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Using CMMI[®] to Improve Earned Value Management

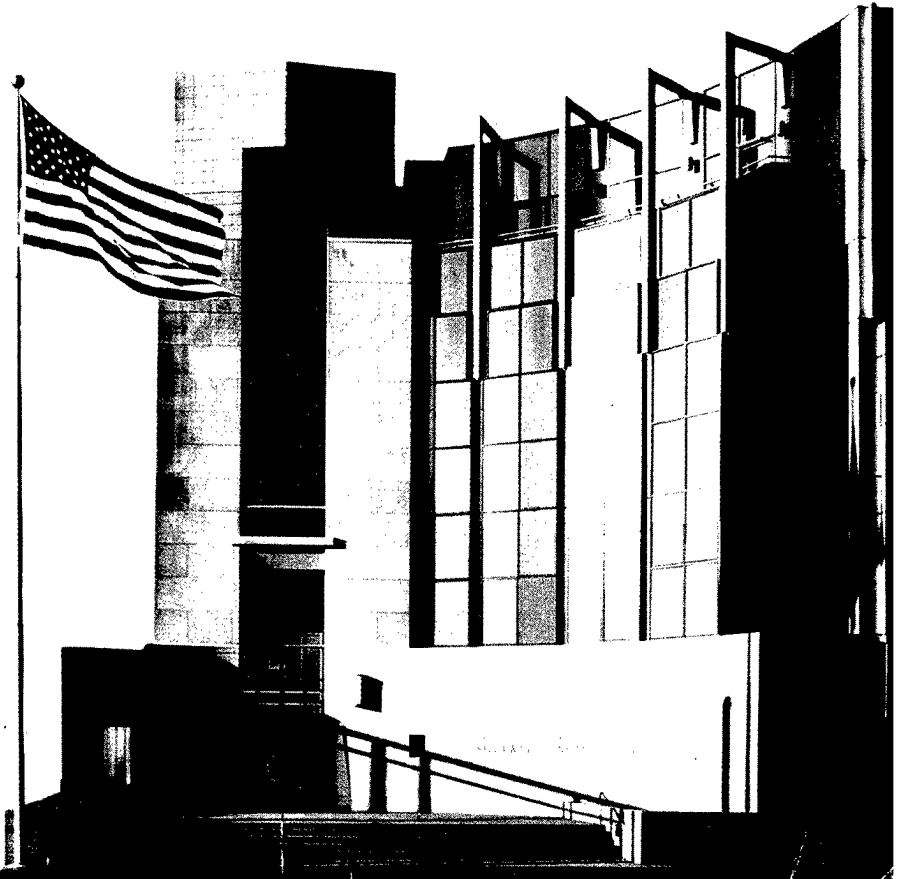
Paul Solomon

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Software Engineering Process Management

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Technical Note
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Abstract

For organizations using Earned Value Management (EVM) or that plan to implement EVM during Capability Maturity Model Integration (CMMI[®]) implementation, this technical note provides guidance for cost-effective process improvement and appraisal. Mapping and comparison tables between CMMI and the U.S. national standard on EVM are provided. These tables can be used to identify practices within CMMI that are not included in the EVM standard but, if added to an organization's processes, will strengthen adherence to EVM principles. The tables also can be used to develop instruments that will provide evidence to an appraisal team to enable it to quickly verify and validate specific practices based upon effective implementation of EVM.

Furthermore, information such as glossary components, typical work products, and examples are included in this technical note to aid those using CMMI for process improvement. For organizations using technical performance measurement, a primary base measure for earned value, additional guidance and information is provided. Finally, additional references and an EVM glossary are provided.

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1 Basics of Earned Value Management

Earned Value Management is a method for integrating work scope, schedule, and budget and for measuring project performance. It compares the amount of work that was planned with what was actually accomplished to determine if cost and schedule performance were achieved as planned.

The principles of an EVM system include the following:

- Break down the program work scope into finite pieces, called work packages, that can be assigned to a responsible person or organization for control of technical, schedule, and cost objectives.
- Integrate program work scope, schedule, and cost objectives into a performance measurement baseline against which accomplishments can be measured.
- Objectively assess accomplishments at the work package level.

Some basics of EVM and a bibliography for obtaining more in-depth information are contained in the technical report *Using EVMS (Earned Value Management System) with COTS-Based Systems* [Staley 02].

1.1 EVMS-Related CMMI Process Areas

The following process areas are those that are primarily related to EVMS:

- Measurement and Analysis
- Project Planning
- Project Monitoring and Control
- Requirements Development
- Requirements Management
- Integrated Project Management

EVMS also relates to specific practices in the following process areas:

- Supplier Agreement Management
- Risk Management
- Process and Product Quality Assurance

Each of the process areas listed has a role in specifying and tracking project work, developing operational definitions of how that work is measured, or verifying that completion criteria for work products have been satisfied.

1.2 Performance-Based Management Systems

The U. S. national standard for EVM is Earned Value Management Systems (EVMS) [ANSI 02]. U. S. government policies for performance-based acquisition management require the use of performance-based management systems that meet the guidelines of EVMS. The Office of Management and Budget also requires that all agencies of the Executive Branch of the government that are subject to Executive Branch review must use performance-based management systems that meet the EVMS standard [OMB 02].

Department of Defense (DoD) Directive 5000.1, Section 4.2.4, Performance-Based Acquisition, requires performance-based strategies for the acquisition of products and services [DoD 02b]. When using performance-based strategies, contractual requirements shall be stated in performance terms.

The related acquisition regulation, DoD 5000.2-R, Section 2.9.3.4.1, states that the program manager shall require that contractors' management information systems used in planning and controlling contract performance meet the EVM system guidelines set forth in the EVMS [DoD 02a].

1.3 National Standards

The primary national standard of EVM is EVMS. The EVMS guidelines incorporate best business practices to provide strong benefits for program or enterprise planning and control. The processes include integration of program scope, schedule, and cost objectives and the use of earned value techniques for performance measurement during the execution of a program. Section 2 of EVMS provides thirty-two guidelines for companies to use in establishing and applying an integrated EVMS. (See Table 3 for an abridged version of the guidelines.)

A secondary national standard that includes guidelines for EVM is the Project Management Institute Guide to the Body of Knowledge (PMBOK¹ Guide) [PMI 00]. The PMBOK Guide describes EVM in Sections 7.4.2.3 and 10.3.2.4 and is the source of some of the definitions in the Glossary.

¹ PMBOK is a trademark registered in the United States and other nations.

2 Comparison of CMMI to EVMS

For organizations using Earned Value Management (EVM) and Capability Maturity Model Integration (CMMI[®]), the comparison tables in this section can be used to identify CMMI practices that are not included in the EVM standard but, if added to an organization's processes, will strengthen adherence to EVM principles.

To assist in preparing for process improvement and appraisals, three tables are provided in this technical note. One table maps relevant CMMI-specific practices and informative components to the corresponding EVMS guidelines and other EVMS information.

The second table lists CMMI expected and informative components that provide more information for achieving the principles of an EVM system than that which is provided by EVMS. The second table could be included within the framework for process improvement by organizations that comply with EVMS because compliance with EVMS does not necessarily provide evidence that the organization has implemented the CMMI practices. The third table lists the EVMS guidelines.

Within CMMI specific practices are expected model components. Expected components describe what an organization will typically implement to achieve required components (i.e., process area goals). These components guide organizations that are implementing improvements or appraisals.

Informative model components, such as subpractices and typical work products, help CMMI users understand model goals and practices and how they can be achieved. EVMS guidelines represent best practices to assist tracking of project progress, so they are frequently mentioned in these components of the relevant CMMI process areas. While "informative" from a CMMI perspective, EVMS guidelines may be "required" in many environments as described above.

2.1 Strong Relationships

CMMI emphasizes an integrated and quantitative approach to project management, including integrating a project's planning parameters for cost, schedule, and technical performance.

There are four process areas that are highly consistent with the EVMS. These process areas have specific practices and informative components that have strong relationships with the

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EVMS guidelines. A strong relationship exists where there is a one-to-one relationship to the material in both documents. A strong relationship may also indicate that an organization that uses EVM may have achieved high levels of capability and maturity, and that EVM implementation may provide objective evidence to substantiate practice implementation during an appraisal.

The following CMMI process areas are highly consistent with EVMS:

- Project Planning
- Project Monitoring and Control
- Supplier Agreement Management
- Integrated Project Management

Table 1 maps the expected and informative components of CMMI that have strong relationships to EVMS. The far right column lists the EVMS section numbers that are described in Table 3.

Table 1: Strong Relationships of CMMI to EVMS

Project Planning		Specific Goal 1: Establish Estimates
Specific Practice 1.1 Estimate the Scope of the Project	<i>Informative Components</i> Typical work products: task descriptions, work package descriptions, and WBS Subpractices: 1. Develop a WBS based on the product architecture. 2. Identify the work packages in sufficient detail to specify estimates of project tasks, responsibilities, and schedule.	<i>EVMS sections</i> 2.1.a 2.1.b
Specific Practice 1.2 Establish Estimates of Work Product and Task Attributes	<i>Informative Component</i> Examples of size measures include the following: number of functions, function points, source lines of code, number of classes and objects, number of requirements, number of interfaces, and number of pages.	<i>EVMS section</i> 2.2.b
Specific Practice 1.4 Determine Estimates of Effort and Cost	<i>Informative Components</i> Typical work products: estimation rationale, project effort estimates, and project cost estimates	<i>EVMS section</i> 2.2.c
Project Planning		Goal 2: Develop a Project Plan
Specific Practice 2.1 Establish the Budget and Schedule	<i>Informative Components</i> Typical work products: project schedules, schedule dependencies, and project budget Subpractices: 1. Identify major milestones. 3. Identify constraints. 4. Identify task dependencies. 5. Define the budget and schedule. Establishing and maintaining the project's budget and schedule typically includes the following: <ul style="list-style-type: none"> • defining the committed or expected availability of resources and facilities • determining time phasing of activities • determining a breakout of subordinate schedules • identifying milestones for delivery of products to the customer • defining a management reserve based on the confidence level in meeting the schedule and budget 	<i>EVMS sections</i> 2.2.b 2.2.a 2.2.a 2.2.c, 2.2.d 2.2.a, 2.2.c 2.1.c 2.2.b 2.2.i

Project Planning		Goal 2: Develop a Project Plan	(continued)
Specific Practice 2.4 Plan for Project Resources	<i>Informative Components</i> Typical work products: WBS work packages, WBS task dictionary, and staffing requirements based on project size and scope		EVMS section 2.2.e
Project Monitoring and Control		Goal 1: Monitor Project Against Plan	
Specific Practice 1.1 Monitor Project Planning Parameters	<i>Informative Components</i> Monitoring typically involves measuring the actual values of project planning parameters, comparing actual values to the estimates in the plan, and identifying significant deviations. Typical work products: Records of project performance and records of significant deviations Subpractices: 1. Monitor progress against the schedule. 2. Monitor the project's cost and expended effort. 3. Monitor the attributes of the work products and tasks.		EVMS section 2.4.a
Specific Practice 1.6 Conduct Progress Reviews	<i>Informative Components</i> Subpractices: 2. Review the results of collecting and analyzing measures for controlling the project. 3. Identify and document significant issues and deviations from the plan. 6. Track change requests and problem reports to closure.		EVMS sections 2.4.d 2.4.d 2.4.e
Project Monitoring and Control		Goal 2: Manage Corrective Action to Closure	
Specific Practice 2.1 Analyze Issues	<i>Informative Components</i> Subpractices: 1. Gather issues for analysis. Examples of issues to be gathered include: • Significant deviations in the project planning parameters from the estimates in the project plan 2. Analyze issues to determine need for corrective action.		EVMS sections 2.4.a 2.4.f 2.4.b, 2.4.c
Specific Practice 2.2 Take Corrective Action	<i>Informative Components</i> Subpractice 1: Determine and document the appropriate actions needed to address the identified issues. Examples of potential actions include the following: • Modifying the statement of work • Modifying requirements • Revising estimates and plans • Renegotiating commitments • Adding resources • Revising project risks		EVMS sections 2.4.e, 2.4.f, 2.5.a, 2.5.e
Specific Practice 2.3 Manage Corrective Action	<i>Informative Component</i> Subpractice 1: Monitor corrective actions for completion.		EVMS section 2.4.e
Supplier Agreement Management		Goal 2: Satisfy Supplier Agreements	
Specific Practice 2.2 Execute the Supplier Agreement	<i>Informative Component</i> Typical work products: supplier progress reports and performance measures		EVMS section 2.2.d

Integrated Project Management Goal 1: Use the Project's Defined Process		
Specific Practice 1.3 Integrate Plans Integrate the project plan and the other plans that affect the project to describe the project's defined process.	<i>Informative Components</i> Subpractice 1: Integrate other plans that affect the project with the project plan.	EVMS section 2.1.c
Integrated Project Management Goal 1: Use the Project's Defined Process (continued)		
Specific Practice 1.4 Manage the Project Using the Integrated Plans	<i>Informative Components</i> Typical work products: work products created by performing the project's defined process; collected measures (actuals) and progress records or reports; revised requirements, plans, and commitments; and integrated plans Subpractices: 2. Monitor and control the project's activities and work products using the project's defined process, project plan, and other plans that may affect the project. This task typically includes the following: Using the defined entry and exit criteria to authorize the initiation and determine completion of the tasks; monitoring the activities that could significantly affect the actual values of the project's planning parameters; tracking the project's planning parameters using measurable thresholds that will trigger investigations and appropriate actions; monitoring product and project interface risks; and managing external and internal commitments based on the plans for the tasks and work products of implementing the project's defined processes. 3. Obtain and analyze the selected measures to manage the project and support the organization's needs. 5. Periodically review and align the project's performance with the current and projected needs, objectives, and requirements.	EVMS sections 2.1.c, 2.1.e, 2.2.d, 2.4.a through 2.4.f, 2.5.a, 2.5.e
Specific Practice 2.2 Manage Dependencies	<i>Informative Component</i> Subpractice 2: Identify each critical dependency.	EVMS section 2.2.a
Measurement and Analysis Goal 1: Align Measurement and Analysis Activities		
Specific Practice 1.1 Establish Measurement Objectives	<i>Informative Components</i> The sources for measurement objectives may be management, technical, project, or process implementation needs. Sources of information needs and objectives may include the following: <ul style="list-style-type: none"> • Project plans • Monitoring of project performance • Established management objectives • Formal requirements or contractual obligations • External industry benchmarks 	EVMS section 2.2.b
Specific Practice 1.2 Specify Measures	<i>Informative Components</i> Subpractice 1: Identify candidate measures based on documented measurement objectives.	EVMS section 2.2b

2.2 CMMI Expected and Informative Components Supporting EVM Principles

In the expected and informative model components of five process areas, CMMI provides more explicit guidance than does EVMS for implementing process improvements towards achieving the principles of an EVM system. CMMI specific practices and informative components provide additional guidance regarding the EVM principles of controlling a project's technical, schedule, and cost objectives and objectively assessing accomplishments. In some instances, EVMS guidelines are nominally similar to CMMI, but are dissimilar in substance or intent. Consequently, an organization that uses EVM may find that, after mapping its processes to the nominally similar CMMI practices, there are gaps between its processes and the practices expected by CMMI. The organization may need to improve its documentation or add activities to its current processes to meet CMMI requirements.

The following process areas have specific practices and informative model components that address control of a project's technical, schedule, and cost objectives or objective assessment of accomplishments but have no counterparts in EVMS:

- Requirements Management
- Measurement and Analysis
- Process and Product Quality Assurance
- Requirements Development
- Risk Management

Table 2 shows the CMMI specific practices and informative components that provide information that will support more effective implementation of EVM principles but which are not included in EVMS. The far right column of Table 2 cites the EVMS section that is nominally similar to CMMI or displays "N" if there is no counterpart to CMMI in EVMS.

Table 2: CMMI Expected and Informative Components Supporting EVM Principles

Requirements Management	Goal 1: Manage Requirements	
Specific Practice 1.5 Identify inconsistencies between Project Work and Requirements	<i>Informative Components</i> Subpractices: 1. Review project's plans, activities, and work products for consistency with the requirements and the changes made to them. 3. Identify changes that need to be made to the plans and work products resulting from changes to the requirements baseline.	<i>EVMS sections</i> 2.1.c 2.5.a, 2.5.d, 2.5.e

Measurement and Analysis		Goal 1: Align Measurement and Analysis Activities	
Specific Practice 1.2 Specify Measures	<i>Informative Components</i> Data for base measures are obtained by direct measurement. Examples of commonly used base measures include the following: estimates and actual measures of work product size (e.g., number of pages), estimates and actual measures of effort and cost (e.g., number of person hours), and quality measures (e.g., number of defects, number of defects by severity). Examples of commonly used derived measures include the following: earned value, schedule performance index, defect density, peer review coverage, and test or verification coverage. Subpractice 3: Specify operational definitions for the measures. Operational definitions are stated in precise and unambiguous terms. They address two important criteria as follows: i. Communication: What has been measured, how it was measured, what are the units of measure, and what has been included or excluded? ii. Repeatability: Can the measurement be repeated, given the same definition, to get the same results?	EVMS section	N
Specific Practice 1.3 Specify Data Collection and Storage Procedures Specify how measurement data will be obtained and stored.	<i>Informative Components</i> Typical Work Product: data collection and storage procedures Subpractice 3: Specify how to collect and store the data for each required measure. Explicit specifications are made of how, where, and when the data will be collected. Procedures for collecting valid data are specified.	EVMS section	N
Process and Product Quality Assurance		Goal 1: Objectively Evaluate Processes and Work Products	
Specific Practice 1.1 Objectively Evaluate Processes	<i>Informative Components</i> Typical work products: evaluation reports, noncompliance reports, and corrective actions	EVMS section 5.3	
Specific Practice 1.2 Objectively Evaluate Work Products and Services Objectively evaluate the designated work products and services against the applicable process descriptions, standards, and procedures.	<i>Informative Components</i> Subpractice 2: Establish and maintain clearly stated criteria for the evaluation of work products.	EVMS section	N
Process and Product Quality Assurance		Goal 2: Provide Objective Insight	
Specific Practice 2.1 Communicate and Ensure Resolution of Noncompliance Issues	<i>Informative Components</i> Typical work products: corrective action reports, evaluation reports, quality trends	EVMS section 5.3	
Specific Practice 2.2 Establish Records	<i>Informative Components</i> Typical work products: evaluation logs, quality assurance reports, status reports of corrective actions, and reports of quality trends	EVMS section 5.3	
Requirements Development		Goal 3: Analyze and Validate Requirements	
Specific Practice 3.3 Analyze Requirements	<i>Informative Components</i> One of the other actions is the determination of which key requirements will be used to track technical progress. Typical work product 4: technical performance measures (TPM) Subpractice 5: Identify TPMs that will be tracked during the development effort.	EVMS sections	2.2.b, 2.2.b
Risk Management		Goal 2: Identify and Analyze Risks	

Specific Practice 2.1 Identify Risks	<i>Informative Components</i> Subpractice 1: Identify the risks associated with cost, schedule, and performance in all appropriate product life-cycle phases.	<i>EVMS section</i> 3.5.4
Risk Management		
Goal 3: Mitigate Risks		
Specific Practice 3.2 Implement Risk Mitigation Plans Monitor the status of each risk periodically and implement the risk mitigation plan, as appropriate.	<i>Informative Components</i> Refer to the Project Monitoring and Control process area for information about revising the project plan. Subpractices: 4. Establish a schedule or period of performance for each risk-handling activity that includes the start date and anticipated completion date. 5. Provide continued commitment of resources for each plan to allow successful execution of the risk-handling strategy. 6. Collect performance measures on the risk-handling activities.	<i>EVMS section</i> 3.5.4

Table 3 shows EVMS guidelines. The narrative description is an abstract of the full text. The shaded section numbers are not related to CMMI. The EVMS sections that are shaded are primarily applicable to indirect costs and financial controls.

Table 3: EVMS Guidelines

Section	Abstract of EVMS Text
2.1.a	Define the authorized work elements for the program. A work breakdown structure (WBS) is commonly used in this process.
2.1.b	Identify the program organizational structure including the major subcontractors responsible for accomplishing the authorized work, and define the organizational elements in which work will be planned and controlled.
2.1.c	Provide for the integration of the company's planning, scheduling, budgeting, work authorization and cost accumulation processes with each other, and as appropriate, the program work breakdown structure and the program organizational structure.
2.1.d	Identify the organization responsible for controlling overhead (indirect costs).
2.1.e	Provide for integration of the program work breakdown structure and the program organizational structure in a manner that permits cost and schedule performance measurement by elements of either or both structures as needed.
2.2.a	Schedule the authorized work in a manner which describes the sequence of work and identifies significant task interdependencies required to meet the requirements of the program.
2.2.b	Identify physical products, milestones, technical performance goals, or other indicators that will be used to measure progress.
2.2.c	Establish and maintain a time-phased budget baseline, at the control account level, against which program performance can be measured.
2.2.d	Establish budgets for authorized work with identification of significant cost elements (labor, material, etc.) as needed for internal management and for control of subcontractors.
2.2.e	To the extent it is practical to identify the authorized work in discrete work packages, establish budgets for this work in terms of dollars, hours, or other measurable units.
2.2.f	Provide that sum of all work package budgets equals the control account budget.
2.2.g	Identify and control level of effort activity (unmeasurable effort).
2.2.h	Establish overhead budgets for expenses that will become indirect costs.
2.2.i	Identify management reserves.
2.2.j	Provide that the program target cost is reconciled with the sum of all internal budgets plus management reserve.
2.3.a through 2.2.f	Miscellaneous accounting considerations.

Section	Abstract of EVMS Text
2.4.a	At least on a monthly basis, generate the following information at the control account and other levels as necessary for management control using actual cost data: (1) comparison of the amount of planned budget and the amount of budget earned for work accomplished (Schedule Variance) (2) comparison of the amount of the budget earned and the actual direct costs for the same work (Cost Variance)
2.4.b	Identify, at least monthly, the significant differences between both planned and actual schedule performance and planned and actual cost performance, and provide the reasons for the variances in the detail needed by program management.
2.4.c	Identify budgeted and actual indirect costs at the level and frequency needed by management for effective control, along with the reasons for any significant variances.
2.4.d	Summarize the data elements and associated variances through the program organization and/or work breakdown structure to support management needs and any customer reporting specified in the contract.
2.4.e	Implement managerial actions taken as the result of earned value information.
2.4.f	Develop revised estimates of cost at completion based on performance to date, commitment values for material, and estimates of future conditions. Compare this information with the performance measurement baseline to identify variances at completion important to company management and any applicable customer reporting requirements including statements of funding requirements.
2.5.a	Incorporate authorized changes in a timely manner, recording the effects of such changes in budgets and schedules.
2.5.b	Reconcile current to prior budgets.
2.5.c	Control retroactive changes to records pertaining to work performed that would change previously reported actual costs, earned value or budgets.
2.5.d	Prevent revisions to the budget except for authorized changes.
2.5.e	Document changes to the performance measurement baseline.

2.2.1 Requirements Management

The purpose of Requirements Management is to manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project's plans and work products.

EVMS addresses only work requirements, not product requirements. Although EVMS discusses the use of a work breakdown structure to segregate work scope requirements into definable product elements (section 3.2) and discusses preventing revisions to the budget except for authorized changes (section 2.5.d), it does not discuss the work, plans, budgets, or schedules in relation to the product requirements.

2.2.2 Measurement and Analysis

CMMI addresses establishing quantifiable measures and operational definitions for the measures, stated in precise and unambiguous terms (SP 1.2). This notion is especially important to developing clear definitions of completion for earning value. EVMS does not require precise, quantifiable measures or operational definitions.

For example, the EVMS process discussion in the guidelines states that objective earned value methods are preferred, but it also states that management assessment may be used to determine the percentage of work completed for a task or a group of tasks and that management assessment may include the use of metrics for work measurement (Section 3.7). CMMI expects that measures be specified to address the measurement objectives, including work package progress and completion. CMMI recognizes earned value as a derived measure built upon defined base measures. EVMS, on the other hand, does not address the definition of the base measures upon which earned value is built. Taking all these points into consideration, an organization's implementation of EVMS may not provide sufficient, objective evidence to substantiate implementation of SP 1.2.

CMMI requires specification of how measurement data will be obtained and stored (SP 1.3). EVMS is silent on this issue.

2.2.3 Process and Product Quality Assurance

CMMI and EVMS differ in both product and process quality assurance.

2.2.3.1 Process Quality Assurance

Both CMMI and the EVMS rely strongly on process quality assurance to provide objective insight into processes and associated work products. The difference is in how they address the documentation of the process. Whereas CMMI consistently addresses objective evaluation of processes for adherence to applicable process descriptions, standards, and procedures, the EVMS does not specifically address this.

2.2.3.2 Product Quality Assurance

There is a difference between CMMI and the EVMS regarding the criteria for completing work and taking earned value. That difference, which concerns measurement of the quality of work products, is similar to the difference in Measurement and Analysis regarding precise, quantifiable measures or operational definitions.

CMMI describes a work product as any artifact produced by a process and a work package as a singular work unit that can be separately assigned, performed, and tracked. A work product may also have attributes that are stated as project planning parameters and have clearly stated criteria for evaluation. Consequently, per CMMI, the completion of a work package is dependent on that work package's work product meeting clearly stated criteria for its evaluation. The criteria for declaring that a work package is complete may include quality and technical criteria, not just a measure of the quantity of work accomplished.

Per SP 1.2, designated work products are objectively evaluated against the applicable process descriptions, standards, and procedures. For example, the criteria for completion of a

software component may be that all planned functionality is included and has been tested successfully.

The EVMS is internally inconsistent regarding the criteria for completing a work package. Per EVMS Section 3.8, Performance Measurement, the following is true:

- Earned value is a measurement of the quantity of work accomplished.
- The quality and technical content of the work performed are controlled by other processes.

This assertion that earned value is dependent only on the quantity of work performed is inconsistent with EVMS Section 3.7.1 that states that a discrete work package has a definable scope and objectives on which progress can be measured.

Because of the inconsistent guidance regarding the quality and technical content of the work performed, and, as discussed above, the EVMS' lack of a requirement for precise, quantifiable measures and operational definitions for the measures, an organization's implementation of EVMS may not provide sufficient, objective evidence to substantiate implementation of SP 1.2 during an appraisal.

2.2.4 Requirements Development

The Requirements Development process area addresses the identification of key requirements to be used in tracking technical progress and asserts that these key requirements have a strong influence on cost, schedule, functionality, risk, or performance. In the CMMI context, these are product and product component requirements.

As discussed in 2.2.1, EVMS addresses only work requirements, not product and product component requirements.

2.2.5 Risk Management

The Risk Management process area relates to several other process areas including the Project Monitoring and Control process area. EVMS is silent on risk management. Risk management is inferred, but not explicitly stated, in the discussion of management reserve. The discussion states management reserve is held for growth within the currently authorized work scope, rate changes, and other program unknowns (EVMS, Section 3.5.4). However, EVMS provides no information regarding the identification, analysis, or mitigation of risks.

3 Framework for Process Improvement

Recommended process improvements are provided in this section to close the gaps and inconsistencies discussed in the previous sections. This section addresses the deficiencies that an organization may have if it were only following the EVMS guidelines without also implementing the practices of the related CMMI process areas. If an organization's documented process descriptions, standards, and procedures for the application of EVM do not achieve the intent of the associated goals, then the organization may need to identify and implement process improvements to achieve the related CMMI specific goals.

3.1 Requirements Management

Refine the documentation of process descriptions, standards, and procedures to ensure that inconsistencies between the project work and requirements are identified. This documentation requires the following:

- The project plans, activities, and work products are reviewed for consistency with the product requirements and the changes made to them.
- Changes are identified that need to be made to the plans and work products resulting from changes to the requirements baseline.

3.2 Measurement and Analysis

Refine the documentation of process descriptions, standards, and procedures for the application of EVM to include the following requirements:

- Base measures of technical progress are derived from the key requirements that are identified during requirements development as having a strong influence on cost, schedule, functionality, risk, or performance.
- Base measures of technical progress for earned value are precise and quantifiable.
- Operational definitions are specified for the measures and are stated in precise and unambiguous terms.

3.3 Process and Product Quality Assurance

Broaden the documentation of process descriptions, standards, and procedures associated with EVM to cover the process areas identified in sections 1 and 2 as primarily related to EVM. This documentation will establish the basis for objectively evaluating adherence of these EVM-related processes to applicable process descriptions, standards, and procedures.

Refine documentation of process descriptions, standards, and procedures for the application of EVM to specify that the completion of a work package may include meeting technical performance or quality criteria as well as the quantity of work accomplished, when appropriate.

3.4 Requirements Development

Refine documentation of process descriptions, standards, and procedures for the application of EVM to identify key requirements that have a strong influence on cost, schedule, functionality, risk, or performance and will be used to track technical progress.

3.5 Risk Management

Refine documentation of process descriptions, standards, and procedures for the application of EVM so that they appropriately integrate with or incorporate the practices of the Risk Management and Project Monitoring and Control process areas.

For example, these refinements to the documentation for applying EVM might address the following:

- Revising the estimate at completion if the likelihood and cost impact of the risk evaluation exceeds defined thresholds.
- Revising the project plan, including the schedule and budget, to incorporate the risk mitigation plan.

4 Technical Performance Measurement (TPM)

Technical performance measures characterize performance attributes of products or product components. For organizations that use TPM, some CMMI references are not sufficient to ensure that measures are specified to address TPM objectives.

Within the systems engineering environment for product development, a technical performance measure is a base measure. Earned value is a derived measure. The effectiveness with which earned value can address the measurement objectives of a project depends on the effectiveness and objectivity of its base measures, including technical performance measures.

There are subpractices regarding technical performance measurement (TPM) in the Requirements Development process area. For example, Specific Practice 3.3, *Analyze Requirements* includes the subpractice, "Identify TPMs that will be tracked during the development effort." However, there are no corresponding examples in the Project Planning or Project Monitoring and Control process areas to plan and monitor technical performance measures.

Technical performance measures are attributes of products or product components, and therefore, are attributes of work products. However, in both the Project Planning and Project Monitoring and Control process areas, the examples of the attributes of work products include size and complexity, but not technical performance measures. For organizations that use TPM, including organizations that must comply with U.S. Government contractual requirements for performance-based management systems, such as EVMS, the cited CMMI references are not sufficient to ensure that measures are specified to address TPM objectives. Thus, these would need to be implemented by organizations that have adopted CMMI and plan to use TPM. For organizations that plan to use TPM, examples of typical work products used in the project plan are a planned value profile, a tolerance band, and technical milestones for TPM evaluation. An example of the attributes of the work products that are monitored is TPM achievement to date.

An organization using TPM should consider addressing the examples cited above, in addition to those included in CMMI specific practices, as part of its framework for process improvement. If its documented process descriptions, standards, and procedures for the application of EVM and TPM within the process areas cited above do not achieve the intent of the associated goals, then the organization may need to identify and implement additional process improvements to achieve the related CMMI specific goals.

5 Guidance for Process Improvement and Appraisal

The tables in section 2 map the CMMI model specific practices to EVMS guidelines. These tables are designed to aid appraisers determining whether an organization's process descriptions, standards, and procedures meet the full intention of EVMS guidelines and CMMI specific practices.

An objective of CMMI is to reduce the cost of establishing and maintaining process improvement efforts across an enterprise using multiple disciplines to produce products or services. Advice for reducing these costs has been provided by the SEI and authorized appraisers as follows:

Regarding the costs of conducting appraisals, the appraised organization should provide sufficient evidence to the appraisal team to enable the team to quickly verify and validate the specific practices rather than to take the additional time to discover and collect evidence for the targeted practices [Phillips 02]. The concept is to shift as much work as possible away from the "on-site" portion of the appraisal and to complete it beforehand. The pre-work should include mapping the organization's processes to CMMI. The better data your appraisal team starts with, the less time it will take the team to complete [Minnich 02].

The CMMI project has produced one method to meet the need for a rigorous appraisal tool for benchmarking, the Standard CMMI[®] Appraisal Method for Process Improvement (SCAMPISM), Version 1.1: Method Definition Document [SEI 01]. Per the SCAMPI Method Definition Document, if an organization has in place assets, mechanisms, and objective evidence that substantiate its implementation of model practices, it is in the organization's best interest to share that knowledge to ensure that the appraisal team obtains a complete and accurate understanding of the organization's implementation of model practices. Many organizations capture this understanding through assets such as traceability and mapping tables from the model to their organization processes and project instantiations. Implementation of the model within the organization may be further reinforced through additional mechanisms, such as documentation, verification, and oversight activities (e.g., internal appraisals, audits, reviews, and status reports).

The SCAMPI method provides for the collection of data from the following sources:

SM SCAMPI is a service mark of Carnegie Mellon University.

- Instruments – Written information related to the organizational unit’s implementation of CMMI model practices. This can include assets such as an organizational mapping of CMMI model practices to its corresponding processes as well as questionnaire responses.
- Documents – Artifacts reflecting the implementation of one or more model practices. These typically include organizational policies, procedures, and implementation-level artifacts.
- Interviews – Focused discussions with organization members regarding CMMI practice implementations.

The tables in this technical note map the CMMI model specific practices to the EVMS guidelines or other EVMS sections, where they exist, and also include the CMMI model specific practices that have no corresponding guidance in the EVMS. Model users should understand the additional information that is provided in Section 3 of the EVMS, *EVMS Process Discussion*. The process discussion is an aid in understanding and applying EVM methods. If an organization’s process descriptions, standards, and procedures meet the full intention of the corresponding EVM standard guidelines and if the same artifacts also map to the CMMI model practices, then the complete mappings are instruments that provide objective evidence that substantiate the organization’s implementation of model practices.

Also, if the organization has additional mechanisms such as oversight activities (e.g., internal appraisals, audits, reviews, and status reports), then documentation of the oversight activities may provide further evidence of the implementation of the targeted practices within the organization. Examples of oversight activities regarding EVM include the following:

- internal appraisals or surveillance of the management system to ensure continued compliance with EVMS guidelines
- audits conducted by external organizations, such as the customer or government agencies

If assets such as these, or indicators of the existence of the assets, are made available to the appraisal team, the appraisal team must verify whether the objective evidence provided is adequate for substantiation of practice implementation and achievement of specific goals.

6 Summary

No single source of guidance to date has reconciled the implementation of EVM with CMMI. This technical note has identified practices within CMMI that are not included in EVMS but, if added to an organization's processes, will strengthen adherence to EVM principles. Additionally, the tables included herein can be used to develop instruments that will provide evidence to the appraisal team that will enable the team to quickly verify and validate specific practices based upon effective implementation of EVMS.

Finally, additional information has been included in this technical note to aid those using CMMI for process improvement.

References

- ANSI 02** American National Standards Institute/Electronic Industries Alliance. *Earned Value Management Systems (ANSI/EIA-748-A-1998, reaffirmed August 28, 2002)*. Washington, D.C.: American National Standards Institute, 2002.
<<http://global.ihs.com>>
- DoD 02a** Department of Defense. *DoD Regulation 5000.2: Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information Systems*. Washington, D.C.: Department of Defense, 2002.
<<http://www.acq.osd.mil/ap/index.html>>
- DoD 02b** Department of Defense. *DoD Directive 5000.1: The Defense Acquisition System*. Washington, D.C.: Department of Defense, 2000.
<<http://www.acq.osd.mil/ap/index.html>>
- EIA 98** Electronic Industries Alliance. *Systems Engineering Capability Model (EIA/IS-731)*. Washington, D.C.: Electronic Industries Alliance, 1998.
<<http://geia.org/sstc/G47/731dwld.htm>>
- Minnich 02** Minnich, Ilene. "CMMI Appraisal Methodologies: Choosing What is Right for You." *CrossTalk: The Journal of Defense Software Engineering* 15, 2 (February 2002): 7-8.
<<http://www.stsc.hill.af.mil/crosstalk/2002/feb/minnich.asp>>
- OMB 02** White House Office of Management and Budget (OMB) Circular A-11, Part 7, June 2002 and Supplement to Part 7, *Capital Programming Guide: Planning, Budgeting, and Acquisition of Capital Assets*, July 1997 (Guide).
<<http://www.whitehouse.gov/omb/circulars/a11/cpgtoc.html>>
- Phillips 02** Phillips, Mike. "CMMI Version 1.1: What Has Changed?" *CrossTalk: The Journal of Defense Software Engineering* 15, 2 (February 2002): 4-6.
<<http://www.stsc.hill.af.mil/crosstalk/2002/feb/phillips.asp>>
- PMI 00** American National Standards Institute/Project Management Institute. *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*,

2000 Edition (ANSI/PMI 99-001-2000). Newton Square, PA: American National Standards Institute, 2000.

<<http://www.psmisc.com>>

- SEI 01** CMMI Product Development Team. *SCAMPI VI.1, Standard CMMI Assessment Method for Process Improvement: Method Definition Document* (CMU/SEI-2001-HB-001). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, December 2001.
<<http://www.sei.cmu.edu/publications/documents/00.reports/00tr009.html>>.
- Solomon 01** Solomon, Paul. "Practical Software Measurement, Performance-Based Earned Value." *CrossTalk: The Journal of Defense Software Engineering* 14, 9 (September 2001): 25-29.
<<http://www.stsc.hill.af.mil/crosstalk/2001/sep/solomon.asp>>
- Solomon 02** Solomon, Paul. "Going From Performance-Based Earned Value to the CMMI." *CrossTalk: The Journal of Defense Software Engineering* 15, 9 (September 2002): 30.
<<http://www.stsc.hill.af.mil/crosstalk/2002/sep/solomon.asp>>
- Staley 02** Staley, Mary Jo; Oberndorf, Patricia; and Sledge, Carol A. *Using EVMS with COTS-Based Systems* (CMU/SEI-2002-TR-022). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, June 2002.
<<http://www.sei.cmu.edu/publications/documents/02.reports/02tr022.html>>

Appendix

This appendix contains other useful information and references.

Glossary Sources

The following sources were used for the glossary terms provided in this section. The terms extracted from each source are listed after the name of the source:

Table 4: Glossary Sources

Glossary Source	Terms Extracted
EIA 98	technical performance measurement, technical performance parameter
EIA 02	actual cost, control account, cost variance, earned value, estimate at completion, level of effort, resource plan, schedule variance
PMI 00	cost performance index, earned value management, effort, planned value, resource-limited schedule, schedule performance index

Glossary Definitions

The following terms and definitions are provided to aid you in applying CMMI as well as EVM to your process improvement program.

actual cost: The costs actually incurred and recorded in accomplishing the work

control account: A management control point at which budgets (resource plans) and actual costs are accumulated and compared to earned value. 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 work breakdown structure. It is where the project cost, schedule, and work scope are integrated, planned, and managed.

cost variance: A measure for the cost performance on a project. It is the difference between the earned value and actual cost.

cost performance index (CPI): The cost efficiency ratio of earned value to actual cost. CPI equals earned value divided by actual cost.

earned value (EV): The value of completed work in terms of the budget assigned to that work.

estimate at completion: The current, most likely estimated total cost for authorized work. It equals actual cost plus the most likely, estimated costs to completion.

planned value: See “resource plan.”

resource plan: The time-phased budget that is the schedule for the planned expenditure of project resources for accomplishment of work scope. The resource plan is also called “planned value.”

resource-limited schedule: A project schedule with start and finish dates that reflect expected resource availability. The final project schedule should always be resource limited.

schedule performance index (SPI): The schedule efficiency ratio of earned value accomplished against the resource plan. $SPI = EV$ divided by the PV .

schedule variance (SV): A metric for the schedule performance. It equals earned value minus the time-phased budget.

technical performance measurement (TPM): The technique of predicting the future value of key technical parameters of the end system based on current assessments of systems that make up that end system.

Notes:

1. *TPM involves the continuing verification of the degree of anticipated and actual achievement for technical parameters. TPM confirms progress and identifies variances that might jeopardize meeting an end system requirement. Assessed values falling outside established tolerances indicate a need for evaluation and corrective action.*
2. *The key characteristics of TPM are as follows:*
 - a. *Achievement-to-Date is the present achieved value of the technical parameter based on estimates or actual measurement.*
 - b. *Current Estimate is the value of the technical parameter predicted to be achieved by the end of the technical effort with remaining resources (including schedule and budget).*
 - c. *Technical Milestone is a point where TPM evaluation is accomplished or reported.*
 - d. *Planned Value Profile is the time-phased achievement projected for the technical parameter from the beginning of the development or as replanned as a result of a corrective projection.*
 - e. *Tolerance Band is an envelope containing the Planned Value Profile and indicating the allowed variation and projected estimation error.*
 - f. *Objective is the goal or desired value at the end of the technical effort.*
 - g. *Threshold is the limiting acceptable value that, if not met, would jeopardize the program.*

- h. *Variation is the difference between the Planned Value and the Achievement-to-Date value.*

technical performance parameter (TPP): a selected subset of the system's performance parameters used as the technical measures tracked in TPM.

TPPs can be any of the following:

- *specification requirements*
- *performance parameters such as measures of effectiveness and other key decision metrics used to guide and control progressive development*
- *design to cost requirements or goals*

Recommended Sources

The following are recommended sources of information concerning base measures for earned value:

- A source of information for information needs and objectives and for specifying measures to address earned value measurement objectives, based on [PSM 01], is the CrossTalk article *Practical Software Measurement, Performance-Based Earned Value* [Solomon 01].
- A source of information for specifying measures to address earned value measurement objectives, based on technical performance, requirements management, and typical work products in CMMI, is the CrossTalk article *Going from Performance-Based Earned Value to the CMMI* [Solomon 02].

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