THE APPLICATION OF PERFORMANCE MEASUREMENT TECHNIQUE IN PROJECT MANAGEMENT : THE EARNED VALUE MANAGEMENT (EVM) APPROACH

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INTRODUCTION

The management of engineering projects in any type of industry is becoming a challenge to professional engineers and technical managers as competitions for business opportunities arise in an increasingly competitive market place for effective project management and control systems in compliance with clients' contractual requirements. Never before have the pressures on project managers been as great as they are today to successfully satisfy the criteria of time, cost and quality in the completion of the projects for which they are responsible. The technology being used in today's projects is increasing in complexity as the state of the art of technology is being pushed to the limit, the level of suitably skilled resources is often limited, and the scope of work and contract costs are continually growing resulting in the need to have efficient monitoring and controlling tools to measure project performance.

Performance measurement is a project planning and control system that goes beyond the traditional concept of comparing the amount of project time elapsed against the amount of actual cost spent to give a comparison of actual value of work accomplished against the planned value of work scheduled. It does this by incorporating the Earned Value methods into the more widely used management principles of organizing, planning, monitoring and controlling work within a project. The purpose of performance measurement is as follows:

a. To maintain the project's cost, schedule, and forecast status including their correlation with technical achievement; and

b. To show how cost, schedule and technical performances are measured and used for project management and control purposes.

This technical seminar is to discuss the application of the Earned Valued technique based on which performance measurement for today's engineering project are being carried out in various industries. The term "Earned Value", by itself, means the worth (or value) in dollars of work actually performed. Earned Value calculations provide visibility to the critical project areas that need further management attention. It provides a clearer picture of the viability of a project than looking at the budget or actual costs alone.

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PERFORMANCE MEASUREMENT

1. Earned Value:

A project control technique which provides integrated, quantitative measurement of work performance against an integrated schedule and budget plan. The earned value approach is a proven method to evaluate work progress in a project in order to identify potential schedule slippages and areas of budget overruns. It differs from conventional performance measurement practices by combining a project's cost and schedule parameters into a common framework, i.e. **the measurement of the budgeted value of the work actually carried out, and its comparison with the budgeted value of the work that should have been carried out and what it actually costs**. The earned value technique, therefore, provides **objective, realistic** assessment of project status information for management. It is an important component of any **effective project management** system, with its **early warning status approach**, resulting in significant improvements to its performance and contributing to a company's competitiveness and overall profitability.

1. Establishment of an Earned Value Management (EVM) system.

Proper development of an earned value system for a project includes widely used management principles of organizing, planning, monitoring and controlling work within a project. These principles form the foundation of an effective earned value based performance measurement. They cover the principal activities associated with project management such as defining the project's workscope, work breakdown structures, responsible organizations for performing the work, planning, scheduling, budgeting, collecting costs, statusing schedules, measuring performance, forecasting, managing subcontracts, controlling materials and production..etc..

1.1. Organizing the Work

The Work Breakdown Structure **(WBS)**

Defining the scope of work through the framework of the Work Break Structure (WBS). The WBS represents a breakdown of all project requirements for products and services, defined and organized as meaningful and manageable tasks by the contractor and its major subcontractors. It defines all project **authorized** work and will be maintained as a common base throughout the life of the project to reflect authorized scope changes or authorize replanning of the cost and schedule parameters. Every project will have its own WBS developed and used by all members of the project team. The WBS, thus, establishes a framework for organizing the project costs, estimates, budgets, schedules and reports for the duration of the contract. It is, therefore, the baseline against which cost, schedule and technical performance are measured and reported to all level of contractor management and to the customer.

The Organization Breakdown Structure **(OBS)**

Identifying performing organizations participating in the project, including subcontractors, based on the requirements of the Statement of Work (SOW) as defined by the contract, the WBS. It identifies members of the project team directly responsible for contract work performance. The organization is subsequently divided into smaller segments (departments, sections, etc.) to better manage project tasks. The OBS, thus,

identifies the functional groups of the project team and provides the organizational framework for work planning, performance and reporting.

Responsibility Assignment Matrix **(RAM)**

The RAM is a record of work assignments. It is produced immediately after the development of the WBS and the OBS, the overall structure which combines the WBS with the OBS by creating **a matrix with the WBS on one axis and the OBS on another**. It is updated and maintained throughout the project implementation effort to incorporate any changes in the WBS and responsibility assignment. Integration of the lowest level of the WBS and the OBS results in the formation of a logical point to integrate all project subsystems called control account where statements of work, schedule, budgets and resources for all lowest WBS elements can be established in a consistent manner. Control account or Cost Account, a management-controlled point, is the most important management element in an earned value system. It is where all key aspects of technical, cost, schedule and performance measurement monitoring are operationally integrated. Control account are key points for the day-to-day management of project activities associated with the planning, analysis and control of the project work. The individual responsible for managing the control account work is called a Control Account Manager **(CAM)** who is appointed from the project team; as far down the project organization as is practically possible. Fig. 1 illustrates the organizing aspect of the earned value technique.

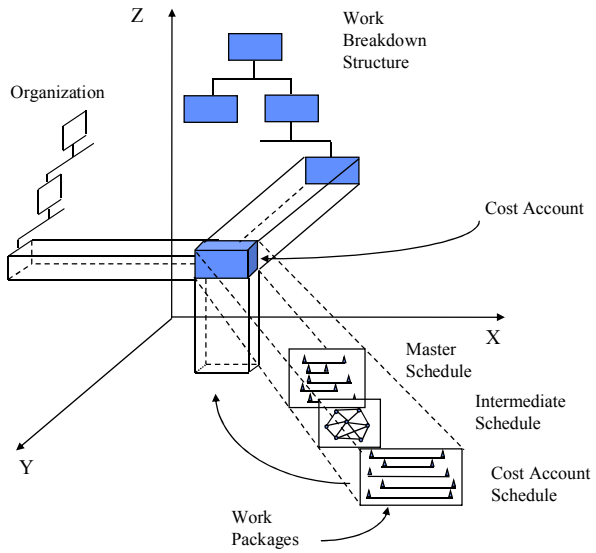


Figure 1. Foundation of the Earned Value Concept

1.2. Planning the project

The planning process must consist of the establishment of the assigned project work effort in terms of the technical, schedule and cost parameters for performance in compliance with customer requirements. Proper planning is essential to good project management.

- The technical parameter (scope) defines and structures project Statement of Work (SOW) into meaningful and manageable tasks through the development of a contract WBS and a WBS dictionary

where definition of each WBS element in terms of technical outputs and work content is provided. It identifies deliverables, materials and services as required by the project and relates the WBS elements of work to each other and to the end product. It also provides the necessary details for the development of the project network. Further expansion of the WBS is then used to establish the framework for workscope definitions and assignments to organizations responsible for performing the work. The extended WBS provides the framework within which all of the contractually authorized work is defined and includes the levels at which required reporting information is summarized.

- The project schedule will be developed, maintained, and baselined for performance measurement purposes. Earned Value is based upon the completion of predefined, prescheduled activity through every level of the WBS. The baselined schedule, generally in the form of a project master schedule, is developed and becomes the controlling schedule for the entire project. All project tasks and subcontractors'activities will be captured and incorporated in the project schedule. It should provide enough detail to manage the overall program, including all scheduling data that facilitate the conduct of project management activities. The master schedule shows the work to be performed in the program and identifies significant milestones and task interdependencies where a number of intermediate level schedules serve as links between the master schedule and the detailed ones. The scope of the intermediate schedule is related to the effort of a number of cost accounts whereas the scope of the detailed schedule is normally associated with that of a control account or a number of work packages. A work package is a specific job which contributes to a clearly defined specific task of accomplishment towards the program objective. e.g., work orders, engineering design task, document or service. It is simply a short-span discrete task, activity or job having scheduled start and finish dates and an end product of some form called work output. Work packages can be classified into discrete (measured effort) Level of Effort (LOE) or Apportioned Effort. The project master schedule intermediate and detailed schedules are developed in sufficient details to assure that work will be performed and milestones met in a logical and timely manner. The schedules are totally integrated to provide traceability of events and to graphically depict the relationships between the project master schedule and all lower level schedules.

- The project cost identifies resources and budgets distributed to individual work items in accordance with the WBS and the SOW. It is developed with the establishment of the budget baselines. The first one is the Contract Budget Baseline (CBB) being the negotiated contract target cost plus the estimated cost for client-authorized changes. It also includes Management Reserve (MR) .i.e., an amount of the total allocated budget withheld for management control purposes rather than designated for the accomplishment of a specific task or set of tasks. MR is, therefore, set aside to provide for unanticipated, in-scope requirements. It is not used to cover budgeted work experiencing schedule delay or cost overrun. The CBB also covers the Undistributed Budget (UB) being the budget applicable to the contract effort which has not yet been identified. The second baseline is the Performance Measurement Baseline (PMB) being the time phased budget plan against which contract performance is measured, i.e., the PMB consists of all budgets assigned to the project-scheduled cost account and the U.B. The budgets, schedules and workscope are the basis for development of the time phased PMB. Project performance measurement becomes impossible and meaningless without the creation of a valid, effective baseline which must be established, approved, and frozen in order to form the basis for all subsequent earned value measurement. The baseline must be maintained and kept current if any changes or modifications of scope are agreed upon. Fig. 2 illustrates the process of establishing the total cost baseline for cost and schedule control purposes during the execution of programs.

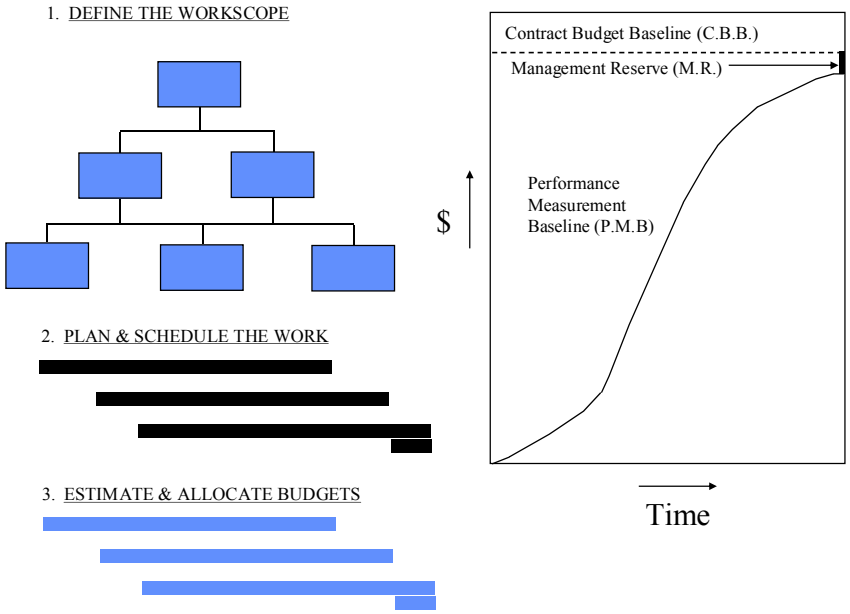


Figure 2. The Establishment of the Baselines

1.3. Monitoring and Controlling project activities

Project activities are planned in all project's control accounts whose budgets, schedules, work scopes, organizational responsibilities, cost collection, progress performance analysis, problem identifications and corrective actions are all integrated. Cost account consists of work packages (WP) which can be classified into discrete, Level of Effort (LOE) or apportioned. A **discrete** work package involves tasks that consist of **well-defined milestones** and **results in measurable end products** (i.e., product delivery, engineering design, factory acceptance test); an **LOE** work package involves effort which **does not produce scheduled measurable outputs** (i.e., liaison, coordination, project management). An **apportioned** work package relates to work that provides **direct support to discrete activities** (i.e., drafting, quality assurance). **Far-term effort** which can not logically be identified into work package can be organized into larger units of effort called **planning work packages**; this is a logical description of work within a control account that can be identified and budgeted in early baseline planning but not yet defined into more detailed work packages to ensure that adequate budgets are set aside for the future work to be done. At all time, the budgets for the work packages and planning packages must sum to the control account budget. Similarly, the summation of the workscope identified by the WP descriptions for particular control account must equal total workscope of that control account. **No work should be performed if not covered in a WP description**. Work package descriptions are prepared by the CAM and accepted by the performing department head who will perform the tasks. A WP is clearly distinguishable from all other work packages.

The essence of the earned value technique is based on five most important basic data elements which must be determined and planned for objective evaluations of program progress and performance measurement. Project activities will be monitored to a satisfactory conclusion throughout the process of work definition, planning, estimating, work authorization, scheduling, budgeting and forecasting with these performance measurement parameters:

- Budgeted Cost for Work Scheduled **(BCWS) or Planned Value (PV) :** The time-phased budget plan, applicable to the work scheduled to be accomplished within a given timeframe, against which performance is measured. For the total contract, Planned Value is the negotiated contract cost plus the estimated cost of authorized but unpriced work (less any management reserve). It is time-phased by the assignment of budgets to scheduled increment of work. Time-phasing budgets must be directly related to scheduled activities milestones so that expenditure trending profiles can be developed for management purposes.

For any given time period, Planned Value is determined at the control account levels by totaling the budgets for all work packages scheduled to be completed, plus the budget for the portion of in-progress work scheduled to be accomplished, plus the budget for LOE (Level of Effort) and apportioned effort scheduled to be completed during the period.

- Budgeted Cost for Work Performed **(BCWP**) or **Earned Value (EV)**: The budgeted cost for all work actually accomplished during a given time period.

- Actual Cost for Work Performed **(ACWP**) or **Actual Costs (AC)**: The cost actually **incurred** and **recorded** in accomplishing the work performed within a particular time period. This includes actual direct costs such as the incurred costs of labor, materials, subcontracts and other direct costs plus the related indirect costs such as overhead and general administrative costs. This is normally accumulated at the control account level although some contractors may accumulate costs at the work package level. Cost data are collected as frequently as required by the cost report distribution schedule. Source data required for the cost collection process include properly completed accounting documentation such as time sheets, purchase orders, travel orders, relocation orders, consulting agreements, etc.

- Budget At Completion **(BAC):** The sum of all budgets allocated to all contract's authorized WBS elements.

- Estimate At Completion **(EAC**): The cost allocated to the work to date plus the estimated of cost for authorized work remaining.

Monthly progress assessment for the cost and schedule performance is based on the following indices:

- Schedule Variance (SV) = BCWP – BCWS = EV - PV
- Cost Variance (CV) = BCWP – ACWP = EV - AC

Negative variance indicates an unfavorable situation, i.e., overrun or behind schedule. Positive variance reflects the reversed trend, a favorable situation.
To better understand the logical calculations of the above-mentioned formulas as well as the Earned Value acronyms (terminology). Let's take a look at the following example:

Assume a scheduled completion of one unit per month at a budgeted cost of $100 per unit. At the end of six months, a cost of $560 has been incurred, but the equivalent of only five units was completed. Under the conventional budget performance control approach, the job is $40 underrun ($600 - 560) and a month behind schedule. Under the earned value approach, the situation would be expressed as follows:

- ACWP (Actual Cost for Work Performed) = AC = $560

- BCWP (Budgeted Cost for Work Performed) = EV = $500
- BCWS (Budgeted Cost for Work Scheduled) = PV = $600
i.e., 6 units @ $100/unit

- Schedule Variance (SV) = BCWP - BCWS = EV – PV = $500 - $600 = -$100
- Cost Variance (CV) = BCWP - ACWP = EV – AC= $500 - $560 = -$60

i.e., The job is really overrun by $60 and $100 (or one month) behind schedule.

To effectively monitor project progress and give management greater earlier visibility into the project's trends, appropriate Earned Value (EV) determination must be used to report progress. It must reflect the way work will be accomplished and represent the most objective method possible for the type of work being done. Work must be planned so that measurable accomplishment can be assessed at reasonable intervals. Fig. 3 shows typical guidelines for earned value determination.

TASK AUTHORIZATION/ ACTIVITY TYPE	CHARACTERISTICS	BCWP CREDITING METHOD
Discrete	Composed of multiple & homogeneous units Short duration Long duration Long duration and high expenditures in early time segments	Percent complete 0% credit at start 100% at completion 50% credit at start 50% at completion 30% credit at start 40% per manager's assessment 30% at completion
Level-of-Effort	Long duration and constant expenditure rate	BCWP=BCWS
Apportioned	Directly supports discrete activities	Credit equals percent complete of support activities time-apportioned budget
Subcontract	Subcontract conducts independent project control	Subcontractor progress payments

Figure 3. Earned Value Progress Determination Guideline

1.3.1. Analysis

Cost, schedule and technical performance data will be collected an analyzed as required by management needs. Performance data will be collected at the work package level and summed upward through the hierarchy of the WBS and the project organizational structure. These should include time phased BCWS (PV) values established for each in-process control account and work package and its associated, designated method to assess earned value.

The Earned Value (EV) of in-process effort is determined based on the predetermined method for measuring performance. The value of work performed in a particular period for each work package is compared to the PV reference value established for the same period. Guidelines and instructions for deriving earned value, under each approved earned value method, are issued to the project staff as part of the performance measurement plan. These data elements, including those of AC and BAC will provide a

mechanism for calculating the current project status and its future trend. The following formulas help to assess project performance:

1. COST/SCHEDULE VARIANCE - Can apply to either current or cumulative data.

   a. CV = EV - AC

   b. SV = EV - PV (Negative variance indicates an unfavorable situation, i.e., cost overrun or schedule slippage)

2. PERCENT COMPLETE/SPENT

   a. $$\text{PERCENT COMPLETE} = \frac{\text{BCWP cum}}{\text{BAC}} = \text{EV/BAC}$$

   b. PERCENT SPENT - There are two ways of looking at this, depending upon whether you are comparing the percent spent to: (1) the contract amount; or (2) the contractor's latest revised estimated cost at completion. These two methods are reflected below:

   $$(1)\ \%\text{SPENT} = \frac{\text{ACWP cum}}{\text{BAC}}$$

   $$(2)\ \%\text{SPENT} = \frac{\text{ACWP cum}}{\text{EAC}}$$

3. PERFORMANCE INDICE (PI) - There are two historical performance indices: cost and schedule. In both cases, the purposes of the PI is to indicate the efficiency with which work has been accomplished.

   a. Cost Performance Index CPI = BCWP/ ACWP = EV/AC

   b. Schedule Performance Index SPI= BCWP/ BCWS = EV/PV

" TO GO " COST PERFORMANCE INDEX (CPI TO GO). This is an assessment of the degree of cost efficiency which must be achieved in order to complete the work being measured (e.g., contract, WBS element, control account) within the existing budget (BAC). It is a comparison of the budget for the remaining work with the "remaining money". If the CPI TO GO is greater than 1.0, that means the CPI to date is less than 1.0. As we get closer to the completion of an effort on which you are experiencing a CPI to date of less than 1.0, the larger the CPI TO GO becomes , the smaller your chances of completing the effort within the BAC become. The formula is as follows:

"CPI" TO GO = Work Remaining/ Resources Remaining

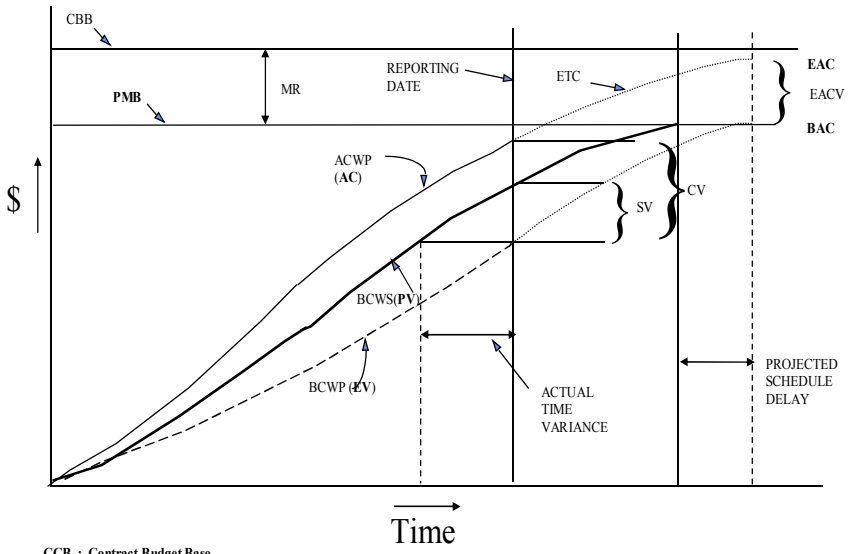
$$= \frac{BAC - BCWP\ cum}{BAC - ACWP\ cum} = BAC - EV\ cum\ /\ BAC - AC\ cum$$

"TO COMPLETE" COST PERFORMANCE INDEX (TCPI). This is a comparison of the budget for the work remaining to the Estimate to Complete (ETC) for that work. This differs from the CPI TO GO in that it measures the cost efficiency at which the contractor must perform to meet his Estimate at Completion (EAC) rather than the budget (BAC). .eg. If the TCPI was 1.20, this means that to complete the contract within the EAC, the contractor must perform at an efficiency of 120 %. If the performance to date is significantly below that, a serious question should be raised. The formula is as follows:

TCPI = Work Remaining / Estimate to Complete

$$= \frac{BAC - BCWP\ cum}{EAC - ACWP\ cum} = BAC - EV\ cum/\ \mathbf{EAC} - AC\ cum$$

Project cost and schedule performance data can also be displayed graphically to illustrate the project's present status as well as its future trends. Fig. 4 shows a graphical summary chart representing the project's performance indices.



CCB : Contract Budget Base
PMB : Performance Measurement Baseline
MR : Management Reserve
UB : Undistributed Budget
EACV: Estimate At Completion Variance
SV : Schedule Variance
CV : Cost Variance

BCWS: Budgeted Cost for Work Scheduled = PV
BCWP: Budgeted Cost for Work Performed = EV
ACWP: Actual Cost for Work Performed = AC
ETC : Estimate To Complete
BAC : Budget At Complete
EAC : Estimate At Completion

Figure 4. Performance Measurement Baseline

1.3.2. Estimate at Completion Forecast

One of the most important aspects of the earned value technique relates to the generation of a contractor's Estimate at Completion (EAC) in a rational and consistent manner to assure its reasonableness. i.e., good reflection of actual performance to date and a rational prediction of the future project cost. The EAC is normally associated with a bottom-up calculation of the remaining work where the estimate is a function of the predicted costs for the specific tasks required to complete the project work. It is recognized that there is no quantitative method or technique to forecast perfectly the EAC as a result of unknown variables affecting future costs.

Numerous techniques are being used to predict the EAC, of which many are based on performance indices derived from values of past performances in the project. The followings are the most frequently used methods:

* EAC = BAC/ PF

* EAC = ACWP cum + (BAC - BCWP cum) / PF

where PF (Performance Factor) = CPI cum= BCWP / ACWP

PF, thus, represents a knowledgeable assessment of the degree of cost efficiency to be achieved so as to complete the work being measured ,.e.g., contract, WBS elements, control accounts. The most common application of the formula is to use the CPI to date as the performance factor. A CPI of 0.85 indicates that 85 dollars worth of planned work has been completed for every 100 actual dollars spent. The "floating average" technique:

EAC = ACWP cum + (BAC - BCWP cum) / CPI n

CPI n = (CPI n + CPI n-1 + ...CPI 1) / n

where n = Number of months.

One should base the PF projection on selective historical performance data in deciding what particular segment of the project's historical past will be representative of expected future results .eg. Different functional organizations have different efficiencies and peak at different times. It is noted that regardless of the particular technique chosen to project the final EAC cost, attempts should be made to use all of the relevant information available.

A comparison of the projected EAC and the original Budget at Completion (BAC) will indicate whether a project is within budget at that particular time. This is reflected through the Estimate at Completion Variance **(EACV).** As this information will have a direct impact on the project's profitability, it is of significant interest for the project manager.

1.3.3. Variance and Problem Analysis

The earned value technique, properly applied, will give cost and schedule variances which may exceed the thresholds established with the contractor's client. Thresholds may either be established by a percentage or a dollar amount or as combination of both. Significant variances result in analyses focused on the most significant problem areas. Explanations are required for what caused the variances (the problems), what the Control Account Manager (CAM) is doing about it, and what the cost and schedule impact will be in the control account, associated control account, and the contract, if any. Explanations must be objective and coherent. Thus, cost and schedule variances can be investigated to determine their causes through the control account variance analysis report. Variance reports are prepared and are used to identify project areas requiring management attention. Fig. 5 illustrates a sample of this report.

		SERIAL NO:	
	CONTROL ACCOUNT VARIANCE ANALYSIS REPORT		
CONTRACT		CA NO:	
CONTRACT TITLE:		DATE:	
		STATUS AS OF:	
WBS NO:		DUE DATE:	
COORDINATOR:		RECEIVED ON:	
VARIANCE	INCREMENTAL	CUMULATIVE	AT COMPLETION
SV	$	$	
CV	$	$	
EACV			$
PROBLEM IDENTIFICATION:			
PROBLEM CAUSE:			
IMPACT: (Cost and Schedule Impact on this Control Account, Associated Control Accounts and the contract, if any)			
CORRECTIVE ACTION PLANNED (Including expected recovery date):			
CAM DATE	DEPARTMENT MANAGER DATE	PROGRAM CONTROL MANAGER DATE	

Figure 5. Variance Analysis Report Form

1.3.4. Reporting project performance:

Reporting of work progress flows upward through the functional organization structure and the project Work Breakdown Structure. The data may be summarized at each level of the functional organization and work breakdown structure for management review. Project performance data will be formatted to convey a concise, integrated cost and schedule of project status, favorable and unfavorable performance trends as well as explanation of variances, problems and corrective actions required. These reports are compiled from approved computer-based cost/schedule management systems and other earned value data base elements. The formats of the report are dependent on the needs of the project. Typical executive summary reports in an earned value project environment are presented .

1.3.5. Controlling and Incorporating contractual changes

Changes to the contract must be controlled and incorporated into the project workscope in a timely manner so as to maintain the integrity of the performance measurement baseline. Changes can come from external sources through customer's requests, or from internal sources through technical or engineering changes.

- Internal replanning is used when there exists revision to plan which causes no impact, e.g., transfer of scope and associated budget from one control account to another. Supporting documents relating to the control of these changes must be prepared and available for auditing purposes. This can be done without prior approvals from the client.

- Major replanning is used when there exists change resulting in significant impact on the PMB and, consequently, must be brought to the attention of the client, e.g., changes in any authorized but unpriced cost for an improved engineering design modification, failed manufacturing due to the fact that initial design is impossible to build. These must be reported contractually in applicable reports to be submitted to the client.

- Formal reprogramming is required when there exist severe performance or technical problems which render the remaining contract budgets inadequate for effective control. This makes performance measurements against these budgets unrealistic. Consequently, formal reprogramming is required to have the PMB exceeding the contract budget baseline **(CBB)** resulting in an over target baseline **(OTB).** After the implementation of this, the planning and control of the cost and schedule information shall continue to be provided by the contractor using applicable contractually required reports. The ground rules for requesting client's approval for any formal reprogramming are:

- The contract must be beyond its early phase during which performance indices typically change more rapidly. The contract should not be so close to completion that reinstitution of a new budget baseline would be unproductive.

- The estimate to complete exceeds the remaining available budget by at least 15%.

- All other reasonable corrective management actions have already been taken.

Fig. 6 shows the consequences of changes in a project.

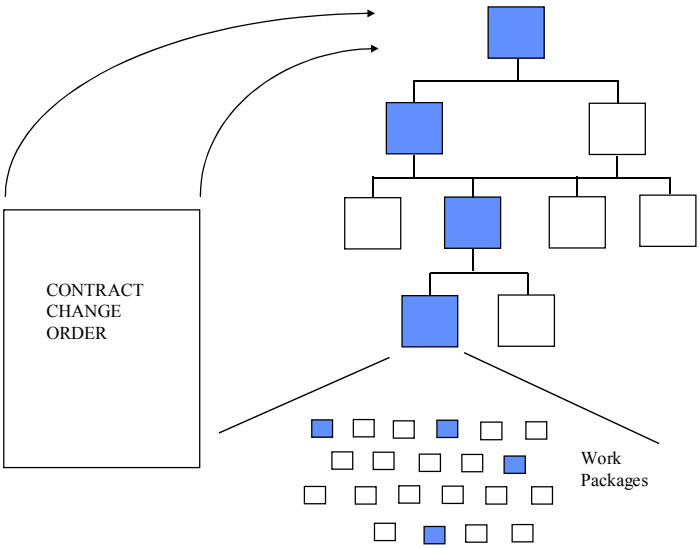


Figure 6. Impact to Incorporate Project Changes

2. Conclusion:

The earned value technique, designed to help contractors and owners better manage their many projects through effective planning, controlling and reporting processes, reflects accurate and objective indication of the project's performance .ie. **where a project stands at a given point in time.** It is an integrating tool for cost, schedule and technical management whose purpose is to provide project's progress measurement by comparing the work performed against the budget planned for that work and, thus, a means to monitor project progress toward achievement of critical project milestones. The technique has been applied successfully to support effective management of different types of projects in all industries and overwhelmingly acknowledged by industry managers as representing good management practices over the years. The Earned Value Management (EVM) technique, therefore, must be the indispensable tool of choice in supporting an effective total cost and schedule management approach for the 21st century.

REFERENCES

1. Nguyen, M. Nghi, CS^2 in High-Tech Program Management. American Association of Cost Engineers (AACE) Transaction, Paper U-1, New York City, New York, July 10-12, 1988.

2. Nguyen, M. Nghi, Cases Impairing C/SCSC Application in Program Management. American Association of Cost Engineers (AACE) Transaction, Paper E-2, San Diego, California, June 25-28, 1989.

3. Nguyen, M. Nghi, Effective Subcontractor Management in High-Tech Projects. American Association of Cost Engineers (AACE) Transaction, Paper D.I.I., Seattle, Washington, June 23-26, 1991.

4. Nguyen, M. Nghi, Cost/Schedule Control in Project Management: A Canadian Approach. Project Management Institute (PMI) Proceedings, Paper 5.2, San Diego, California, October 1-7, 1993.

5. United States Department of Defense Instruction (DoDI) 5000.2, Defense Acquisition Management Policies and Procedure (1991).

6. Fleming, W. Quentin, Cost and Schedule Control Systems Criteria: The Management Guide to C/SCSC. Chicago, Probus Publishing Company (1992)

7. Fleming, W. Quentin, Put Earned Value Into Your Scalable 'Commercial' Management Control System. "In Control" 6: 33-54 (March 1993)

8. Christensen, S. David and Ferens. Daniel, Using Earned Value for Performance Measurement on Software Development Projects. Acquisition Review Quarterly (1993)

9. Chen, T. Mark, Applying Earned Value Procedure to Engineering Management. American Association of Cost Engineers(AACE) Transactions, Paper O.4.1-O.4.5 (1991)

10. Lambert, R. Lambert, Understanding the Value of Earned Value or Where Have All Your Dollars Gone? American Association of Cost Engineers(AACE) Transactions, Paper H.2.1-H.2.4 (1989)

11. United States Department of Defense(DoD) and National Security Industrial Association, Joint DoD/Industry Total Quality Management Team Report for Program Management on the Cost/Schedule Control System Criteria (May 1991)

12. McConnell, R. Daniel, Earned Value Technique for Performance Measurement. American Society of Civil Engineers (ASCE) Engineering Management Conference, Cincinnati, OH, pp. 88-89 (1984)

ACRONYMS

ACWP - Actual Cost for Work Performed = **Actual Cost (AC)**
BAC - Budget At Completion
BCWP - Budgeted Cost for Work Performed = **Earned Value (EV)**
BCWS - Budgeted Cost for Work Scheduled = **Planned Value (PV)**
CA - Control Account (Cost Account)

CAM - Control Account Manager
CBB - Contract Budget Baseline
CPI - Cost Performance Index
CV - Cost Variance
EAC - Estimate At Completion
EACV - Estimate At Completion Variance
ETC - Estimate To Complete
LOE - Level Of Effort
MR - Management Reserve
OBS - Organization Breakdown Structures
PMB - Performance Measurement Baseline
PF - Performance Factor
PI - Performance Indices
RAM - Responsibility Assignment Matrix
SOW - Statement of Work
SPI - Schedule Performance Index
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WBS - Work Breakdown Structures
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