PART ONE

The Measurement Process

Today's systems are increasingly complex. The integration of new computer-based technology and the expanded reliance on software to implement new system functions and capabilities have significantly impacted the way systems are developed and managed over an extended life cycle. To cope with these complexities, project and technical managers are adopting new tools, processes, and techniques to make better and more informed decisions in a rapidly changing development and support environment. Measurement, a key element in every well-established engineering discipline, has become a primary tool of both software and system engineering managers to ensure that the delivered products meet defined project objectives.

Practical Software and Systems Measurement: A Foundation for Objective Project Management presents a proven approach for defining and implementing an effective measurement process for software and system projects. The goal of *Practical Software and Systems Measurement* is to provide project and technical managers with the quantitative information required to make informed decisions that impact project cost, schedule, and technical performance objectives.

PSM describes measurement as a systematic, but flexible process that can be applied to both software and systems engineering, as well as management activities. The process is adapted to meet the specific information needs and characteristics of each project. The PSM measurement process is based on a proven set of measurement principles derived from actual experience on government and industry projects. These principles represent measurement "best practices." They make the PSM measurement process an effective management tool, not just another project management "requirement."

The PSM measurement process provides a foundation for objectively managing software and system projects throughout their life cycles. Today's systems contain increasing numbers of interacting hardware, software, and human components. They are deployed in ever more critical applications, making their management both more difficult and more important.

The PSM measurement process establishes a basis for informed decision making and communication throughout the project organization. The measurement process works best when integrated with other management disciplines such as risk management and financial performance management.

Part 1 of *Practical Software and Systems Measurement* describes the principles and techniques for tailoring, applying, implementing, and evaluating an effective project measurement process. It presents a top-level view of the measurement approach in terms of "what" should be done. Other parts of the Guide contain detailed "how to" information for the measurement activities described in Part 1.

Part 1 of the Guide is organized into five chapters:

- **Chapter 1, Managing Software and System Projects,** explains how measurement can help a software or systems project meet defined objectives.
- **Chapter 2, Measurement Process Overview,** summarizes the PSM measurement process and the component activities that describe tailoring and applying measures for a specific project, implementing the measurement process, and evaluating and improving the measurement program.
- **Chapter 3, Measurement Principles,** describes the measurement principles, or "Best Practices," that are the foundation for the PSM process.
- **Chapter 4, Life Cycle Application,** describes how the focus of measurement changes over a project's life cycle.
- **Chapter 5, Enterprise and Organizational Context,** provides a perspective on how project-level measurement supports broader level performance measurement and information needs.

1

Managing Software and System Projects

This chapter explains the benefits of adopting a quantitative approach to managing the planning, development, operation, and maintenance of software and system projects. It describes how measurement works together with other technical and project management disciplines, such as risk management and financial performance management, to improve project performance.

1.1 Motivation for Measurement

Effective management has become increasingly important to the success of both government and commercial enterprises. System delivery, operations, and maintenance have become increasingly challenging due to reductions in resources and rapid technological changes. Project managers require methods to plan, monitor, and control the complex software and system processes and products that now comprise a large part of every project.

Why should a project manager measure software and system projects? Recent changes in the government acquisition process demand more effective management tools and techniques. Similar forces affect industry, where new technologies and complex systems have become a major factor in corporate investment and business strategies. The use of Commercial Off The Shelf (COTS) and reusable software and hardware components and the implementation of common system architectures are changing the way systems are acquired, developed, and maintained. Project managers must have more objective information about new technologies and complex life-cycle processes to succeed. Integrated Product Team (IPT) and concurrent engineering approaches improve the management of large, complex systems. These approaches require continuous and effective team communications to develop effective solutions. Measurement provides the objective information essential for these communications.

Measurement has proven to be an effective tool to help manage software and system projects in both government and industry. Measurement, when integrated into the overall project management process, helps the project manager identify risks; track specific problems; assess the impacts of these problems on project cost, schedule, and technical performance objectives; develop alternative solutions; and select the best approach for correcting problems. Measurement provides the insight a project manager needs to make decisions critical to project success.

Measurement helps the project manager to define and implement more realistic plans and to accurately monitor performance against those plans. Measurement provides the information required to make key project decisions and to take appropriate action. It also helps integrate information derived from other project and technical management disciplines, providing an overall project assessment for the decision maker. Specifically, measurement provides objective information to help the project manager:

- **Communicate effectively throughout the project organization** - Objective information reduces the ambiguity that often surrounds complex software and system projects. Measurement helps managers identify, prioritize, track, and communicate issues at all levels of the organization. Measurement supports communication between the acquirer and the supplier. PSM defines the “acquirer” as the organization purchasing the system, and the "supplier" as the organization responsible for systems development and operations and maintenance.

- **Identify and correct problems early** - Measurement facilitates a pro-active management strategy. Potential problems are identified as risks to be assessed and managed. Measurement focuses attention on the early discovery and correction of technical and management problems that can be more difficult to resolve later. Project managers do not wait for problems to arise; they anticipate problems.

- **Make key tradeoffs** - Every project has constraints. Costs, schedules, quality, functionality, and technical performance have to be managed to make the project a success. Decisions in one area often impact other areas. Measurement helps the project manager objectively assess these impacts and make tradeoffs to best meet project objectives, even in highly constrained project environments.

- **Track specific project objectives** - Measurement describes the status of life-cycle processes and products. It objectively represents the progress of activities and the quality of products. It helps to answer key questions such as: "Is the project on schedule?" and "Is the system ready to be delivered?"

- **Defend and justify decisions** - Government and industry acquisition environments emphasize successful project performance. Project managers must effectively defend and justify performance decisions. Measurement provides an effective rationale for selecting the best alternatives.

Like any project management tool, measurement cannot guarantee that a project will be successful. However, it does help the project manager take a pro-active approach in dealing with the critical issues of software and system projects. Measurement helps the project manager succeed.

1.2 Quantitative Management Disciplines

Measurement does not replace other management skills and techniques. Moreover, measurement is not as effective if it is implemented as a stand-alone process, "in a vacuum." Measurement is a supporting discipline that helps a project manager gain the insight necessary to make technical and management decisions, and shows how important software and systems issues are related. Measurement works best when integrated with other project management disciplines such as risk management and financial performance management. Together, these quantitative management disciplines enable the project manager to identify and prioritize key concerns, track their resolution, and manage the allocation of resources to optimize project cost, schedule, and technical performance.

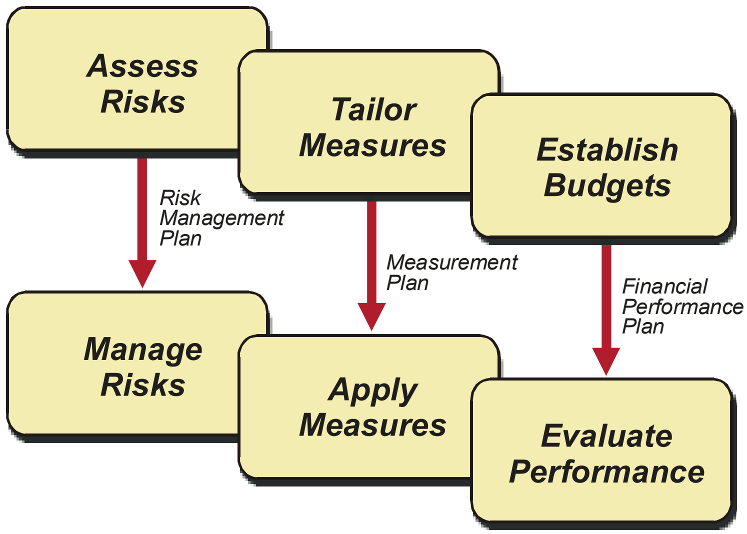

Figure 1-1. Quantitative Management Disciplines

Figure 1-1 shows that these three disciplines have parallel activities that define expectations and concerns, establish associated project plans, and provide appropriate information and feedback. While these disciplines can be implemented independently, an integrated approach yields the greatest value. Risk analysis helps to identify and prioritize the software and systems engineering concerns that the measurement process should track. The measurement process helps quantify the likelihood and impact of risks. The measurement process also provides an objective basis for reporting financial performance, using techniques such as earned value or activity-based cost accounting. The project manager must consider risks, measurement results, and financial performance when making decisions. Together, these three quantitative management disciplines complement traditional management skills and techniques.

While detailed treatments of risk management and financial performance management are beyond the scope of this Guide, some understanding of these topics is necessary to gain the full benefit of measurement. The Guide describes the interface between these disciplines and the measurement process.

1.3 Scope of Software and System Projects

The PSM Guide's language, techniques, and examples are oriented towards the planning, development, and operations and maintenance of computer-based software intensive systems. A system is considered to be a combination of interacting components that consists of one or more of the processes, hardware, software, facilities, and people that provide a capability to satisfy a stated need or objective. The scope of a system is defined by the project requirements. Software is a critical component of today's systems. PSM is applicable to the overall planning, requirements analysis, design, implementation, and integration of systems (also referred to as systems engineering) and software (also referred to as software engineering) activities. PSM encompasses both the technical and management activities associated with these disciplines. However, the current version of this Guide does not specifically address the hardware and people components of systems. This does not mean that PSM concepts cannot be applied in those domains. PSM principles can be applied to *any* measurement process.

Software and system projects pervade all sectors of government and industry. Most, if not all, of today's complex systems have a significant software component. Historically, software development involves substantial risk, and thus requires increased management insight and attention to ensure success.

Software and system projects may be undertaken using a variety of business models:

- Under contract for an external customer
- As an in-house project for an internal customer
- As shrink-wrap packages for mass marketing

However, all of these scenarios involve a project manager and a customer. The term “project manager” may refer to an individual or a project management team. The project manager is the decision maker with overall responsibility for achieving cost, schedule, and technical performance objectives of systems development or operations and maintenance projects.

In a contractual or outsourcing scenario, both the acquirer and the supplier usually establish project managers for their respective organizations. For internal systems development or operations and maintenance efforts, the project manager is usually a member of (or is co-located with) the engineering team. However, an increasingly common practice is to combine project management functions for many projects in a single project management office. In the commercial sector, software or systems produced for a mass-market are often treated as internal developments, with the marketing organization playing the role of the customer. While the final consumer may have little insight into the production process, the marketing representative usually does.

The PSM approach can be applied in all of these situations.

2

Measurement Process Overview

This chapter introduces a flexible approach for implementing measurement to support project management objectives. This approach applies to all types of software and system projects, in both government and industry. *Practical Software and Systems Measurement* defines a systematic process that uses measurement to help satisfy the information needs of the project manager.

2.1 Basic Elements of the Measurement Process

How does an organization that wants to benefit from measurement proceed? A number of government and industry measurement "prescriptions" have met limited success. Rather than present another fixed measurement scheme, this Guide presents a flexible measurement approach. PSM views measurement as a process that must be adapted to the technical and management characteristics of each project. This measurement process is issue-driven; issues are the objectives, risks, problems, and uncertainties that must be managed to achieve project success.

As shown in Figure 1-2, the PSM approach defines four measurement activities. The first two activities, *Tailor Measures* and *Apply Measures,* form the core measurement process that directly serves the decision-maker. The third activity, *Implement Process*, includes the tasks that establish the measurement process within an organization. The fourth activity, *Evaluate Measurement*, identifies assessment and improvement tasks for the measurement program as a whole.

The *Tailor Measures* activity addresses the selection of an effective and economical set of project measures. This activity includes identifying and prioritizing project issues, selecting and specifying appropriate measures, and integrating measures into the project's life-cycle processes. The *Apply Measures* activity involves collecting, analyzing, and making recommendations based upon the data defined in the tailoring process. The *Implement Measures* activity addresses the cultural and organizational changes necessary to establish a measurement process. Successful implementation requires the support of project and executive managers as well as the entire project team. The *Evaluate Measurement* activity assesses the measurement process and measures, and identifies potential improvements.

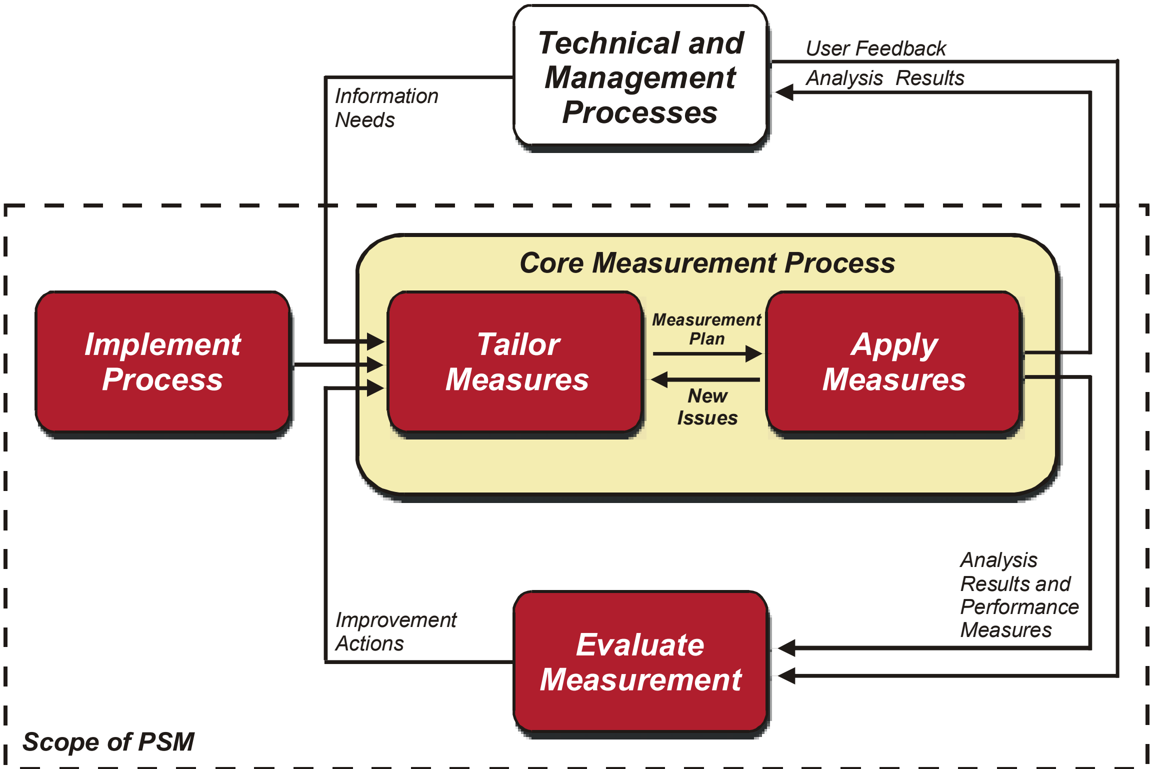

Figure 1-2. PSM Measurement Process

The measurement process must be integrated into the life-cycle processes of software and system projects. Since these life-cycle processes are dynamic, the measurement process also must change and adapt as the project evolves. The activities of *Tailor Measures* and *Apply Measures* are iterative throughout the project life cycle; issues, measures, and analysis techniques may change over time to meet the project's needs.

The following sections provide an overview of the PSM process activities.

2.2 Tailor Measures

The objective of the *Tailor Measures* activity is to define the set of software and system measures that provides the greatest insight into project issues at the lowest cost. The *Tailor Measures* activity focuses on getting information on high-priority issues first. A measurement plan documents the results of this activity.

Project issues drive the entire measurement process. The issues determine which measures are selected, how measurement results are analyzed, and what decisions managers must make. Figure 1-3 illustrates the tasks of the measurement tailoring activity. (This figure expands the *Tailor Measures* activity depicted in Figure 1-2.) The first task is to *Identify and Prioritize Project Issues* that have the greatest potential impact on the project. Issues are derived from project information such as objectives, constraints, technical strategies, estimates, and risk analysis results, as well as general organizational requirements.

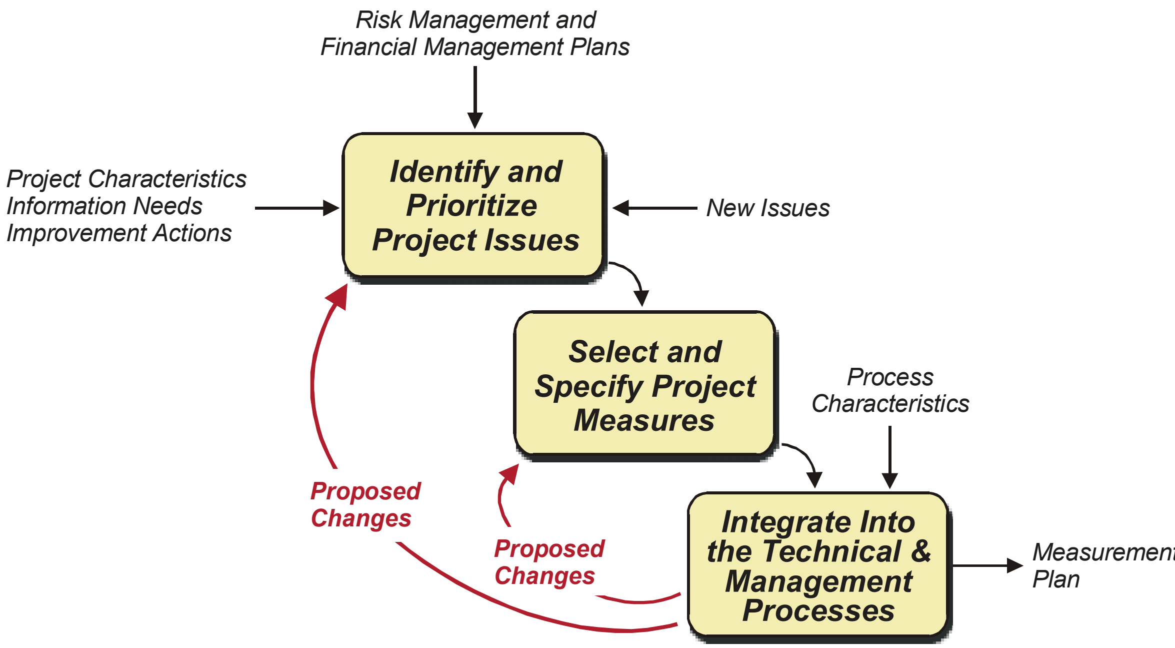

Figure 1-3. ***Tailor Measures*** **Activity**

The second task selects and defines appropriate project-specific measures. PSM provides an experience-based framework that maps project issues to applicable measures. Project-specific issues are grouped into common issue areas. These common issue areas make it easier to relate identified issues to potentially useful measures and provide a basis for understanding how the issue areas interrelate with and influence each other.

The final tailoring task integrates the measures into the technical and management processes. The life-cycle processes, tools, development approach, and management processes affect the definition and utility of the desired measures. Existing measurement implementations should be considered for their applicability to the project information needs. The results of this integration task are documented in a project measurement plan. The plan may be formal or informal, depending on the nature of the project. The plan should also include success criteria for the measurement program.

Part 2 of this Guide describes the *Tailor Measures* activity in more detail.

2.3 *Apply Measures*

Figure 1-4 expands the *Apply Measures* activity depicted in Figure 1-2. During *Apply Measures*, the measures are analyzed to provide the feedback necessary for effective decision making. Risk and financial performance information must also be considered during decision making. During this activity, questions may be raised and new issues may be identified, causing the process to iterate.

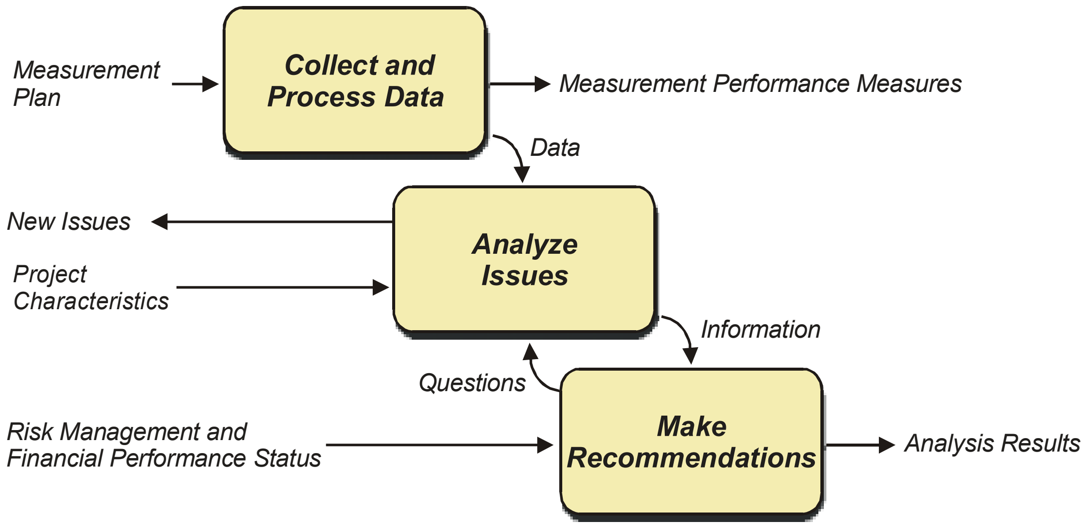

Figure 1-4. ***Apply Measures*** **Activity**

The three *Apply Measures* tasks identified in Figure 1-4 are summarized below and detailed in Part 4 of this Guide.

Collecting and processing measurement data is a prerequisite to analyzing project issues. Getting good data is the foundation of any measurement process. The term "data" in this context may include estimates, plans, and historical data, as well as data characterizing current activities and products. The data should reflect the nature of the products and the technical and management processes. The key steps in collecting and processing data are accessing the data, verifying the data, and normalizing the data.

During the *Analyze Issues* task, measurement indicators are generated from the data. An indicator is a measure or combination of measures that provides insight into a software or systems issue or concept. This process results in quantifying the project status relative to the objectives, calculating estimates to complete, and assessing *known issues*. As shown in Figure 1-4, this analysis is based on both measurement and project information. Measurement results usually cannot stand alone; only the integration of quantitative and qualitative data produces true project insight. The results of the analysis are the basis for identifying *new issues* and taking corrective action.

The purpose of measurement is to help project and technical managers make better decisions. The *Make Recommendations* task includes two major steps: reporting measurement information to the decision maker and identifying alternative courses of action. The manager is responsible for taking appropriate action based on that information.

2.4 *Implement Process*

Implementing a measurement process within an organization is similar to implementing any new initiative or function. Measurement represents a significant change in how an organization conducts business. The resistance generated by this change must be addressed directly.

Three key tasks (as shown in Figure 1-5) support measurement implementation in an organization. These tasks are summarized below and described in detail in Part 6 of this Guide.

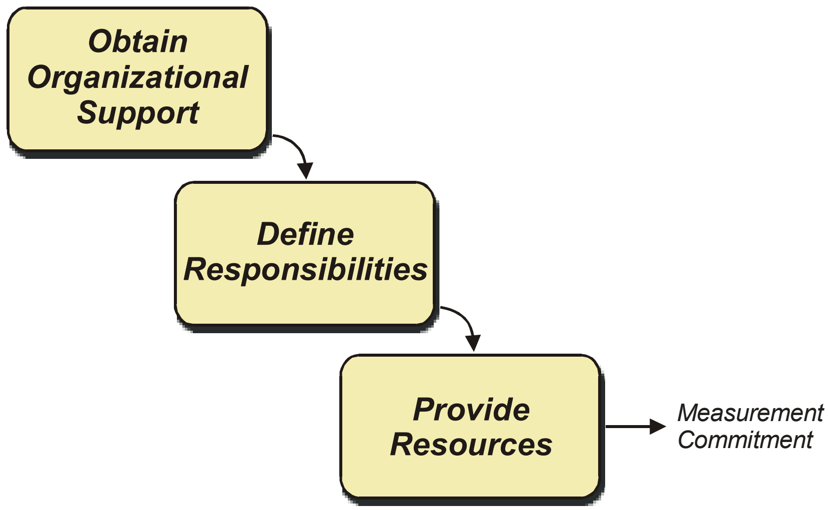

Figure 1-5. *Implement Process* Activity

The first task is to *Obtain Organizational Support*. This includes generating support for measurement at all levels within the organization. Management-mandated measurement seldom succeeds without organizational support. Members of the organization at all levels need to understand how measurement will directly benefit their projects and work processes. As part of this task, enterprise- or organization-level issues and information needs should be identified.

The second task is to identify and assign measurement-related responsibilities within the organization. The key positions that are generally responsible for measurement include the organizational and project managers, the measurement analyst(s), and other members of the technical and management staff involved with acquisition and development activities. It is important to define who is responsible for each part of the measurement process to achieve a successful implementation. Typical positions and responsibilities include the following:

- **Executive manager** - The executive manager is generally an organizational or enterprise manager responsible for multiple projects. This manager defines higher-level performance and business objectives, and ensures that individual projects support the overall organizational strategy. The executive manager uses measurement results to make organizational and enterprise level decisions.

- **Project or technical manager** - This person or group of people, generally referred to as the "project manager" in PSM, is responsible for identifying issues, reviewing analysis results, and acting on measurement information. In many cases, both the acquirer and supplier organizations have project managers who use measurement information to make decisions and to communicate objectively between organizations.

- **Measurement analyst** - This role can be assigned to either an individual or a team of personnel. The analyst's responsibilities include developing the project measurement plan, collecting and analyzing measurement data, and reporting results throughout the project organization. Usually, both the acquirer and supplier organizations have a measurement analyst or group assigned to these responsibilities.

- **Project team** - This is the team of project personnel responsible for the day-to-day development or operations and maintenance of software and system projects. The project team may include both government and industry organizations, and may be defined within an IPT structure. The project team collects measurement data on a periodic basis and uses the measurement results to guide engineering activities. PSM uses the terms “supplier” to refer to organizations responsible for both new development projects and operations and maintenance efforts.

All participants in the measurement process must understand and commit to their responsibilities. Once responsibility has been assigned, resources must be allocated to implement these responsibilities. The third task, *Provide Resources*, involves acquiring the necessary tools and personnel to implement the measurement process within the organization.

The experiences of many government and industry organizations show that the cost of implementing and sustaining a measurement process ranges from one to five percent of a project’s budget. This is a relatively small amount when compared to the cost of conventional review and documentation-based techniques for project monitoring.

2.5 *Evaluate Measurement*

The last major activity in the measurement process involves assessing the measurement program and indentifying improvements. Figure 1-6 illustrates this activity’s four tasks, which are detailed in Part 7 of this Guide.

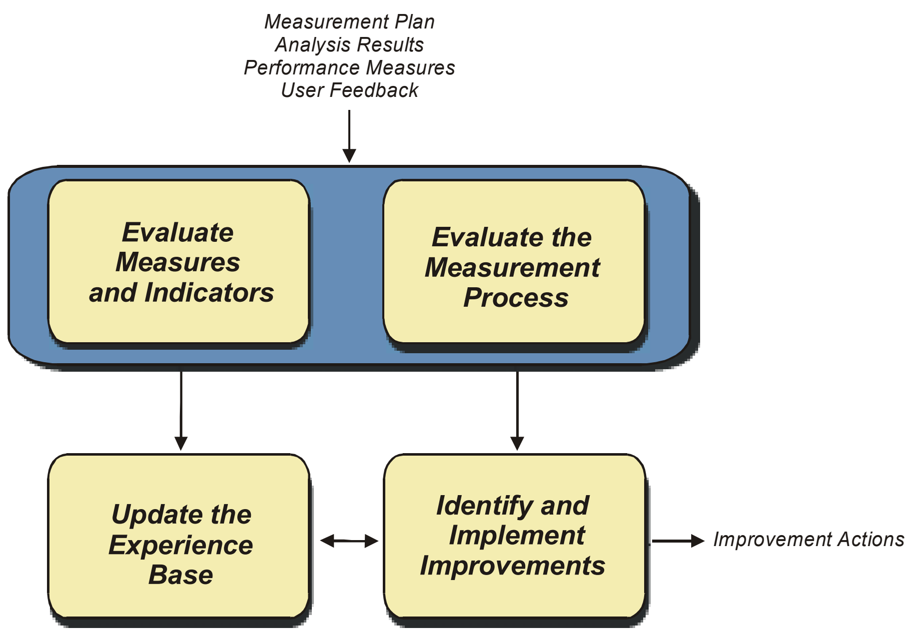

Figure 1-6. *Evaluate Measurement* Activity

The first task is to evaluate the measures, indicators, and measurement results. Ideally, this evaluation is based on success criteria that were developed during the *Tailor Measures* activity. The evaluation should include a review of the analysis results to assess their fitness for purpose, accuracy and reliability.

The second task is to *Evaluate the Measurement Process*. This involves three dimensions: evaluating the quantitative performance of the process, evaluating the conformance of the measurement process to the plan, and evaluating the measurement capability relative to a standard.

The third task is to update the measurement experience base with lessons learned. The scope of lessons learned should include both the measurement process, as well as the measures and indicators. This task considers both strengths and weaknesses of the measurement approach, capturing what did not work as well as what did work. The Issue-Category-Measure tables provide a framework for building an experience base. As described in Part 3, issues, categories, and measures can be modified or created to address organization-specific needs or to capture local measurement experience.

The last task in this activity is to identify changes (improvements) to the measurement process. These changes may address bottlenecks, take advantage of improvement opportunities, or adopt lessons learned. Typically, changes are implemented by adjusting the measurement plan through the *Tailor Measures* activity.

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3

Measurement Principles

Every project is characterized by different technical and management attributes, as well as unique software and system issues and objectives. PSM explains how to tailor and apply a measurement program to meet specific project information needs. To accomplish this, PSM defines nine principles that describe the characteristics of an effective measurement program.

The nine measurement principles are:

- Use issues and objectives to drive the measurement requirements.
- Define and collect measures based on the technical and management processes.
- Collect and analyze data at a level of detail sufficient to identify and isolate problems.
- Implement an independent analysis capability.
- Use a systematic analysis process to trace the measures to the decisions.
- Interpret the measurement results in the context of other project information.
- Integrate measurement into the project management process throughout the life cycle.
- Use the measurement process as a basis for objective communications.
- Focus initially on project-level analysis.

The following subsections discuss each of the nine principles. Experience shows that a measurement program is more likely to succeed if it adheres to these principles.

3.1 Project Issues and Objectives

Use issues and objectives to drive measurement the requirements. The purpose of measurement is to help management achieve project objectives by identifying, tracking, and managing actual problems and potential obstacles to success. Project ***objectives*** are goals and requirements expressed in terms of cost, schedule, quality, functionality, and technical performance. ***Issues*** are areas of concern that present obstacles to achieving project objectives. Issues include problems, risks, and lack of information.

PSM emphasizes identifying project issues at the start of a project and then using the measurement process to provide insight into those issues throughout the project. Conducting a thorough risk analysis at the beginning of a project facilitates the initial identification and prioritization of issues. However, even without a formal risk analysis, issues still can be identified. Note that not all risks or issues are quantifiable. As a project progresses, risks may evolve into problems or may be mitigated. Identifying risks does not necessarily mean that a project is in trouble, but that the potential for trouble has been recognized so that it can be managed.

Most project-specific issues fall into one of the following seven common issue areas:

- Schedule and Progress
- Resources and Cost
- Product Size and Stability
- Product Quality
- Process Performance
- Technology Effectiveness
- Customer Satisfaction

While the PSM common issue areas are applicable to most projects, each project typically has some unique issues. Moreover, the priority of issues usually varies from project to project. Focus attention on high-priority project issues to minimize the measurement effort. Do not expend resources collecting data that will not be used.

3.2 Technical and Management Processes

Define and collect measures based on the technical and management processes. To collect measurement data cost effectively, consider processes of the supplier and the acquirer. The technical and management processes determine what and how specific data items should be collected. Attempt to define measures in ways that make their collection a natural by-product of the work performed.

Since one of the purposes of the measurement process is to provide insight into performance, the collected measures must objectively represent the activities and products of the technical and management processes. Select measures that are normally reported only if they are relevant. Also consider the processes of subcontractors or other project team members when selecting measures.

3.3 Level of Data Collection and Analysis

Collect and analyze data at a level of detail sufficient to identify and isolate problems. The PSM process depends on the periodic collection, processing, and analysis of measurement data rather than on the review of pre-packaged analysis reports. This data includes estimates, plans, changes to plans, and counts of actual activities, products, and expenditures. The unit level (as defined by the product component structure or system architecture) and the activity level (as defined by the work breakdown structure) are the most commonly used levels of detail.

Mature organizations can provide a wide range of data items. The specific data items needed for project or technical management depend on the project issues. When a proposed measure proves difficult to collect or does not provide required information, an effective substitute may be found in related measures. Collecting detailed data allows the measurement analyst to perform a variety of different analyses with the same data.

3.4 Independent Analysis Capability

Implement an independent analysis capability. All projects should include an assessment of measurement data by a group that is independent of the organization producing the data. This ensures that the measurement process is objective and provides an accurate, unbiased assessment of the project.

In an outsourcing or acquisition scenario, both the supplier and the acquirer should perform their own analysis of the project's measurement data. Objective communication can only occur when both parties understand the data. Because each party has its own perspective on project issues, independent analysis allows each organization to assess the impact of problems identified by measurement data. Ideally, both supplier and acquirer should perform analysis continually. They should also meet frequently to discuss progress and to understand measurement results. The need for both supplier and acquirer analysis is applicable in both the government and industry sectors.

In projects with integrated project teams (IPTs) that combine acquirer and supplier personnel, assign analysis responsibility to a single project element. The function could also be performed by an Independent Verification and Validation (IV&V) organization, an engineering and management support contractor, or another third-party organization. For an internal development, this independent assessment might be done by quality assurance, an organizational measurement group, or a process improvement group. The independent organization must have access to the measurement data or should regularly receive data for analysis.

Note that without a true analysis capability, the delivery of data or measurement reports to an independent organization has little value and may be counterproductive. Similarly, without sufficiently detailed data, the ability of the independent organization to conduct its own detailed analysis will be seriously limited.

3.5 Systematic Analysis Process

Use a systematic analysis process to trace measures to decisions. Measurement-based conclusions and recommendations must be generated in a systematic manner to form a sound basis for management decisions and subsequent action. The information must be traceable and repeatable. Traceability means that the conclusions and recommendations are generated from measurement data in a defined sequence of steps. Repeatability means that different analysts following the same sequence of steps are likely to arrive at the same conclusions and recommendations. An ad-hoc analysis approach does not provide management with the confidence to act on measurement information.

PSM addresses three types of analyses. At the start of a project or when major changes are implemented, develop *estimates* as the basis for planning. Then, analyze the plans in terms of their *feasibility*. For example, ask questions such as: "Is this a reasonable size estimate?" or "Can the product be completed on time with the proposed amount of effort?" Once the project is underway, evaluate *performance*. Key questions focus on tracking against plans: "Is the project on schedule?" or "Are we developing quality work products?" PSM provides a systematic approach to all three types of analysis.

3.6 Project Context

Interpret the measurement results in the context of other project information. Measurement provides an indication that a problem may exist. No measurement result is good or bad by itself. For example, assume that the number of unit designs completed to date is lower than planned. This situation might occur because the project is not yet fully staffed. It might also occur because productivity is lower than planned even while fully staffed. The variance between planned and actual values only indicates that attention to this issue is important *now*. Additional information must be collected to evaluate the cause and severity of the situation and to assess its impact on project success.

Some aspects of, or contributors to, an issue may not be easily quantified. For example, getting the requirements correct may depend on adequate interaction with the system's intended users. Even if production of the requirements document is on schedule, it may not have the right content. Thus, *qualitative data* must be considered when assessing progress. Examine measurement results in the context of other project information to determine whether action is warranted, and what action should be taken.

3.7 Life-Cycle Integration

Integrate measurement into the project management process throughout the life cycle. Measurement results should be provided to managers as an integral part of decision support information, rather than be reported separately. The issue-driven PSM measurement approach applies to the entire life cycle. For purposes of this document, three major life-cycle phases are defined: *Project Planning*, *Development*, and *Operations and Maintenance*. Measurement results must be provided periodically and at appropriate decision points throughout the life cycle.

Decisions made in one project phase affect the results of other project activities. Measurement provides insight into the current phase, as well as helping to project the consequences of current actions on later phases. Consequently, it is important to adopt a life-cycle perspective when implementing a measurement process. Over the course of the life cycle, the critical issues may change. The measures used to monitor those issues should change accordingly.

3.8 Objective Communication

Use the measurement process as a basis for objective communications. Measurement activities should not be conducted by either the supplier or acquirer organization in isolation. Communicate with the entire project team each step of defining the measurement requirements and analyzing the measurement data. Most decisions that are based on the data affect more than one party. A corrective action that is planned with all participants in mind is more likely to succeed than one that is arbitrarily imposed.

The concept of Integrated Product and Process Development (IPPD) and the functioning of an Integrated Product Team (IPT) depend on frequent and objective communication about issues among all team members. Measurement provides an effective vehicle for this communication.

It is important to ensure that all parties use the same data and have a common understanding of the data definitions. In contractual situations, most data comes from the supplier; therefore, the burden is primarily on the acquirer to understand the supplier's process and measurement data.

3.9 Project-Level Analysis

Focus initially on project-level analysis. Project success means meeting specific project objectives. While the larger organization may have concerns and objectives that span multiple projects, PSM stresses the need to measure and understand individual projects before attempting to make cross-project comparisons. Nevertheless, at several points in the measurement process, composite data and simple models based on a large number of projects may help project-level analysis.

Although PSM focuses on project-level measurement and analysis, the issue-driven measurement process is equally applicable to organization- and enterprise-level requirements. However, the analysis techniques used at these higher levels require valid data from the project level to evaluate overall impacts in areas such as return on investment and cycle time reduction. In order to facilitate organization- or enterprise-level analysis, it is necessary to implement a consistent measurement process on all individual projects. Chapter 5 contains more information about measurement within an enterprise or organizational context.

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4

Life Cycle Application

The PSM issue-driven measurement approach and flexible analysis process apply throughout the project life cycle. Issues, measures, and analysis focus may change as a project progresses. This Guide discusses a three-phase life-cycle model consisting of *Project Planning, Development,* and *Operations and Maintenance*. Project management, systems, software, and hardware engineering activities continue in parallel throughout these phases. However, each phase raises unique measurement concerns, as discussed below.

4.1 Project Planning

During *Project Planning*, the project manager's primary concern is estimating project magnitude in terms of size, cost, effort, and schedule. The systems engineering staff develops a set of requirements that address the customer's needs. This frequently takes the form of an operations concept and a system specification. As the technical approach for satisfying the customer's requirements evolves, more detailed plans can be developed. This phase is complete when the team reaches a firm understanding of what must be accomplished and how it will be accomplished.

Outsourcing or Acquisition Scenarios

In an outsourcing or acquisition scenario, the acquirer's project manager must select among alternative suppliers. The alternative suppliers propose the detailed plans and technical approaches for the software or system project based on the efforts of their engineers. In this situation, two sets of estimates must be developed and corresponding plans must be analyzed:

- **Project plan** - The acquirer's organization develops an estimate as a basis for overall planning. The acquirer assesses the required functionality, resources, and schedule defined for the project. Constraints may make it difficult to adjust the level of resources and schedule. Therefore, the result of the feasibility assessment may be a risk quantification rather than revised budgets and milestones.

- **Supplier plan** - The supplier produces an estimate and plan for the contracted portion of the project. The acquirer assesses the supplier's estimates and plan approach in terms of required functionality, resources, and schedule. The technical approach, quality, and capability of each potential supplier is also assessed.

Since overall schedule objectives are usually established by the acquirer's project manager, the major criteria for supplier selection include the proposed technical approach, proposed cost, historical product quality, and development capability. These criteria are based on current and historical project performance.

Measurement data can help evaluate a potential supplier's capabilities. Measurement-related information used for supplier selection should include:

- **Past performance data** - The supplier should provide size, effort, schedule, and quality data from past projects. When comparing potential suppliers' past performance, the acquirer must compensate for differences in how measures such as size, effort, and problem reports are defined.

- **Overall process maturity** - The measurement maturity of an organization is one dimension of its overall process maturity. Organizations with an ad-hoc development process may have difficulty providing the basic measurement data described in this Guide.

- **Maturity of the measurement process** - Sometimes organizations that rate well in overall process maturity have weak measurement processes. Consider also the ability of the supplier to provide accurate measurement data that is relevant to the anticipated project issues.

Of course, the choice of a supplier cannot be based solely on measurement-related factors. The measurement capability of potential suppliers is just one factor that needs to be considered along with other technical, management, and experience factors. However, measurement results do help determine if the supplier has the potential to achieve project objectives and play an important role in performance-based acquisition.

Internal Developments

With internal development, the project manager produces a project plan that addresses the required functionality, resources, and schedule. The measurement plan may be incorporated into the overall project plan. This plan goes through the normal management approval cycle within an organization, but does not generally require the formality of a contract.

4.2 Development

During the *Development* phase, the project manager continues to be concerned with the issues identified in project planning. Process capability must be tracked for changes. For example, a high level of personnel turnover could result in lower productivity. During this phase, the focus of analysis turns to performance relative to the plans, rather than the feasibility of the plans themselves. However, any changes to estimates and plans should continue to be assessed for feasibility.

Development tasks are often categorized into four activities: requirements analysis, design, implementation, and integration and test. Typically, development begins with system requirements analysis and system design activities. The systems requirements are allocated to software and hardware components, and a high level design is developed. These activities are typically followed by parallel software and hardware activities. For software components, requirements analysis, design, implementation (code), and integration and testing are accomplished. Hardware follows a similar strategy, with implementation focusing on fabrication or purchase of components. Following these activities, systems engineering completes the systems integration and testing activities. Systems, software, and hardware engineering activities may proceed in parallel. Systems engineering plays an important role in coordinating dependencies among hardware and software activities. Depending on the development model adopted for the project, these activities may be organized using incremental, evolutionary, or sequential approaches. Each activity introduces new opportunities for measurement.

During the ***requirements analysis*** activity, typical issues are *product size and stability*, *schedule and progress*, and *product quality*. Each issue impacts project cost. The overall magnitude and stability of requirements can be tracked by counting requirements and changes. However, progress and quality are more difficult to measure during this phase. In part, this difficulty is caused by the ad-hoc nature of the requirements process in many organizations. Measurement can only reflect the existing process and product; it does not add structure.

The requirements analysis process must be well defined to obtain meaningful measures. One effective requirements technique is to plan and conduct a series of technical reviews. This technique offers several opportunities for measurement. Completion of the reviews can be tracked to assess progress. Action items from reviews can be tracked to assess quality.

During ***design*** and ***implementation*****,** the focus is typically on *schedule and progress*, *product quality*, and *technology effectiveness*. The project manager must continue to track *product size and stability* to avoid surprises. Again, the opportunity to gain insight into project status depends on the structure of the process. To the extent that the life-cycle process defines discrete design and implementation activities, progress is easier to measure. Sometimes progress comes at the expense of quality. For example, component testing might be scaled down in order to meet interim delivery milestones. It is easy to address this situation if the component test activities are discretely planned and tracked as part of the measurement process. During design and implementation, the adequacy of the technical approach should be assessed. Any deficiencies must be recognized as soon as possible so that alternative solutions can be implemented.

During ***integration and test*****,** the project focus is on both product readiness and *customer satisfaction*. This usually means that the focus is on evaluating *product quality*. Integration and test is often one of the shortest and most intense activities. Consequently, the measurement process must provide rapid data collection, analysis, and feedback for timely and effective decision making. On many projects, this results in increased analysis of problem reports. A weekly reporting interval for problem reports often is used during this activity. In some cases, daily test progress and problem report status are provided. The determination of the reporting interval depends on many factors, but usually there is an increase in measurement activity during testing.

Testing may proceed through many levels, especially for systems development efforts. Initial hardware-only and software-only tests are often followed by integration testing as systems engineers fit the components together.

4.3 Operations and Maintenance

The *Operations and Maintenance* phase continues to focus on the issue of *product quality.* The operations and maintenance process may be implemented in many different ways. In an outsourcing or acquisition scenario, an organization other than the supplier is often responsible for operations and maintenance. The new organization is likely to use a different management structure, personnel, and process than the supplier responsible for development. Furthermore, operations support may be provided by an organization different than the maintainer. Even though the basic measurement principles still apply in operations and maintenance, the measurement process for operations and maintenance organizations should be planned separately from that of the developer.

The typical maintenance organization is responsible for two different types of change efforts: major enhancements that adapt the product to mission and technology changes, and basic maintenance that integrates small enhancements and problem corrections. Basic maintenance also includes preventive maintenance. These are discussed below. Some organizations define a special category of basic maintenance to implement emergency corrections to problems.

Major Enhancements

Software and system projects often experience significant changes in mission and functional requirements over their life cycles. Moreover, the trend toward incremental and evolutionary development has resulted in more projects that include the development and integration of additional capability after the project is initially fielded. These large enhancements are usually managed as new development efforts utilizing the requirements analysis, design, implementation, and integration and test activities described in section 4.2. They do not follow the typical “change and fix” process for basic maintenance discussed below.

Basic Maintenance

Basic maintenance includes small adaptive changes as well as fixes for errors previously inserted into the system. The measures available during maintenance often differ significantly from those during development and enhancement efforts. For example, during development, work unit progress measures may be collected to track the design, coding, and integration of components. During maintenance, the unit of work tracked often becomes the change request rather than the component. A typical goal of the maintenance organization is the reduction of outstanding change requests, using a fixed level of staffing.

During basic maintenance, problem reports and change requests may be handled individually or bundled together under a planned product release cycle. It is easier to measure and control a version-based process. However, the nature of the system often dictates the version release strategy and other aspects of the software and systems engineering process. The measurement process must be adapted to the engineering process.

Most release maintenance processes have three phases: analysis, release planning, and implementation. During analysis, change requests are reviewed, impacts assessed, and customer commitments are made. During release planning, changes are packaged into releases, budgets are assigned, and schedules are set. During implementation, the changes assigned to a release are designed, coded, and tested.

Throughout this process, key issues are controlling the quantity and scope of changes, minimizing the impact of changes on the performance of the deployed system, and ensuring that changes are implemented in time to support the user's needs.

Emergency problems are usually handled individually, because the schedule is critical. This impacts the measures available for use. Systems with significant hardware components may also require scheduled servicing to keep them in top condition.

Operations

The typical operations organization provides the staff and other resources necessary for the system to perform its intended function. During operations, concern may narrow to system availability and technical performance issues. Usually, these are specific to the application domain.

5

Enterprise and Organizational Context

PSM focuses on the measurement process for a specific software or system project. However, limiting one's perspective to a single project may result in missed opportunities to minimize the cost and maximize the value of measurement. Costs may be reduced when multiple projects share the same approach. Value is increased when a measure satisfies multiple information needs. While measurement for enterprise and organizational purposes are not detailed in this Guide, the PSM principles still apply, as discussed in the following sections.

5.1 Enterprise and Organizational Measurement Needs

While PSM focuses on assisting project and technical managers, the issue-driven measurement process can also support organization- and enterprise-level measurement requirements. Executive managers may need information to address issues outside the scope of individual projects, such as establishing fee-for-service rates or determining return on investment. These issues can only be addressed by analyzing data across multiple projects at the organizational level. Measure selection and specification at the organizational level is similar to that at the project level.

In addition to organization-wide objectives, usually a subset of issues is common across all projects within an organization. These recurring issues produce similar measurement requirements that can be standardized. Figure 1-7 illustrates this combination of organization and common or recurring project requirements into a set of integrated measurement requirements. All of these issues should be considered in the *Tailor Measures* activity. The same measures should be used to address both organizational and project issues, whenever possible.

This combination of common project issues and strategic objectives forms the basis of an enterprise measurement set for various organizational levels and functions. These measures may be used for tracking strategic initiatives, establishing a quantitative management program, or calibrating predictive models.

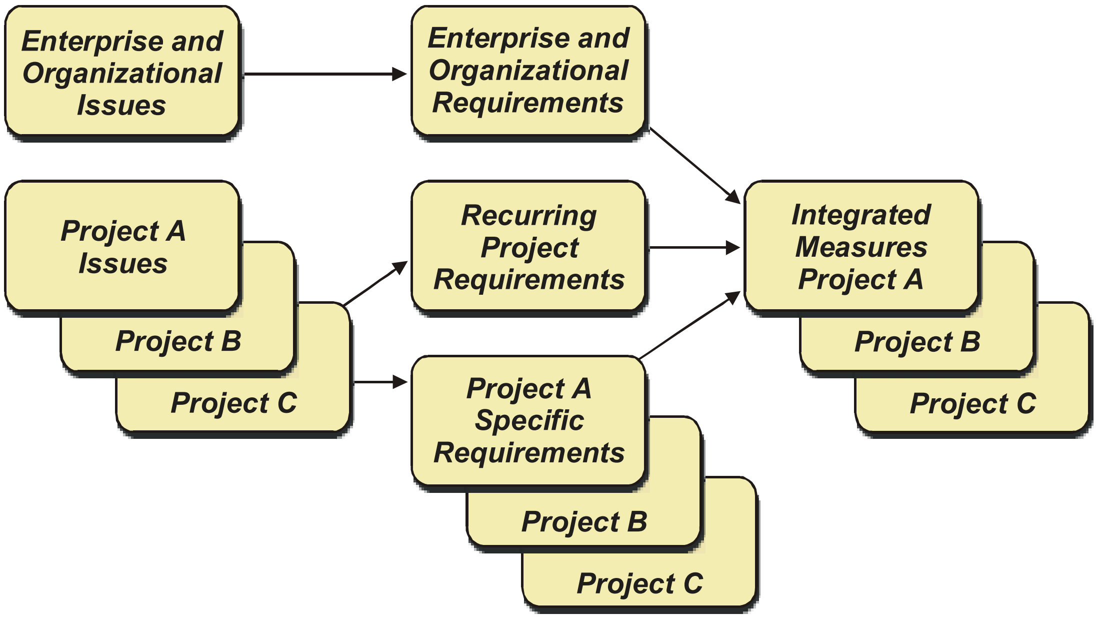

Figure 1-7. Measurement Across Multi-Project Organizations

As a result of this approach, descriptions of objectives and critical success factors are driven downward through the organization to the projects, where measurement data are defined and associated with issues. At each level of the organization, the original issue may be reinterpreted, based on the particular perspective of the organizational and its unique ability to contribute to the objective.

By decomposing objectives and issues in this manner, and by defining indicators to satisfy lower level objectives as they are redefined, measures are always focused on satisfying the original requirement. Reporting and using these measures follows a similar path upward through the organizational levels - lower level measures are aggregated into derived data and higher order indicators designed to satisfy the appropriate level of management consolidation.

While these measures may be defined and created using the same PSM techniques and templates used for defining project measures, they also create a new set of challenges. Multiple project data require standard definitions (agreed to by multiple users); defined project characteristics, common data collection methods, validation routines, databases and access requirements, aggregation formulas and normalizing techniques; and identification of new indicators (also agreed to by multiple stakeholders).

5.2 Organizational Measurement Plan

Most large projects will require the development of a unique measurement plan. However, some organizations may be able to define a common measurement plan that covers many projects. This implies that a common measurement set can be defined for the organization. This is often true within a product line or family of related projects. Adopting a common measurement *set* usually means that tools and other resources can be shared across projects. A common measurement set makes sense for a group of projects that share the following characteristics:

- Similar software and system issues

- Common life-cycle processes (standards, practices)
- Stable, shared technology (languages, tools, platforms)
- Similar application domains

Imposing a standard measurement set in situations where these conditions are not satisfied may burden individual projects with unnecessary measurement requirements while missing important project issues that should be tracked.

Even if the processes and technologies are different, defining standard data items such as problem reports and hours of effort may increase commonality. While projects may define different ways of categorizing the problem reports and hours for tracking purposes, at least the totals will be comparable.

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