Project Management Institute Practice Standard for Earned Value Management

Exposure Working Draft

Contents

Preface

The *Earned Value Management* (*EVM*) *Practice Standard* has been developed as a supplement to *A Guide to the Project Management Body of Knowledge* (*PMBOK® Guide*). The *EVM Practice Standard* is designed to provide readers who are familiar with the *PMBOK® Guide* with a fundamental understanding of the principles of EVM and its role in facilitating effective project management.

The *EVM Practice Standard* assumes that the reader has a basic working knowledge of the project management process groups, knowledge areas and other key concepts, such as work breakdown structures (WBS) and critical path method (CPM) scheduling, which are outlined in the *PMBOK® Guide*. If that is not the case, it is recommended that the reader undertake a review of the *PMBOK® Guide* before reading the *EVM Practice Standard*.

The *EVM Practice Standard* is organized as follows:

> **Introduction.** A brief overview of EVM, highlighting the key management questions EVM can help answer and exploring where EVM fits into the project management universe.
>
> **Basic Elements of Earned Value Management.** This section discusses the three cornerstones of EVM: ***Planned Value (PV)***, ***Earned Value (EV)*** and ***Actual Cost (AC)***. It examines how these three data points are determined and how they relate to one another.
>
> **EVM Performance Analysis and Forecasting.** This section describes variances, indices and forecasts that can be developed using ***Planned Value, Earned Value*** and ***Actual Cost***. The chapter also examines how these variances, indices and forecasts can be used to answer essential management questions.
>
> **Guidance for the Use of Key EVM Practices.** This section outlines basic EVM practices in their project management context, and shows how EVM practices facilitate project planning and control for better management of project cost and schedule performance.
>
> **Glossary.** This section provides concise definitions of key terms used in earned value management that are introduced in the practice standard.
>
> **Appendices.** These offer additional sources of EVM concepts and methods for further study and information related to the development of the practice standard.

Chapter 1 Introduction

1.1 The Role of Earned Value Management

Feedback is critical to the success of any project. Timely and targeted feedback can enable project managers to identify problems early and make adjustments that can keep a project on time and on budget.

Earned Value Management (EVM) has proven itself to be one of the most effective performance measurement and feedback tools for managing projects. It enables managers to close the loop in the classic business formula, “Plan, Do, Check, Act.”

EVM has been called “management with the lights on” because it can help clearly and objectively illuminate where a project is and where it is going—compared to where it was supposed to be and where it was supposed to be going. EVM uses the fundamental principle that patterns and trends in the past can be good predictors of the future.

EVM provides organizations with the methodology needed to integrate the management of project scope, schedule, and cost. EVM can play a crucial role in answering management questions that are critical to the success of every project, such as:

- Are we ahead of or behind schedule?
- How efficiently are we using our time?
- When is the project likely to be completed?
- Are we under or over our budget?
- How efficiently are we using our resources?
- What is the remaining work likely to cost?
- What is the entire project likely to cost?
- How much will we be under or over budget?

If the application of EVM to a project reveals that it is behind schedule or over budget, the project manager can use the EVM methodology to help identify:

- Where problems are occurring;
- Whether the problems are critical or not;
- What it will take to get the project back on track.

1.2 EVM and the Project Management Process

Effective use of EVM requires that it be used on projects where the principles of good project management, as outlined in the *PMBOK® Guide*, are being applied. To establish a basic foundation for understanding EVM’s role in effective project management, it is important that we examine the relationship between EVM and the *PMBOK® Guide’s* process groups and knowledge areas.

Project management is primarily a matter of planning, executing and controlling work. Figure 1-1 indicates the areas of project management to which EVM is most applicable.

Figure 1-1: EVM and Project Management

Knowledge Areas	**Process Groups**				
	Initiating	Planning	Executing	Controlling	Closing
Integration		✕	✕	✕	
Scope		✕		✕	
Time		✕		✕	
Cost		✕		✕	
Quality					
Human Resources					
Communications		✕	✕	✕	
Risk		✕		✕	
Procurement					

Project planning is mostly a matter of determining:

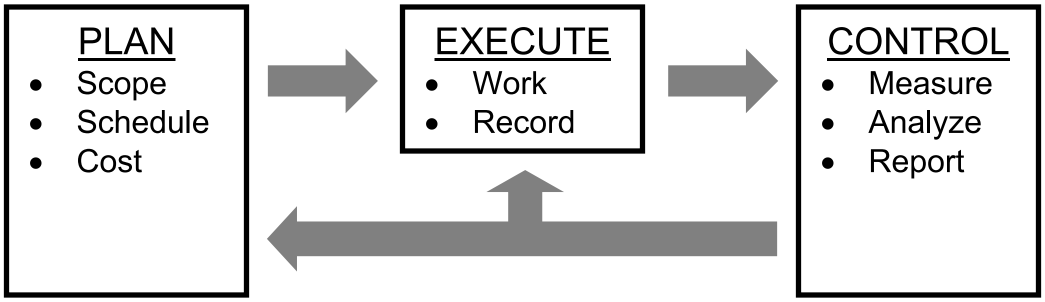
- What work must be done (scope) and in what pieces (work breakdown structure);
- Who is going to perform and manage the work (responsibility assignment matrix);
- When the work is going to be done (schedule);
- How much labor, materials and related resources the work is going to require (cost).

Project execution is primarily a matter of doing the planned work and keeping workers and managers informed.

Project control focuses mostly on monitoring and reporting the execution of project plans related to scope, schedule and cost, along with quality and risk. In other words, project control is a process for keeping work performance and results within a tolerable range of the work plan.

As a performance management methodology, EVM adds some critical practices to the project management process. These practices occur primarily in the areas of project planning and control, and are related to the goal of measuring, analyzing, forecasting, and reporting cost and schedule performance data for evaluation and action by workers, managers and other key stakeholders. See Figure 1-2.

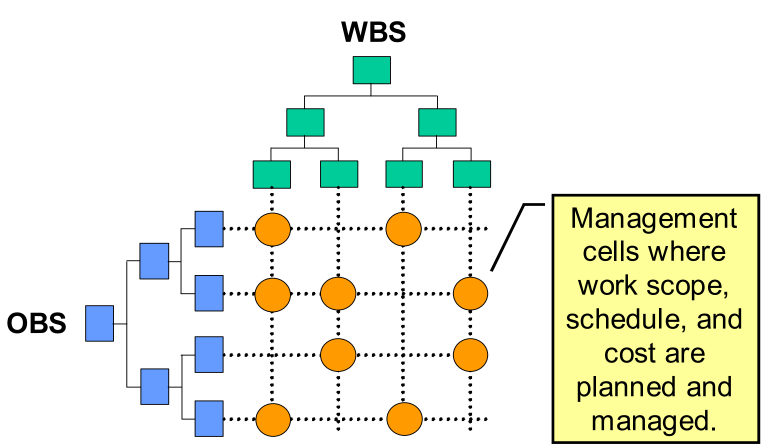
Figure 1-2: EVM and the Basic PM Process



During the project Planning Process Group, EVM requires that a performance measurement baseline (PMB) be established. This requirement amplifies the importance of project planning principles, especially those related to scope, schedule and cost. EVM elevates the need for project work to be executable and manageable, and for the workers and managers to be held responsible and accountable for its performance.

Project work needs to be broken down (using a work breakdown structure) into executable tasks and manageable elements (often called control accounts). Each of the work elements needs to be managed by an individual or a team. All of the work needs to be assigned to the workforce for execution (using an organization breakdown structure, or OBS, yielding a responsibility assignment matrix). See Figure 1-3 and Box 1-1.

Figure 1-3: Manageable Work Elements



Project work needs to be logically scheduled and resourced in a work plan, and the work scope, schedule, and cost need to be integrated and recorded in a time-phased budget, referred to as a performance measurement baseline (see Figures 1-4, 1-5, and 1-6).

Also in the planning process, the means for assessing physical work progress and assigning budgetary earned value need to be established. In addition to routine project management planning, earned value measurement techniques are selected and applied for each work task, based on scope, schedule and cost considerations.

In the project execution process, EVM requires that resource utilization (i.e., labor, materials, and the like) be recorded for the work performed within each of the work elements included in the project plan. In other words, actual costs need to be captured in such a way that permits their comparison with the performance measurement baseline.

In the project control process, EVM requires that physical work progress be assessed and budgetary earned value be credited (using the selected earned value measurement techniques) as prescribed in the project plan. With these earned value data, the planned value data from the PMB, and the actual cost data from the project cost tracking system, the project team can perform EVM analysis at the control account and other levels of the project WBS, and report the EVM results as needed.

In summary, EVM strategically augments good project management to facilitate the planning and control of cost and schedule performance. The key practices of EVM are the following:

- Establish a Performance Measurement Baseline (PMB)
    - Decompose work scope to a manageable level
    - Assign unambiguous management responsibility
    - Develop time-phased budget for each work task
    - Select EV measurement techniques for all tasks
    - Maintain integrity of PMB throughout the project.
- Measure and analyze performance against the baseline
    - Record resource usage during project execution
    - Objectively measure the physical work progress
    - Credit earned value according to EV techniques
    - Analyze and forecast cost/schedule performance
    - Report performance problems and/or take action.

Chapter 2 provides a detailed explanation of the three basic elements of EVM: ***Planned Value, Earned Value*** and ***Actual Cost***.

Figure 1-4: Work Plan – Gantt Chart

Task						May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		4	4										
1	8												
			8	8	8	8							
2	32												
						0	14						
3	14												
								6	6				
4	12												
									9		9		
5	18												
											8		8
6	16												
∑	100	4	12	8	8	8	14	6	15	0	17	0	8
CUM	-	4	16	24	32	40	54	60	75	75	92	92	100

Figure 1-5: Work Plan -- Area Chart

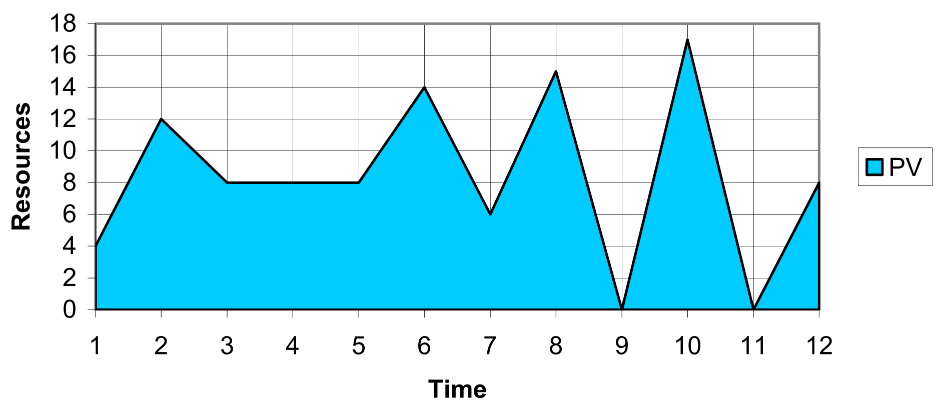
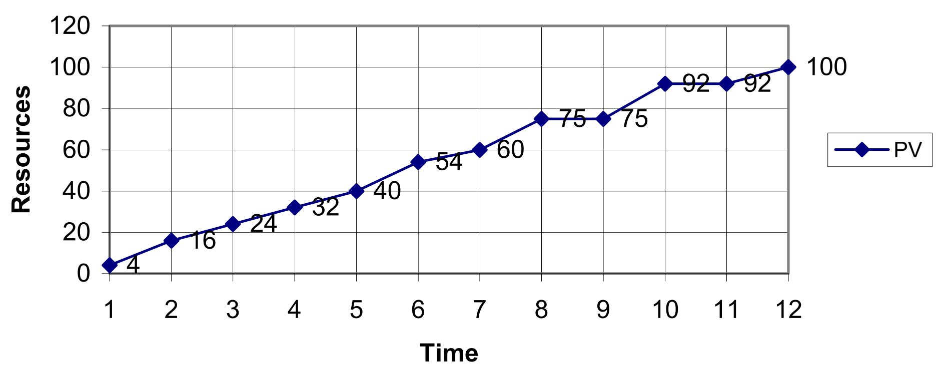


Figure 1-6: Performance Measurement Baseline (PMB)

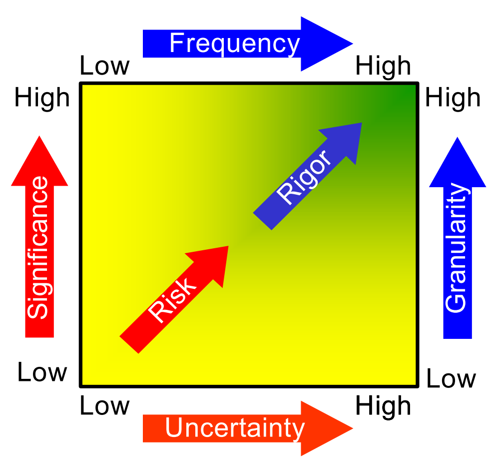


Box 1-1: Scaling EVM to Fit Varying Situations

Obviously, project situations can and do vary in numerous ways. EVM, as well as project management, needs to be tailored to fit the specific situation if it is to be effective and efficient. Project situations vary along two fundamental dimensions: the significance and the uncertainty of the project. The first has to do with the impact of success or failure and the second has to do with the likelihood of success or failure. Factors that affect significance include financial, political, and environmental considerations, while factors that contribute to project uncertainty include its size, complexity, and duration. These and other uncertainty factors can interact with the project management maturity of the performing organization to amplify or dampen their effects.

As project significance and uncertainty increase, the rigor with which EVM is applied also needs to increase. There are two basic dimensions to EVM rigor: the granularity and the frequency of the measurement of project performance. Granularity refers to the level of detail to which the project work scope is broken down using a WBS. Frequency is the time interval at which project performance is assessed, analyzed and reported, ranging from daily to monthly or longer. EVM implementation can be scaled along these two dimensions (granularity and frequency) to achieve the degree of rigor required by the significance and the uncertainty of the project. The figure below shows a notional model of the "risk-rigor" relationship.

EVM Rigor as a Function of Project Risk



Chapter 2 Basic Elements of Earned Value Management

As indicated in Chapter 1, EVM relies on three key data points:

- **Planned Value**
- **Earned Value**
- **Actual Cost**

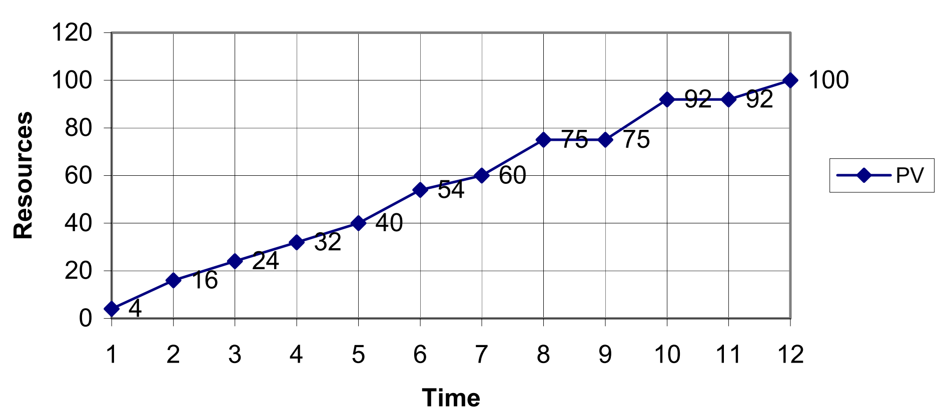
This chapter will describe each of these data points and discuss how they are derived. We will use a simple example, "Project EZ", throughout this chapter and the next to help explain these data points and other essential elements of EVM. Project EZ is a hypothetical project that could represent anything from the building of a house, to the development of a new software program, to the production of an airplane, or a host of other projects. The fundamentals of EVM are the same, regardless of the type or size of project to which they are being applied.

2.1 Descriptions of the Basic EVM Elements

What is Planned Value?

Planned Value (PV) describes how far along a project is supposed to be at any given point in the project schedule. It is a numeric reflection of the budgeted work that is scheduled to be performed, and it is the established baseline (also known as the performance measurement baseline) against which the actual progress of the project is measured. Once it is established, this baseline may change only to reflect cost and schedule changes necessitated by changes in the scope of work. Also known as the ***Budgeted Cost for Work Scheduled (BCWS)***, ***Planned Value*** is usually charted showing the cumulative resources budgeted across the project schedule. Figure 2-1 shows the ***Planned Value S-Curve*** for Project EZ.

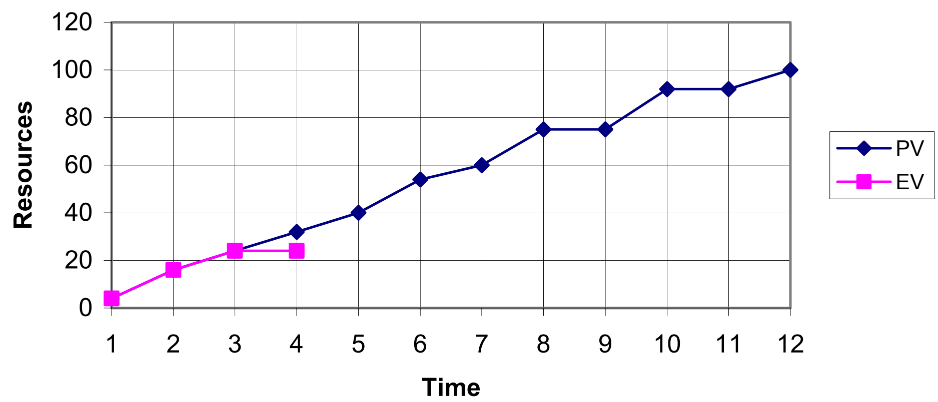
Figure 2-1: Cumulative PV for Project EZ



What is Earned Value?

Earned Value (EV) is a snapshot of a project at a given point in time. Also known as the ***Budgeted Cost for Work Performed (BCWP),*** it reflects the amount of work that has actually been accomplished, expressed as the planned value for that work. Figure 2.2 shows the ***Earned Value*** for Project EZ at the four-month mark, and indicates that less work than planned has been accomplished.

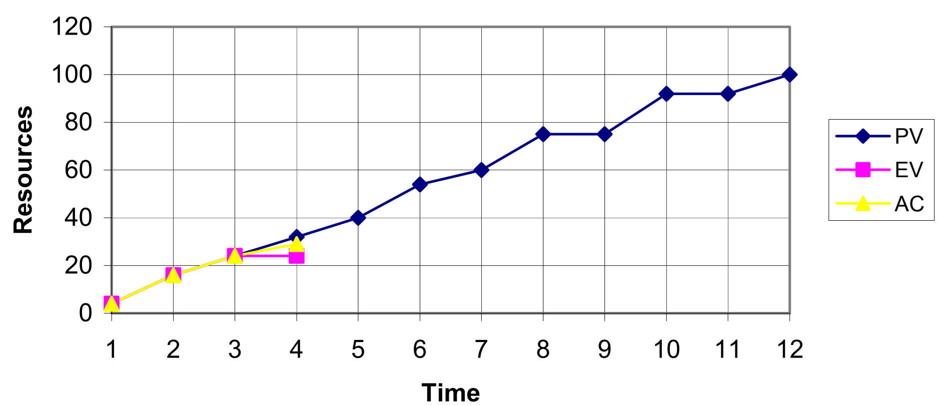
Figure 2-2: Cumulative PV and EV for Project EZ



What is Actual Cost?

Actual Cost (AC), also known as the ***Actual Cost of Work Performed (ACWP),*** is an indication of the level of resources that have been expended to achieve the actual work performed to date or in a time period. Figure 2-3 shows the ***Actual Cost*** for Project EZ at the four-month mark, and indicates that the organization has spent more than it planned to spend to achieve the work performed to date.

Figure 2-3: Cumulative PV, EV and AC for Project EZ



2.2 Derivations of the Basic EVM Elements

How is Value Planned?

Figure 2-4 represents the work plan for Project EZ. It is the basis for the ***Planned Value (PV)*** and the ***Performance Measurement Baseline (PMB)*** for the project (see Figure 2-1). In this plan, a time-phased budget is established for each task in the project. For example, Task 2 has a budget of 32 resource units, which are phased evenly over a four-month period. The plan for Task 2 calls for an increment of 8 units of ***Planned Value*** to be earned in each month of the task. As the planned work is accomplished, its budgeted cost becomes ***Earned Value***.

Tasks may be planned and measured in whatever resource units are most suitable to the work, including labor hours, material quantities, and the monetary equivalent of these resources. As we will see in the next section, however, performance management works best when the physical progress of work is objectively planned and measured. The techniques used in EVM to achieve this goal are EV Measurement Techniques (sometimes called earning and crediting methods).

Figure 2-4: Work Plan for Project EZ

Task						May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		4	4										
1	8												
			8	8	8	8							
2	32												
						0	14						
3	14												
								6	6				
4	12												
									9		9		
5	18												
											8		8
6	16												
∑	100	4	12	8	8	8	14	6	15	0	17	0	8
CUM	-	4	16	24	32	40	54	60	75	75	92	92	100
PV	100	4	12	8	8	8	14	6	15	0	17	0	8
EV	0	0	0	0	0	0	0	0	0	0	0	0	0
AC	0	0	0	0	0	0	0	0	0	0	0	0	0

EV Measurement Techniques

Earned Value is a measure of work performed. Techniques for measuring work performed are selected during project planning, and are the basis for performance measurement during project execution and control. Earned value techniques should be selected based on key attributes of the work, primarily the duration of the effort and the tangibility of its product.

The performance of work efforts that result in distinct, tangible products can be measured directly. This work is called *discrete effort*. Other work is measured indirectly as a function of either discrete efforts or elapsed time. Work that is linked to discrete effort is called *apportioned effort*, while that based on elapsed time is referred to as *level of effort*.

Work performance is measured periodically: weekly, monthly or the like. The EV technique selected for measuring the performance of discrete effort will depend on its duration and the number of measurement periods it spans. Discrete efforts that span one to three periods are often measured with fixed formula techniques, where a fixed percentage of work performance is credited at the start of the work and the remaining percentage is credited at the completion of the work. Discrete efforts of longer duration (greater than three periods) are measured with other techniques, including weighted milestone and percent complete.

The preceding guidelines for selection of EV measurement techniques are outlined in Figure 2-5, and examples of the most common techniques are described in the paragraphs that follow.

Figure 2-5: EV Measurement Techniques

Product of Work	**Duration of Work Effort**	
	1-3 Measurement Periods	>3 Measurement Periods
Tangible	*Fixed Formula*	*Weighted Milestone* *Percent Complete*
Intangible	*Apportioned Effort* *Level of Effort*	

Fixed Formula
A typical example of fixed formula is the ***50/50*** technique. With this method, 50 percent of the work is credited as complete for the measurement period in which the work begins, regardless of how much work has actually been accomplished. The remaining 50 percent is credited when the work is completed. The 50/50 technique is most effectively used on small, short-duration tasks.

In Figure 2-4, the 50/50 technique has been selected to determine ***Earned Value*** for Tasks 1 4, 5 and 6 of Project EZ. Other variations of the fixed formula method are 0/100 and 25/75. The 0/100 technique has been selected to determine ***Earned Value*** for Task 3 of Project EZ.

Weighted Milestone
The ***weighted milestone*** technique divides the task work to be completed into segments ending with observable milestones and then assigns a value to the achievement of each milestone. The weighted milestone technique is more suitable for longer duration tasks having intermediate products. In Figure 2-4 the weighted milestone technique has been used for Task 2 of Project EZ.

Percent Complete
The ***percent complete*** technique is among the simplest and easiest, but can be the most subjective, of the EV measurement techniques. This is the case when at each measurement period, the responsible worker or manager makes an estimate of the percentage of the work complete. These estimates are usually for the cumulative progress made against the plan for each task. However, if there are objective indicators that can be used to arrive at the percent complete (for example, number of units of product completed divided by the total number of units to be completed), then this can be a more useful technique.

Apportioned Effort
If a task has a direct, supportive relationship to another task that has its own ***Earned Value***, the value for the support task may be determined based on (or apportioned to) the ***Earned Value*** for the reference activity. Examples of proportional tasks might include quality assurance or inspection activities.

For instance, in Figure 2-4, Task 2 of Project EZ might have a quality assurance function associated with it. Using the apportioned effort technique, the project manager might determine that the ***Planned Value*** for the quality assurance task is 10 percent of the value of the main task. The total apportioned ***Planned Value*** for the quality assurance effort related to Task 2, therefore, would be 3.2 or 10 percent of 32 (the ***Planned Value*** for Task 2). ***Earned Value*** for each measurement period would be assigned for the quality assurance component in direct proportion to the ***Earned Value*** assigned for Task 2.

Level of Effort
Some project activities do not produce tangible outcomes that can be measured objectively. Examples include project management, operating a project technical library, and the like. These activities consume project resources and should be included in EVM planning and measurement. In these cases, the level of effort (LOE) technique is used for determining ***Earned Value***. A ***Planned Value*** is assigned to each LOE task for each measurement period. This ***Planned Value*** is automatically credited as the ***Earned Value*** at the end of the measurement period.

LOE activities will never show a schedule variance. Consequently, the technique always biases the project data toward an on-schedule condition. LOE should be utilized conservatively and should be considered only when the task does not lend itself to a more objective measurement technique.

How is Value Earned?

Value is planned and measured using the EV techniques previously outlined. It is earned by accomplishing the planned work. ***Earned Value*** is credited when progress is demonstrated in accordance with the EV technique selected for the planned work. For discrete work, observable evidence of a tangible product or progress is required.

Figure 2-6 shows the status of Project EZ after four months. This progress report indicates that all of the work planned for Task 1 has been accomplished. This discrete work was planned and measured using the 50/50 EV technique. It was credited with an ***Earned Value*** of 4 by demonstrating physical and objective evidence that the task began in January, and it earned the remaining value of 4 in February by demonstrating completion of the work in the same manner.

Task 2 of Project EZ is discrete work that was planned and measured using the weighted or valued milestone measurement technique. The progress report in Figure 2-6 shows that some of the work planned for completion by the end of April has not been accomplished. Two of the three scheduled milestones have been reached, but the third milestone has not, and the ***Planned Value*** for that intermediate product has not been credited. To receive the ***Earned Value*** for the first two milestones required observable evidence of those tangible outcomes.

Figure 2-6: Work Plan and Status for Project EZ
(As of April 30)

Task								Jul	Aug	Sep	Oct	Nov	Dec
		4	4										
1	8												
			8	8	8	8							
2	32												
						0	14						
3	14												
								6	6				
4	12												
									9		9		
5	18												
											8		8
6	16												
∑	100	4	12	8	8	8	14	6	15	0	17	0	8
CUM	-	4	16	24	32	40	54	60	75	75	92	92	100
PV	32	4	12	8	8	8	14	6	15	0	17	0	8
EV	24	4	12	8	0								
AC	29	4	12	8	5								

How is Cost Derived?

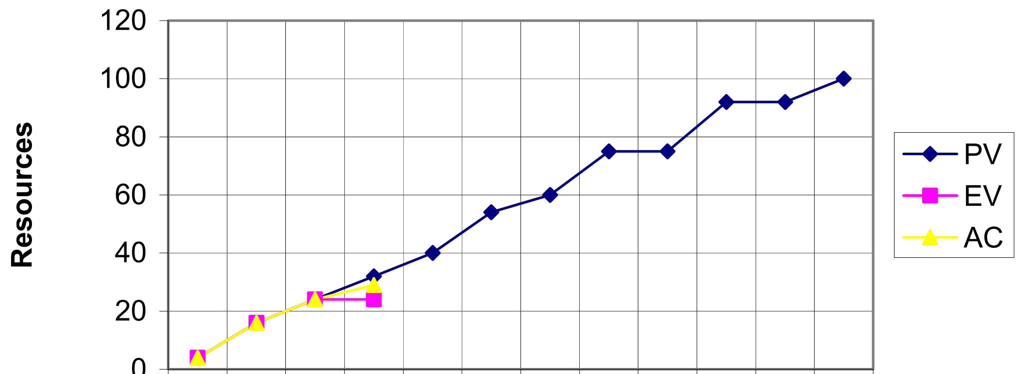
To determine ***Actual Cost (AC),*** an organization needs to have a system for tracking costs over time and by project component. The sophistication and complexity of this system will vary by organization and project, but, at minimum, some type of cost tracking system must be in place that can tie costs to the plan and to the way ***Earned Value*** is credited.

The status of Project EZ in Figure 2-6 shows that, although no ***Earned Value*** was credited for Task 2 in April, some costs were reflected for that month, which put the task and the project over budget at the end of April, as the ***Actual Cost*** exceeded the ***Earned Value*** (see also Figure 2-3).

2.3 Putting it All Together

Once ***Planned Value, Earned Value*** and ***Actual Cost*** have been determined, a manager can use these data points to analyze where a project is and forecast where it is headed. Chapter 3 looks at EVM analysis and forecasting techniques utilizing the ***Planned Value***, ***Earned Value*** and ***Actual Cost*** for Project EZ after four months, as shown in Figure 2-7.

Figure 2-7: Cumulative PV, EV and AC for Project EZ (As of April 30)



	1	2	3	4	5	6	7	8	9	10	11	12
PV	4	16	24	32	40	54	60	75	75	92	92	100
EV	4	16	24	24								
AC	4	16	24	29								

Time

Chapter 3 EVM Performance Analysis and Forecasting

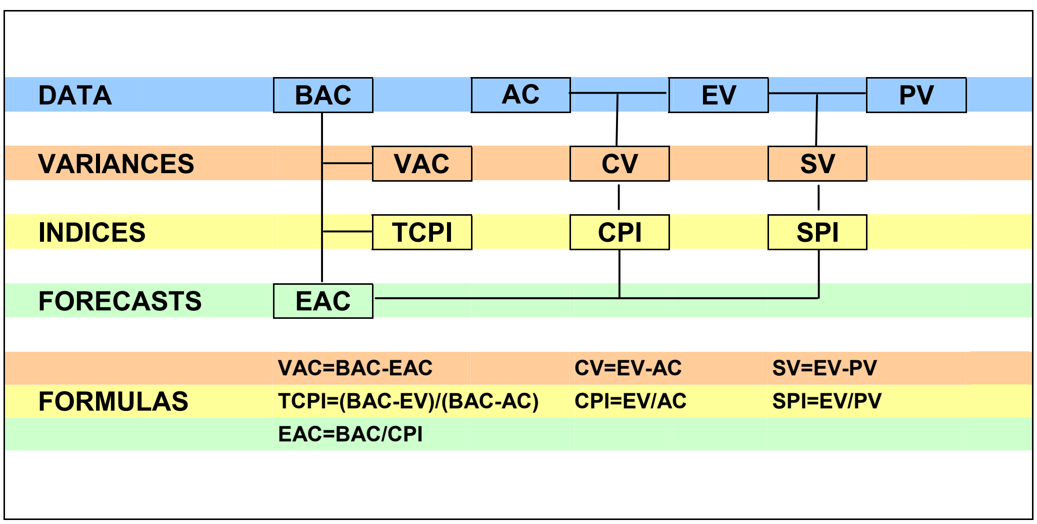
Chapter 2 introduced the three cornerstones of EVM:
- **Planned Value**
- **Earned Value**
- **Actual Cost**

In this chapter we will examine how these **data points** can be used to analyze the current status of a project and forecast its likely future. The Project EZ data in Figure 2-7 will be used. In this chapter we also will discuss a fourth data point, ***Budget at Completion (BAC)***, which is the final data point on the Performance Measurement Baseline. ***BAC*** represents the total ***Planned Value*** for the project. For instance, on Project EZ the ***BAC*** is 100.

In this chapter, we will examine:
- **Variances:** Schedule Variance (SV); Cost Variance (CV); and Variance at Completion (VAC)
- **Indices:** Schedule Performance Index (SPI); Cost Performance Index (CPI); and To-Complete Performance Index (TCPI)
- **Forecasts:** Time Estimate at Completion (EAC_t); Estimate at Completion (EAC); and Variance at Completion (VAC)

Figure 3-1 shows relationships among the EVM performance measures.

Figure 3-1: EVM Performance Measures



These variances, indices and forecasts can be used to answer the key project management questions raised in Chapter 1. Figure 3-2 shows the relationship between those PM questions and the EVM performance measures.

Figure 3-2: EVM and Basic PM Questions

Project Management Question	EVM Performance Measures
How are we doing time wise?	Schedule Analysis & Forecasting
- *Are we ahead or behind schedule?*	- Schedule Variance (SV)
- *How efficiently are we using time?*	- Schedule Performance Index (SPI)
- *When are we likely to finish work?*	- Time Estimate at Completion (EAC_t)
How are we doing coastwise?	Cost Analysis & Forecasting
- *Are we under or over our budget?*	- Cost Variance (CV)
- *How efficiently are we using our resources?*	- Cost Performance Index (CPI)
- *How efficiently must we use our remaining resources?*	- To-Complete Performance Index (TCPI)
- *What is the project likely to cost?*	- Cost Estimate at Completion (EAC)
- *Will we be under or over budget?*	- Variance at Completion (VAC)
- *What will the remaining work cost?*	- Estimate to Complete (ETC)

Figure 3-3 shows "at-a-glance" what EVM performance measures indicate about a project in regard to its planned work schedule and resource budget.

Figure 3-3: Interpretations of Basic EVM Performance Measures

Performance Measures		SV & SPI		
		>0 & >1.0	**=0 & =1.0**	**<0 & <1.0**
CV & CPI	**>0 & >1.0**	**Ahead of Schedule Under Budget**	**On Schedule Under Budget**	**Behind Schedule Under Budget**
	=0 & =1.0	**Ahead of Schedule On Budget**	**On Schedule On Budget**	**Behind Schedule On Budget**
	<0 & <1.0	**Ahead of Schedule Over Budget**	**On Schedule Over Budget**	**Behind Schedule Over Budget**

3.1 Schedule Analysis and Forecasting *(How are we doing time wise?)*

Schedule Variance *(Are we ahead or behind schedule?)*

Schedule Variance (SV) is determined by subtracting ***Planned Value (PV)*** from ***Earned Value (EV)***. For Project EZ:

SV = EV – PV = 24 – 32 = –8 {unfavorable}

Schedule Variance (SV) can be translated into a percentage by dividing ***Schedule Variance (SV)*** by ***Planned Value (PV)***:

SV% = SV / PV = –8 / 32 = –25% {unfavorable}

In other words, the project is 25 percent behind schedule, meaning that 25 percent of the planned work has not been accomplished (see Box 3-1).

Schedule Performance Index *(How efficiently are we using our time?)*

The ***Schedule Performance Index (SPI)*** is calculated by dividing ***Earned Value (EV)*** by ***Planned Value (PV)***. For Project EZ:

SPI = EV / PV = 24 / 32 = 0.75 {unfavorable}

This SPI indicates that, on average, for each 8-hour day worked on the project, only six hours worth of the planned work is being performed; that is, work is being accomplished at 75 percent efficiency.

Time Estimate at Completion *(When are we likely to finish the work?)*

Using the SPI and the average ***Planned Value*** per unit of time, the project manager can generate a rough estimate of when the project will be completed, if current trends continue, compared to when it was originally supposed to be completed (see Box 3-1). For Project EZ:

$$EAC_t = (BAC / SPI) / (BAC / MONTHS) = (100 / 0.75) / (100 / 12) = 16 \text{ months}$$

The originally estimated completion time for the project was 12 months, so the project manager now knows that if work continues at the current rate, the project will take four months longer than originally planned. Obviously, this method generates a fairly rough estimate and must always be compared with the status reflected by a time-based schedule method, such as CPM. It is possible that an earned value analysis could show no schedule variance and yet the project is still behind schedule; for example, when tasks that are planned to be completed in the future are performed ahead of tasks on the critical path.

Box 3-1: Time-Based Schedule Measures -- An Emerging EVM Practice

In the current practice of EVM, schedule variance and schedule performance are both measures of work scope, not time. The work is represented by its budgeted cost as recorded in the performance measurement baseline. The EVM schedule variance is the difference between work performed and work scheduled, and the schedule performance index is the ratio of work performed to work scheduled. These measures indicate that Project EZ's work is not being accomplished as quickly or as efficiently as planned:

SV = EV – PV = 24 – 32 = –8   **SPI = EV / PV = 24 / 32 = 0.75**

If the work were to continue at this rate, then all of the work of Project EZ would take 16 months to accomplish instead of the 12 months planned (12 / 0.75 = 16).

The SV and SPI measures are useful indicators and predictors of performance and results. But, because they are based on work and not time, they can behave in ways that are not normally expected of schedule indicators and predictors. The problem can be illustrated with Project EZ: Whether all of the work is completed as planned at 12 months or at 16 months, as predicted by the four-month SPI of 0.75, it will be completed, and the work-based schedule variance and schedule performance will indicate perfect performance. For when the work is completed: EV = PV, and so SV = 0 and SPI = 1.0. This is fine if the work is being accomplished according to plan, but problematic if it is not. If Project EZ does take 16 months, SV will nonetheless equal 0 and SPI equal 1.0, when it's clear that Project EZ is 4 months late and averaged only 75% efficiency.

There is an emerging practice in EVM, which uses time-based measures of schedule variance and schedule performance as an alternative or supplement to the traditional work-based measures. This new method avoids the problems of the work-based method illustrated above. Whereas the traditional work-based method compares work performed and work scheduled at, or to, a point in time, the time-based method compares the *elapsed time* with the *planned time* for the work performed. In the case of Project EZ, the work performed after four months had a planned time of three months (refer to Figures 2-6 and 2-7). In a manner that parallels the use of AC and EV in traditional EVM, practitioners are beginning to use elapsed time (ET) and planned time (PT) to compute SV and SPI:

SV(t) = PT – ET = 3 – 4 = –1 month   **SPI(t) = PT / ET = 3 / 4 = 0.75**

While the work- and time-based methods provide comparable results at the four-month point in Project EZ, look at the difference at project completion after 16 months:

SV(t) = PT – ET = 12 – 16 = – 4 months   **SPI(t) = PT / ET = 12 / 16 = 0.75**

SV($) = EV – PV = 100 – 100 = 0   **SPI($) = EV / PV = 100 / 100 = 1.0**

3.2 Cost Analysis and Forecasting *(How are we doing cost wise?)*

Cost Variance *(Are we under or over budget?)*

A project's ***Cost Variance (CV)*** is determined by subtracting the ***Actual Cost (AC)*** from the ***Earned Value (EV)***. To return to the Project EZ example:

CV = EV – AC = 24 – 29 = –5 {unfavorable}

This number can be converted to a percentage by dividing the ***Cost Variance (CV)*** by the ***Earned Value (EV)***.

CV% = CV / EV = –5 / 24 = –21% {unfavorable}

In other words, the project's cost to date is 21 percent over budget for the work performed to date.

Cost Performance Index *(How efficiently are we using our resources?)*

Earned Value and ***Actual Cost*** also can be used to calculate the ***Cost Performance Index (CPI)***, which is one of the clearest indicators of the cost efficiency of a project. The ***CPI*** is determined by dividing the ***Earned Value (EV)*** by the ***Actual Cost (AC)***. For Project EZ:

CPI = EV / AC = 24 / 29 = 0.8276 = 0.83 {unfavorable}

If we translate this into dollars, it would mean that Project EZ has a cost efficiency of $0.83 worth of work for every dollar spent to date.

To-Complete Performance Index *(How efficiently must we use our remaining resources?)*

Another very useful index is the ***To-Complete Performance Index (TCPI)***, which can tell a manager the efficiency that must be achieved for a project to meet a specified endpoint such as the ***Budget at Completion*** (***BAC)***. ***TCPI*** is calculated by dividing the *work remaining* by the *budget remaining* as follows:

TCPI = (BAC – EV) / (BAC – AC) = (100 – 24) / (100 – 29) = 1.07

This means that for Project EZ to achieve BAC, performance must improve from a CPI of 0.83 to a TCPI of 1.07 for the remaining work.

Estimate at Completion *(What is the entire project likely to cost?)*

The ***Estimate at Completion (EAC)*** tells a manager where the cost of a project is likely to end up if current performance trends continue. One common method for determining the EAC is to divide the ***Budget at Completion (BAC)*** by the ***Cost Performance Index (CPI)***. For Project EZ:

EAC = BAC / CPI = 100 / 0.8276 = 120.83

This forecasting formula assumes that the cumulative performance reflected in the CPI is likely to continue for the duration of the project. Other methods used to estimate cost at completion are outlined in Box 3-2.

Variance at Completion *(Will we finish under or over budget?)*

With the EAC figure in hand, the manager can now compute the cost ***Variance at Completion (VAC)*** by subtracting the ***EAC*** from the ***BAC***. For Project EZ:

VAC = BAC – EAC = 100 – 120.83 = –20.83

In other words, if current trends continue, the project will cost 20.83 units worth of resources more than originally planned. This can be translated into a percentage by dividing ***VAC*** by ***BAC***.

VAC% = VAC / BAC = –20.83 / 100 = –20.83%

Estimate to Complete *(What will the remaining work cost?)*

There are two ways to develop the ***Estimate to Complete (ETC)*** for the work remaining. One is a ***revised ETC*** developed by workers and managers based on an analysis of the remaining work. The ***revised ETC*** can be added to the ***Actual Cost*** to derive the ***Latest Revised Estimate (LRE)*** of the total cost of the project at completion.

LRE = AC + ETC = 29 + ? = ?

As a check on these revised estimates, organizations can use a ***calculated ETC*** based on the efficiency-to-date measured by the ***CPI***. The ***calculated ETC*** is used to calculate the ***Estimate at Completion (EAC)*** for comparison with the ***LRE***. For Project EZ, the ***ETC*** and ***EAC*** are calculated as follows:

ETC = (BAC – EV) / CPI = (100 – 24) / 0.8276 = 91.83

EAC = AC + ETC = 29 + 91.83 = 120.83

Note that this ***EAC*** formula is equivalent to the following (see Box 3-2):

EAC = AC + [(BAC – EV) / CPI] = BAC / CPI

Box 3-2: Alternative Calculations of Estimate at Completion (EAC)

The hallmark of EVM measures is that they provide objective information used to “check” a project in the “plan, do, check, act” process of project management. They serve as a check of progress against plans using ***Earned Value*** and its derivative variances and performance indices: SV, CV, SPI, and CPI. Among the checks is the comparison of the project BAC with the EAC calculated using the CPI cost efficiency measure: **EAC = BAC / CPI**. In addition to checking original project estimates, like BAC, efficiency measures also are used to check revised project estimates, especially estimates of cost at completion, like the LRE.

Forecasting with EVM measures should take project performance patterns and trends into account. The simple EAC calculation noted above assumes that the cumulative CPI adequately reflects past performance that will continue to the end of the project. There may be reasons to conclude otherwise and, therefore, to use an alternative calculation. One consideration is schedule performance. If the project is underperforming in this regard, there may be reason to include the SPI in the forecasting calculation on the assumption that additional costs will be incurred in an attempt to recover and get the project back on schedule.

Another forecasting consideration is the trend exhibited in cost performance. An examination of periodic cost performance may show better or worse performance in recent periods, suggesting that a CPI capturing the recent trend may be a better predictor of future performance. In this case, the average performance for the last three periods, for example, could be used in the calculation instead of the cumulative CPI. All calculations of EAC are estimates of the cost to do the work remaining on the project, plus the ***Actual Cost***. The *remaining work* is the *total planned work* minus the *work performed*, captured in the expression: ***BAC – EV***.

Here is a sample of the most common alternative ways of calculating the EAC:

Assumption	Example Formula
Future cost performance will be the same as all past cost performance	$EAC = AC + [(BAC - EV) / CPI] = BAC / CPI$
Future cost performance will be the same as the last three measurement periods (i, j, k)	$EAC = AC + [(BAC - EV) / ((EV_i + EV_j + EV_k) / (AC_i + AC_j + AC_k))]$
Future cost performance will be influenced additionally by past schedule performance	$EAC = AC + [(BAC - EV) / (CPI \times SPI)]$
Future cost performance will be influenced jointly in some proportion by both indices	$EAC = AC + [(BAC - EV) / (.8\ CPI + .2\ SPI)]$

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3.3 Management by Exception

EVM provides an organization with the capability of practicing “management by exception” on its projects. This practice contributes greatly to the efficiency and effectiveness of project management, by allowing managers and others to focus on project execution and invoke control actions only when and where they are needed. EVM performance measures, used in conjunction with the project work breakdown structure, provide the objective data needed to practice “management by exception.”

Using EVM, an organization can establish acceptable levels of performance for a project and its work tasks. Variance percentages and efficiency indices are most often used. For instance, an organization may consider a Cost Variance of plus or minus 10 percent to be an acceptable range of variance from the project plan. In such a case, no management action would be taken, except when and where a Cost Variance falls outside of this acceptable range. While a negative variance is potentially problematic, a positive variance may represent an opportunity.

Because EVM occurs first at the task level, where the scope, schedule, and cost of work is planned and controlled, “management by exception” also starts at this level. Managers use EVM performance measures to determine whether action thresholds have been reached for their tasks and control accounts. Also, in conjunction with a work breakdown structure, which ties the tasks and control accounts of a project together, EVM and “management by exception” can be used at any level of the project (as specified in the WBS).

While variance and efficiency thresholds are commonly used in EVM, trends in the performance measures for a project can help a project manager to decipher or anticipate a potential performance problem. For instance, a cumulative CPI that is within an acceptable range, but has been “trending down” toward the efficiency threshold for several measurement periods, may be cause for some concern and prompt an examination of the underlying cause of the trend. If the trend is seen at the project level, a WBS will enable the manager to “drill down” to lower levels to see what underlies the trend.

Graphs of variance and efficiency data are helpful tools in performing this kind of earned value analysis. Plotting the CV% or the CPI over time, for example, will indicate their values and show their trends. Computer software, particularly some developed especially for project and earned value management, is capable of producing such graphs. Box 3.3 outlines other basic kinds of performance management and reporting displays that are frequently used in earned value management. Appendix A provides additional sources of information on EVM concepts, methods, and practices.

Box 3-3: Performance Reporting

Earned Value Management (EVM) can provide a great deal of useful information to key stakeholders about a project. However, the level and type of information needed about a project may vary greatly from one stakeholder to another. The client, owner or upper management may simply need a top-line report that indicates whether the project is on time and on schedule. By contrast, the project manager will need much more detail that will allow him or her to make any necessary adjustments to the project.

A number of different methods have evolved for presenting EVM data. These methods are designed to address diverse stakeholder needs. Several of these methods may be used on a given project to meet the needs of different stakeholder audiences. The most commonly used methods include:

- S-curves
- Tables
- Charts

S-Curves
S-curves have been used throughout this *Practice Standard* to illustrate the basic concepts of Earned Value Management. The typical EVM S-curve is displayed on an X-Y axis with Time across the bottom and Resources up the side. An example is Figure 2-3, which shows the ***Planned Value, Earned Value*** and ***Actual Cost*** lines for Project EZ. This type of display can be very effective for providing a quick look at the overall performance of a task, a control account, or a project.

Tables
A tabular format can be an effective method for displaying the EVM results by project component. For instance, the individual components of a project could be listed down one side with various EVM calculations including ***Planned Value, Earned Value, Actual Cost, Cost Variance, Schedule Variance, Cost Performance Index, Schedule Performance Index*** and ***Estimate at Completion*** going across. A tabular format provides the overall project manager and other top-level stakeholders with a complete, concise picture of what is happening with each major component of the project. It can be used as a logical follow-on to an S-curve to provide more detail on where the project is at a given point in time.

Bar Charts
Bar charts can be a useful tool for comparing data such as ***Planned Value*** to ***Earned Value***, as demonstrated in Figure 2-6.

Chapter 4 Guidance for the Use of Key EVM Practices

EVM strategically augments good project management with key practices that facilitate the planning and control of cost and schedule performance. In this chapter we will outline guiding principles for the use of these key EVM practices, which were introduced in Chapter 1. This outline shows the interdependence of the fundamental practices of EVM and project management.

- Establish a Performance Measurement Baseline (PMB)
  - Decompose work scope to a manageable level
  - Assign unambiguous management responsibility
  - Develop time-phased budget for each work task
  - Select EV measurement techniques for all tasks
  - Maintain integrity of PMB throughout the project
- Measure and analyze performance against the baseline
  - Record resource usage during project execution
  - Objectively measure physical work progress
  - Credit earned value according to EV techniques
  - Analyze and forecast cost/schedule performance
  - Report performance problems and/or take action

4.1 Establish a Performance Measurement Baseline (PMB)

Decompose Work Scope to a Manageable Level

All project work must be executed, and effective and efficient execution requires planning and control. Most work scopes are broken down for optimal planning, execution, and control. EVM requires that scope, schedule, and resources (or cost) be managed as integrated parts of project work. This integration occurs at the task or activity level where physical work is performed. Work scope (tasks or activities) to which EVM is applied is grouped into control accounts for integrated management.

Assign Unambiguous Management Responsibility

All project work must be managed; its execution must be planned and controlled. Integrated management of work scope, schedule, and cost requires that a single individual or product delivery team be held responsible and accountable for the work grouped in each control account. An individual or team can be responsible for more than one control account, but each control account must be managed by only one control account manager or team.

Develop Time-Phased Budget for Each Work Task

The full scope of work for each task or activity must be scheduled and resourced. This results in a time-phased budget, which integrates the scope, schedule, and cost for the work (task or activity). In EVM these time-phased budgets are the planned value (PV) for the work, and represent its performance measurement baseline (PMB). The vertical integration of a work breakdown structure (WBS) facilitates aggregation of these time-phased budgets to higher levels including the control account, project, and levels in between.

Select EV Measurement Techniques for All Tasks

In EVM the progress of all work must be measured. Measurement of work scope accomplishment is planned at the task level in conjunction with the performance measurement baseline. An EV technique is selected for each task based on the temporal and physical qualities of the work. Objective measurement of physical progress on tasks with tangible outcomes is superior to all other forms of measurement. Subjective assessments of progress are considered inferior. Tasks that can be completed in one progress-reporting period require only one measurement and are preferred. Tasks that span several reporting periods should be measured objectively with milestones representing intermediate, tangible outcomes.

Maintain Integrity of PMB throughout the Project

The aforementioned four key practices are interdependent and should be undertaken in concert to establish a realistic and durable performance measurement baseline. Once the baseline is established, its integrity as an integrated measurement tool, relating scope, schedule, and cost, should be strictly maintained. There are two basic reasons to change the baseline: 1) If the work scope is changed, then the cost and possibly the schedule will change, and all of these changes need to be reflected in a revised baseline. 2) If poor performance in the past is rendering the baseline worthless as a tool for measuring present performance, then a revised baseline may be justified.

4.2 Measure and Analyze Performance Against the Baseline

Record Resource Usage During Project Execution

In EVM costs associated with the performance of work scope must be recorded on a regular basis. Costs should be measured at the level at which work scope, schedule, and cost are integrated in the time-phased budgets of the performance measurement baseline. The lower the level of cost measurement, the higher the level of rigor at which cost performance can be managed. If resource usage can only be recorded at a higher level of work scope, the vertical integration of a work breakdown structure will facilitate cost performance management at that higher level. While monetary costs are the common denominator for resources used on most projects, and are therefore preferred, some projects, and some tasks within a project, may find labor hours or material quantities adequate or preferable.

Objectively Measure the Physical Work Progress

EVM strives to objectively measure the physical progress of work. The more it achieves this goal, the better it performs its role of performance management and the more it contributes to effective project management. Projects vary a lot in regard to the physical qualities of their work. For example, most construction projects consist largely of tangible products, which can be readily and directly measured, whereas many research projects yield only intangible outcomes until their final product emerges at the end. Although objective measures of physical progress are vastly preferred, some measure of work scope accomplishment, including a subjective assessment of progress, is better than none at all.

Credit Earned Value According to EV Techniques

Physical work progress on tasks is credited in terms of predetermined techniques that are selected during project planning and are included in the performance measurement plans for the tasks. Adherence to the measurement plans during project execution assures that assessments of work progress yield earned values that can be compared with the planned values and the actual costs for the task. It also assures that earned values are credited in the same measurement units used to establish planned values and record actual costs (labor hours, material quantities, or their monetary value).

Analyze and Forecast Cost/Schedule Performance

Cost and schedule performance should be measured and analyzed, wherever feasible, with regularity and intensity that is consistent with project management requirements, including the magnitude of performance risk. Analysis should be progressive and should follow the principle of management by exception. Variance thresholds should be established in the planning phase and should be used to guide the examination of performance. Tasks whose performance falls within the prescribed tolerance range should not require additional scrutiny. However, when performance data at higher levels of the work breakdown structure are reviewed, caution should be exercised, since compensating good performance can mask poor performance at lower levels. The function of EVM forecasts is to compare their objective values with the more subjective management estimates offered by project delivery team members.

Report Performance Problems and/or Take Action

The goal of EVM is better cost and schedule performance in the accomplishment of work scope. However, performance is not simply a function of execution; it depends also on the quality of planning and control. EVM data do not reveal the causes of performance; project managers and others must decide where the problems lie and what actions to take or recommend. Poor execution may call for recovery, while poor planning may call for replanning. It is critical that EVM provide the best possible feedback to those who must make the decisions and take the actions. Simple metrics alone may not be enough, especially if decisions and actions appear to be warranted. Patterns and trends in periodic and cumulative data should be displayed in tables and graphs for review, and explanations and interpretations should be provided by the managers having that information and insight.

Appendix A The Project Management Institute Standards–Setting Process

(This is a standard PMI Appendix, which will be added to the final document. Content not subject to Exposure Draft Process)

Appendix B Evolution of PMI's Practice Standard for Earned Value Management

(This is a standard PMI Appendix, which will be added to the final document. Content not subject to Exposure Draft Process)

Appendix C Contributors and Reviewers of the Practice Standard for Earned Value Management

(This is a standard PMI Appendix, which will be added to the final document. Content not subject to Exposure Draft Process)

Appendix D Guidelines for a PMI Practice Standard

(This is a standard PMI Appendix, which will be added to the final document. Content not subject to Exposure Draft Process)

Appendix E Additional Sources of Information

This standard focuses on the fundamentals of earned value management that can be applied to most projects most of the time. It does not address specifics that apply only to particular situations, such as government contracts—with their budgeting, accounting, and reporting requirements. This standard also avoids describing concepts, methods, and practices that are commonly considered to be central to project management, such as scoping and scheduling—except as they vary to enable the use of earned value management. Readers are encouraged to pursue the subject of earned value management beyond the fundamentals presented in this standard. To facilitate further study, we offer the following basic guide to additional sources.

Publications

To learn about project management in general, we recommend:

- Project Management Institute (2000). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*—2nd Edition. Newtown Square, PA: Project Management Institute.

Details on the subject of the work breakdown structure appear in:

- Project Management Institute (2002). *PMI Practice Standard for Work Breakdown Structures*. Newtown Square, PA: Project Management Institute.

Reviews of the following books on earned value are in Appendix B:

- Fleming, Quentin W. and Joel M. Koppelman (2000). *Earned Value Project Management*—2nd Edition. Newtown Square, PA: Project Management Institute.

- Humphreys & Associates, Inc (2002). *Project Management Using Earned Value*.

- Kemps, Robert R. (2000). *Fundamentals of Project Performance Measurement.* Humphreys & Associates, Inc.

- Lambert, Lee R. and Erin Lambert (2000). *Project Management: The Common Sense Approach*. Columbus, Ohio: LCG Publishing.

The following standards and guides are available:

- American National Standards Institute/Electronic Industries Alliance (1998). *ANSI-EIA-748-98, Earned Value Management Systems*. Arlington, VA: Electronic Industries Alliance.

- Earned Value Management Committee, Council of Standards Australia (2003). *AS4817: Project Performance Measurement Using Earned Value*. Sydney, Australia: Standards Australia International, LTD.

- The Association for Project Management (2002). *Earned Value Management APM Guideline for the UK.* Buckinghamshire, United Kingdom: The Association for Project Management.

An extensive bibliography on earned value is available at this Web site:

- http://www.suu.edu/faculty/christensend/ev-bib.html

Organizations

The following organizations are recommended sources of information:

- The Project Management Institute (PMI)
  http://www.pmi.org/info/default.asp

- The PMI College of Performance Management http://www.cpm-pmi.org/

- The PMI College of Scheduling
  http://www.pmicos.org/

Education and Training

For opportunities consult the preceding organizations and the R.E.P. portion of PMI's Web site:

- http://www.pmi.org/info/PDC_REPOverviewFile.asp?nav=0406

Appendix F Reviews of Selected Books on EVM

(This is a standard PMI Appendix, which will be added to the final document. Content not subject to Exposure Draft Process)

Glossary

Actual Cost (AC). The costs actually incurred and recorded in accomplishing work performed within a given time period. *

Actual Cost of Work Performed (ACWP). See Actual Cost. *

Apportioned Effort (AE). Effort that by itself is not readily divisible into discrete work efforts, but which is related in direct proportion to measured discrete work efforts (see Discrete Effort). *

Budget at Completion (BAC). The sum of all the budgets established for the work to be performed on the project. BAC is equal to the total Planned Value for the project. *

Budgeted Cost for Work Performed (BCWP). See Earned Value. *

Budgeted Cost for Work Scheduled (BCWS). See Planned Value. *

Control Account. A management control point at which budgets (resource plans) and actual costs are accumulated and compared to earned value for management control purposes. A control account is a natural management point for planning and control, since it represents the work assigned to one responsible organizational element on one project's work breakdown structure element (see Work Breakdown Structure). *

Cost Performance Index (CPI). A measure of cost efficiency on a project. It is the ratio of Earned Value to Actual Cost (Cost Performance Index = Earned Value / Actual Cost.) A value equal to or greater than 1.0 indicates a favorable position and a value less than 1.0 indicates an unfavorable condition. *

Cost Variance (CV). A measure of cost performance on a project. It is the arithmetic difference between Earned Value and Actual Cost (Cost Variance = Earned Value - Actual Cost.) A positive value indicates a favorable position and a negative value indicates an unfavorable condition. *

Critical Path Method (CPM). A network analysis technique used to predict project duration by analyzing which sequence of activities (i.e., which path) has the least amount of scheduling flexibility (i.e., the least amount of float). *

Discrete Effort. Tasks that are related to the completion of specific end products or services and can be directly planned and measured. *

Earned Value (EV). The value of work performed expressed in terms of the budget assigned to that work. Also referred to as the Budgeted Cost for Work Performed (BCWP). *

Earned Value Techniques (EVT). A method for planning and measuring the performance of work, used to establish the Performance Measurement Baseline (PMB) for a task, control account, or project. EVT is also referred to as the Earning Rules and Crediting Methods. *

Estimate at Completion (EAC). The estimated total cost of completing all of the project work. Equal to the Actual Cost plus the estimated cost of completing all of the remaining project work. The EAC may be calculated based on performance to date or estimated by the project team based on other factors, in which case it is often referred to as the Latest Revised Estimate (LRE). *

Estimate to Complete (ETC). The estimated cost of completing all of the remaining project work. *

Latest Revised Estimate (LRE). See Estimate at Completion. *

Level of Effort (LOE). Effort of a general or supportive nature, such as project management, which does not produce definitive end products. *

Organization Breakdown Structure (OBS). A function-oriented breakdown of the performing organization, which is used to assign responsibility for the performance of the project work. *

Performance Measurement Baseline (PMB). The integrated scope-schedule-cost plan for all the work to be performed on a project, against which project schedule and cost execution are compared to measure and manage their performance. *

Planned Value (PV). The value of work planned, expressed in terms of the budget assigned to that work. PV is also referred to as the Budgeted Cost for Work Scheduled (BCWS). *

Responsibility Assignment Matrix (RAM). A depiction of the relationship between Work Breakdown Structure elements and Organization Breakdown Structure elements that are assigned responsibility for ensuring accomplishment of the project work. *

Schedule Performance Index (SPI). A measure of schedule efficiency on a project. It is the ratio of Earned Value to Planned Value (Schedule Performance Index = Earned Value / Planned Value.) A value equal to or greater than 1.0 indicates a favorable position and a value less than 1.0 indicates an unfavorable condition. *

Schedule Variance (SV). A measure of schedule performance on a project. It is the arithmetic difference between Earned Value and Planned Value (Schedule

Variance = Earned Value – Planned Value.) A positive value indicates a favorable position and a negative value indicates an unfavorable condition. *

S-Curve. A graphic display of cumulative costs plotted against time, used to depict Planned Value, Earned Value and Actual Cost of project work. *

Variance at Completion (VAC). The difference between the total budget assigned to a project, otherwise known as budget at completion (BAC), and the total cost estimate at completion (EAC). Variance at Completion = Budget at Completion – Estimate at Completion. It represents the amount of expected overrun or under run. *

Work Breakdown Structure (WBS). A deliverable-oriented grouping of project elements that organizes and defines the total scope of the project. Each descending level represents an increasingly detailed definition of project work. *

** This is a delimiter for sorting. It will be removed when the glossary is finalized.*

References

- Project Management Institute (2000). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*—2nd Edition. Newtown Square, PA: Project Management Institute.