<u>Earned Schedule</u>

…an emerging enhancement to EVM

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Abstract. *Earned Schedule (ES) is a method of extracting schedule information from Earned Value Management (EVM) data. The method has been shown to provide reliable schedule indicators and predictors for both early and late finish projects. ES is considered a breakthrough technique to integrated performance management and EVM theory and practice. The method has propagated rapidly and is known to be used as a management tool for software, construction, commercial and defense projects in several countries, including the United States, Australia, United Kingdom, Belgium, and Sweden. The principles of Earned Schedule have been included in the Project Management Institute-College of Performance Management, <u>Practice Standard for Earned Value Management</u> as an "emerging practice" [1].*

Earned Value Management (EVM) was created within the United States Defense Department in the 1960s and has shown over the four decades from that time to be a very valuable project management and control system. EVM uniquely connects cost, schedule, and requirements thereby allowing for the creation of numerical project performance indicators. Managers now have the capability to express the cost and technical performance of their project in an integrated and understandable way to employees, superiors and customers.

For all of the accomplishments of EVM in expressing and analyzing cost performance, it has not been as successful for schedule performance. The EVM schedule indicators are, contrary to expectation, reported in units of cost rather than time. And, because cost is the unit of measure, the schedule indicators require a period of familiarization before EVM users and project stakeholders become comfortable with them and their use. Beyond this problem, there is the much more serious issue: the EVM schedule indicators fail for projects executing beyond the planned completion date.

Because these problems are well known to EVM practitioners, over time the application has evolved to become a management method focused primarily on cost. The schedule indicators are available, but are not relied upon to the same extent as the indicators for cost. The resultant project management impact from the EVM schedule indicator issues is cost and schedule analyses of project status and performance have become disconnected. Cost analysts view the EVM cost reports and indicators while schedulers tediously update and analyze the network schedule. Frequently for large projects, these separate skills are segregated and, often, their respective analyses are not reconciled.

It has been a long expressed desire by EVM practitioners to have the ability to perform schedule analysis from EVM data similarly to the manner for cost. Various approaches to using earned value for this analysis have been proposed and studied from time to time. However, none of the methods have proven to be satisfactory for both early and late finishing projects.

Before discussing the ES approach to overcoming the described cost-schedule dilemma, let us first review EVM.

EVM Measures and Indicators

Earned Value Management has three measures: planned value (PV), actual cost (AC), and earned value (EV). Refer to Figure 1, Earned Value, as an aid to this discussion. The planned values of the tasks comprising the project are summed for the periodic times (e.g., weekly or monthly) chosen to status project performance. The time-phased representation of the planned value is the performance management baseline (PMB). Actual costs and earned value are accrued and are likewise associated with the reporting periods. For each measure, the time-phased graphs are characteristically seen to be "S-curves." Observe that PV concludes at the Budget at Completion (BAC), the planned cost for the project. The BAC is the total amount of PV to be earned.

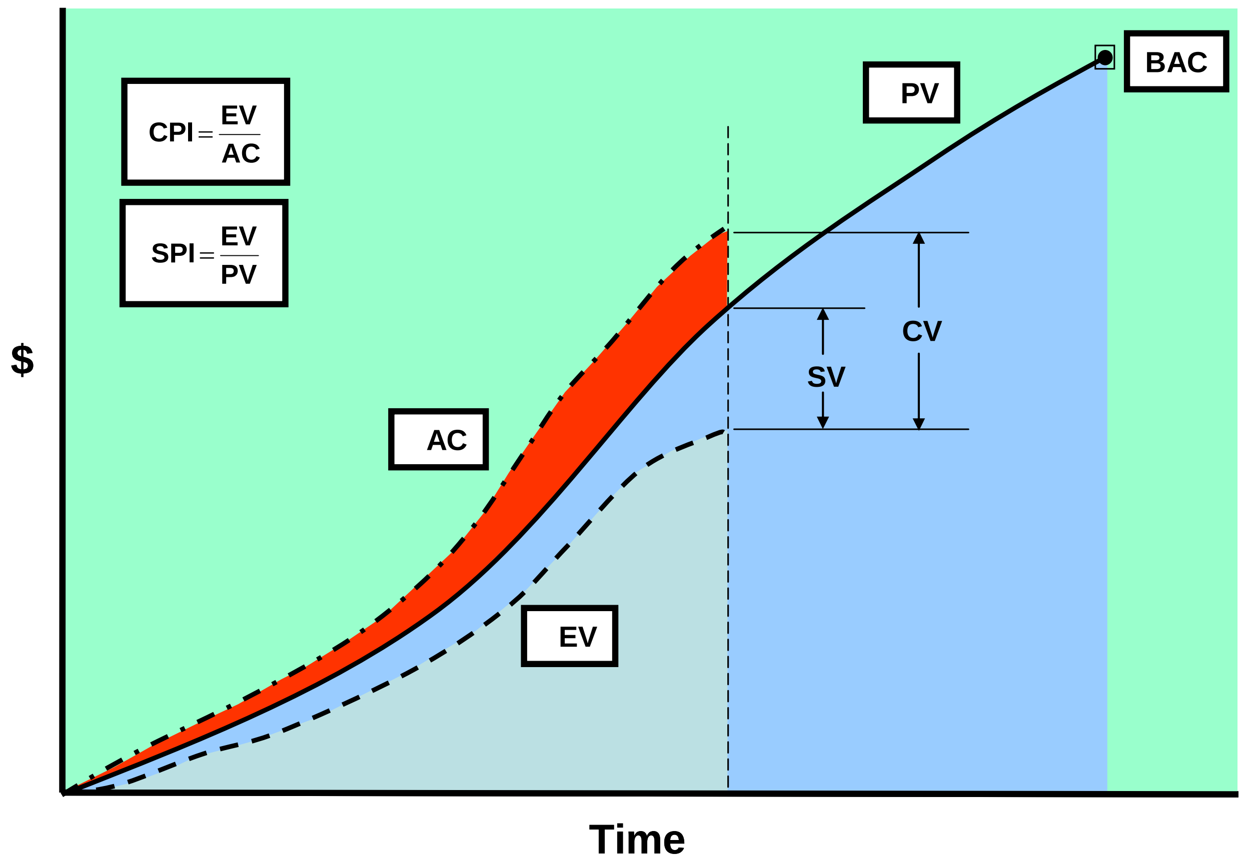

Figure 1. Earned Value

From the three measures, project performance indicators are formed. The cost variance (CV) and cost performance index (CPI) are created from the EV and AC measures, as follows: CV = EV – AC and CPI = EV / AC. In a similar manner, the schedule indicators are: SV = EV – PV, and SPI = EV / PV, where SV is the schedule variance and SPI is the schedule performance index.

Now, examine the formulation of the schedule indicators and recall that the PV and EV curves conclude at the same value, BAC. The fact that PV equals BAC at the planned completion point and does not change when a project runs late causes the schedule indicators to falsely portray actual performance. In fact, it is commonly observed that the schedule indicators begin this behavior when the project is approximately 65 percent complete.

The irregular behavior of the schedule indicators causes problems for project managers. At some point it becomes obvious when the SV and SPI indicators have lost their management value. But, there is a preceding gray area, when the manager cannot be sure of whether or not he should believe the indicator and subsequently react to it. From this time of uncertainty until project completion, the manager cannot rely on the schedule indicators portion of EVM.

Earned Schedule Description

The technique to resolve the problem of the EVM schedule indicators is Earned Schedule (ES). 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 2, Earned Schedule Concept, illustrates how the ES measure is obtained. Projecting the cumulative EV onto the PV curve (i.e., the 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 formed. 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.

The graphic and the box in the lower right of figure 2 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.

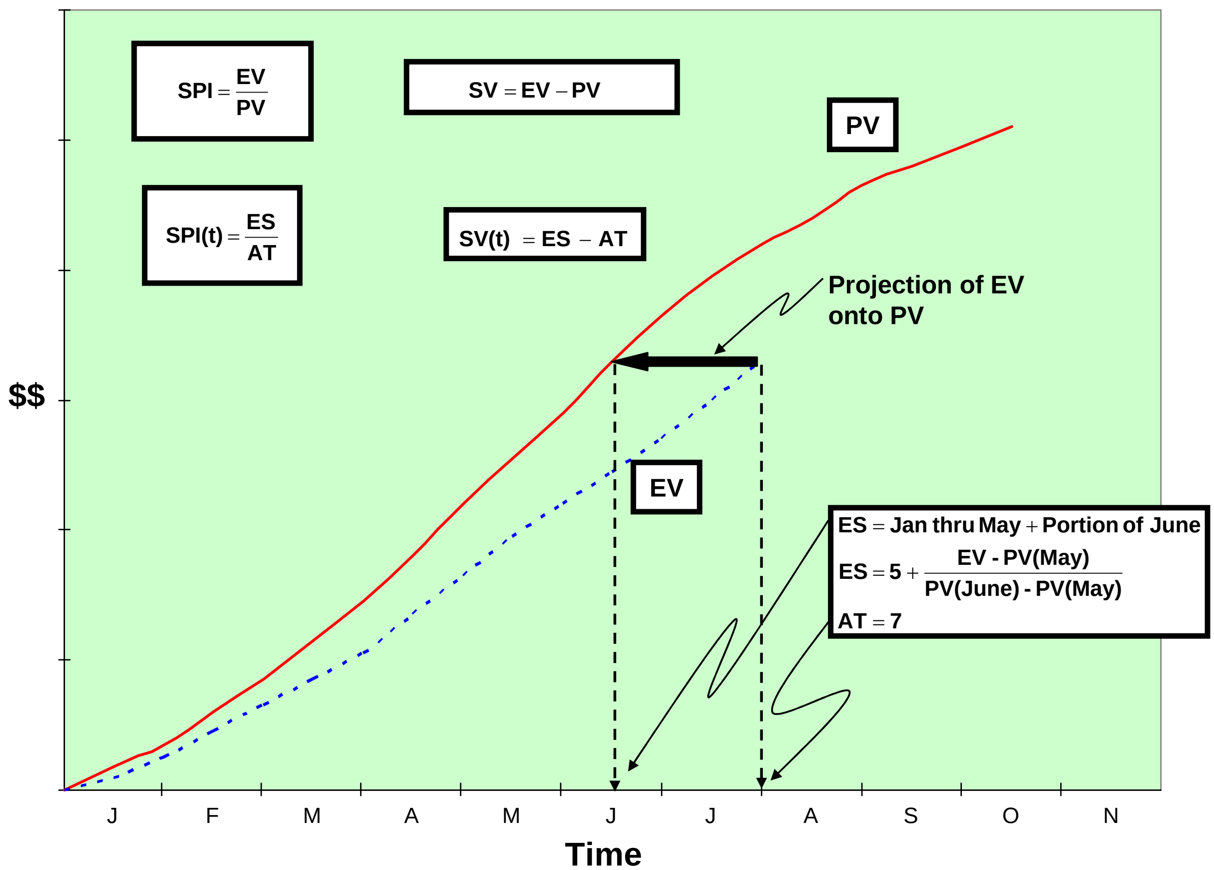

Figure 2. Earned Schedule Concept

Evolution of Earned Schedule

The ES concept was conceived during the summer of 2002 and was publicly introduced in March 2003 with *The Measurable News* article, "Schedule is Different" [2]. The initial article was quickly followed a few months later by the complimentary paper, "Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data" [3]. Using EVM data from several completed real projects, this second article verified the ES measure and its derivative indicators functioned as described in the seminal paper. From that time, the behavior of the calculated measure of ES and its indicators has been verified many times by practitioners using real data from various types of projects.

The seminal article alluded to the potential of using ES to forecast when a project would complete, but did not develop the equations. The second paper identified a schedule duration predictor analogous to the predictor for final cost, BAC / CPI. This schedule predictor, PD / SPI(t), where PD is the planned duration, was applied to real data and demonstrated the potential of project duration and completion date prediction using Earned Schedule.

Following the second paper was the article, "Further Developments in Earned Schedule" [4]. This paper further expanded the ES schedule prediction and algebraically compared the ES methods with other published techniques. Two ES predictive calculation methods were identified as the "short form" and "long form." The short form is as described previously, IEAC(t) = PD / SPI(t), where IEAC(t) is termed the "Independent Estimate at Completion (time)." The long form, just as for the short form, mimics an equation for forecasting final cost: IEAC = AC + (BAC – EV) / PF, where PF is a selected performance factor [1]. The long form schedule duration equation is as follows: IEAC(t) = AT + (PD – ES) / PF(t), where AT is the actual duration, and PF(t) is a selected time performance factor.

In the "Further Developments …" paper, two common methods of schedule prediction were used for comparison to the predictive performance of ES [5]. One uses SPI from EVM, and the other applies a performance factor termed the "Critical Ratio." The critical ratio is equal to SPI multiplied by CPI. The short form results were compared against two scenarios, early finish and late finish performance. Using data from two real projects discussed in the paper, the results for the three forecasting methods are tabulated in Table 1, IEAC(t) Comparison [4]. Only the ES forecast yielded correct results for both early and late completion. Neither of the other two methods provided correct results in either scenario.

	Early Finish **- Weeks -**	**Late Finish** **- Weeks -**
Planned Duration	**25**	**20**
Actual Duration	**22**	**34**
CPI	**2.08**	**0.52**
SPI	**1.17**	**1.00**
SPI(t)	**1.14**	**0.59**
PD / SPI(t)	**22.0**	**34.0**
PD / SPI	**21.4**	**20.0**
PD / (CPI ∗ SPI)	**10.3**	**38.7**

Table 1. IEAC(t) Comparison

In the same article, the long form equation was shown to provide correct end point results, regardless of the PF(t) used [4]. Thus, the long form equation possesses the identical characteristic of its companion equation for forecasting final cost. This characteristic of calculating and obtaining the correct result at project completion is required for the exploration and research of potential schedule based performance factors.

As the application of ES grew, it was recognized that there needed to be a common set of terminology. The principals involved agreed to a common theme: the terms should be parallel to, but readily distinguishable from those of EVM. It was thought that these characteristics would encourage the application of ES by minimizing the learning curve required. As seen from Table 2, Earned Schedule Terminology, the chosen terms are comparable to those from EVM. In most instances, the ES term is simply the analogous EVM term appended by the suffix "(t)."

After the ES method was published in March 2003, it rapidly became viewed as a viable extension to EVM practice. By the fall of 2003, the Project Management Institute - College of Performance Management (PMI-CPM) had become interested in the new practice. Within the next year an "emerging practice" insert citing the principles of Earned Schedule was included in the 2004 release of the PMI-CPM *Practice Standard for Earned Value Management* [1].

With increasing use and interest in ES came the question, "Does ES provide the long sought "bridge" between EVM and the network schedule?" Mainstream EVM thought is that other than the creation of the PMB, there can never be a strong connection between these two management components. The reasoning is EVM provides a macro-type assessment of performance, but cannot yield the detail required to assess the true schedule performance.

	EVM	Earned Schedule
Status	Earned Value (EV)	Earned Schedule (ES)
	Actual Costs (AC)	Actual Time (AT)
	SV	SV(t)
	SPI	SPI(t)
Future Work	Budgeted Cost for Work Remaining (BCWR)	Planned Duration for Work Remaining (PDWR)
	Estimate to Complete (ETC)	Estimate to Complete (time) ETC(t)
Prediction	Variance at Completion (VAC)	Variance at Completion (time) VAC(t)
	Estimate at Completion (EAC) (supplier)	Estimate at Completion (time) EAC(t) (supplier)
	Independent EAC (IEAC) (customer)	Independent EAC (time) IEAC(t) (customer)
	To Complete Performance Index (TCPI)	To Complete Schedule Performance Index (TSPI)

Table 2. Earned Schedule Terminology

Two papers, one published June 2005 and the other spring 2005, addressed the question of how ES contributes to making the direct connection between the schedule and the EVM data. The June 2005 paper is appropriately titled, "Connecting Earned Value to the Schedule," while the spring 2005 article is "Earned Schedule in Action" [6, 7]. The June 2005 paper describes how ES facilitates the bridge. The value of ES coincides with a PV point on the PMB. In turn, the PV is directly connected to specific tasks or work packages either completed or in work. Having this identification allows determination of how well the schedule is being followed. Differences in plan versus the actual distribution of EV provide insight as to which tasks may have impediments constraining progress, and which have the possibility of future rework. The article introduces a measure of schedule adherence, directly connecting EVM to the network schedule, termed the "P-Factor" [6]. This new measure has lead to a theory which may prove to yield earlier and better prediction for both cost and schedule.

A considerable amount of interest has been shown for the paper, "Earned Schedule in Action." The paper compares the results from applying ES and Critical Path (CP) duration prediction methods to a small scale but time critical IT project. What was observed during project execution is the duration predicted from ES converged to the actual final value from the pessimistic side, while the forecast from CP analysis converged optimistically. Because the ES predictive method takes into account past schedule performance while the CP method may not, it has been conjectured that, in general, ES yields a more consistently reliable schedule forecast. Further research is needed to confirm this hypothesis.

One advantage of ES became obvious in the CP study. Prediction obtained from ES calculations is considerably less effort than the CP approach, which requires very detailed task-level bottom-up analysis of the network schedule.

As a final point, the two papers just discussed provide rationale for the position that ES "bridges" the two disciplines of EVM and network schedule analysis. Even so, just as for cost, neither EVM nor ES can completely supplant bottom-up estimation techniques. For both, their respective predictive calculations are useful as macro methods for rapidly generating estimates and as a cross-check of the corresponding bottom-up analysis.

Applications

Early in the existence of Earned Schedule, some construed that the methods are limited in application. They believed that ES could only be used successfully for small Information Technology (IT) type projects. This perception occurred because software and IT projects were the environments in which the concept was created and first applied. The presumption is demonstrably false. ES is scalable up or down, just as is EVM. As well, ES is applicable to all types of projects, as is EVM. It follows that the scalability and applicability characteristics must exist; *after all, ES is derived from EVM*.

ES is known to be used in several organizations and countries for a variety of project types. Small Information Technology (IT) and construction projects as well as large defense and commercial endeavors have employed and continue to include ES as part of their management tool-set. The users have reported an increased ability to forecast future outcomes and the capability to identify late occurring problems that are masked when viewing EVM data alone. Significant applications in the United States (USA) are at Lockheed Martin, Boeing Dreamliner®, and the Air Force use in acquisition oversight. The United Kingdom Ministry of Defence has identified two major programs applying ES, Nimrod (maritime patrol aircraft) and Type 45 (Naval destroyer). Several smaller applications, mostly IT related projects, have occurred in Belgium by Fabricom Airport Systems, as well as in the USA and Australia.

Research

Small scale research has occurred throughout the evolution of ES. Each idea and next step has been applied and examined against real project data. However, due to data limitations, the testing and conclusions are not considered sufficiently complete. Although lack of testing is a drawback, the risk associated with ES usage is minimal. One compelling point supporting ES is that, regardless of the circumstances of the application (who, project type, company, country), the findings from all sources are consistent. The ES method, in every application, outperforms other EVM-based methods for representing schedule performance.

A research team at the University of Ghent, Belgium has recently published findings comparing ES to other project duration methods based on EVM measures [8]. Their conclusions coincide with the statement above; ES is the better performer. This research team has aspirations to perform rigorous testing of ES and the other prediction methods, using simulation techniques. They have also indicated interest in exploring the implications of the P-Factor (the measure of schedule adherence) discussed above.

What's Next?

The expectation is the application of Earned Schedule will continue to expand and propagate, coincident with the world-wide expansion of EVM. As ES is used more and more, it is reasonable to believe there will be increasing demand for its inclusion in EVM tools. Our conjecture is that the availability of tools employing ES is forthcoming in the near future. Along with increased application and tool availability, ES training will be requested as part of the provided EVM course. And most certainly as the use of ES expands, more information will be published, which will improve and mature the method and add to a rapidly expanding "ES Body of Knowledge". Ultimately, we foresee that ES will become generally accepted and subsequently included within EVM standards and guidance. Finally, it is our belief that ES will lead to improved prediction techniques for both cost and schedule.

Available Resources

There is a considerable amount of accessible ES information to aid current and potential users. Published papers, conference presentations and workshop material are available from two websites: www.earnedschedule.com and http://sydney.pmichapters-australia.org.au/ (Education, then Papers and Presentations). Both sites offer downloading of the information free of charge. Additionally, calculators facilitating the application of ES are available from the 'earnedschedule' site.

Summary

Earned Schedule was created as a non-complex solution to resolve the problem of the EVM schedule indicators failing for late finishing projects. The ES method requires only the data available from EVM and has been shown to provide better prediction than other EVM-based methods. Duration forecasting using ES is easier to do than detailed, bottoms-up estimation, and possibly yields better results, as well. ES is scalable up or down, and is applicable to any project using EVM. ES facilitates identification of tasks with possible impediments, constraints, or future rework and has the potential to improve both cost and schedule prediction.

Earned Schedule is a powerful new dimension to integrated project performance management and practice. *It has truly become …a breakthrough in theory and application*

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Additional Reading

Papers two through seven of the references for this article are available for download from either of the two websites identified previously in the *Available Resources* section. For a very easy to understand description of Earned Schedule, please read "Not Your Father's Earned Value" by Ray Stratton. His article is available from both websites, as well.

About the Authors

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. 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.

Kym Henderson's Information Technology (IT) career features broad experiences covering, Project and Program Management, Software Quality Assurance Management and Project Planning and Control. He has worked for a number of reputable IT companies across many industry sectors including commercial IT, Defence, Government, Manufacturing, Telecommunications and Financial Services. The focus has been large, complex project and corporate environments. He has a Masters of Science (Computing) from the University of Technology Sydney. He has also received a number of awards including a Reserve Force Decoration (RFD) for 15 years efficient service as a commissioned officer in the Australian Army Reserve. He is currently the Education Director of the PMI Sydney Australia Chapter and is also a member of the PMI College of Performance Management. Kym has extensive experience in "project recovery", where the use of simplified EVM techniques to assist in rapidly evaluating current project status, statistically predicting a likely range of project Costs at Completion and objectively measuring project progress to completion have proven invaluable.