The Magazine of the Project Management Institute's College of Performance Management

"Integrating Project Management with Performance Measurement"

THE MEASURABLE NEWS

MARCH 2•0•0•2

CONTENTS

From Performance-Based Earned Value℠ (PBEV℠) to the CMMI℠

by Paul J. Solomon, PMP

Abstract: Earned Value Management (EVM) can be a process thread to enable effective process integration and improvement during transition to the CMMI. Organizations that already use EVM can achieve lower cost process improvements and appraisals by using the maps and guidance that follow. Others should consider implementing EVM during transition so that future projects will achieve their cost, schedule and technical objectives.

Many organizations are planning to transition their framework for process improvement efforts from the Software Capability Maturity Model (SW-CMM) to the Capability Maturity Model-Integration (CMMI℠). The CMMI is consistent with the guidelines of the primary external industry benchmarks for Earned Value Management (EVM), ANSI/EIA 748-1998, "EVM Systems Standard"[1] (EVM Standard).

Those organizations that already use EVM can develop efficient process improvement plans and minimize transition costs, including appraisal costs, if they understand and utilize the relationships between the CMMI and external industry benchmarks.

Other organizations should consider implementing EVM as a process improvement. In the CMMI context, EVM is a process thread that crosses many discipline boundaries and is critical to effective process integration. Consequently, implementation of EVM during the transition will be more efficient if it is part of an overall plan to improve and integrate processes.

The CMMI has increased emphasis on integrated, quantitative project management, the core of EVM, including:

- Managing requirements development and the technical solution for the total system; systems engineering, not just software engineering
- Integrating a project's cost, schedule and technical planning parameters
- Establishing precise, quantifiable measures of progress towards meeting an organization's measurement objectives

Information and guidance follows for preparing objective evidence of an organization's EVM capabilities in relation to CMMI standards and for mapping organizational processes to the CMMI as a first step towards process improvement.

History of CMMI

In 1997, the Office of the Undersecretary of Defense (Acquisition, Technology and Logistics), (OUSD) joined with the NDIA to initiate the CMMI project to integrate process improvement models that would build on the success of the Software Engineering Institute's (SEI) SW-CMM. The SW-CMM had begun as the SEI's answer to a challenge by the Air Force to find a set of key questions about a company's software processes that would guide their selection of the most competent, or mature, software developer.[2] The latest release is of the CMMI is Version 1.1, December 2001.

At the recent CMMI Technology and User Group Conference, Dr. Nancy Spruill, Director of Acquisition Resources and Analysis, OUSD, discussed future plans for the Department of Defense (DoD) to move toward the CMMI for greater breadth of coverage for software intensive systems. Recently, OUSD has

Continued on page nine.

Cover Story: Continued from page one.

asked the Aerospace Industries Association to comment on several questions about the current policy. That policy mandates CMM-SW compliance as a requirement for bidders on ACAT I programs and on the rationale for the DoD to allow the CMMI to join the SW-CMM as an equivalent model in comparing the capabilities of potential suppliers. The questions were posed by Joe Jarzombek, Deputy Director for Software Intensive Systems, OUSD.

Mr. Jarzombek also encourages the insertion of more EVM content into the CMMI in terms of making amplifications to existing specific practices or elaborations to the existing generic practices…However, to really have an impact on the way organizations do business, EVM might need to be introduced as part of the 'required' or 'expected' parts of the model/assessment…I hope you can help us get more EVM into CMMI.[3]

A primary discussion of using EVM to manage software projects is in my article, "Practical Software Measurement, Performance-Based Earned Value."[4]

Comparison of CMMI to SW-CMM

There are significant differences between the CMMI and the SW-CMM, in the process areas (PA) emphasized for process improvement, in the component structure, and in the specific guidance. The following comparisons are limited to those differences that are relevant to implementing EVM during process improvement. All references are based on the CMMI-SE/SW/IPPD model (systems engineering, software engineering, and integrated product and process development model.

Process Areas

The CMMI has three PAs that emphasize quantitative and integrated project management whereas the SW-CMM does not emphasize these areas. They are Measurement and Analysis (MA), Project Monitoring and Control (PMC), and Integrated Project Management (IPM).

The most significant difference between the CMMI and the SW-CMM, with regard to EVM, is MA. As described by two of the CMMI authors, "Measurement has been elevated to the status of a separate PA…MA provides a focus area and foundation for the various applications of measurement in project management and process improvement activities. The PA provides greater consistency and understanding with respect to the practice of measurement."[5]

Another CMMI author identified sixteen Measurement-related PAs including six within Project Management (Project Planning (PP), PMC, Supplier Agreement Management (SAM), IPM, Risk Management (RM), and Quantitative Project Management (QPM). Per the author, the integration of MA activities into project processes supports the following:

- Objective planning and estimating
- Tracking actual performance against established plans and objectives
- Identifying and resolving process-related issues[6]

Table 1 is a comparison of the MA specific practices (SP) and subpractices in the CMMI to similar activities in the SW-CMM.

The Project Monitoring and Control PA complements MA in its emphasis on quantitative project management. As shown in Table 2, PMC SP 1.1 requires monitoring of actual performance against project planning parameters and identification of significant deviations. In contrast, the SW-CMM discusses only quantitative process management. It does not include project planning parameters or the management practices of comparing actual values to a plan and identifying deviations.

Table 1, CMMI MA: Specific Practice	CMMI MA: TWP, Subpractice, Clarification	SW-CMM : Quantitative Process Management

1.2 *Specify measures to address the measurement objectives*	• Precise
	• *Quantifiable*
	• Derived examples:
	  • *Earned Value*
	  • *Schedule Performance Index*
	• *Operational definitions for measures*
		Activity 4, Measurement data:
		• Size, cost, schedule
		• Quality measurements
		• Test coverage

Finally, whereas the CMMI requires in IPM, SP 1.4, managing the project using the integrated plans, the SW-CMM does not address integrated plans or measurable planning parameters (Table 3).

CMMI Components

The CMMI components include specific practices, subpractices and typical work products (TWP). A SP describes the activities expected to result in achievement of the associated specific goal of a PA. Subpractices are detailed descriptions that provide guidance for interpreting SPs or generic practices. TWPs are informative model components that provide example outputs from an SP or generic practice.

In the following discussion and mappings, guidance and information is provided to identify those SPs, subpractices and TWPs that are consistent with the institutionalization of EVM.

Measurement Objectives

The CMMI, and other external industry benchmarks, stress the importance of identifying measurement objectives. In the CMMI, MA has improved coverage of goals and practices to establish measurement objectives (SP 1.1) and to establish precise, quantifiable measures that meet the objectives (SP 1.2). Per SP 1.1:

Table 2, CMMI PMC: Specific Practice	CMMI PMC: TWP, Subpractice, Clarification	SW-CMM: SW Project Tracking & Oversight
1.1 Monitor project planning *parameters*: • *Attributes of work products* • Cost, effort, schedule	• *Compare* actual values to plan • *Identify significant variances*	Activities 6, 8, 9: • Cost estimates and work completed • Schedule activities • Technical activities

Establish and maintain measurement objectives that are derived from identified information needs and objectives…Sources of information needs and objectives include:

- Established management objectives
- Project plans
- Monitoring of project performance
- External industry benchmarks

For most businesses, established management objectives include achieving financial performance goals and customer satisfaction. These objectives are supported, at the project level, by achieving the project's cost, schedule and technical objectives. The project objectives are incorporated into the project plans. Then project performance is monitored against the plans. Consequently, the specification of earned value measures will address the first three measurement objectives.

Continued on page ten.

Cover Story: Continued from page nine.

External Industry Benchmarks

For organizations that seek external industry benchmarks as a source of measurement objectives, there are three benchmarks that address EVM:

- Project Management Institute (PMI) Guide to the Project Management Body of Knowledge (PMBOK®)[iii]
- ANSI/EIA 748-1998, "EVM Systems Standard" (EVM Standard)[ii]
- Practical Software and Systems Measurement: A Foundation for Objective Project Management (PSM)[7]

PMBOK is a guide for project management that is referenced internationally by members of the Project Management Institute and others. It has guidance to use EVM as a project integrating methodology and to use EV as a tool to measure performance against the project plan. It is also an ANSI standard.

Table 3, CMMI IPM: Specific Practice	CMMI IPM: TWP, Subpractice, Clarification	SW-CMM : Quantitative Process Management
1.4 Manage Project Using Integrated Plans	• *Integrated plans* • *Track planning parameters using measurable methods that trigger investigations* • *Align performance with current and projected needs, objectives, requirements*	Activity 4, Project Management, does *not* address: • Integrated plans • Measurable planning parameters

The EVM Standard is the only benchmark that exclusively addresses EVM. It includes thirty-two guidelines for EVM. Full compliance with ANSI is contractually required by some government contracts. However, in my opinion, a tailored, partial implementation of the guidelines in ANSI would be sufficient to meet the relevant measurement objectives of most organizations. Both the EVM Standard and PMBOK provide guidance for integrated project management and for using EV as a derived measure.

The PSM provides an excellent source of base measures for EV measures. It has principles for identifying, collecting and tracking project measures and metrics. PSM starts with defining the issue being addressed then breaking down the issues into categories and measures. One of the PSM issues is "Schedule and Progress." The philosophy found in the MA PA closely follows that found in PSM. Recommended base measures for earned value, from PSM, are in reference iv.

Specific Guidance

Although EVM is not cited as a specific goal or a SP in the CMMI, the implementation and institutionalization of EVM, consistent with external industry standards, provide evidence of achieving twenty-six SPs within eleven PAs.

Table 4: SPs Mapped to PMBOK®	PA: Measurement & Analysis	PMBOK Guide #
Specific Practice	TWP, Subpractice	
1.1 Establish management objectives derived from information needs and objectives	• Sources: project plans, monitoring performance, external industry benchmarks • Base measures • Derived measures (EV, SPI) • Operational definitions	5.2.3.1 Project objectives-Quantifiable criteria that must be met for the project to be considered successful...must include cost, schedule, and quality measures

A sample of the SPs that map to external industry benchmarks is provided in the following tables. Tables 4 maps SPs within MA to the PMBOK. Tables 5 through 9 map SPs within IPM, RM, RD, MA and PMC to the EVM Standard.

Specific Measures

Measurement and Analysis SP 1.2, Specify Measures, includes the only direct reference to earned value. Both earned value and the earned value metric, schedule performance index, are listed as examples of commonly used derived measures.

A common misconception about earned value is that "Its major weakness for software effort is its inability to assess technical progress (percent complete) accurately and objectively."[8] This misconception is based on a misunderstanding of earned value.

Earned value is a derived measure. Therefore, its effectiveness as a measure of schedule progress is a function of its underlying base measures.

The underlying base measures are:

1. The selected measure of schedule progress for completion of an activity
2. The budget value allocated to the activity

Incidentally, CMMI's definition of earned value, in the SP cited above, is erroneous. I have submitted a change request to correct the definition in a future version of the CMMI. A correct definition, per the EVM Standard, is the value of completed work expressed in terms of the budget assigned to that work.

Focus MA and EVM on Requirements

Specific Goal 1 of Requirements Management (RM) is: manage requirements. To achieve this goal, the project must maintain the relationships between the requirements, the project plans, and the work products. RM refers to the PMC PA for information about tracking and controlling the activities and work products that are based on the requirements. In specifying the measures to be used to monitor progress towards the project's cost, schedule and technical objectives, it is recommended that the practices of RM, MA and PMC be closely related. According, it is recommended that the base measures for EVM be focused on RM.

RM, SP 1.4, requires that bidirectional traceability of requirements be maintained. It states, "When the requirements are managed well…traceability can be established from the source requirement to its lower level requirements and …back. Requirements traceability can also cover the relationships to other entities such as intermediate and final work products, changes in design documentation, test plans, and work tasks."

The relationship of measurement to requirements traceability is described by P. Baxter. Baxter examines the application of the measurement process in providing visibility into the RM process. "The measurement process provides an independent mechanism for quantifying the activities performed in the other essential project functions…The measurement process greatly enhances the control and monitoring of requirements engineering by quantifying the status and progress of requirements-related activities…Popular measurement selection techniques include...PSM…a systematic means for selecting specific metrics that support the defined needs of management."[9]

A similar emphasis on requirements is found in reference 4. "Establishing a time-phased requirements baseline against which progress can be consistently measured is the most important EVM step. It drives

Continued on page seventeen.

Cover Story: Continued from page ten.

the…budget…and the schedule. The technical requirements also establish the criteria for completing tasks…Of equal importance are a disciplined requirements traceability process and a requirements traceability matrix."

It is highly recommended that RM and EVM be closely integrated to ensure that the most effective measures of Schedule and Progress are specified.

Table 5: SPs Mapped to EVM Std. Guideline	PA: Int. Project Mgt.	EVM Guideline #
Specific Practice	TWP, Subpractice	
1.3 Integrate Plans	• Integrate other plans with project plan • Incorporate into plan definitions of measures and measurement activities	2.1.c. Provide for integration of planning, scheduling, budgeting, work authorization, cost processes... and WBS

PBEV

Performance-Based Earned Value (PBEV) is a lean variant of legacy EVM that has a higher focus on requirements and on specifying the most effective measures of project performance. It is consistent with the CMMI and can be used as a framework for reducing the cost of implementing EVM as a process improvement during transition to the CMMI. The recurring costs of institutionalizing PBEV are also lower than legacy EVM.

PBEV is fusion of EVM, Requirements Management and lean, or cost-effective, business practices. It evolved from legacy EVM techniques in response to the demands and business objectives of highly competitive organizations, including commercial businesses. Compared with legacy EVM, PBEV eliminates non-essential planning and control effort, is consistently focused on progress towards meeting a project's system requirements, and requires specifying the most effective measures of project progress. In legacy EVM, all activities are budgeted. They are periodically assessed to determine an earned value that must be stored, reported and analyzed. Legacy EVM includes all immeasurable, support activities, sometimes called level of effort, and all discrete activities, even if their completion is not a measure of progress towards completing a work product. Examples of activities that do not directly constrain the completion of work products are coordination meetings, project status reviews, and program management and control activities.

In contrast, PBEV plans and monitors only those activities that result in completion of work products or in components of work products. A work product is any artifact produced by a process. These artifacts can include files, documents, files, parts of the product, services, processes, specifications, and invoices. In a more extreme, lower cost variant of PBEV, only those activities that eventually result in completion of a product, or a component of a product, are measured. A product is a work product that is delivered to a customer or end user. Consequently, the budget for the level of effort activities and other discretely scheduled activities may be allocated to the activities that result in completion of work products.

PBEV is consistent with effective systems engineering and project management (and with RD SP 3.3) in that it begins with the identification of the key requirements that have the biggest impact on cost, schedule, functionality, technical performance and risk. Based on the organization's business and measurement objectives, PBEV leads to the selection of

Continued on page eighteen.

Cover Story: Continued from page seventeen.

the most effective measures of schedule and progress and to a performance measurement baseline that is tied to requirements. Because of the traceability to requirements, there is rapid and disciplined integration of project scope changes.

PBEV is lean because it limits the number of activities to be planned, measured and monitored to those that result in typical work products such as those in the CMMI. The work products within the Requirements Development and Technical Solution PAs receive the largest budget allocations. However, the work products of Requirements Management, Validation, Verification, and Measurement and Analysis are also emphasized because of their roles in controlling the project. A sample of typical work products in the CMMI follows.

Table 6: SPs Mapped to EVM Std. Guideline	PA: Requirements Management	EVM Guideline #
Specific Practice	TWP, Subpractice	
1.4 Bidirectional Traceability of Requirements (among requirements, project plans, intermediate and final work products)	• For each level of product decomposition • For impact of requirements changes on project plans, activities, work products • TWP: Requirements traceability matrix	2.1.a. Define WBS for internal management control. 2.5.a. Incorporate changes in a timely manner, recording effects of changes on budgets and schedules

Typical Work Products:

- Requirements Development TWP
- Customer requirements
- Derived requirements
- Product requirements
- Product-component requirements
- Interface requirements
- Functional architecture
- Activity diagrams and use cases
- Object-oriented analysis with services identified
- Key requirements
- Technical performance measures
- Record of analysis methods and results

- Technical Solution TWP
- Product component operational concepts, scenarios and environments
- Use cases
- Product-component selection decisions
- Technical Data Package
- Allocated requirements
- Product component descriptions
- Key product characteristics
- Required physical characteristics and constraints
- Interface requirements
- Material requirements
- Verification criteria used to ensure requirements have been achieved
- Conditions of use (environments) and operating/usage scenarios, modes and states for operations, support, training, and verifications throughout the life cycle
- Comprehensive interface
- Interface design specifications
- Interface control documents
- Interface specification criteria
- Implemented design
- Product support documentation (Training materials, user's manual, maintenance manual, online help
- RM TWP
- Requirements traceability matrix
- Validation TWP
- Validation results
- Verification TWP
- Exit and entry criteria for work products
- Verification results
- MA TWP
- Specifications of base and derived measures
- Process Improvement and Appraisal

Table 7: SPs Mapped to EVM Std. Guideline	PA: Requirements Development	EVM Guideline #
Specific Practice	TWP, Subpractice	
3.3 Analyze Requirements	• Identify key requirements... influence cost, schedule, functionality, risk, performance • Identify technical performance measures	2.2.b. Identify physical products, milestones, technical performance goals... measure progress

Table 8: SPs Mapped to EVM Std. Guideline	PA: Measurement & Analysis	EVM Guideline #
Specific Practice	TWP, Subpractice	
1.1 Establish management objectives derived from information needs and objectives 1.2 Specify measures: Precise, quantifiable	• Sources: project plans, monitoring performance, external industry benchmarks • Base measures • Derived measures (EV, SPI) • Operational definitions	2.2.b. Identify physical products, milestones, technical performance goals... measure progress

To initiate process improvement and minimize appraisal time and costs, for organizations that have used EVM, it is recommended that artifacts be prepared based on the referenced tables. Map existing procedures and practices to the CMMI and to the selected external industry benchmarks. Analyze the gaps and begin process improvement. The artifacts can be used in planning the appraisals and shown as evidence of institutionalizing the practices and achieving specific goals. For organizations that are implementing EVM as a process improvement, follow a similar process. Identify and close gaps between existing EVM practices and the CMMI.

EVM Process Improvements

Organizations that are compliant with the EVM Standard may need to identify and implement process improvements in order to achieve the related CMMI specific goals. The SGs in Requirements Development (Table 7) and in Measurement and Analysis (Table 8) are more specific than the related guidelines in the EVM Standard with regard to focusing on requirements and on defining objective measures of progress.

The Requirements Development PA includes SP 3.3, Analyze Requirements. One of its required actions is to determine which 'key requirements will be used to track technical progress. Following that determination, measures of technical progress towards meeting those requirements must be specified.

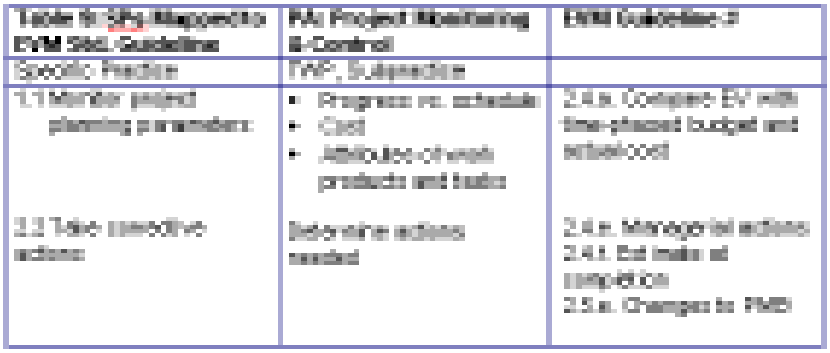
Regarding objective measurement, MA SP 1.2 requires that precise and quantifiable measures be specified and that the base measures be obtained by direct measurement. SP 1.2 also includes a typical work product, specifications of base and derived measures (such as earned value), and a subpractice to specify operational definitions for the measures. The subsequent SP 1.3 requires specification of how measurement data

Continued on page nineteen.

Cover Story: Continued from page eighteen.

will be obtained and stored.

By comparison, the EVM Standard requires measurement of the project's total work scope and does not address the importance of identifying and tracking the progress of meeting key requirements. Furthermore, the EVM Standard does not require, objective assessment of earned value. The relevant EVM Guideline 2.2.a requires only identification of physical product, milestones and technical performance goals or other indicators to measure progress. In the discussion of discrete effort, the EVM Standard states that management assessment may include the use of metrics for work measurement.



It is recommended that the process improvement plan include objectives to intensify the organization's focus on key requirements, to require objective earned value and to achieve the specific goals and practices of MA.

It is further recommended that process improvement include plans to address the objectives of PBEV, including selecting measures of progress towards completing work products or products.

Finally, the CMMI includes a Process Area, Organizational Training. It includes specific goals to establish an organizational training ability and to provide training. The specific practices include establishing training records and assessing training effectiveness. Organizations should assess their EVM training processes to identify and close any gaps with the CMMI.

Conclusion

These actions will support the objectives of achieving higher capability and maturity in the CMMI process areas, of institutionalizing EVM, and of integrating EVM with the organizations systems engineering and enterprise-wide processes. Quantitative project management, with the effective use of EVM, will reduce the risks of failing to achieve a project's cost, schedule and technical objectives.

References

[1] American National Standards Institute/Electrical Industries Associa

Continued on page twenty.

Cover Story: Continued from page nineteen.

tion. Industry Guidelines for Earned Value Management Systems (ANSI/EIA 748-1998). Washington, D.C.

[2] M. Phillips and S. Shrum, Creating an Integrated CMM for Systems and Software Engineering, CrossTalk, The Journal of Defense Software Engineering, (September 2000), available at www.stsc.hill.af.mil/crosstalk/2000/sep/phillips.pdf

[3] J. Jarzombek, Email to Paul Solomon, Subject: DCMA Presentation of SIS Initiatives, August 9, 2001.

[4] P. Solomon, Practical Software Measurement, Performance-Based Earned Value, CrossTalk, The Journal of Defense Software Engineering, (September 2001), available at www.stsc.hill.af.mil/crosstalk/2001/sep/solomon.pdf

[5] S. Lucero, Up Close with Lt. Col (Ret.) Joe Jarzombek, Bruce Allgood, CrossTalk, The Journal of Defense Software Engineering, (July 2000)

[6] D. Zubrow, Putting "M" in the Model: Measurement and CMMI[SM], Software Technology Conference, Salt Lake City, Utah, May 2, 2001

[7] Practical Software and Systems Measurement: A Foundation for Objective Project Management. U.S. Department of Defense and U.S. Army. October 2000, Version 4.0b, available at www.psmsc.com.

[8] R. Young, Effective Requirements Practices. Addison-Wesley, 2001, p. 256.

[9] P. Baxter, Focusing the Measurement Process on Requirements: Integrating DOORS and MetricCenter, white paper, copyrighted, available at www.distributive.com

[SM] *Performance-Based Earned Value and PBEV are service marks of Paul J. Solomon. CMM® Integration™ and CMMI are service marks of Carnegie Mellon University.*

[1] American National Standards Institute/Electrical Industries Association. Industry Guidelines for Earned Value Management Systems (ANSI/EIA 748-1998). Washington, D.C.

[2] M. Phillips and S. Shrum, Creating an Integrated CMM for Systems and Software Engineering, *CrossTalk, The Journal of Defense Software Engineering*, (September 2000), available at www.stsc.hill.af.mil/crosstalk/2000/sep/phillips.pdf

[3] J. Jarzombek, Email to Paul Solomon, Subject: DCMA Presentation of SIS Initiatives, August 9, 2001.

[4] P. Solomon, Practical Software Measurement, Performance-Based Earned Value, *CrossTalk, The Journal of Defense Software Engineering*, (September 2001), available at www.stsc.hill.af.mil/crosstalk/2001/sep/solomon.pdf

[5] S. Lucero, Up Close with Lt. Col (Ret.) Joe Jarzombek, Bruce Allgood, *CrossTalk, The Journal of Defense Software Engineering*, (July 2000)

[6] D. Zubrow, Putting "M" in the Model: Measurement and CMMI[SM], *Software Technology Conference*, Salt Lake City, Utah, May 2, 2001

[7] *Practical Software and Systems Measurement: A Foundation for Objective Project Management.* U.S. Department of Defense and U.S. Army. October 2000, Version 4.0b, available at www.psmsc.com.

[8] R. Young, *Effective Requirements Practices.* Addison-Wesley, 2001, p. 256.

[9] P. Baxter, *Focusing the Measurement Process on Requirements: Integrating DOORS*â *and MetricCenter*â, white paper, copyrighted