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Systems and software engineering — Measurement process

Ingénierie des systèmes et du logiciel — Processus de mesure

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In accordance with the provisions of Council Resolution 21/1986, this document is **circulated in the English language only**.

Contents

Page

List of Figures

Foreword

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This first edition cancels and replaces ISO/IEC 15939:2007, which has been revised to align with revisions of ISO/IEC/IEEE 15288:2015.

Introduction

Measurement supports the management and improvement of processes and products. Measurement is a primary tool for managing system and software life cycle activities, assessing the feasibility of project plans, and monitoring the adherence of project activities to those plans. System and software measurement is also a key discipline in evaluating the quality of products and the capability of organizational processes. It is becoming increasingly important in two-party business agreements, where it provides a basis for specification, management, and acceptance criteria.

Continual improvement requires change within the organization. Evaluation of change requires measurement. Measurement itself does not initiate change. Measurement should lead to action and not be employed purely to accumulate data. Measurements should have a clearly defined purpose.

This document defines a measurement process applicable to system and software engineering and management disciplines. The process is described through a model that defines the activities of the measurement process that are required to adequately specify what measurement information is required, how the measures and analysis results are to be applied, and how to determine if the analysis results are valid. The measurement process is flexible, tailorable, and adaptable to the needs of different users.

The measurement process defined in this document, while written for system and software domains, can be applied in other domains.

The purpose of this document is to describe the activities and tasks that are necessary to successfully identify, define, select, apply and improve measurement within an overall project or organizational measurement structure. It also provides definitions for measurement terms commonly used within the system and software disciplines.

This document does not catalog measures, nor does it provide a recommended set of measures to apply on projects. It does identify a process that supports defining a suitable set of measures that addresses specific information needs.

This document is intended to be used by suppliers and acquirers. Suppliers include personnel performing management, technical and quality management functions in system and software development, maintenance, integration and product support organizations. Acquirers include personnel performing management, technical and quality management functions in procurement and user organizations.

The following are examples of how this document can be used:

— by a supplier to implement a measurement process to address specific project or organizational information requirements;

— by an acquirer (or third-party agents) for evaluating conformance of the supplier's measurement process to this document;

— by an acquirer (or third-party agents) to implement a measurement process to address specific technical and project management information requirements related to the acquisition;

— in a contract between an acquirer and a supplier as a method for defining the process and product measurement information to be exchanged.

Systems and software engineering — Measurement process

1 Scope

This document establishes a common process and framework for measurement of systems and software. It defines a process and associated terminology from an engineering viewpoint. The process can be applied to the project and products across the life cycle. The measurement process can be applied throughout the life cycle to aid the planning, managing, assessing, and decision-making in all stages of a system or software life cycle.

This document also provides activities that support the definition, control and improvement of the measurement process used within an organization or a project.

This document does not assume or prescribe an organizational model for measurement. The user of this document decides, for example, whether a separate measurement function is necessary within the organization and whether the measurement function should be integrated within individual projects or across projects, based on the current organizational structure, culture and prevailing constraints.

This document does not prescribe a specific set of measures, method, model or technique. The users of this document are responsible for selecting a set of measures for the project and defining the application of those measures across the process, products, and other elements of the life cycle. The parties are also responsible for selecting and applying appropriate methods, models, tools and techniques suitable for the project.

This document is not intended to prescribe the name, format, explicit content, or recording media of the information items to be produced. This document does not imply that documents be packaged or combined in some fashion. These decisions are left to the user of this document. ISO/IEC/IEEE 15289 addresses the content for life cycle process information items (documentation).

The measurement process is supposed to be appropriately integrated with the organizational quality system. Not all aspects of internal audits and non-compliance reporting are covered explicitly in this document as they are assumed to be in the domain of the quality system.

This document is not intended to conflict with any organizational policies, standards or procedures that are already in place. However, any conflict should be resolved and any overriding conditions and situations need to be cited in writing as exceptions to the application of this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO, IEC and IEEE maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEEE Standards Dictionary Online: available at http://ieeexplore.ieee.org/xpls/dictionary.jsp

NOTE Definitions for other terms typically can be found in ISO/IEC/IEEE 24765, available at <www.computer.org/sevocab>.

3.1
acquirer
stakeholder that acquires or procures a product or service from a supplier

Note 1 to entry: Other terms commonly used for an acquirer are buyer, customer, owner, purchaser or internal/organizational sponsor.

[SOURCE: ISO/IEC/IEEE 15288:2015]

3.2
attribute
property or characteristic of an entity that can be distinguished quantitatively or qualitatively by human or automated means

3.3
base measure
measure defined in terms of an attribute and the method for quantifying it

Note 1 to entry: A base measure is functionally independent of other measures.

Note 2 to entry: Based on the definition of “base quantity” in the International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, 2012.

3.4
data
collection of values assigned to base measures, derived measures or indicators

3.5
data provider
individual or organization that is a source of data

3.6
data store
organized and persistent collection of data and information that allows for its retrieval

3.7
decision criteria
thresholds, targets, or patterns used to determine the need for action or further investigation, or to describe the level of confidence in a given result

3.8
derived measure
measure that is defined as a function of two or more values of base measures

Note 1 to entry: Adapted from the definition of “derived quantity” in the International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, 2012.

3.9
entity
object that is to be characterized by measuring its attributes

Note 1 to entry: An entity can be a process, product, project or resource.

3.10
indicator
measure that provides an estimate or evaluation of specified attributes derived from a model with respect to defined information needs

3.11
indicator value
numerical or categorical result assigned to an indicator

3.12
information need
insight necessary to manage objectives, goals, risks and problems

3.13
information product
one or more indicators and their associated interpretations that address an information need

EXAMPLE A comparison of a measured defect rate to planned defect rate along with an assessment of whether or not the difference indicates a problem.

3.14
measurable concept
abstract relationship between attributes of entities and information needs

3.15
measure, noun
variable to which a value is assigned as the result of measurement

Note 1 to entry: The plural form "measures" is used to refer collectively to base measures, derived measures and indicators.

3.16
measure, verb
make a measurement

[SOURCE: ISO/IEC 25000:2014]

3.17
measurement
set of operations having the object of determining a value of a measure

Note 1 to entry: Adapted from the International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, 2012.

3.18
measurement analyst
individual or organization that is responsible for the planning, performance, evaluation and improvement of measurement

3.19
measurement experience base
data store that contains the evaluation of the information products and the measurement process as well as any lessons learned during the measurement process

3.20
measurement function
algorithm or calculation performed to combine two or more base measures

3.21
measurement method
logical sequence of operations, described generically, used in quantifying an attribute with respect to a specified scale

Note 1 to entry: The type of measurement method depends on the nature of the operations used to quantify an attribute. Two types can be distinguished:

— subjective: quantification involving human judgment; and

— objective: quantification based on numerical rules.

Note 2 to entry : Based on the definition of "method of measurement" in the International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, 2012.

3.22
measurement procedure
set of operations, described specifically, used in the performance of a particular measurement according to a given method

[SOURCE: International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, 2012, Modified, editorially revised.]

3.23
measurement process
process for establishing, planning, performing and evaluating measurement within an overall project or organizational measurement structure

3.24
measurement process owner
individual or organization responsible for the measurement process

3.25
measurement sponsor
individual or organization that authorizes and supports the establishment of the measurement process

3.26
measurement user
individual or organization that uses the measurement information products

3.27
model
algorithm or calculation combining one or more base or derived measures with associated decision criteria

3.28
observation
instance of applying a measurement procedure to produce a value for a base measure

3.29
operator
entity that performs the operation of a system

3.30
organizational unit
part of an organization that is the subject of measurement

3.31
process
set of interrelated or interacting activities that use inputs to deliver an intended result

[SOURCE: ISO 9000:2015 Modified, Notes to entry 1, 2, 3, 4, 5 and 6 have been removed.]

3.32
product
result of a process

Note 1 to entry: Adapted from the definition of "Output" in ISO 9001:2015.

3.33
project
endeavor with defined start and finish criteria undertaken to create a product or service in accordance with specified resources and requirements

Note 1 to entry : A project is sometimes viewed as a unique process comprising coordinated and controlled activities and composed of activities from the Technical Management Processes and Technical Processes defined in ISO/IEC/IEEE 15288:2015.

[SOURCE: ISO/IEC/IEEE 15288:2015, Modified, Note 1 to entry editorially revised.]

3.34
scale
ordered set of values, continuous or discrete, or a set of categories to which the attribute is mapped

Note 1 to entry: The type of scale depends on the nature of the relationship between values on the scale. Four types of scale are commonly defined:

— nominal: the measurement values are categorical;

— ordinal: the measurement values are rankings;

— interval: the measurement values have equal distances corresponding to equal quantities of the attribute; and

— ratio: the measurement values have equal distances corresponding to equal quantities of the attribute, where the value of zero corresponds to none of the attribute.

These are just examples of the types of scale. Roberts [17] defines more types of scale. Annex A contains examples of each type of scale.

Note 2 to entry: Based on the definition of “scale (of a measuring instrument)” in the International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, 2012.

3.35
service
performance of activities, work or duties

[SOURCE: ISO/IEC/IEEE 15288:2015, Modified, Notes 1 and 2 to entry have been removed.]

3.36
stakeholder
individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations

Note 1 to entry: Within this document, an individual or organization that sponsors measurement, provides data, is a user of the measurement results or otherwise participates in the measurement process.

[SOURCE: ISO/IEC/IEEE 15288:2015, Modified, EXAMPLE has been removed and Note 1 to entry has been editorially revised.]

3.37
supplier
organization or an individual that enters into an agreement with the acquirer for the supply of a product or service

Note 1 to entry: Other terms commonly used for supplier are contractor, producer, seller or vendor.

Note 2 to entry: The acquirer and the supplier sometimes are part of the same organization.

[SOURCE: ISO/IEC/IEEE 15288:2015]

3.38
system
combination of interacting elements organized to achieve one or more stated purposes

Note 1 to entry: A system is sometimes considered as a product or as the services it provides.

[SOURCE: ISO/IEC/IEEE 15288:2015, Modified, Notes 2 and 3 to entry have been removed.]

3.39
unit of measurement
particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitude relative to that quantity

[SOURCE: International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, 2012]

3.40
user
individual or group that interacts with a system or benefits from a system during its utilization

[SOURCE: ISO/IEC/IEEE 15288:2015, Modified, Note 1 to entry has been removed.]

3.41
value
numerical or categorical result assigned to a base measure, derived measure or indicator

4 Conformance

4.1 Intended usage

The requirements in this document are contained in Clause 6. There are two ways that an implementation can be claimed to conform to the provisions of this document – full conformance and tailored conformance.

There are two criteria for claiming full conformance. Achieving either criterion suffices for conformance, although the chosen criterion (or criteria) is to be stated in the claim. Claiming "full conformance to tasks" asserts that all of the requirements of the activities and tasks of the measurement process are achieved. Alternatively, claiming "full conformance to outcomes" asserts that all of the required outcomes of the measurement process are achieved.

It is the responsibility of the organization to maintain appropriate evidence of satisfaction of the normative clauses for the purposes of demonstrating conformance.

NOTE The process has a set of objectives (phrased as "outcomes") and a set of activities and tasks that represent one way to achieve the objectives. Users who implement the activities and tasks can assert full conformance to tasks. Some users, however, might have innovative process variants that achieve the objectives (i.e., the outcomes) of the declared set of processes without implementing all of the activities and tasks. These users can assert full conformance to the outcomes. The two criteria—conformance to task and conformance to outcome—are not necessarily equivalent since specific performance of activities and tasks may require, in some cases, a higher level of capability than just the achievement of outcomes.

4.2 Tailoring this document

This document contains a set of activities and tasks that comprise a measurement process that meets the specific needs of organizations and projects. An organization tailoring this document may delete content that is not applicable, and may also add new activities and tasks.

4.3 Full conformance to outcomes

Full conformance to outcomes is achieved by demonstrating that all of the outcomes have been achieved. In this situation, the provisions for activities and tasks are guidance rather than requirements, regardless of the verb form that is used in the provision.

4.4 Full conformance to tasks

Full conformance to tasks is achieved by demonstrating that all of the requirements of the activities and tasks have been achieved. In this situation, the provisions for the outcomes are guidance rather than requirements, regardless of the verb form that is used in the provision.

4.5 Tailored conformance

When this document is tailored per 4.2, the tailored text, for which tailored conformance is claimed, is declared. Tailored conformance is achieved by demonstrating that the outcomes, activities, and tasks, as tailored, have been achieved.

5 Application of this document

This clause presents an overview of the measurement process. The objective is to orient the users of this document so that they can apply it properly within context.

This document defines the activities and tasks necessary to implement a measurement process. An activity is a set of related tasks that contributes towards achieving the purpose and outcomes of the measurement process (see 6.1 and 6.2). A task is a well-defined segment of work. Each activity is comprised of one or more tasks. This document does not specify the details of *how* to perform the tasks included in the activities.

The properties of the activities of the measurement process that are defined in this document are the same properties defined in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207. This means that other properties such as entry and exit criteria for each of the activities are *not* defined in this document.

NOTE 1 This measurement process supports the measurement requirement defined in ISO 9001:2015, 8.2.

NOTE 2 This document provides an elaboration of the measurement process from ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207. More detail is provided via additional activities and tasks. As part of this elaboration, one additional outcome (commitment is established and sustained) is added, with associated activities and tasks. This outcome is addressed in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 at the organization level.

The measurement process consists of four activities as illustrated in the process model in Figure 1. The activities are sequenced in an iterative cycle allowing for continuous feedback and improvement of the measurement process. The measurement process model in Figure 1 is an adaptation of the Plan-Do-Check-Act cycle commonly used as the basis for quality improvement. Within activities, the tasks are also iterative.

The “Technical and Management Processes” of an organizational unit or project are not within the scope of this document, although they are an important external interface to the measurement activities that are included in this document.

Two activities are considered to be the Core Measurement Process: Prepare the Measurement Process, and Perform the Measurement Process. These activities are included in the Measurement process in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 and mainly address the concerns of the measurement user. The other two activities, Establish and Sustain Measurement Commitment and Evaluate Measurement, provide a foundation for the Core Measurement Process and provide feedback to it. These latter two activities address the concerns of the measurement process owner. They are included in the set of life cycle processes as activities in the Project Planning process and the Quality Assurance process, respectively. At the organization level, this is handled by the Life Cycle Model Management process, which evaluates and improves the organization’s processes.

Figure 1 shows that the Core Measurement Process is driven by the information needs of the organization. For each information need, the Core Measurement Process produces an *information product* that satisfies the information need. The information product is conveyed to the organization as a basis for decision-making. The link between measures and an information need is described as the *Measurement Information Model* in Annex A. This annex also includes examples.

Performance of the normative activities and tasks defined in this document satisfies *at least* the Capability Level 1 requirements in ISO/IEC 33020. However, the guidance included in this document provides the basis for implementing the measurement process at progressively higher levels of capability.

The process defined in this document includes an evaluation activity, as shown in Figure 1. The intent is to emphasize that evaluation and feedback are an essential component of the measurement process, and should lead to improvements of the measurement process and measures. Evaluation can be simple, and performed in an ad hoc manner when capability is low, or it can be quantitative with sophisticated statistical techniques to evaluate the quality of the measurement process and its outputs when capability is high. Measures should be evaluated in terms of the added value they provide for the organization, and only deployed where the benefit can be identified.

Included in the cycle is the "Measurement Experience Base". This is intended to capture information products from past iterations of the cycle, previous evaluations of information products, and evaluations of previous iterations of the measurement process. This would include the measures that have been found to be useful in the organizational unit. No assumptions are made about the nature or technology of this "Measurement Experience Base", only that it be a persistent storage. Artefacts (for example, information products, historical data, and lessons learned) stored in the "Measurement Experience Base" are intended to be reused in future iterations of the measurement process.

Since the process model is cyclical, subsequent iterations may only update measurement products and practices. This document does not imply that measurement products and practices need to be developed and implemented for each iteration of the process. The wording used in this document adopts the convention that one is implementing the measurement process for the first time (i.e., the first iteration). During subsequent iterations, this wording should be interpreted as updating or changing documentation and current practices.

The typical functional roles mentioned in this document are: stakeholder, sponsor, measurement user, measurement analyst, data provider, and measurement process owner. These are defined in Clause 4 of this document.

A number of work products are produced during the performance of the measurement process. The work products are described in Annex B, and mapped to the tasks that produce them.

This document includes a set of activities and tasks. Tasks are sometimes broken into lower-level tasks. These are described in the order in which they typically are performed. However, iteration from one activity or task to a preceding or following one frequently occurs. The order in which these are presented does not necessarily imply an order of implementation. For each task, one or more normative requirements on the implementation are defined. There is also informative guidance to help with the interpretation of the normative requirements and the implementation in practice. This guidance is presented in *italics*.

The informative lists within the tasks in the annexes are not presumed to be exhaustive — they are intended only as examples.

In implementing a measurement process in conformance with this document, the organizational unit shall perform the activities described below. The "Requirements for Measurement" from the Technical and Management processes trigger the measurement process.

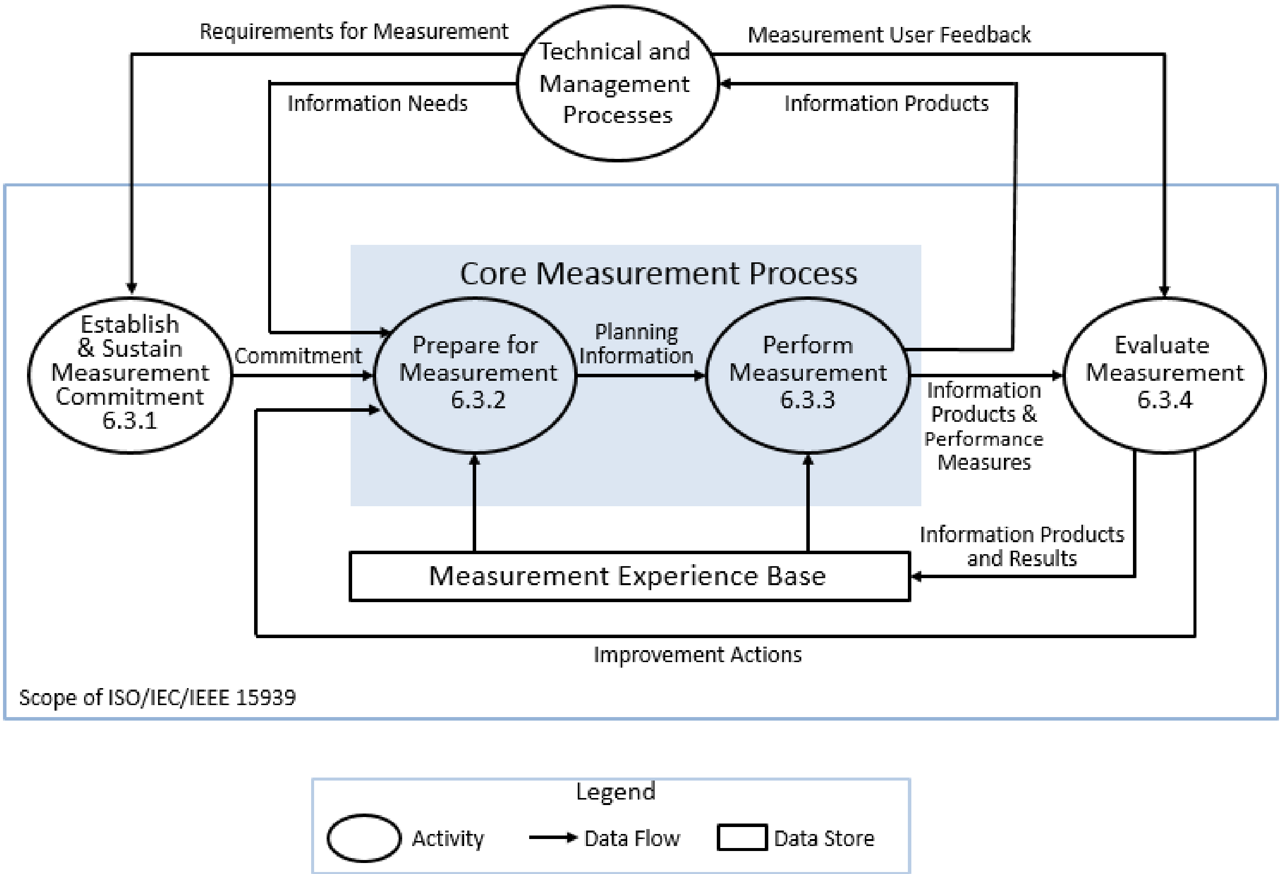

Figure 1 - Measurement process model

6 Measurement process

6.1 Purpose

The purpose of the Measurement process is to collect, analyze, and report objective data and information to support effective management and demonstrate the quality of the products, services, and processes.

[ISO/IEC/IEEE 15288:2015, 6.3.7.1 and ISO/IEC/IEEE 12207]

6.2 Outcomes

As a result of successful implementation of the Measurement process:

a) Information needs are identified.

b) An appropriate set of measures, based on the information needs are identified or developed.

c) Required data is collected, verified, and stored.

d) The data is analyzed and the results interpreted.

e) Information items provide objective information that support decisions.

f) Organizational commitment for measurement is sustained.

g) Identified measurement activities are planned.

h) The measurement process and measures are evaluated.

i) Improvements are communicated to the measurement process owner.

[ISO/IEC/IEEE 15288:2015, 6.3.7.2 and ISO/IEC/IEEE 12207]

6.3 Activities and tasks

The project shall implement the following activities and tasks in accordance with the applicable organization policies and procedures with respect to the measurement process.

NOTE 1 This document provides an elaboration of the measurement process in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207. It provides a more detailed set of activities and tasks that are aligned with those in 15288 and 12207. Through the rest of this document, only the references to 15288 are included, since the clause numbering is the same in both documents.

NOTE 2 Clause 9 of ISO 9001:2015 specifies Quality Management System requirements for measurement and monitoring of processes and products.

6.3.1 Establish and sustain measurement commitment

In ISO/IEC/IEEE 15288, measurement commitment is established and sustained as part of the Project Planning and Project Assessment and Control processes.

6.3.1.1 Accept the requirements for measurement

6.3.1.1.1 Identify the scope of measurement

The scope of measurement defines an organizational unit for purposes of this document. This can be a single project, a functional area, the whole organization, a single site, or a multi-site organization. This consists of projects or supporting processes, or both.

The scope of the organizational unit can be identified through interviews and the inspection of documentation, such as organizational charts.

In addition, all stakeholders need to be identified. For example, these can include project managers, the Information Systems manager, or the head of Quality Management. The stakeholders can be internal or external to the organizational unit.

The purpose and information needs for measurement are identified by the stakeholders.

6.3.1.1.2 Establish commitment of management

Commitment is established when "Requirements for Measurement" are defined (see Figure 1).

This includes the commitment of resources to the measurement process and the willingness to maintain this commitment. For example, one way the organizational unit establishes its commitment is through a measurement policy for the organizational unit, allocation of responsibility and duties, training, and the allocation of budget and other resources. Commitment often comes in the form of a contract with an acquirer requiring measurement.

6.3.1.1.3 Communicate commitment to the organizational unit

This can be achieved, for example, through organizational unit-wide announcements or newsletters.

6.3.1.2 Assign resources

6.3.1.2.1 Assign responsibility for measurement

The sponsor of measurement assigns this responsibility to competent individuals. Competence includes knowledge of the principles of measurement, how to collect data, perform data analysis, and communicate the information products. At a minimum, individuals are assigned the responsibility for the following typical roles:

— *measurement user; and*

— *measurement analyst.*

The number of typical roles shown above does not imply the specific number of actual roles or number of people needed to perform the roles. The number of people is dependent on the size and structure of the organizational unit. These roles could be performed by as few as one person for a small project.

6.3.1.2.2 Provide resources to plan, perform, and evaluate measurement

The sponsor of measurement is responsible for ensuring that resources are provided. Resources include funding and staff. Resource allocations are updated as needed.

6.3.2 Prepare for measurement

This activity consists of the following tasks.

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a)]

Information products and evaluation results in the "Measurement Experience Base" are consulted during the performance of this activity.

Examples of the measurement planning details that shall be addressed during this activity are described in Annex F.

6.3.2.1 Define the measurement strategy

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a) 1)]

This includes details covering:

— *roles, responsibilities, accountabilities and authorities;*

— *activities appropriate for suppliers or subcontractors;*

— *the flow of information between levels in the supply chain, and the flow of information to decision makers;*

— *identification of resources; and*

— *integration with other processes.*

6.3.2.2 Describe the characteristics of the organization that are relevant to measurement

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a) 2)]

This includes the characteristics that are relevant to selecting measures and interpreting the information products. The organization provides the context for measurement, and therefore it is important to make explicit this context and the assumptions that it embodies and constraints that it imposes. Characterization can be in terms of organizational processes, application domains, technology, interfaces amongst divisions/departments and organizational structure. Processes can be characterized in the form of a descriptive process model.

It is important to take the organization characterization into account in all subsequent activities and tasks.

6.3.2.3 Identify and prioritize the information needs

NOTE The information needs are based on the organization's business objectives, the project objectives, identified risks, and other items related to project decisions.

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a) 3)]

6.3.2.3.1 Identify Information needs

Information needs originate from the technical and management processes. The information needs can be derived from the business, organizational, regulatory (such as legal or governmental), product or project objectives.

Information needs often address questions such as: "How do I get insight into the likelihood of meeting the technical objectives?", "How do I know the status of implementation?", "How do I evaluate product quality during development?", or "How do I estimate the productivity for a future project?"

Useful guidance on risks that are a source for information needs can be found in ISO/IEC/IEEE 16085.

6.3.2.3.2 Prioritize identified information needs

This prioritization is normally accomplished by, or in conjunction with, the stakeholders. Often, only a subset of the initial information needs are pursued further. This is particularly relevant if measurement is being tried for the first time within an organization, where it is preferable to start small.

An example of a simple and concrete prioritization approach is to ask a group of stakeholders to rank the information needs. For each information need calculate the average rank. Then order the average ranks. This ordering provides a prioritization of the information needs.

6.3.2.3.3 Select information needs to be addressed

From the prioritized information needs, a subset is selected to be addressed during the measurement process. This selection is likely driven by a trade-off among resource constraints, and criticality/urgency of information needs.

In some large development efforts, information that is needed later is identified, but not fully defined nor implemented until it is required by the measurement users.

6.3.2.3.4 Record and communicate selected information needs

No assumptions are made about the type of records. It can be paper or electronic. It is only necessary that the record is retrievable.

The selected information needs are communicated to all stakeholders. This is to help ensure that they understand why certain data is to be collected and how they are to be used.

6.3.2.4 Select and specify measures that satisfy the information needs

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a) 4)]

6.3.2.4.1 Identify candidate measures that satisfy the selected information needs

There needs to be a clear link between the information needs and the candidate measures. Such a link can be made using the measurement information model described in Annex A.

New measures need to be defined in sufficient detail to allow for a selection decision. See the Bibliography for other documents that define some commonly used measures.

A new measure can involve an adaptation of an existing measure.

6.3.2.4.2 Select measures from the candidate measures

The selected measures reflect the priority of the information needs. Further example criteria for the selection of measures are included in Annex C.

Context information is necessary to interpret or normalize measures. For example, when comparing "lines of code" from different sources, the programming language is specified. As another example, when comparing requirements information from different sources, attributes of the system are specified.

6.3.2.4.3 Specify selected measures

Measures that have been selected are fully specified. This includes measure name; the unit of measure; a formal definition; the method of data collection, storage, and analysis; and the link to the information need.

The formal definition describes how the values are to be computed, including input measures and constants for derived measures. Some definitions already exist in the "Measurement Experience Base".

The method of data collection can be, for example, a performance analysis or diagnostic data capture tool, a data collection form, or a questionnaire.

Annex A provides guidelines for linking the measures to the information needs through the measurement information model.

6.3.2.5 Define data collection, analysis, access, and reporting procedures

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a) 5)]

6.3.2.5.1 Define procedures for data collection, storage, access, and verification

The procedures specify how data is to be collected, as well as how and where they are to be stored, accessed, and verified. Data verification can be accomplished through an audit. See Annex F for more detailed candidates of items to be defined.

6.3.2.5.2 Define procedures for data analysis and reporting of information products

The procedures specify the data analysis method(s) and methods for reporting the information products.

The range of tools that are needed to perform the data analysis is identified.

6.3.2.5.3 Define configuration management procedures

Items such as the raw data, information products, and selected information needs are placed under configuration management. This can be the same configuration management procedure used in other parts of the organization.

NOTE See the Configuration Management process in ISO/IEC/IEEE 15288 for more information.

6.3.2.6 Define criteria for evaluating the information items and the measurement process

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a) 6)]

6.3.2.6.1 Define criteria for evaluating information products

These criteria would allow one to determine whether the data that are needed have been collected and analyzed with sufficient quality to satisfy the information needs. The criteria need to be defined at the beginning of the project or process, and act as success criteria.

The criteria need to be defined within the context of the technical and business objectives of the organizational unit. Example criteria for the evaluation of information products are the accuracy of a measurement procedure and the reliability of a measurement method. Further criteria are included in Annex D. However, it is often necessary to define new criteria and measures for evaluating the information products.

6.3.2.6.2 Define criteria for evaluating the measurement process

The criteria need to be defined within the context of the technical and business objectives of the organizational unit. Examples of such criteria are timeliness and efficiency of the measurement process. Further criteria are provided in Annex E. However, it is sometimes necessary to define additional criteria and measures for evaluating the measurement process.

6.3.2.7 Identify and plan for the enabling systems or services to be used

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 a) 7)]

Enabling systems or services for measurement include the tools and services used to collect, store, analyze, and report information.

6.3.2.8 Review, approve, and provide resources for measurement tasks

This task is covered in the Project Planning process, in ISO/IEC/IEEE 15288.

6.3.2.8.1 Review and approve measurement planning

The measurement planning tasks constitute all tasks from 6.3.2.1 to 6.3.2.6. The results of measurement planning include the data collection procedures, storage, analysis and reporting procedures, evaluation criteria, schedules and responsibilities. Details of the elements of measurement planning are included in Annex F.

Measurement planning takes into consideration improvements and updates proposed from previous measurement cycles ("Improvement Actions" in Figure 1), or projects, as well as relevant experiences in the "Measurement Experience Base". Criteria such as the feasibility of making changes to existing plans in the short-term, the availability of resources and tools for the realization of changes, and any potential disruptions to projects from which data is collected is considered when selecting proposed improvements to implement.

If measurement planning information already exists, for example, from a previous measurement cycle, then the plan only needs to be updated as opposed to being "developed". Also, if measurement planning information already exists, then some of the elements in Annex F are not necessary. For instance, if an update involves deleting a measure, then a pilot implementation of the changes is not necessary.

Stakeholders review and comment on the measurement planning information. The sponsor of measurement then reviews and approves the measurement planning information. Approval demonstrates commitment to measurement.

6.3.2.8.2 Provide resources for implementing and evaluating measurement tasks

The measurement planning information is agreed to by the management of the organizational unit, and resources allocated. For approval, the planning information often undergoes a number of iterations. Note that measurement is often piloted on individual projects before committing to organization-wide use. Therefore, resource availability is staged in this case.

6.3.2.9 Acquire and deploy supporting technologies

6.3.2.9.1 Evaluate and select appropriate supporting technologies

Supporting technology consists of, for example, automated tools and training courses.

The types of automated tools that are often needed include graphical presentation tools, data analysis tools, and databases. Tools for collecting data also are required. This involves the modification or extension of existing tools, and the calibration and testing of the tools.

Based on the evaluation and selection of supporting technologies, the measurement planning information is sometimes updated.

6.3.2.9.2 Acquire and deploy supporting technologies

If the supporting technologies concern the infrastructure for information management, then access rights to the data or information are implemented in accordance with organizational security policies, and any additional confidentiality constraints.

6.3.3 Perform measurement

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 b)]

These tasks are intended to be performed in accordance with the planning tasks described in 6.3.2. Examples of measurement planning information are described in Annex F.

Information products and evaluation results in the "Measurement Experience Base" are consulted during the performance of this activity.

6.3.3.1 Integrate procedures for data generation, collection, analysis, and reporting into the relevant processes

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 b) 1)]

6.3.3.1.1 Integrate data generation and collection into the relevant processes

Integration often involves slightly modifying current processes to accommodate data generation and collection activities. For example, the inspection process is changed to require that the moderator of an inspection provide the preparation effort sheets and defect logs to the measurement analyst at the closure of every inspection. This necessitates modifying inspection procedures accordingly. Integration involves a trade-off between the extent of impact on existing processes that is tolerable and the needs of the measurement process. Changes with moderate to large impacts on the existing processes are usually not cost effective and sometimes disrupt efficiency or effectiveness. The required changes to collect data are minimized, whenever possible.

The extent of integration varies depending on the type of measures and the information needs. For example, a one-time staff morale survey requires little integration. Alternatively, filling in time sheets at the end of every week requires integration with Work Breakdown Structures or cost accounts and accounting procedures.

The data that need to be collected often includes extra measures defined specifically to evaluate the information products or performance measures to evaluate the measurement process.

6.3.3.1.2 Integrate data analysis and reporting into the relevant processes

Data analysis and reporting usually is performed on a regular basis. This requires that data analysis and reporting be integrated into the current organizational and project processes.

6.3.3.1.3 Communicate data procedures to the data providers and stakeholders

This communication is accomplished during, for example, staff training, an orientation session, or via an organization's newsletter.

The objective of communicating the data generation and collection procedures is to help ensure that the data providers are competent in the required data generation and collection. Competence is achieved, for example, through training in the data generation and collection procedures. This increases confidence that data providers understand exactly the type of data that are required, the format that is required, the tools to use, when to provide data, and how frequently. For example, if the data providers are trained on how to complete a defect data form, this helps ensure that they understand the defect classification scheme, and the meanings of different types of effort (such as isolation and correction effort).

The objective of communicating the data access and reporting procedures is to help ensure that all data providers understand the data being collected and follow the appropriate collection and reporting procedures.

6.3.3.2 Collect, store, and verify data

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 b) 2)]

6.3.3.2.1 Collect data

The selected attributes are measured using the designated measurement method. The data collection is accomplished by manual or automated means. Data is collected by automated means, for example, with a requirements management tool every time the requirements database is updated. Data is collected manually, for example, by completing a defect data form and sending it to the measurement analyst.

6.3.3.2.2 Store the collected data, including context information

The context information includes that necessary to verify, understand, or evaluate the data.

The data store does not have to be an automated tool. It is possible to have a paper-based data store, for example, in the situation where only a few measures are collected for a short period of time in a small organization.

Measurement data is often stored through the Information Management process.

6.3.3.2.3 Verify the collected data

Data verification is often performed by inspecting the data against a checklist. The checklist is constructed to verify that missing data is minimal, and that the values make sense. Examples of the latter include checking that a defect classification is valid, or that the size of a component is not ten times greater than all previously entered components. In case of anomalies, the data provider or providers are consulted and corrections to the raw data are made where necessary. Automated range and type checks are also used.

Data verification is the responsibility of the measurement analyst in conjunction with the data provider(s).

6.3.3.3 Analyze data and develop information items

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 b) 3)]

6.3.3.3.1 Analyze collected data

Data is aggregated, transformed, normalized, or re-coded prior to analysis. During this task, data is processed to produce the planned indicators. The data and indicators are reviewed and analyzed. The amount of rigor in the analysis is determined by the nature of the data and the information needs.

6.3.3.3.2 Develop information items

The data analysis results, indicators, interpretations, and supporting information make up the information items. All interpretations need to take into account the context of the measures.

The measurement analyst(s) need to be able to draw some initial conclusions based on the results. However, since the analyst(s) sometimes are not directly involved in the technical and management processes, such conclusions need to be reviewed by other stakeholders as well (see 6.3.3.3.3).

6.3.3.3.3 Review information items

The review is intended to help ensure that the analysis was performed and interpreted properly and that the information needs were satisfied. It can be an informal self-review, or a more formal inspection process. Examples of the types of things to look for during such a review are provided in Annex G.

The information products are reviewed with the data providers and the measurement users. This is to help ensure that they are meaningful, and if possible, actionable. Qualitative information is considered as a support to interpreting quantitative results.

6.3.3.4 Record results and inform the measurement users

NOTE The measurement analysis results are reported to relevant stakeholders in a timely, usable fashion to support decision making and assist in corrective actions, risk management, and improvements. Results are reported to decision process participants, technical and management review participants, and product and process improvement process owners.

[ISO/IEC/IEEE 15288:2015, 6.3.7.3 b) 4)]

6.3.3.4.1 Record results

The results include an analysis of a set of information items, along with the recommended actions.

6.3.3.4.2 Inform the measurement users

The information items and results are made available to the data providers and other stakeholders.

Feedback is provided to the stakeholders, as well as being sought from the stakeholders. This helps ensure useful input for evaluating the information items and the measurement process. Tasks 6.3.3.3 and 6.3.3.4 are typically performed in an iterative manner.

Useful guidance on communicating measurement results as an input to the risk management process can be found in ISO/IEC 16085:2006.

6.3.4 Evaluate measurement

This task is covered by Quality Assurance in ISO/IEC/IEEE 15288, since it is applied to every process, in addition to measurement. It is included in this standard to emphasize the importance of evaluation to measurement. At the organization level, this is handled in 15288 by the Life Cycle Model Management process, which evaluates and improves the organization’s processes.

6.3.4.1 Evaluate information products and the measurement process

6.3.4.1.1 Evaluate information products against the specified evaluation criteria

Conclusions on strengths and weaknesses of the information items are identified and recorded.

The evaluation of information products can be accomplished through an internal or independent audit. Example criteria for the evaluation of information products are included in Annex D. The evaluation criteria have been defined in 6.3.2.6.

The inputs to this evaluation are the performance measures, the information products, and the measurement user feedback.

The evaluation of information products sometimes concludes that some measures ought to be removed, for example, if they no longer meet a current information need.

6.3.4.1.2 Evaluate the measurement process against the specified evaluation criteria

Conclusions on strengths and weaknesses of the information items are identified and recorded.

The evaluation of measurement process may be accomplished through an internal or independent audit. Example criteria for the evaluation of the performance of the measurement process are included in Annex E. The evaluation criteria have been defined in 6.3.2.6.

The quality of the measurement process influences the quality of the information products.

The inputs to this evaluation are the performance measures, the information products, and the measurement user feedback.

6.3.4.1.3 Store lessons learned in the Measurement Experience Base

Lessons learned take the form of strengths and weaknesses of the information products, of the measurement process, of the evaluation criteria themselves, or experiences in measurement planning (for example, "there was great resistance by the data providers to collecting a specific measure at a specific frequency").

6.3.4.2 Identify potential improvements

6.3.4.2.1 Identify potential improvements to the information products

Examples of changes to information products are changing the format of an indicator; changing from a linear measure to an area measure; minutes to hours, months, or years; or a line of code size measure to a functional size measure; or reclassification of defect categories.

Some changes to the information products require changes to the measurement process.

6.3.4.2.2 Identify potential improvements to the measurement

Such "Improvement Actions" are used in future instances of the "Plan the Measurement Process" activity.

The costs and benefits of potential improvements need to be considered when selecting the "Improvement Actions" to implement. Note that making a particular improvement is not always cost effective or the measurement process is good enough as it is, and therefore no potential improvements are identified.

6.3.4.2.3 Communicate potential improvements

Measurement process changes usually are provided to the process owner, and measurement product changes are usually provided to the measurement analyst(s).

If no potential improvements are identified in 6.3.4.2.1 and 6.3.4.2.2, then that is communicated.

Annex A
(informative)

The measurement information model

A.1 General

The measurement information model is a structure linking information needs to the relevant entities and attributes of concern. Entities include processes, products, projects, and resources. The measurement information model describes how the relevant attributes are quantified and converted to indicators that provide a basis for decision making.

The selection or definition of appropriate measures to address an information need begins with a measurable concept: an idea of which measurable attributes are related to an information need and how they are related. The measurement planner defines measurement constructs that link these attributes to a specified information need. This measurement information model (see Figure A.1) identifies basic terms and concepts. The measurement information model helps to determine what the measurement planner needs to specify during measurement planning, performance, and evaluation.

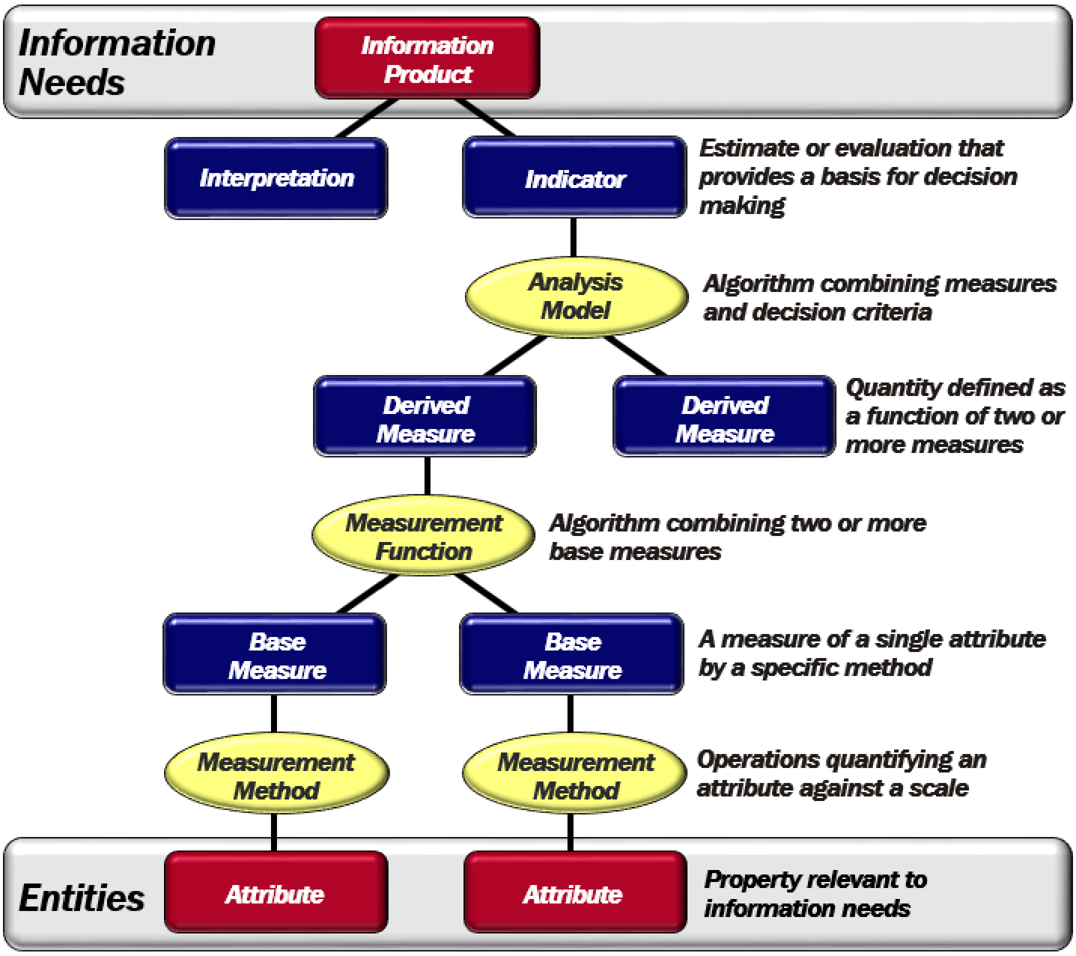

Figure A.1 — Key relationships in the measurement information model

A.2 Model description

Figure A.1 illustrates the relationships among the key components of the measurement information model. The model defines three types of measures: base measures, derived measures, and indicators. The information content of measures increases as they become closer in the model to the information need. Clause A.3 provides examples of instantiations of the model that address specific information needs. The individual components of the generic information model are described below.

A.2.1 Entity

An entity is an object (for example, a process, product, project, or resource) that is to be characterized by measuring its attributes. Typical engineering objects can be classified as products (e.g., design document, network, source code, and test case), processes (e.g., design process, testing process, and requirements analysis process), projects, and resources (e.g., the systems engineers, the software engineers, the programmers and the testers). An entity may have one or more properties that are of interest to meet the information needs. In practice, an entity can be classified into more than one of the above categories.

A.2.2 Attribute

An attribute is a property or characteristic of an entity that can be distinguished quantitatively or qualitatively by human or automated means. An entity may have many attributes, only some of which may be of interest for measurement. The first step in defining a specific instantiation of the measurement information model is to select the attributes that are most relevant to the measurement user's information needs. A given attribute may be incorporated in multiple measurement constructs supporting different information needs.

A.2.3 Base measure

A measure is defined in terms of an attribute and the method for quantifying it. (A measure is a variable to which a value is assigned.) A base measure is functionally independent of other measures. A base measure captures information about a single attribute. Data collection involves assigning values to base measures. Specifying the expected range or type of values of a base measure helps to verify the quality of the data collected.

A.2.3.1 Measurement method

A measurement method is a logical sequence of operations, described generically, used in quantifying an attribute with respect to a specified scale. The operations may involve activities such as counting occurrences or observing the passage of time. The same measurement method may be applied to multiple attributes. However, each unique combination of an attribute and a method produces a different base measure. Some measurement methods may be implemented in multiple ways. A measurement procedure describes the specific implementation of a measurement method within a given organizational context.

A.2.3.1.1 Type of measurement method

The type of measurement method depends on the nature of the operations used to quantify an attribute. Two types of method may be distinguished:

— Subjective — quantification involving human judgment.

— Objective — quantification based on numerical rules such as counting. These rules may be implemented by human or automated means.

A.2.3.1.2 Scale

A scale is an ordered set of values, continuous or discrete, or a set of categories to which the attribute is mapped. The measurement method maps the magnitude of the measured attribute to a value on a scale. A unit of measurement often is associated with a scale.

A.2.3.1.2.1 Type of scale

The type of scale depends on the nature of the relationship between values on the scale. Four types of scale are commonly defined:

Nominal — the measurement values are categorical. For example, the classification of defects by their type does not imply order among the categories.

Ordinal — the measurement values are rankings. For example, the assignment of defects to a severity level is a ranking.

Interval — the measurement values have equal distances corresponding to equal quantities of the attribute. For example, cyclomatic complexity has the minimum value of one, but each increment represents an additional path. The value of zero is not possible.

Ratio — the measurement values have equal distances corresponding to equal quantities of the attribute where the value of zero corresponds to none of the attribute. For example, the size in terms of the number of requirements is a ratio scale because the value of zero corresponds to no requirements and each additional requirement defined represents an equal incremental quantity.

NOTE These are just examples of the types of scales. Roberts [17] defines more types of scales.

The method of measurement usually affects the type of scale that can be used reliably with a given attribute. For example, subjective methods of measurement usually support only ordinal or nominal scales.

A.2.3.1.2.2 Unit of measurement

A particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitude relative to that quantity. Only quantities expressed in the same units of measurement are directly comparable. Examples of units include the hour and the meter.

A.2.4 Derived measure

A derived measure is a measure that is defined as a function of two or more values of base measures. Derived measures capture information about more than one attribute or the same attribute from multiple entities. Simple transformations of base measures (for example, taking the square root of a base measure) do not add information, thus do not produce derived measures. Normalization of data often involves converting base measures into derived measures that can be used to compare different entities.

A.2.4.1 Measurement Function

A function is an algorithm or calculation performed to combine two or more base measures. The scale and unit of the derived measure depend on the scales and units of the base measures from which it is composed as well as how they are combined by the function.

A.2.5 Indicator

An indicator is a measure that provides an estimate or evaluation of specified attributes derived from a model with respect to defined information needs. Indicators are the basis for analysis and decision-making. These are what should be presented to measurement users. Measurement is always based on imperfect information, so quantifying the uncertainty, accuracy, or importance of indicators is an essential component of presenting the actual indicator value.

A.2.5.1 Model

An algorithm or calculation combining one or more base or derived measures with associated decision criteria. It is based on an understanding of, or assumptions about, the expected relationship between the component measures or their behavior over time. Models produce estimates or evaluations relevant to defined information needs. The scale and measurement method affect the choice of analysis techniques or models used to produce indicators.

A.2.5.1.1 Decision criteria

Decision criteria are numerical thresholds or targets used to determine the need for action or further investigation, or to describe the level of confidence in a given result. Decision criteria help to interpret the results of measurement. Decision criteria may be calculated or based on a conceptual understanding of expected behavior. Decision criteria may be derived from historical data, plans, and heuristics, or computed as statistical control limits or statistical confidence limits.

A.2.6 Measurable concept

A measurable concept is an abstract relationship between attributes of entities and information needs. For example, an Information Need may be the need to compare the development productivity of a project group against a target rate. The Measurable Concept in this case is "development productivity rate". To evaluate the concept might require measuring the size of the system or software products and the amount of resource applied to create the products (depending on the chosen model of productivity). Additional examples of Measurable Concepts include quality, risk, performance, capability, maturity, and customer value.

A.3 Examples

The following subclauses provide examples of instantiations of the measurement information model that address specific information needs. These examples are not designed to recommend best measurement practices, but rather to show the applicability of the measurement information model in a variety of common situations.

A.3.1 A productivity example

The decision-maker in this example (Figure A.2) needs to select a specific productivity level as the basis for project planning. The measurable concept is that productivity is related to effort expended and number of requirements implemented. Thus, effort and requirements are the measurable entities of concern. This example assumes that the productivity is estimated based on past performance. Thus, data for the base measures (numbered entries in table below) needs to be collected and the derived measure computed for each project in the data store.

Regardless of how the productivity number is arrived at, the uncertainty inherent in engineering means that there is a considerable probability that the estimated productivity will not be realized exactly. Estimating productivity based on historical data enables the computation of confidence limits that help to assess how close actual results are likely to come to the estimated value.

Information Need	Estimate productivity of future project
Measurable Concept	Project productivity
Relevant Entities	1. Requirements implemented by past projects 2. Effort expended by past projects
Attributes	1. Shall Statements 2. Timecard entries (recording effort)
Base Measures	1. Project X Requirements 2. Project X Hours of Effort
Measurement Method	1. Count “Shalls” in Requirements Specification 2. Add timecard entries together for Project X
Type of Measurement Method	1. Objective 2. Objective
Scale	1. Integers from zero to infinity 2. Real numbers from zero to infinity
Type of Scale	1. Ratio 2. Ratio
Unit of Measurement	1. Line 2. Hour
Derived Measure	Project X Productivity
Measurement Function	Divide Project X Requirements Implemented by Project X Hours of Effort
Indicator	Average productivity
Model	Compute mean and standard deviation of all project productivity values.
Decision Criteria	Computed confidence limits based on the standard deviation indicate the likelihood that an actual result close to the average productivity will be achieved. Very wide confidence limits suggest a potentially large departure and the need for contingency planning to deal with this outcome.

Figure A.2 — Measurement construct for “productivity”

A.3.2 A quality example

The decision-maker in this example (Figure A.3) needs to evaluate detailed design quality as the design is being produced. The measurable concept is that design quality is related to the amount of design produced and the number of defects found. Thus, the design packages and the lists of defects are the entities of concern. Quality of design packages can be normalized by computing defect rate. Thus, data for the base measures (number entries in table below) is collected and the derived measure computed for each package as it is reviewed.

Since we do not really expect to get exactly the same defect rate for every package, we can compute control limits to determine if the defect rate on any package is different enough from the average to warrant concern.

Information Need	Evaluate product quality during design
Measurable Concept	Product quality
Relevant Entities	1. Design packages 2. Design inspection reports
Attributes	1. Text of inspection packages 2. Lists of defects found in inspections
Base Measures	1. Package X size 2. Total defects for package X
Measurement Method	1. Count number of lines of text for each package 2. Count number of defects listed in each report
Type of Measurement Method	1. Objective 2. Objective
Scale	1. Integers from zero to infinity 2. Integers from zero to infinity
Type of Scale	1. Ratio 2. Ratio
Unit of Measurement	1. Lines 2. Defects
Derived Measure	Inspection defect density
Measurement Function	Divide Total Defects by Package Size for each package
Indicator	Design defect density
Model	Compute process center and control limits using values of defect density
Decision Criteria	Results outside the control limits require further investigations

Figure A.3 — Measurement construct for "quality"

A.3.3 A project progress example

The decision-maker in this example (Figure A.4) needs to evaluate whether or not the rate of progress on a project is sufficient. The measurable concept is that progress is related to the amount of work planned and the amount of work completed. Thus, planned work items (system elements) are the entities of concern. This example assumes that the status (degree of completion) of each system element is reported monthly by the supplier assigned to it. Thus, data for the base measures (numbered entries in Figure A.4) needs to be collected and the derived measure computed for each work item in the plan.

Since the status of system elements is a subjective assessment, a simple numerical threshold is used as a decision criterion rather than statistical limits.

Information Need	Assess status of testing activity
Measurable Concept	Activity status
Relevant Entities	1. Plan/schedule 2. System elements completed or in progress
Attributes	1. System elements identified in plan 2. System element status
Base Measures	1. System elements planned to date 2. System element percent complete
Measurement Method	1. Count number of system elements scheduled to be completed by this date 2. Ask responsible individual for percent complete of each system element
Type of Measurement Method	1. Objective 2. Subjective
Scale	1. Integers from zero to infinity 2. Integers from zero to one hundred
Type of Scale	1. Ratio 2. Ordinal
Unit of Measurement	1. Unit 2. Percentage
Derived Measure	Progress to date
Measurement Function	Add status for all system elements planned to be complete to date
Indicator	Status expressed as a ratio
Model	Divide Progress to Date by (Units Planned to Date times 100)
Decision Criteria	Resulting ratio should fall between 0.9 and 1.1 to conclude the project is on schedule

Figure A.4 — Measurement construct for "progress"

Annex B
(informative)

Measurement process information items and records

This annex contains a mapping between the information items and records mentioned in this document and the activities or tasks that produce them (Figure B.1). Note that this annex only presents the final information items and records, not all of the intermediate information items and records that may need to be produced during the performance of the activities and tasks.

This document is not intended to prescribe the name, format, or explicit content of the information items and records to be produced. The document does not imply that information items and records be stored, packaged, or combined in some fashion. These decisions are left to the user of this document.

Information items and records	**Activity/Task producing Information items and records**
Information items and records produced externally	
Requirements for measurement	Technical and Technical Management Processes
Information Needs	Technical and Technical Management Processes
Measurement User Feedback	Technical and Technical Management Processes
Information items and records produced by “Plan the Measurement Process”	
Measurement strategy	6.3.2.1 Define the measurement strategy
Characterization of the Organization	6.3.2.2 Describe the characterizations of the organization
Selected and prioritized information needs	6.3.2.3 Identify and prioritize the information needs
Instantiated measurement information model for selected measures	6.3.2.4 Select and specify measures
Definition of selected measures	6.3.2.4 Select measures
Procedures for data collection, storage, and verification	6.3.2.5 Define data collection, analysis, and reporting procedures
Procedures for data analysis and reporting	6.3.2.5 Define data collection, analysis, and reporting procedures
Configuration management procedures	6.3.2.5 Define data collection, analysis, and reporting procedures
Criteria for the evaluation of the information products	6.3.2.6 Define criteria for evaluating the information products and the measurement process
Criteria for the evaluation of the measurement process	6.3.2.6 Define criteria for evaluating the information products and the measurement process
Selected supporting technologies	6.3.2.7 Acquire and deploy supporting technologies

Approved results of measurement planning	6.3.2.8 Review, approve, and provide resources for measurement tasks
Information items and records produced by “Perform the Measurement Process”	
Integrated data collection procedures	6.3.3.1 Integrate procedures
Stored data	6.3.3.2 Collect, store, and verify data
Data analysis results and interpretations	6.3.3.3 Analyze data and develop information items
Information items	6.3.3.4 Record results and inform users
Information items and records produced by “Evaluate Measurement”	
Measurement Experience Base (update)	6.3.4.1 Evaluate information products and the measurement process
Evaluation results	6.3.4.1 Evaluate information products and the measurement process
Improvement actions	6.3.4.2 Identify potential improvements

Figure B.1 — Information items and records of measurement activities

Annex C
(informative)

Example criteria for selecting measures

Many different combinations of base measures, derived measures, and indicators may be selected to address a specific information need. The following criteria are for considerations when selecting among alternatives:

- relevance to the prioritized information needs;
- feasibility of collecting the data in the organizational unit;
- availability of human resources to collect and manage data;
- ease of data collection;
- extent of intrusion and disruption of staff activities;
- availability of appropriate tools;
- protection of privacy;
- potential resistance from data provider(s);
- number of potentially relevant indicators supported by the base measure;
- increase or reduction of storage requirements;
- ease of interpretation by measurement users and measurement analysts;
- number of users or consumers of the information products utilizing the indicator;
- personal preference (e.g., individuals sometimes have their "favorite measure");
- life cycle stage applicability;
- evidence (internal or external to the organizational unit) as to the measure's fitness for purpose or information need, and its utility; and
- sensitivity to context (e.g., in some environments measures of inheritance depth for object oriented classes do not exhibit variation because inheritance is not used extensively; such a measure would not exhibit interesting behavior in this environment).

The costs of collecting, managing, and analyzing the data at all levels should also be considered. Costs include the following:

- Measures utilization costs: associated with each measure are the costs of collecting data, automating the calculation of the measure values (when possible), analyzing the data, interpreting the analysis results, and communicating the information products;
- Process Change Costs: the set of measures may imply a change in the development process, for example, through the need for new data acquisition;
- Organizational Structure Change Costs: the set of measures may imply a change in the organizational structure.

- Special Equipment: system, hardware, or software tools may have to be located, evaluated, purchased, adapted or developed to implement the measures; and
- Training: the quality management/control organization or the entire development team may need training in the use of the measures and data collection procedures. If the implementation of measures causes changes in the development process, the changes needs to be communicated to the staff.

NOTE This is adapted from IEEE Standard for a Software Quality Metrics Methodology, IEEE Std 1061-1998.

Annex D
(informative)

Example criteria for evaluating an information product

D.1 General

The effectiveness of each measurement construct used by the measurement process needs to be evaluated using pre-defined criteria. The following are examples of such criteria (i.e., this is not an exhaustive list). Some criteria are specific to base measures, derived measures, or indicators. Some of these criteria have been adapted from ISO/IEC TR 25023 for the evaluation of product measures. The following criteria are not necessarily independent of each other. In some cases the criteria can be used for a quantitative evaluation, and in other situations a qualitative evaluation may be appropriate. These criteria become even more important when the information products are part of a contractual agreement.

D.2 Use of information products

Use is the extent to which the information products produced by the measurement process are actually used for decision making in the management or technical processes supported by measurement.

For example, if as part of the analysis performed using the measurement data a decision model was constructed to decide whether a re-inspection should be performed, and the inspection moderator rarely uses the decision model to make the re-inspection decision, then the information products are not used.

Most of the criteria described below have an influence on the use of information products.

D.3 Confidence in an information product

Confidence is the extent to which the consumers of the information product (measurement users) have confidence in the base measures, derived measures, indicators and interpretations incorporated in the information product.

Confidence is improved when procedures to prevent misuse or misrepresentation of data have been adopted (for example, through traceability of all data items).

Greater confidence can be achieved by ensuring that the analysts are competent and unbiased, they are perceived to be competent and unbiased, and that the measurement users are involved in the process (for example, through regular feedback sessions).

D.4 Evidence of fitness for purpose of an information product

Fitness for purpose is the extent to which the information product can be demonstrated to be effective for the identified information need.

The interpretation of indicators should take into account the context in which measurement is being performed. Not all indicators work well in all situations. Data for a given base measure may be easier or harder to collect under different circumstances, thus affecting the desirability of an information product incorporating it. Confidence in the fitness for purpose of an information product increases as evidence accumulates for its effectiveness in this or similar environments.

Fitness for purpose includes the following:

— the extent to which the measure measures what it purports to measure; and

— measures that are used in a predictive sense should have a demonstrated capability to predict what they are supposed to predict.

To the extent that an information product provides comprehensive and appropriate feedback relative to its intended information need, the information product may be judged to be fit for its purpose.

D.5 Understandability of information products

Understandability is the ease with which the indicators and the interpretations of them can be understood by the intended measurement user.

If the information product is difficult to understand, then it is less likely to be used. This may be caused by the use of jargon in the interpretation or presenting indicators in ways that are not natural to the user. Volume alone may be an obstacle to understandability - lengthy reports are less likely to be read carefully.

D.6 Satisfaction of the assumptions of an indicator model

Satisfaction is the extent to which assumptions inherent in the model on which an indicator is based have been satisfied (e.g., data distributions, measurement scales, units of measure, sample size).

Statistical techniques often rely on assumptions about the data input to them. Even simple numerical techniques usually depend on some assumptions about what is being measured. The assumptions need to be documented and validated.

D.7 Accuracy of a measurement procedure

Accuracy is the extent to which the procedure implementing a base measure conforms to the intended measurement method. An accurate procedure produces results similar to the true (or intended) value of the base measure.

Measurement procedures implement the measurement methods described for base measures. These procedures may produce results different from what was intended due to problems such as systematic error in the procedure, random error inherent in the underlying measurement method, and poor execution of the procedure.

The actual human procedure or automated implementation of a base measure may depart from the measure's definition. For example, a static analysis tool may implement a counting algorithm differently from the way it was originally described in the literature. Discrepancies also may be due to ambiguous definitions of measurement methods, scales, units, etc. Even good measurement procedures may be inconsistently applied, resulting in the loss of data or the introduction of erroneous data.

Subjective methods depend on human interpretation. The formulation of questionnaire items, for example, may leave respondents uncertain about the question and even bias the responses. Clear and concise instructions help to increase the accuracy of surveys.

Accuracy can be enhanced by ensuring that, for example,

— the extent of missing data is within specified thresholds;

— the number of flagged inconsistencies in data entry are within specified thresholds;

— the number of missed measurement opportunities are within specified thresholds (e.g., the number of inspections for which no data were collected);

— inappropriate selection in the sampling process is avoided (e.g., not just satisfied users are surveyed to evaluate user satisfaction, or if only successful projects are evaluated to determine overall productivity); and

— all base measures are well-defined and those definitions are communicated to data providers.

Poorly defined measures tend to yield inaccurate data. The repeatability and reproducibility of the underlying measurement method (see below) may also limit the accuracy achievable by a measurement procedure.

D.8 Repeatability of a measurement method

Repeatability is the degree to which the repeated use of the base measure in the same Organizational Unit following the same measurement method under the same conditions (e.g., tools, individuals performing the measurement) produces results that can be accepted as being identical. Subjective measurement methods tend to experience lower repeatability than objective methods. Random measurement error reduces repeatability.

D.9 Reproducibility of a measurement method

Reproducibility is the degree to which the repeated use of the base measure in the same Organizational Unit following the same measurement method under different conditions (e.g., tools, individuals performing the measurement) produces results that can be accepted as being identical. Subjective measurement methods tend to experience lower reproducibility than objective methods. Random measurement error reduces reproducibility.

Annex E
(informative)

Example criteria for evaluating the performance of the measurement process

E.1 General

The quality of a process may be judged by assessing its capability (as described in ISO/IEC 33002) or by measuring and evaluating its performance. While this document, as a whole, may be used as a reference model for assessing the capability of a measurement process, this annex only addresses the evaluation of the performance of the measurement process.

Below is a set of *example* criteria that may be used for evaluating the performance of the measurement process. In some cases the criteria can be used for a quantitative evaluation, and in other situations a qualitative evaluation may be appropriate.

The following criteria may be regarded as potential information needs of the measurement process owner. The measurement process described in this document may be applied to produce information products that address the information needs identified by the measurement process owner.

E.2 Timeliness

The measurement process should provide information products in time to support the needs of the measurement user. Appropriate timing depends on the schedule of the management or technical process being supported.

E.3 Efficiency

The measurement process should not cost more to perform than the value of the information that it provides. The more efficient the process, the lower its cost, and the greater the cost/benefit.

E.4 Defect containment

The measurement process should minimize the introduction of erroneous data and results, while removing any that do get introduced as thoroughly and soon as possible.

E.5 Customer satisfaction

The users of information products should be satisfied with the quality of the information products (see Annex D) and the performance of the measurement process in terms of timeliness, efficiency, and defect containment. Satisfaction may be affected by the user's expectation of the level of quality and performance to be provided.

E.6 Process compliance

The execution of measurement activities should comply with any plans and procedures developed to describe the intended measurement process. This may be judged by quality management audits or process capability assessments.

Annex F
(informative)

Example elements of measurement planning

Subclause 6.3.2 identified the key measurement tasks that should be planned. The results of that planning effort and any other planning efforts may be collected into a measurement plan

The following are example elements that may be included in a measurement plan:

— characterization of the organizational unit;

— business and project objectives;

— prioritized information needs, and how they link to the business, organizational, regulatory, product or project objectives;

— definition of the measures and how they relate to the information needs;

— responsibility for data collection and sources of data;

— schedule for data collection (e.g., at the end of each inspection, monthly);

— tools and procedures for data collection (e.g., instructions for executing a static analyzer);

— data storage;

— requirements for data verification;

— data entry and verification procedures;

— data analysis plan including frequency of analysis and reporting;

— necessary organizational or process changes to implement the measurement plan;

— criteria for the evaluation of the information products;

— criteria for the evaluation of the measurement process;

— confidentiality constraints on the data and information products, and actions/precautions necessary to help ensure confidentiality;

— schedule and responsibilities for the implementation of measurement plan including pilots and organizational unit wide implementation;

— procedures for configuration management of data, measurement experience base, and data definitions.

Annex G
(informative)

Guidelines for reporting information items

The following items constitute a set of general criteria for reporting information items:

- limitations of the results and any other qualifications (e.g., limitations to the validity of the conclusions drawn);
- date or period when the data were collected;
- names and versions of tools used for performing statistical analysis;
- number of observations from which conclusions are drawn;
- sampling procedures that are used;
- assumptions underlying the analysis techniques that are used, and the results of any sensitivity analysis performed to check for robustness to violation of assumptions;
- precisely how aggregates are performed (e.g., average or weighted average);
- unit of observation about which conclusions are drawn (e.g., inspection package, configuration item);
- how missing data and anomalies were dealt with, where applicable;
- how outliers were dealt with during data analysis, where applicable;
- how combining data across different data sets was performed, where applicable;
- for any statistical tests, whether they are one or two sided;
- for any statistical tests, the alpha levels used (amount of acceptable error);
- for any statistical tests, how p values are calculated (the probability of getting the observed result or a more extreme one by chance);
- how confidence intervals are calculated, where applicable; and
- statistical methods used (including limits).

Not meeting the above criteria makes it difficult for the consumer of the information products to interpret them properly, and to have confidence in the conclusions drawn. Note that further reporting requirements may be necessary for particular data analysis techniques. Also, note that some of these reporting details may be included in appendices of analysis reports if they are not appropriate for the primary audience. The level of analysis may need to be tailored to the level of sophistication of the consumer or user.

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Abstract: This document provides an elaboration of the measurement process from ISO/IEC 15288 and ISO/IEC 12207. The measurement process is applicable to system and software engineering and management disciplines. The process is described through a model that defines the activities of the measurement process that are required to adequately specify what measurement information is required, how the measures and analysis results are to be applied, and how to determine if the analysis results are valid. The measurement process is flexible, tailorable, and adaptable to the needs of different users.

This document identifies a process that supports defining a suitable set of measures that address specific information needs. It identifies the activities and tasks that are necessary to successfully identify, define, select, apply, and improve measurement within an overall project or organizational measurement structure. It also provides definitions for commonly used measurement terms.

Keywords: 15939, measure, measurement, information needs, data, process, base measure, derived measure, indicator, measurable concept

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