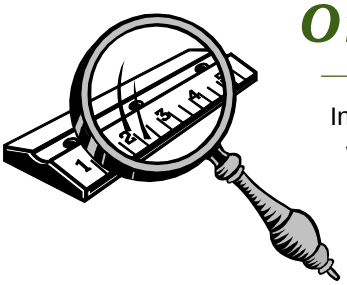
The Army's Software Metrics Newsletter

Insight

Sponsored by the U.S. Army Evaluation Center and G6
http://www.armysoftwaremetrics.org

Spring 2002
Volume 6, Number 1

Tailoring and Implementing an Organizational Measurement Process



In February 2002, the Software Enterprise of TACOM-ARDEC,* Picatinny Arsenal, New Jersey was the first U.S. government organization to successfully achieve a formal, level 3 assessment under the Capability Maturity Model-Integrated (CMMI). This was the culmination of several years of organizational process improvement activities. As part of the process improvement project, the organization began collecting measurement data in July 2001. Data collection was actually the apex of an extensive effort to define and implement an organizational measurement process. The major challenge in establishing this process was to implement a new way of doing business that used objective, quantitative data to support management decisions at all levels of the organization. New business procedures required cultural change by requiring all members of the organization to collect, report, and assess data for defined organizational measures. The underlying, critical task was to define a set of measures that not only addressed the management goals of TACOM-ARDEC, but also supported the information needs of fourteen diverse projects within the Software Enterprise.

Background

The environment of the TACOM-ARDEC Software Enterprise is dynamic, continually adapting to the changing business opportunities in the Army research and acquisition communities. Projects are created and terminated to meet the evolving technical needs of Army customers. To perform effectively in a dynamic environment, the Software Enterprise must continually collect, analyze, and use measurement data to support various management decisions.

The Software Enterprise consists of fourteen diverse projects. Customer needs determine which engineering processes these projects employ, such as systems engineering, software engineering, acquisition support services, or a mix of all three. Each project is assigned to one of three categories:

- Mission Support - Development or maintenance of software products
- Acquisition Services - Independent Verification & Validation, testing, or project management support for Army program offices
- Internal Support - Quality assurance, configuration management, and various services for other Software Enterprise projects

The size of the TACOM-ARDEC projects ranges from a single employee to 40 employees, including contractor support.

In the interview that follows, Cheryl Jones, head of the Software Enterprise performance management project, describes how the Software Enterprise structured the overall organizational measurement process and defined a standard set of organizational measures. She also explains some of the challenges, the lessons learned, and how the organization continues to monitor and respond to its measurement needs.

Where did you start in planning such a challenging measurement program?

The objective of the measurement program is to improve the overall performance of the Software Enterprise, so we started at the top level of the organization. The first step was to define the informa-

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* *Tank, Automotive, and Armament Command – Armament Research and Development Engineering Center*

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tion needs of the organization, then identify a common set of measures that would be reported by all fourteen of the projects within the organization.

However, like most technology-based organizations, the Software Enterprise is a composite of many types of projects. It was difficult to define a set of common organizational measures without violating the first principle of the Practical Software and Systems Measurement (PSM) process: "The project information needs and objectives shall drive the measurement requirements." Therefore, all of our decisions in defining a top-down organizational measurement process were evaluated for their impact at the project level.

We wanted to ensure that the organizational measurement process provided each project with the necessary data to make informed project management decisions. In an optimum measurement process, the same data can be used to support the information needs of higher management levels. Based on these concepts, we continued our planning process with these two steps:

- Define the information needs of the projects.
- Identify project measures that address both the organizational and project-specific information needs.

How did you structure the organizational measurement process?

The purpose of our measurement process is to define and improve the collective performance of all activities in the Software Enterprise. To accomplish this, we designed measures to monitor two levels of performance: the Software Enterprise as a whole and the individual projects. Organizational measures monitor the overall performance of the Software Enterprise, and project-level measures address the fourteen individual projects.

Software Enterprise managers defined the organizational information needs and the six common measures that were documented in the Organizational Measurement Plan (see Table 1 on page 3). These common measures were selected to monitor the combined performance of all projects within the Software Enterprise. The difficulty in collecting and reporting these measures varied with each project. The common organizational measures are closely related to the information needs and measures of a software development process, so those projects in the Mission Support category had the least difficulty in reporting the measures because these projects develop or maintain software products. However, many of the projects in the Acquisition Services and Internal Support categories had different information needs.

We structured the organizational measurement process to collect its input, or base measures, from two sources:

- Software Enterprise activities that were common to all projects, including training, customer satisfaction, and overall financial performance
- Project management activities that define the individual information needs

The Software Enterprise uses the information gained from the organizational measurement efforts to support Software Enterprise and project management activities, including:

- Process Performance - Provide feedback on the organization's ability to meet defined objectives.
- Process Improvement - Identify those process areas that need improvement, define requirements for training, and identify resources required to support process improvement.
- Customer Satisfaction - Evaluate customer satisfaction with the services and products provided by the Software Enterprise.
- Business Cases - Develop additional business cases to acquire future work.

About Insight

Insight is the newsletter of the U.S. Army Software Metrics Office. The newsletter is intended to provide information on efforts to measure software. Readers are encouraged to submit articles for the newsletter that address any facts, opinions, or points of interest.

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Software Enterprise Information Need	Common Organizational Measure
Schedule and Progress	• Schedule Performance - Milestones
Resources and Cost	• Effort • Cost
Product Size and Stability	• Size - Measured by the number of Lines of Code (LOC) for the development projects or the number of tasks for the acquisition services and support projects
Product Quality	• Defect profiles or peer review profiles
Process Performance	• Audit Profiles

Table 1. All projects report data for a set of six common organizational measures.

- Project Estimation and Planning - Organizational and other historical data will be used as a basis for estimation during future project planning.
- Project Monitoring and Control - Ensure that projects are completing defined tasks within budget and on schedule, while meeting performance and quality objectives.

Project leaders define their own project-level measurements and document them in their Project Measurement Plan. The plan must address the common organizational measures, as well as any additional measures based on project-specific information needs. Project leaders are responsible for collecting their project data and delivering the six organizational measures to the organizational measurement database for aggregation and analysis. The key to success is to define organizational measures that are useful at the project level, as well as the organizational level.

Managers evaluate data on the performance of individual projects at Senior Management Reviews (SMRs) that are held every quarter. The SMRs also support two secondary activities:

- Process Improvement - The measures are used to report the process maturity of individual projects. This data is used to identify key process areas that need improvement, define requirements for training, and identify project resource and staffing requirements. The measures also provide an opportunity to disseminate lessons learned among other projects.
- Project Planning - The measures are entered into the organizational measurement data repository. The Software Enterprise will use this data and any other historical data as a basis for future project planning.

Software Enterprise managers review the organizational measurement needs and processes at least every six months. Periodic reviews of individual measurement processes are also scheduled with the individual projects. These reviews ensure that the measurement processes conform to plans and that project-level performance measurements are integrated with business-area performance requirements.

What guidance did you use to plan the organizational measurement process?

We followed three process guidelines: ISO/IEC 15939, CMMI, and PSM.

ISO/IEC 15939, Software Measurement Process, is the international standard that defines the required tasks and outcomes of a measurement program.

The CMMI Measurement and Analysis process was used to plan for the process improvement effort and provided the baseline for evaluating the measurement process. The CMMI was selected because it provides a single model that integrates the various technical activities of systems engineering and software engineering. The CMMI concepts were extrapolated to provide a process model that could be used to evaluate the Acquisition Support projects in the Software Enterprise. (For more information, see the CMMI article on page 11 of this issue of *Insight* or visit www.sei.cmu.edu/cmmi/.)

The PSM Guidebook provided the detailed "how-to" instructions for implementing an effective measurement process. The PSM process allows managers to tailor their measurement process to the appropriate information needs and characteristics of their activity. The nine principles defined in the PSM Guidebook were the foundation for all of the Software Enterprise measurement efforts (see Table 2, page 4.)

How did you select the organizational measures?

We used the PSM process. PSM ensures that an iterative measurement program is tailored to the characteristics and information needs of both the individual projects and the Software Enterprise as a whole. The PSM process was originally developed to describe the measurement process for a single project, so of course it was directly useful in defining project-specific measures. The challenge was to apply the PSM process to an organizational measurement program that spans fourteen projects.

The primary activities of the PSM measurement process (shown in Figure 1, page 5) are:

1. **Obtain and Sustain Commitment** by gaining organizational support for measurement and analysis by addressing and continually updating the information needs.
2. **Plan Measurement** by identifying and prioritizing the organizational and project information needs, selecting measures that address these information needs, and integrating the mea-

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surement into existing management and technical processes.

3. **Perform Measurement** by collecting and processing the measurement data, analyzing the data, and converting the data into management information for appropriate courses of action at both the project and Software Enterprise levels.

PSM Measurement Principles	Software Enterprise Implementation
The project information needs and objectives shall drive the measurement requirements.	Organizational business goals and objectives were first defined. From these, required organizational measures were specified. Projects then defined measures based on project-specific information needs and required organizational measures (tailoring was allowed).
The project processes shall define how the defined information needs are actually measured.	Both organizational and project-specific measures were specified, based on project processes. Specific tools, practices, and available data influenced the measures selected and their specification, for each project. For example, to address the defined information need of increasing quality, development projects provided problem-reporting data while acquisition support projects provided data on peer reviews.
Data shall be collected and analyzed at a level of detail sufficient to identify and isolate problems and risks.	Based on the base measures collected by each project, derived measures and indicators are generated and analyzed at both the project and Software Enterprise levels. The organizational analysis describes problems and risks for the organization, and identifies specific projects that had problems. The projects are responsible for providing detailed analysis and explanations of project-level problems.
An independent analysis capability shall be implemented.	The smaller Software Enterprise projects (under three staff months) have a team member who is responsible for project-specific measurement. Larger projects have an independent analyst. Organizational measurement is performed by a separate internal quality organization.
A systematic analysis process shall be utilized to trace the measures to the decisions.	The organizational measurement reports are based on the analysis process outlined in the organizational measurement plan. At the project level, measurement results and associated management decisions are reviewed at quarterly Senior Management Reviews (SMRs), following a specified template. All projects received training and individual consulting to establish the measurement analysis capability. Analysis capability has been improved by Process Engineering Group briefings on useful analysis methods.
The measurement results shall be interpreted in the context of other project information.	Projects are responsible for providing detailed analysis and explanations of project-level problems.
Measurement shall be integrated into the project and organizational processes throughout the life cycle.	The organizational and project measures are tailored to the project processes to address the defined information needs.
The measurement process shall be used as a basis for objective communication.	Organizational measurement analyses are provided monthly via measurement reports and quarterly through SMRs. Project analysis is provided quarterly through SMRs and on a monthly/weekly basis through management summaries.
Measurement shall initially be focused on project level analysis.	The initial focus was to ensure that all projects implemented effective measurement programs. As these matured, additional organizational analysis could be performed.

Table 2. The nine PSM measurement principles ensure that the information needs of the specific projects and the organization are addressed.

4. **Evaluate Measurement** by continually assessing and improving the selected measures, the indicators, and the collection and analysis process.
5. **Integrate the Measurement Process** by establishing those activities as essential steps in the organization's processes. This activity was an essential step in the success of the Software Enterprise organizational measurement process.

How did you tailor your organizational measures to the needs of the Software Enterprise?

In the PSM approach, all measures are driven by the organization's information needs. We followed this approach by first identifying the information needs that our measurement process would address. Software Enterprise executives participated in a March 2001 workshop to identify and prioritize the top-level information needs for our organization. Table 3 (on page 5) outlines the information needs they identified.

Based on these information needs, they identified a set of common organizational measures that every project should collect. Participants worked with an Executive Measurement Planning Template to identify and rank candidates for organizational measures, completing the following categories for each nominated measure:

- Business Goals
- Software Process (Strategy) Goals
- Relative Importance
- Indicator to Support Analysis
- Base Measures
- Availability of the Base Measures in the Existing Process

The end product was an Organizational Measurement Plan that describes twenty-three selected organizational measures, the organizational measurement repository, and the procedure for incorporating project data into that repository. Although twenty-three organizational mea-

sures were identified, only six were considered to be common to the information needs of all fourteen projects. These six common organizational measures were slated for collection (to the extent applicable) by all fourteen projects. The other seventeen measures were identified for reporting only if they provide information that could improve either the project's or organization's defined processes.

The workshop participants also established process implementation goals, such as providing tools and software to assist with establishing and formalizing the measurement process.

How did you tailor your organizational measures to the needs of the projects?

TACOM-ARDEC requires project managers to define and tailor a set of issue-driven measures to manage their process. However, identifying information needs has been one of the most difficult tasks for the project measurement programs. Mangers of the smaller projects usually have not implemented a formal measurement and analysis process, so, for them, PSM is a new way of doing business. A major difficulty that these projects had was to explain their information needs in enough detail to select appropriate measures.

To strengthen this process, Software Enterprise Measurement and Analysis leads also attended a series of measurement planning workshops to identify project-specific information needs and to select appropriate measures based on both project-specific needs *and* the organizational measures. During the workshop, project leaders completed a spreadsheet that identified each information need as it related to key processes and products. They also reviewed sample rationales for measurement, including:

- To provide feedback on high-priority, project-specific information needs
- To meet organizational requirements, satisfy customer goals, provide feedback on a process element or product
- To provide feedback on a process improvement area

Project leaders were then responsible for identifying their project-specific measures, organizational measures applicable to their project, and their use of the organizational measures. Projects are allowed to tailor the organizational measures to meet their specific requirements, but each project should develop one list of measures—rather than separate lists of project and organizational measures.

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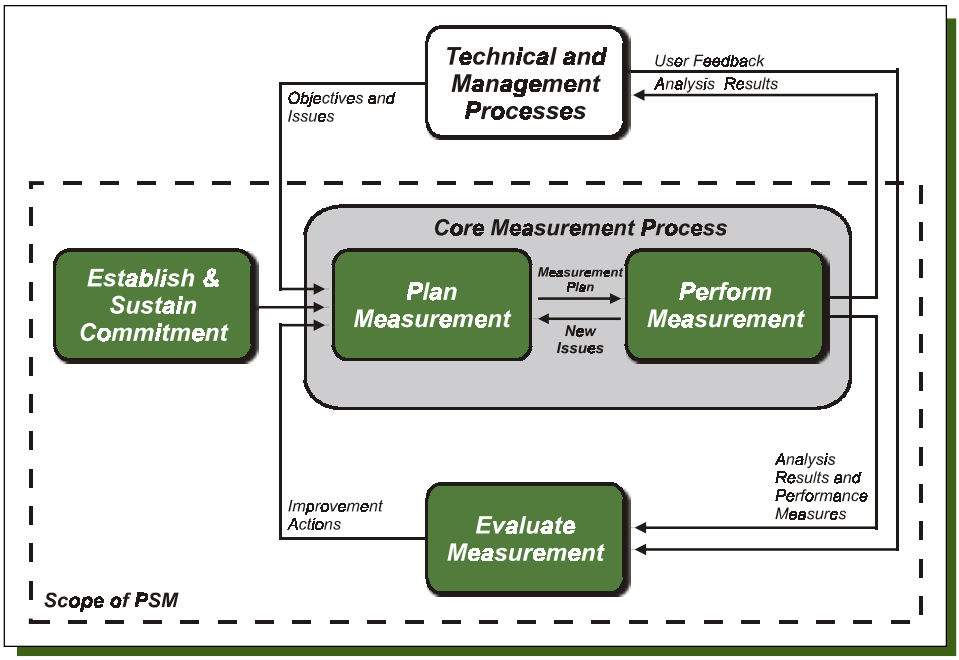

Figure 1. The Software Enterprise used the PSM process to design an iterative measurement program that is tailored to the characteristics and information needs of both the Software Enterprise and the individual projects within it.

Software Enterprise Information Needs Identified through Tailoring Workshops
Enterprise Organization Objectives
• Maintain and enhance our core competencies. • Improve quality and consistency of services and products. • Increase productivity and reduce cycle time. • Improve customer satisfaction. • Improve our competitive advantage.
Strategic Training Needs
• Maintain and enhance core competency knowledge and skills. – Organizational standard process – Domain experience needed to support software intensive systems • Develop multi-skilled personnel capable of addressing a variety of customer needs. • Understand the Department of Defense environment.
Measurement Objectives
• Quantify and assess project performance. • Quantify and assess process performance. • Quantify and assess overall organizational performance. • Quantify and assess customer satisfaction.

Table 3. Software Enterprise managers identified these organizational information needs during planning workshops, and then selected measures to support them.

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What other kinds of guidance have you provided to the projects?

We work closely with the projects to help guide measurement planning as well as the data collection process. We often focus on the following areas:

- Measurement should be a daily activity of all team members, not the sole responsibility of a single "measurement analyst."
- Measurement specifications and measurement plans serve different functions. Measurement specifications represent the technical description of the data or "what" needs to be collected; the measurement plan specifies details on "how."
- The objectives and tasks of each project must be clearly defined. We created a common Work Breakdown Structure for the Software Enterprise to help projects identify their tasks—especially the Acquisition Services projects.
- Projects must understand the difference between "process" and "products" and define appropriate measures.
- Specific measures may be used for more than one information need, but the projects must differentiate between the information that is obtained to address each information need.

It's also important to address how measurement is integrated into each project's overall process, especially regarding risk management and estimation procedures. Many projects were missing a link to the risk measures. Any measures that are identified as part of the risk profile (measures and thresholds) must be specified as part of the measurement plan.

Launching a measurement program often changes existing procedures, causing cultural impact and opposition. How did you address this?

Implementing any new process changes the way people conduct their day-to-day activities. The challenge is to overcome the personal resistance that is usually inherent in change. The Software Enterprise used two guidelines to minimize personal resistance: start small and gain the support of the project personnel.

PSM guidance clearly states that all measurement processes must "start small." A small initial effort has the least impact on the resources and workload of project personnel. So we've used an incremental approach to implement our organizational measurement process. Right now, in the first phase, all projects are required to collect a small set of six measures. Projects are also encouraged to start small with their own list of additional project measures. If a project has an extensive list of project measures, they are encouraged to prioritize the measures for incremental implementation.

During the planning phase, we evaluated how the measurement process would impact cost, schedule, and personnel. The potential resource impact was monitored at each step of the planning process—from specification of the organizational measures, through the early draft plans, to the first implementation of data collection. The impact was minimized by a step-by-step approach in which all participants learned from early mistakes and improved their practices. For example, the initial data collection effort allowed the project representatives to deliver any data that was currently available. In subsequent data deliveries, Software Enterprise representatives worked with the projects to refine and standardize the data to conform to the six common base measures.

A major difficulty in minimizing the size of the organizational measurement program was to define a single, concise set of measures that could address the information needs of all fourteen projects and higher management levels in the organization. The underlying problem is that the objectives of different groups in the same organization are not the same and may often be contradictory.

For example, every organization measures schedule. However, the underlying data and the importance of schedule measures will vary within the organization. Most project managers are primarily concerned with developing a product that will meet the stated requirements for functional capability and reliability. The importance of schedule and cost objectives is determined by other sources, such as the customer and senior managers. Senior managers in the organization may be primarily concerned with estimating the length of time until delivery of the next major software product. The marketing or business manager may be concerned with the time it takes to market a new capability and the impact of a possible delay on market share. A process manager may be concerned with an overall increase or decrease of the average software development time and its impacts on other processes in the organization. The organizational measurement process must select a common schedule measure that will address all of these information needs.

Efforts to gain the support of the project personnel were focused on providing the participants with an understanding of the measurement process and the potential benefits to their projects. During the months of planning, formal training programs were conducted for both the PSM and CMMI processes, as well as measurement planning workshops that helped project representatives identify effective information needs and measures. These workshops ensured that project personnel were part of the measurement planning process. Then, during the early stages of implementation, Software Enterprise representatives provided one-on-one coaching with project personnel.

The measurement process will become increasingly successful as project managers experience the benefits first-hand, when the initial set of measures is used more extensively to support the project decision-making process.

What tools do you use to support the actual collection of measurement data?

The PSM Insight tool was selected to support the centralized data management effort of the Software Enterprise. PSM Insight is a desktop tool that the Army Software Metrics Office developed to support the PSM process. PSM Insight is a Windows-based program that uses Borland's Delphi, Version 2.0. Windows provides a familiar, easy-to-use interface to the advanced Delphi data management capabilities. This combination provides a novice user with a high level of flexibility in data management, including data modification, data browsing, and sophisticated graphing capabilities. It can be used at each individual's desktop, and training is available in a program that can be downloaded from the web at www.psmsc.com.

PSM Insight supports many of the objectives of the Software Enterprise measurement process, including:

- Allowing project personnel to define and collect their own data for the six organizational measures and their project measures. PSM Insight was tailored to the defined organizational and project-specific measures. Templates were defined, along with valid entries for data validation.
- Minimizing the size and cost of the measurement effort by allowing the projects to work with any data that may be available in existing project management processes. Many projects already had cost, schedule, quality, and other records that had been collected in Excel, Access, Microsoft Project, or other formats. PSM Insight provides the capability to automatically access these different databases with dissimilar data formats, import, and normalize the data to support the six common organizational measures. The PSM Insight electronic import module handles ASCII-delimited files precisely and imports "comment" data when needed.
- Allowing project personnel to make mistakes while working with their data and learning the new process. PSM Insight responds to missing or potentially corrupt data with a warning to the user. Also, because missing values can lead to misinterpreting a graph, PSM Insight handles blank or missing values and reports them in indicator legends.
- Providing project personnel the ability to calculate derived measures from their existing base measures. This feature allows the collected data elements to be processed with a user-defined formula and displayed as derived measures in report formats.

What analyses are you doing on the data?

PSM Insight supports data analysis by project personnel by providing a series of pre-defined information needs, measures, and indicators that can be tailored to support analysis of the six organizational measures and unique project measures. The PSM Insight tool can query data for specific information and generate tailored graphics and reports.

The Software Enterprise currently uses three types of regular reports:

- Level 1 reports provide a combination of all data that has been reported by the projects. This report addresses organizational information needs.
- Level 2 reports provide the first-level managers in the Software Enterprise with the data that has been reported by each project. These reports allow the organizational managers to identify potential problems with a project if the data exceeds the quantitative decision criteria that are established for each of the six common measures in the Organizational Measurement Plan.
- Level 3 reports provide only the measurement indicators to the Measurement and Analysis process lead within each project. The Measurement and Analysis lead uses these indicators for project analysis and for reporting at the SMR and other project briefings.

What benefits have you received so far?

The Software Enterprise has already received benefits from the analysis of organizational data. They include:

- Better definition of the tasks performed in each of the project's processes. This benefit was first realized in the measurement planning process and verified as data was reported.
- Early and improved visibility into the performance of each project.
- Improved communication between Software Enterprise managers and project personnel. The data results help to focus attention on the important information needs of the projects and the overall organization.
- A baseline of actual data to improve the accuracy of estimates for the cost, schedule, and performance of future projects. ■

Cheryl Jones is a software engineer in the Software-Intensive Systems Evaluation business area at TACOM-ARDEC in Picatinny Arsenal, New Jersey. She is the lead for the performance management project and is responsible for measurement and analysis, risk management, and estimation within the Software Enterprise. Ms. Jones is also the project manager of Practical Software and Systems Measurement (PSM) and one of the authors of *Practical Software Measurement: Objective Information for Decision Makers.* She is a technical expert to the U.S. Technical Advisory Group to International Standards Organization SC7, Software Engineering, and serves as the U.S. Head of Delegation to Working Group 13, Software Measurement Progress, which is developing ISO/IEC 15939. Ms. Jones holds a B.S. degree in Computer Science/Mathematics from the University of Georgia and an MBA in Management Information Systems from the University of Rhode Island.

An Introduction to Organizational Performance Measurement

By Dave Zubrow, Software Engineering Institute (SEI), Carnegie Mellon University

Organizations in increasingly competitive environments must seek ways to understand and improve their performance. To do this, they must address the challenging tasks of defining organizational performance goals, selecting appropriate measures, and implementing measurement at the organizational level. These tasks are challenging because little guidance is available for implementing organizational-level measurement. Most attention has been given to measurement below the organizational level—at the project, process, and program levels. In this article, we'll take a quick look at a seven-step method for defining organizational performance measures and provide some tips for implementing OPM.

OPM Defined

Organizational performance measurement (OPM) can be defined in general terms as *the quantitative characterization of an organization's accomplishment of some aspect of its goals*. This definition warrants a closer look. Note that the focus is on the organization or enterprise, rather than on a specific project or program. "Quantitative" indicates that the characterization is more discriminating and informative than the flat alternatives of success/failure or yes/no answers. Established goals are an indispensable part of the definition; measurement is meaningful only if the organization has a reference point for comparison and judgment. Also, the organization must realize that, although measurement addresses some aspect of the organization's goals, performance is multidimensional and the aspect to measure is not always obvious.

The ultimate objective of OPM is to improve organizational performance. Organizational performance is determined by the wise selection of projects that the organization will undertake, as well as the level of quality that is achieved in executing them. Successful OPM supports this process by evaluating prospective projects against the organization's goals and abilities, then setting and tracking success criteria for project execution. Richard Lynch and Kelvin Cross, authors of *Measure Up: Yardsticks for Continuous Improvement*, summarize it this way: "The purpose of performance measurement … is to motivate behavior leading to continuous improvement in customer satisfaction, flexibility, and productivity."[1] In other words, OPM must lead to management action; otherwise, the measurement process provides no return on the investment.

Government Mandates for Performance Measurement

Both commercial and government organizations can implement the same OPM processes. In fact, the Government Performance and Results Act (GPRA) of 1993 mandated OPM for government organizations. Measurement guidelines from the General Accounting Office (GAO) and directives from the Chief Information Officers of many agencies have been established to comply with the GPRA.

The GPRA was enacted in response to several Congressional findings on poor performance in federal organizations, including:

- Waste and inefficiency in federal programs that undermine public confidence and reduce the government's ability to address vital public needs
- Insufficient articulation of program goals by federal managers, and inadequate information on program performance
- Lack of information on program performance and results to support Congressional policymaking, spending decisions, and program oversight

As a result, the GPRA aims to improve federal program effectiveness and public accountability by promoting a new focus on results, quality of service, and customer satisfaction. The GPRA requires most federal agencies to submit a strategic plan, including performance goals. They must "express such goals in an objective, quantifiable, and measurable form" and "establish performance indicators to be used in measuring or assessing the relevant outputs, service levels, and outcomes of each program activity." The agencies must "provide a basis for comparing actual program results with the established performance goals; and … describe the means to be used to verify and validate measured values." Beginning in 2000, the agencies must submit the results of these efforts in an annual performance report to Congress.[2]

A Seven-Step Method for Organizational Performance Measurement

The U.S. General Services Administration has outlined eight steps for developing and using OPM effectively.[3] Adapting these steps to software organizations results in the following seven steps:

1. Link engineering processes to organizational goals and objectives.
2. Develop performance measures.
3. Develop data collection, analysis, and reporting procedures.
4. Integrate use of performance measures with management processes.
5. Establish a baseline to compare future performance.
6. Collect, analyze, and report results.
7. Evaluate the utility of performance measures and improve.

This article focuses on steps 1, 2, and 4. (These three steps were selected because they were the major tasks of the

TACOM-ARDEC Software Enterprise organizational measurement effort, featured on page 1 of this issue of *Insight*.)

Step 1. Link Engineering Processes to Organizational Goals and Objectives.

Figure 1 diagrams the process of linking engineering processes to organizational goals. Note that the "Business Strategy Goals" in this figure are the equivalent of the "Information Needs" in the overall ISO/IEC 15939 measurement process, shown in Figure 1 of the Software Enterprise article, on page 5 of this issue. As noted earlier, organizational goals should be characterized in terms of outcomes and results. In this step, we want to understand how the software engineering processes contribute to product or system development efforts that, in turn, are used to perform a mission. For managers at the organizational or enterprise level, such an understanding is vital.

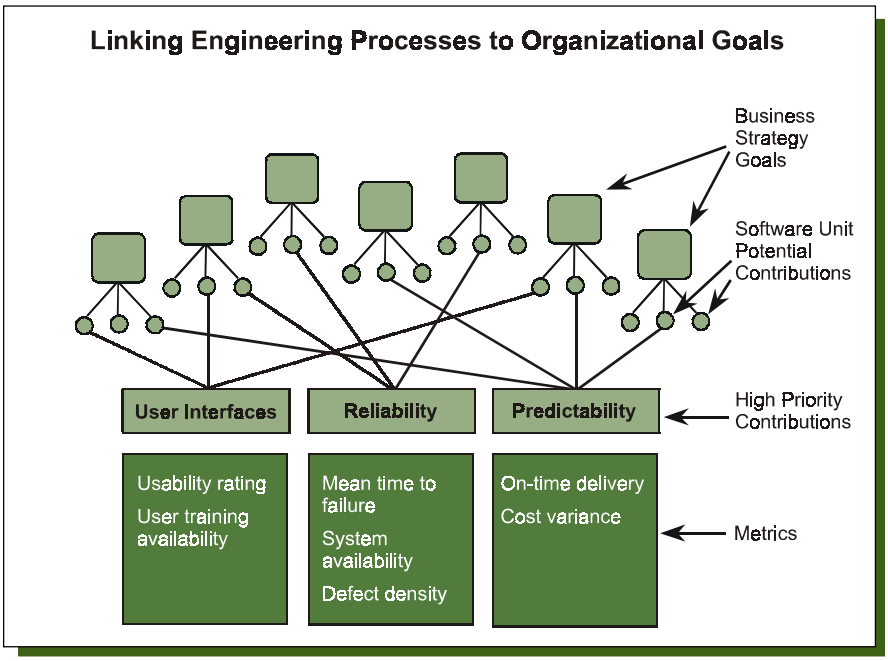


Figure 1. Measurement planners must decompose organizational goals to the associated processes and performance attributes.

Managers and measurement analysts need to work together to identify the critical development processes that impact organizational goals. Some goals will be more influenced by software development than others. These critical few should receive priority for measurement. Measurement analysts cannot do this alone. They cannot be responsible for setting the goals or the priorities for measurement. It is management's responsibility to define the information they want and need, as illustrated in the ISO 15939 measurement process.

Organizational performance is characterized by the outcomes or results that the organization achieves. This suggests that performance measures should be derived from operational definitions of outcomes. When selecting and defining performance measures, preference should be given to outcome measures. Outcome measures can characterize how a system affects a user's capability to perform a mission, the ability of a program to meet its performance targets, or the extent to which a service unit has improved customer satisfaction. A key element from a measurement perspective is that actually collecting the desired measures usually means getting the data from outside of the development or service organization. Data must be collected from the field during operational use or from customers. This contrasts with other types of measures—such output, process, and input measures—that have been used to characterize performance. None of these capture the outcome or results as well as an outcome measure.

Understanding processes requires knowledge of their efficiency, effectiveness, and the degree to which they are used and followed (compliance). Characterizing process efficiency, effectiveness, and compliance requires measures of the inputs consumed, outputs produced, the quality of the outputs, and whether or not the process was followed. Recognizing each of these elements is important for OPM, because too often organizations want to only measure their outputs and inputs and then infer the outcomes. These organizations assume that whatever and however products and systems are made, they will create the desired outcomes and results. This is a dangerous assumption. Through analysis, we want to measure both the development processes and the outcomes to better understand how the organization delivers capabilities and value to its customers and users.

The above discussion is silent on what types of goals to select. The "balanced scorecard" concept is a useful tool for selecting goals and linking them to measures.[4] The balanced scorecard directs organizations to consider four perspectives that contribute to the organization's *outcomes*:

- **The financial perspective:** How do we look to our shareholders or sponsors?
- **The customer perspective:** How do customers see us?
- **The internal business perspective:** What must we excel at?
- **The innovation and learning perspective**: Can we continue to improve and create value through research, development, and infrastructure improvement?

Managers should define each quadrant in the balanced scorecard and address the associated questions. This provides a means for checking the coverage of existing organizational goals.

The balanced scorecard shows that performance is multi-dimensional, and that profit alone does not adequately represent the accomplishments and vitality of the organization. It means characterizing aspects of the organization's internal development processes and correlating these with the out-

(Continued on page 10)

comes that customers realize by using the products and services. In other words, the organization needs to understand how it delivers value to its customers—understanding this chain of causality is the foundation for selecting meaningful performance measures.

Step 2. Develop Performance Measures.

Performance measures need to be developed for each goal. Developing measures requires establishing their operational definitions and providing a mechanism for their collection. When considering alternatives, managers and analysts may quickly realize that it is more difficult to measure outcomes than it is to measure outputs, processes, or inputs. One reason is that the latter are within the scope and under the control of the organization. Their use as organizational performance measures must be done with caution. Consider the following examples.

Example 1

Goal: Improve the nation's health status.

- Outcomes - trends in health status, infant mortality, trends in prevalence and incidence of diseases
- Outputs - patients treated, population vaccinated, women receiving prenatal care
- Inputs - health care expenditures, per capita ratios
- Process - doctor visits

Example 2

Goal: Improve customer satisfaction.

- Outcomes - trends in customer satisfaction survey data, number of defects reported after release
- Outputs - number of new features released, resolution time for customer service calls
- Inputs - dollars spent on customer service training, dollars spent on quality assurance
- Process - number of work product inspections performed, number of tests performed

Example 3

Goal - Increase market share.

- Outcomes - percentage of target customer base captured, number of competing products displaced
- Outputs - volume of product shipped, number of new features and products released to the market
- Inputs - advertising expenses, research and development expenses
- Process - number of focus groups held, number of sales visits

In each example, notice how the measures become less directly connected to the goal as they move from outcome to output to input and process.

Step 4. Integrate with Management Processes.

The *use* of performance measures—as a basis for management action—must be institutionalized. Managers should perform a regular review of performance measures at meetings and report on the measures to the rest of the organization. Most importantly, they should act on what they find. OPM yields value to the organization only when managers use the measures to decide on continuing a current strategy or altering its course. Many times, measurement activities do not generate any value and are simply a rote activity with no economic justification. This is a waste of the time and effort of those providing the measures, including engineers, project managers, analysts, and others. The steps in the OPM process ensure that the measures can yield value. It is up to the managers to use the measures and realize their value.

In addition to their use with respect to current programs and operations, organizational performance measures should provide input to decision criteria for project selection, as well as input to future operational and strategic planning. For instance, by understanding how current projects and processes have influenced organizational performance, managers are better informed to evaluate and select new projects and initiatives. If the performance measures fail to provide useful information, they should be changed. The right course of action is to make the performance measures useful and valuable. The wrong course is to abandon or ignore them. The bottom line is that OPM must lead to management action or its value is lost, while the costs are still incurred.

Summary

If information is power, then OPM surely is a strategic weapon. Unfortunately, it may be viewed simply as a bureaucratic exercise. This is a shame and a waste. Perhaps this happens because OPM is inextricably entwined with our ability to understand how our organizations work and our ability to align the development processes with our goals. Neither task is trivial. The insight and understanding that can come from well-designed performance measures can greatly aid management in both its current operational responsibilities and its long-term strategic planning. ■

The author gratefully acknowledges the contributions of Lara Lutz, of Independent Engineering, Inc., and Lauren Heinz, of SEI, to this article. Comments and criticisms, however, should be directed to the author.

[1] Lynch, Richard L. and Cross, Kelvin F., *Measure Up: Yardsticks for Continuous Improvement.* Cambridge, MA: Blackwell Business, 1995.

[2] Government Performance and Results Act of 1993, at http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html#h1.

[3] General Services Administration, "Performance-Based Management: Eight Steps to Develop and Use IT Performance Measures Effectively," nd. For more extensive discussion of these steps, see http://www.itpolicy.gsa.gov/mkm/pathways/pp03link.htm.

[4] Kaplan, Robert S. and Norton, David P., "The Balanced Scorecard - Measures that Drive Performance," *Harvard Business Review*, January/February 1992.

The Capability Maturity Model Integration (CMMI): An Increased Focus on Measurement

Background

In August 2000, the Capability Maturity Model® Integration (CMMI℠) became the new baseline for process improvement for many industry and government organizations. The CMMI brought order to the confusion caused by the many independent, process-improvement models that have been inspired by the original Capability Maturity Model (CMM), which was developed by the Software Engineering Institute (SEI) of Carnegie Mellon University and released to the public in 1991.

Although the CMM was originally designed for software engineering, its success led to the rapid proliferation of more than 30 CMM-based models for systems engineering, software acquisition, human resource management, and other related disciplines. Most of these models shared common goals, but their content, structure, and terminology varied widely. Often, several of these models were applied within the same organization. This was confusing and expensive. In response, government, industry, and academia teamed up to launch the CMMI Project. The goal was to create a set of integrated base models that could be tailored to various disciplines while maintaining compatible content, terminology, structure, and assessment techniques.

Features & Structure

The CMMI is based on three source models: the CMM for Software V2, draft C (SW-CMM V2C), the EIA Interim Standard 731 (EIA IS 731) System Engineering Capability Model (SECM); and the Integrated Product Development Capability Maturity Model, draft V0.98 (IPD-CMM). The set of integrated models in the current version of the CMMI (V1.1) addresses software engineering, systems engineering, and integrated product and process development. SEI has recently released the CMMI-SE/SW/IPPD/SS, which incorporates supplier sourcing. Details on the CMMI model process areas, goals, and associated practices are available at the SEI web site (www.sei.cmu.edu).

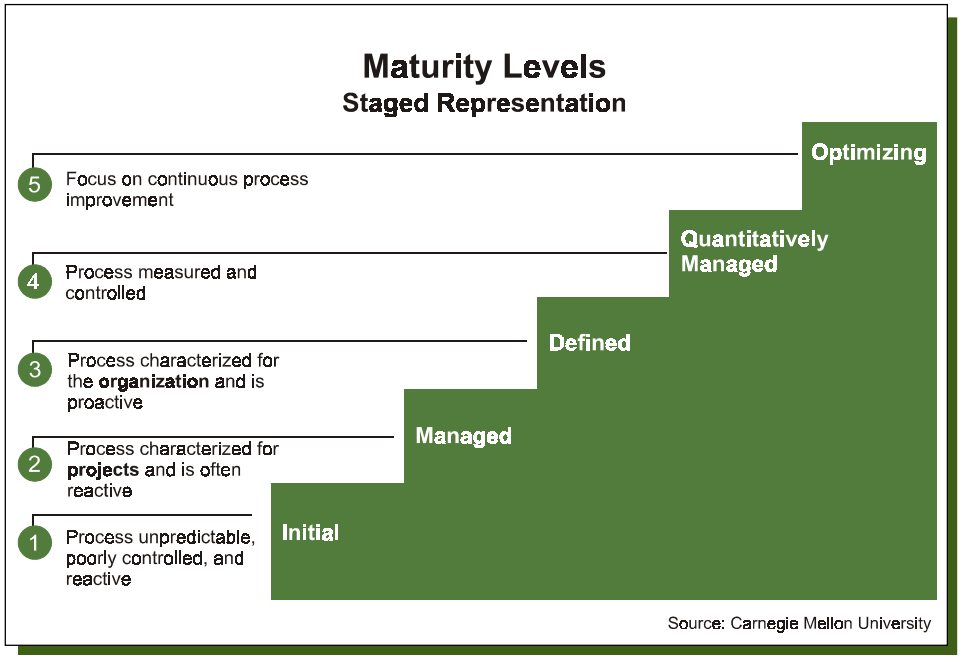


Figure 1. The staged representation of the CMMI rates the overall organization by assigning the appropriate maturity level.

An organization can implement the CMMI using one of two approaches: organizational maturity or process capability. Each approach is supported by a different representation. An organization can work with either representation because the coverage of both is virtually identical.

In the first approach, the organization as a whole is assigned a CMMI maturity level, on a scale of 1 to 5. Each maturity level is characterized by a set of process areas, with corresponding goals. The organization's maturity level is determined by its ability to achieve the goals of the specified process areas. It must then maintain these achievements as it moves on to the next cluster of process areas at the next highest maturity level. Each process area resides at only one maturity level. This is the *staged representation* of the CMMI (see Figure 1 above and Figure 2 on page 12).

In the second approach, the CMMI rating is based on the organization's various, individual process capabilities, rather than its performance as a whole. The organization works to show increasing levels of sophistication in all process areas throughout the improvement effort. This is the *continuous representation* (see Figure 3 on page 12).[1]

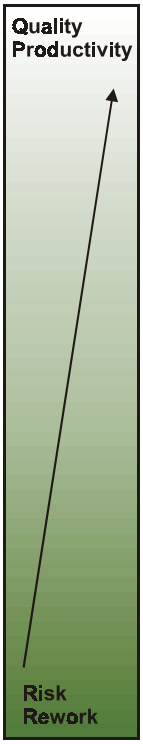
The process areas of both representations contain the same generic goals and practices. For example, some generic

(Continued on page 12)

The CMMI: An Increased Focus on Measurement *(from p. 11)*

CMMI Maturity Levels and Corresponding Process Areas

Level	Focus	Process Areas
5: Optimizing	Continuous Process Improvement	Organizational Innovation and Deployment Causal Analysis and Resolution
4: Quantitatively Managed	Quantitative Management	Organizational Process Performance Quantitative Project Management
3: Defined	Process Standardization	Requirements Development Technical Solution Product Integration Verification Validation Organizational Process Focus Organizational Process Definition Organizational Training Integrated Project Management Risk Management Decision Analysis and Resolution
2: Managed	Basic Project Management	Requirements Management Project Planning Project Monitoring and Control Supplier Agreement Management Measurement and Analysis Process and Product Quality Assurance Configuration Management
1: Intitial		



Source: Carnegie Mellon University

Figure 2. In the staged representation, a cluster of process areas is assigned to each of the maturity levels. Each process area resides at only one maturity level.

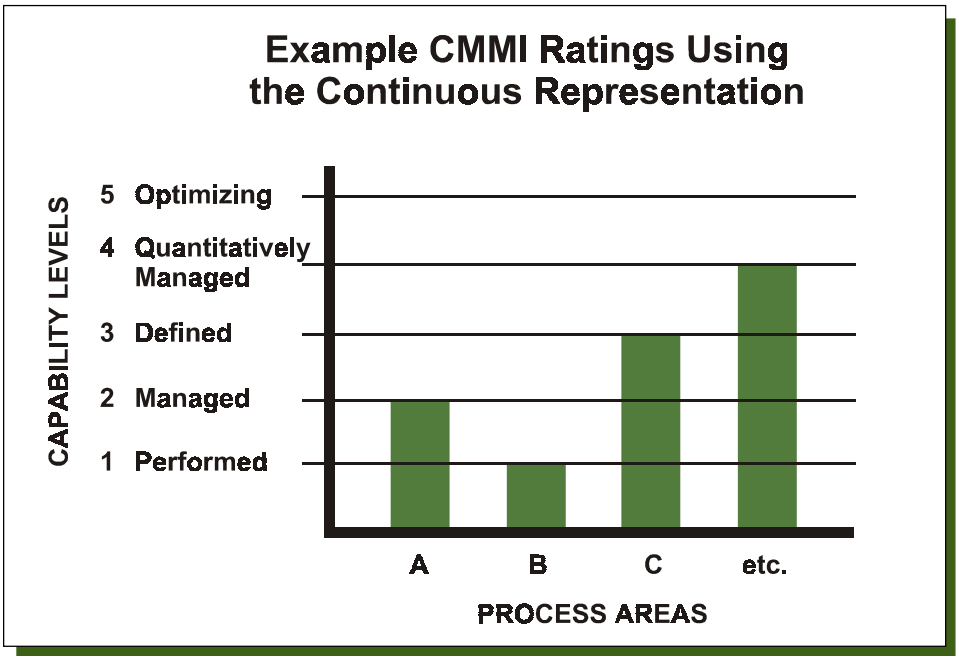


Figure 3. In the continuous representation, each process area is assigned the appropriate capability level. Each process area is rated separately.

goals are to establish an organizational policy, establish a plan to enact the policy, assign responsibility, provide training, perform the process, measure the process, etc. These types of goals and practices apply to all process areas. However, the staged representation also includes numerous goals and practices that are specific to a particular process area.[2]

The Expanding Role of Measurement

One notable difference between the CMM base models and the CMMI is the introduction of Measurement and Analysis as a new process area. Several factors led to the creation of this new process area.

First, measurement is integral to process improvement. It monitors the organization's progress and helps to direct and justify the improvement program. Measurement is pervasive at all levels of the source CMMs, and it supports at least one generic practice from level 2 to level 5 in the CMMI. In the staged representation, Measurement and Analysis resides at maturity level 2, which is relatively early in the improvement process. The International Standards Organization (ISO) has also emphasized the importance of a measurement process by initiating the standardization effort for measurement, ISO 15939.

Second, the importance and practice of measurement clearly needs to be elevated. Despite its benefits, measurement is one of the most neglected and misused management tools. Historic measurement data is especially vital to efficient process management; organizations that do not implement an early measurement program will face additional struggles later. As one author of the CMMI explained, "Organizations that have achieved the highest CMM ratings have reported… that a clear focus on measurement at lower levels

would have saved them significant efforts later on."[3] Organizations that turned to the original CMM for a description of good measurement practices could not find the information in a single, obvious location.

The CMMI introduced the Measurement and Analysis process area to address these needs. Assigning measurement its own process area raises its stature and helps to promote management support. By placing Measurement and Analysis at maturity level 2, organizations will institutionalize their measurement program early in the improvement process and create a useful foundation for future advances. The Measurement and Analysis process area provides clear access to detailed measurement guidance, based on ISO 15939 and the Practical Software and Systems Measurement (PSM) approach.

The Measurement and Analysis process area is structured around three goals, each with a cluster of associated practices, depicted in Figure 4.

The first goal is to *Align Measurement and Analysis Activities*. As Dave Zubrow of the SEI explains, the aim is to establish the game plan. He writes, "[These practices] address: Why are we measuring? What are we going to measure? How are we going to measure? And, what will be done with the data once we have it? ....Planning is crucial if we want to achieve our goals. The goal and associated practices ... explicitly recognize this need and its importance."[4]

The second goal is to *Provide Measurement Results*. The emphasis, says Zubrow, is to follow through with the plan and deliver results into the hands of those who will take action. He writes, "The results must be communicated to those needing the information. It does no good to the organization to populate a 'write-only' database."

The third goal is to *Institutionalize a Managed Process*. Previously, measurement was only a component of other processes that needed to be institutionalized. With CMMI, Measurement and Analysis is "a process in its own right and, therefore, must be institutionalized along with the other work processes."[5]

Measurement and Analysis Process Area with Related Goals and Practices

Goals	Practices
Align Measurement and Analysis Activities	• Establish Measurement Objectives • Specify Measures • Specify Data Collection and Storage Procedures • Specify Analysis Procedures
Provide Measurement Results	• Collect Measurement Data • Analyze Measurement Data • Store Data and Results • Communicate Results
Institutionalize a Managed Process	• Establish an Organizational Policy • Plan the Process • Provide Resources • Assign Responsibility • Train People • Manage Configurations • Identify and Involve Relevant Stakeholders • Monitor and Control the Process • Objectively Evaluate Adherence • Review Status with Higher Level Management
Institutionalize a Defined Process*	• Establish a Defined Process • Collect Improvement Information

* This goal is not required and its practices are not expected for a maturity level 2 rating, but they are required and expected for a maturity level 3 rating and above.

Figure 4. The Measurement and Analysis process area is organized around three goals, each with a corresponding set of practices.

The PSM project is also developing a template intended as a "jump start" for implementing a measurement program consistent with the CMMI. ■

[1] *CMMI: An Update* (ppt), Jeffrey L. Dutton, Sverdrup Technology, Inc., CMMI Product Development Team, 20 February 2001.

[2] *CMMI Overview* (ppt), CMMI Project and Practical Software Measurement (PSM), 4 June 1998.

[3] "The Capability Maturity Model Integration (CMMI): An Interview with Bruce Allgood and LTC Jarzombek," Army Software Metrics Office, *Insight* newsletter, Vol. 3, No. 4, Spring 1999.

[4] Zubrow, Dave, "The Measurement and Analysis Process Area in CMMI," *Newsletter of the American Society for Quality-Software Division*, Spring 2001.

[5] Zubrow, Dave, "The Measurement and Analysis Process Area in CMMI," *Newsletter of the American Society for Quality-Software Division*, Spring 2001.

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The next Army Software Metrics course will take place August 5-7, 2002, at the AEC headquarters in Alexandria, VA. For more information, visit http://www.armysoftwaremetrics.org or call (703)681-3823 or DSN 761-3823.

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