5	0	15	12	0	14	0	0	
ACcum	0	0	5	15	27	32	32	47	59	59	73	73	73	

Table 2. Performance Baselines and Earned Value Measures

The project management baselines for the total project (PMB) and critical path (PMB<sub>c</sub>) are their respective PVcum rows. The PVper rows represent the summation of the planned values of the representative tasks for the specific performance period. As described previously, the PVcum is obtained from the PVper values. For example the calculation for PVcum for period three of the total project is determined by adding PVper for period three to PVcum of period two:  $PVcum(3) = PVcum(2) + PVper(3)$ . Using the values from the Table 2, the calculation can be performed:  $PVcum(3) = 10 + 35 = 45$ .

The remainder of Table 2 contains the performance data, earned value (EV) and actual costs (AC), for the total project and for the specific critical path tasks. The accumulation of this information allows analysis and prediction to occur for both the total project and the critical path.

The EVM performance indicators and duration forecasts calculated from the Table 2 data are aggregated in Table 3, Performance Indicators and Duration Forecasts. The “p” and “c” appended to the indicators shown in the table indicate *period* and *cumulative*, respectively.

From Table 2 it can be determined that the project is planned to complete in 10 time periods, but actually completes in 12. Similarly, Table 2 indicates the tasks on the critical path completed at the planned time, 10 periods. For comparison purposes both SPI and SPI(t) indicators are shown in Table 3. The familiar behavior of the two indicators is seen for the critical path and total project. The values for SPI(t) compare favorably to those for SPI for the critical path which completes as planned. However for the total project, the values for the two indicators are significantly different. The corresponding values for SPI(t)c and SPIc noticeably begin departing in period eight, and conclude as expected for late finishing projects; at project completion, SPI(t)c is a valid number (0.8333) truly depicting the actual schedule performance efficiency, while SPIc illogically equals 1.0.

		●●● Performance Period ●●●												
Indicator		0	1	2	3	4	5	6	7	8	9	10	11	12
Total Project	CPIp	xxx	xxx	0.8000	0.8000	0.8269	0.7714	0.9000	0.8378	0.7273	0.9000	0.7500	0.6000	1.0000
	CPIc	xxx	xxx	0.8000	0.8000	0.8182	0.8036	0.8182	0.8225	0.8115	0.8159	0.8100	0.8053	0.8079
	SPI(t)p	xxx	0.0000	0.8000	1.4857	1.3143	0.7750	0.4500	0.9750	0.7000	0.4500	1.9500	0.5000	0.6000
	SPI(t)c	xxx	0.0000	0.4000	0.7619	0.9000	0.8750	0.8042	0.8286	0.8125	0.7722	0.8900	0.8545	0.8333
	SPIp	xxx	0.0000	0.8000	0.4571	1.4333	0.6750	0.6000	1.5500	3.2000	0.9000	3.0000	xxx	xxx
	SPIc	xxx	0.0000	0.4000	0.4444	0.8400	0.7826	0.7448	0.8424	0.9118	0.9111	0.9676	0.9838	1.0000
	IEAC(t)	xxx	xxx	25.00	13.13	11.11	11.43	12.44	12.07	12.31	12.95	11.24	11.70	12.00
Critical Path 1-4-8-10	CPIp	xxx	xxx	0.8000	0.8000	0.8333	0.6000	xxx	0.8000	0.6667	xxx	0.7143		
	CPIc	xxx	xxx	0.8000	0.8000	0.8148	0.7813	0.7813	0.7872	0.7627	0.7627	0.7534		
	SPI(t)p	xxx	0.0000	0.8000	1.6000	2.0000	0.6000	0.0000	1.7000	1.3000	0.0000	2.0000		
	SPI(t)c	xxx	0.0000	0.4000	0.8000	1.1000	1.0000	0.8333	0.9571	1.0000	0.8889	1.0000		
	SPIp	xxx	0.0000	0.8000	1.6000	2.0000	0.6000	0.0000	1.2000	1.6000	0.0000	2.0000		
	SPIc	xxx	0.0000	0.4000	0.8000	1.1000	1.0000	0.8333	0.9250	1.0000	0.9000	1.0000		
	IEAC(t)	xxx	xxx	25.00	12.50	9.09	10.00	12.00	10.45	10.00	11.25	10.00	xxx	xxx

Table 3. Performance Indicators and Duration Forecasts

By inspection of Table 2, it is obvious the critical path changed during project execution. Knowing this begs the question, “Does the simultaneous application of ES to both the critical path and total project provide advance warning of this condition?” If the answer is “Yes,” then applying ES has been shown to yield analysis advantages to project managers.

One significant implication of a response of “Yes” is detailed schedule performance information can be obtained solely from the EVM data ... *without the laborious bottom-up analysis performed by skilled schedulers.*

Another point is detailed schedule analysis takes time and considerable effort by sometimes several people, oftentimes becoming a distraction to those performing project work. For any size, but especially for larger projects, performing a detailed schedule analysis involving several subcontractors in the time-frame the ES schedule forecasting calculations can be made is virtually impossible.

The time advantage offered by IEAC(t) does not mean to imply that detailed bottom-up schedule analysis should never be performed. Certainly, just as the final cost estimate obtained from IEAC is not relied on solely at critical points without a detailed cost analysis, a bottom-up schedule estimation should be performed for confirmation of the ES forecast.

By reviewing and comparing the IEAC(t) numbers for the total project and critical path we can answer the question posed a few paragraphs earlier. The answer is “Yes,” it can be observed that the critical path is likely to have changed. From examining Table 3 it is seen very early, beginning with period 3, that the forecast duration for the total project is always greater than the forecast for the critical path. It is reasonably clear that the critical path changed early in the project execution from tasks 1-4-8-10. From this example, it may be said that ES can provide advance warning that the critical path has changed.

Without going into the detail, the project duration forecasting method from ES can further be used to identify the longest duration path; i.e., the changed critical path. By forecasting duration for each task and inserting the forecasts into the network structure of the schedule, the actual critical path can be determined as well as conditions for float. With some technical ingenuity, this analysis could be completely automated.

### Summary

The Earned Schedule analysis method is demonstrated in this paper to be applicable to more than the total project. Segregating and grouping EVM data for a specific portion of the project is the technique by which ES is made applicable to the total project and any sub-level desired. Specifically, the technique is shown to be capable of analyzing the schedule performance for the critical path. By employing the same techniques to analyze critical path, schedule performance by individual tasks can be evaluated, which then allows identification of the longest duration path for the project (actual critical path) along with schedule float.

### References

1. Lipke, Walt. “Connecting Earned Value to the Schedule,” *CrossTalk*, June 2005: On-line (<http://www.stsc.hill.af.mil/crosstalk/2005/06/0506Lipke.html>).
2. Lipke, Walt. “Schedule is Different,” *The Measurable News*, March 2003: 10-15.
3. Henderson, Kym. “Further Developments in Earned Schedule,” *The Measurable News*, Spring 2004: 15-22.
4. <http://www.earnedschedule.com/Calculator.shtml>

### About the Author

**Walt Lipke** recently retired as the deputy chief of the Software Division at the Oklahoma City Air Logistics Center. The division employs approximately 600 people, primarily electronics engineers. He has over 35 years of experience in the development, maintenance, and management of software for automated testing of avionics and jet

engines as well as automation of industrial processes. During his tenure, the division achieved several software process improvement milestones:

- 1993 - first Air Force activity to achieve Level 2 of the Software Engineering Institute's Capability Maturity Model® (CMM®)
- 1996 - first software activity in federal service to achieve CMM® Level 4 distinction
- 1998 – division achieved ISO 9001/TickIT registration
- 1999 - division received the 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* (Copyright © 2003 Lipke), 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, ΣΠΣ. Lipke achieved distinguished academic honors with the selection to ΦΚΦ.