Applications of the CMMI Model to Architecture

Lecture 52, v01

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About CMMI

About This Courseware

- As of this writing, the Capability Maturity Model Integration (CMMI) Model is at version 2.0
- Version 1.0 (and its subversions) were developed and maintained by the Software Engineering Institute (SEI) at the Carnegie Mellon University
- Version 2.0 are developed and maintained by the CMMI Institute at ISACA (Information Systems Audit and Control Association
- The majority of the material presented in this course is sourced from the Technical Report “CMMI for Development, Version 1.3”, Report Number CMU/SEI-2010-TR-033, by the Software Engineering Institute
- I, John Artus, make no claim of ownership of the material sourced from this technical report
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- This lecture material is currently being updated to reflect the contents of “CMMI for Development, Version 2.0”

What is CMMI?

- CMMI stands for Capability Maturity Model Integration
- This is a model by which Systems Engineering entities are independently assessed for the capability and maturity of their Systems and Software development processes and procedures
- Such entities generally prepare for an assessment in order to claim this industry-standard indication of their level of capability and maturity
- CMMI is a globally recognized assessment and is maintained and managed by the CMMI Institute at ISACA (Information Systems Audit and Control Association)
- According to ISACA:
  - ISACA owns and continually improves the CMMI model and authorizes partner organizations around the world to leverage the CMMI intellectual property to deliver CMMI appraisals and conduct official CMMI training

The CMMI Family of Models

- CMMI-ACQ Model
  - Focuses on activities for initiating and managing the acquisition of products and services
- CMMI-DEV Model
  - Focuses on activities for developing quality products and services
- CMMI-SVC Model
  - Focuses on activities for providing quality services to the customer and end users

As Systems Engineers, we are primarily concerned about applying the CMMI-DEV Model to our organizational activities

The CMMI-DEV Model

The CMMI-DEV Model

- CMMI-DEV is Capability Maturity Model Integration - Development
  - CMMI-DEV is an integrated set of best practices that improves performance and key capabilities for organizations that develop products, components, and services
  - It addresses practices that cover the product's lifecycle from conception through delivery and maintenance
  - The emphasis is on the work necessary to build and maintain the total product
- CMMI-DEV contains 22 process areas
  - 16 core process areas
  - 1 shared process area
  - 5 development-specific process areas

CMMI-DEV Process Areas

The 22 process areas are:

The System Architecture Development process exists within the CMMI-DEV Technical Solution (TS) Process Area

- Causal Analysis and Resolution (CAR)
- Configuration Management (CM)
- Decision Analysis and Resolution (DAR)
- Integrated Project Management (IPM)
- Measurement and Analysis (MA)
- Organizational Process Definition (OPD)
- Organizational Process Focus (OPF)
- Organizational Performance Management (OPM)
- Organizational Process Performance (OPP)
- Organizational Training (OT)
- Product Integration (PI)
- Project Monitoring and Control (PMC)
- Project Planning (PP)
- Process and Product Quality Assurance (PPQA)
- Quantitative Project Management (QPM)
- Requirements Development (RD)
- Requirements Management (REQM)
- Risk Management (RSKM)
- Supplier Agreement Management (SAM)
- Technical Solution (TS)
- Validation (VAL)
- Verification (VER)

Yellow highlighting indicates the 5 CMMI-DEV development-specific process areas

Improvement Paths

Improvement Path Representations

- CMMI-DEV describes two evolutionary paths of improvement for an organization's processes that it uses to develop products or services
- CMMI-DEV uses "levels" to describe advancement along these paths
- Continuous Improvement
  - This path enables organizations to incrementally improve processes corresponding to an individual process area (or group of process areas) selected by the organization
  - The continuous representation enables organizations to achieve "capability levels"
- Staged Improvement
  - This path enables organizations to improve a set of related processes by incrementally addressing successive sets of process areas
  - The staged representation enables organizations to achieve "maturity levels"

Capability Levels

CMMI Addresses Four Capability Levels

Continuous Improvement Representation

- Capability Level 0 – Incomplete
  - This describes a process that either is not performed or is partially performed
  - One or more of the specific goals of the process area are not satisfied
  - No generic goals exist for this level since there is no reason to institutionalize a partially performed process
- Capability Level 1 – Performed
  - This process is characterized as a performed process
  - This is a process that accomplishes the needed work to produce work products
  - The specific goals of the process area are satisfied
  - Although capability level 1 results in important improvements, those improvements can be lost over time if they are not institutionalized

CMMI Addresses Four Capability Levels (continued)

Continuous Improvement Representation

- Capability Level 2 – Managed
  - Characterized as a managed process
  - A managed process is a performed process that
    - Is planned and executed in accordance with policy
    - Employs skilled people having adequate resources to produce controlled outputs
    - Involves relevant stakeholders
    - Is monitored, controlled, and reviewed
    - Is evaluated for adherence to its process description
  - The process discipline reflected at this level helps to ensure that existing practices are retained during times of stress
  - The standards, process descriptions, and procedures can be quite different in each specific instance of the process (e.g., on each project)

CMMI Addresses Four Capability Levels (continued)

Continuous Improvement Representation

- Capability Level 3 – Defined
  - A defined process is a managed process that is tailored from the organization's set of standard processes according to the organization's tailoring guidelines
    - It has a maintained process description
    - It contributes process-related experiences to the organizational process assets
    - It clearly states the purpose, inputs, entry criteria, activities, roles, measures, verification steps, outputs, and exit criteria
  - The standards, process descriptions, and procedures for a project are tailored from the organization's set of standard processes
    - To suit a particular project or organizational unit
    - Therefore are more consistent
    - Except for the differences allowed by tailoring guidelines
  - Processes are typically described more rigorously than at capability level 2
  - Processes are managed more proactively using an understanding of the interrelationships of the process activities and detailed measures of the process and its work products

Maturity Levels

CMMI Addresses Five Maturity Levels

Staged Improvement Representation

- Maturity Level 1 – Initial
  - Processes are usually ad hoc and chaotic
  - The organization usually does not provide a stable environment to support processes
  - Success in these organizations depends on the competence and heroics of the people in the organization and not on the use of proven processes
  - In spite of this chaos, maturity level 1 organizations often produce products and services that work, but they frequently exceed the budget and schedule documented in their plans
- Maturity Level 2 – Managed
  - Projects have ensured that processes are planned and executed in accordance with policy
  - Projects employ skilled people who have adequate resources to produce controlled outputs
  - Projects involve relevant stakeholders
  - Projects are monitored, controlled, and reviewed
  - Projects are evaluated for adherence to their process descriptions
  - The process discipline helps to ensure that existing practices are retained during times of stress
  - When these practices are in place, projects are performed and managed according to their documented plans

Maturity Levels (continued)

Staged Improvement Representation

- Maturity Level 3 – Defined
  - Processes are well characterized and understood, and are described in standards, procedures, tools, and methods
  - The organization's set of standard processes, which is the basis for maturity level 3, is established and improved over time
  - These standard processes are used to establish consistency across the organization
  - Projects establish their defined processes by tailoring the organization's set of standard processes according to tailoring guidelines
  - The standards, process descriptions, and procedures for a project are tailored from the organization's set of standard processes to suit a particular project or organizational unit and therefore are more consistent except for the differences allowed by the tailoring guidelines
  - Processes are typically described more rigorously
    - A defined process clearly states the purpose, inputs, entry criteria, activities, roles, measures, verification steps, outputs, and exit criteria
  - Processes are managed more proactively using an understanding of the interrelationships of process activities and detailed measures of the process, its work products, and its services

Maturity Levels (continued)

Staged Improvement Representation

- Maturity Level 4 – Quantitatively Managed
  - The organization and projects establish quantitative objectives for quality and process performance and use them as criteria in managing projects
    - Quantitative objectives are based on the needs of the customer, end users, organization, and process implementers
  - Quality and process performance is understood in statistical terms and is managed throughout the life of projects
    - For selected subprocesses, specific measures of process performance are collected and statistically analyzed
    - When selecting subprocesses for analyses, it is critical to understand the relationships between differen subprocesses and their impact on achieving the objectives for quality and process performance
    - Such an approach helps to ensure that subprocess monitoring using statistical and other quantitative techniques is applied to where it has the most overall value to the business
  - Process performance baselines and models can be used to help set quality and process performance objectives that help achieve business objectives

Maturity Levels (continued)

Staged Improvement Representation

- Maturity Level 5 – Optimizing
  - The organization continually improves its processes based on a quantitative understanding of its business objectives and performance needs
    - The organization uses a quantitative approach to understand the variation inherent in the process and the causes of process outcomes
  - The organization continually improves its performance through incremental and innovative process and technological improvements
    - The organization's quality and process performance objectives are established, continually revised to reflect changing business objectives and organizational performance, and used as criteria in managing process improvement
    - The effects of deployed process improvements are measured using statistical and other quantitative techniques and compared to quality and process performance objectives
  - The project's defined processes, the organization's set of standard processes, and supporting technology are targets of measurable improvement activities

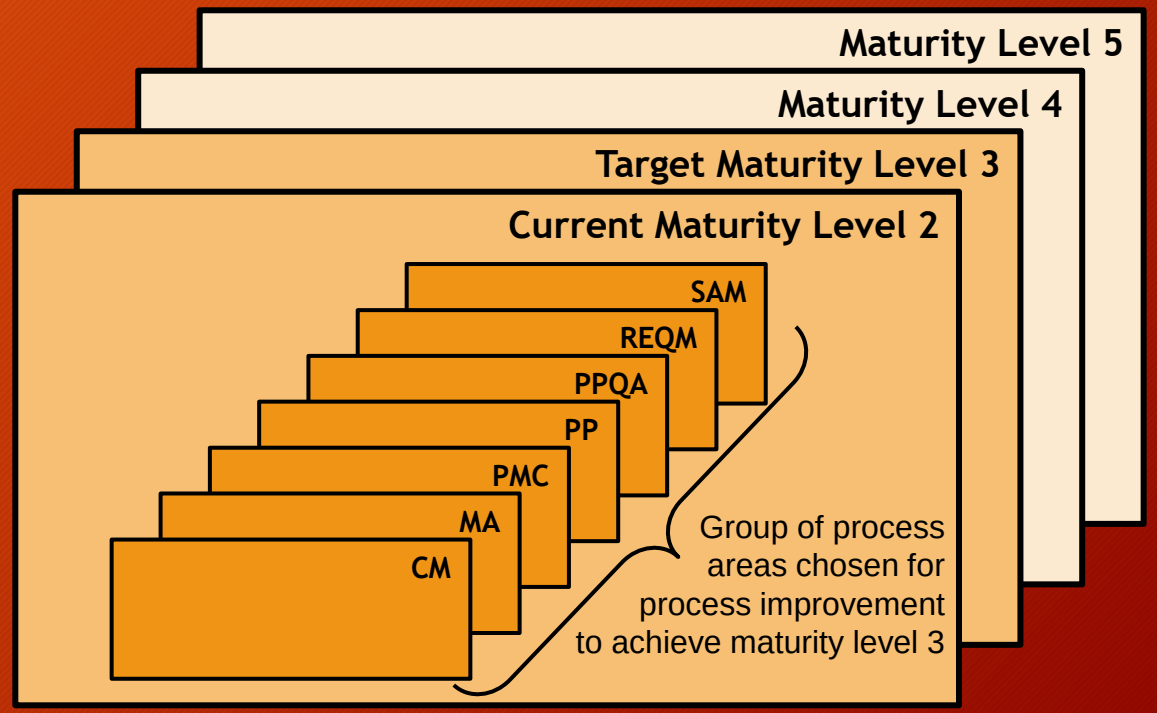
Level Comparison

Comparison of Capability and Maturity Levels

LEVEL	Continuous Representation Capability Levels	Staged Representation Maturity Levels
0	Incomplete	
1	Performed	Initialed
2	Managed	Managed
3	Defined	Defined
4		Quantitatively Managed
5		Optimizing

Improving Maturity (Staged Representation)

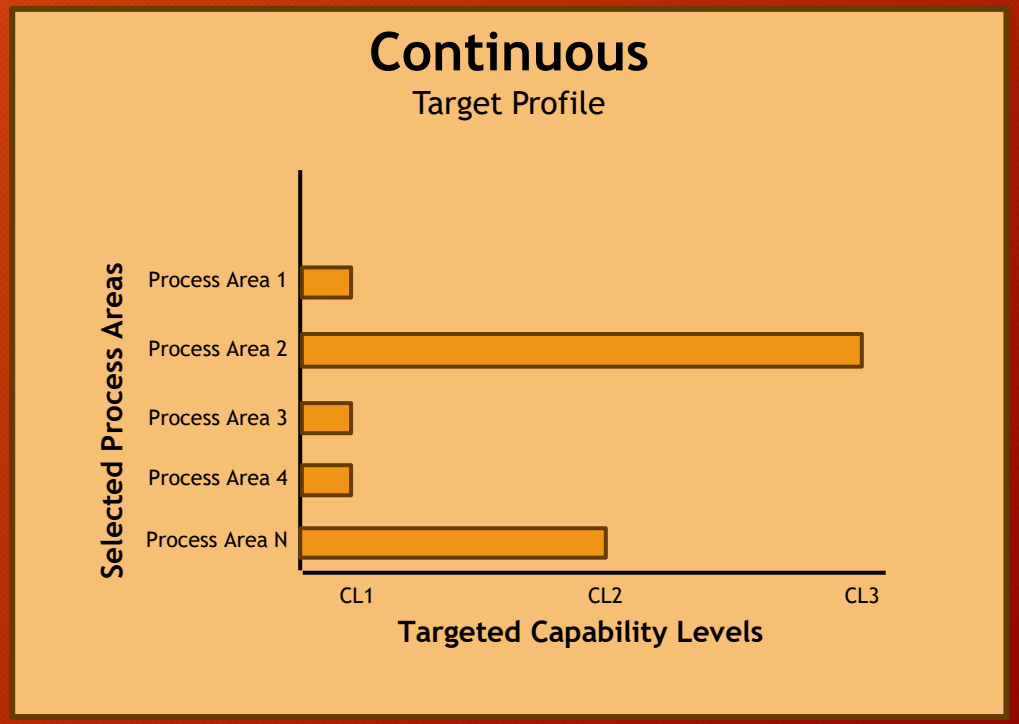
- Organizations can achieve progressive improvements in their maturity by
  - Achieving control first at the project level
  - Then continuing to the most advanced level:
    - Organization-wide performance management and continuous process improvement
    - Using both qualitative and quantitative data to make decisions
- As the organization achieves generic and specific goals for the set of process areas in a given maturity level
  - It increases its organizational maturity
  - It reaps the benefits of process improvement
- Each maturity level forms a necessary foundation for the next level
- Process improvement efforts should focus on the needs of the organization in the context of its business environment
- Process areas at higher maturity levels can address the current and future needs of an organization or project



Process Areas in the Staged Representation

Improving Maturity (Continuous Representation)

- The organization to chooses the focus of its process improvement efforts by choosing those process areas, or sets of interrelated process areas, that best benefit the organization and its business objectives
- Although there are some limits on what an organization can choose because of the dependencies among process areas, the organization has considerable freedom in its selection
- To support those who use the continuous representation, process areas are organized into four categories:
  - Process Management
  - Project Management
  - Engineering
  - Support
- These categories emphasize some of the key relationships that exist among the process areas
- Once process areas are selected, the next step is to select how much you would like to mature the processes associated with those process areas (i.e., select the appropriate capability level)
- Capability levels and generic goals and practices support the improvement of processes associated with individual process areas



Process Areas in the Continuous Representation

CMMI Goals and Practices

Process Area Goals and Practices

GOAL - The object toward which an endeavor is directed

PRACTICE – The performance or application of an action intended to advance an endeavor toward a goal

Generic Goals

- Called “generic” because the same goal statement applies to multiple process areas
- A generic goal describes the characteristics that must be present to institutionalize processes that implement a process area
- A generic goal is a required model component and is used in appraisals to determine whether a process area is satisfied

Generic Practicees

- Generic practices are called “generic” because the same practice applies to multiple process areas
- The generic practices associated with a generic goal describe the activities that are considered important in achieving the generic goal and contribute to the institutionalization of the processes associated with a process area
- A generic practice is an expected model component

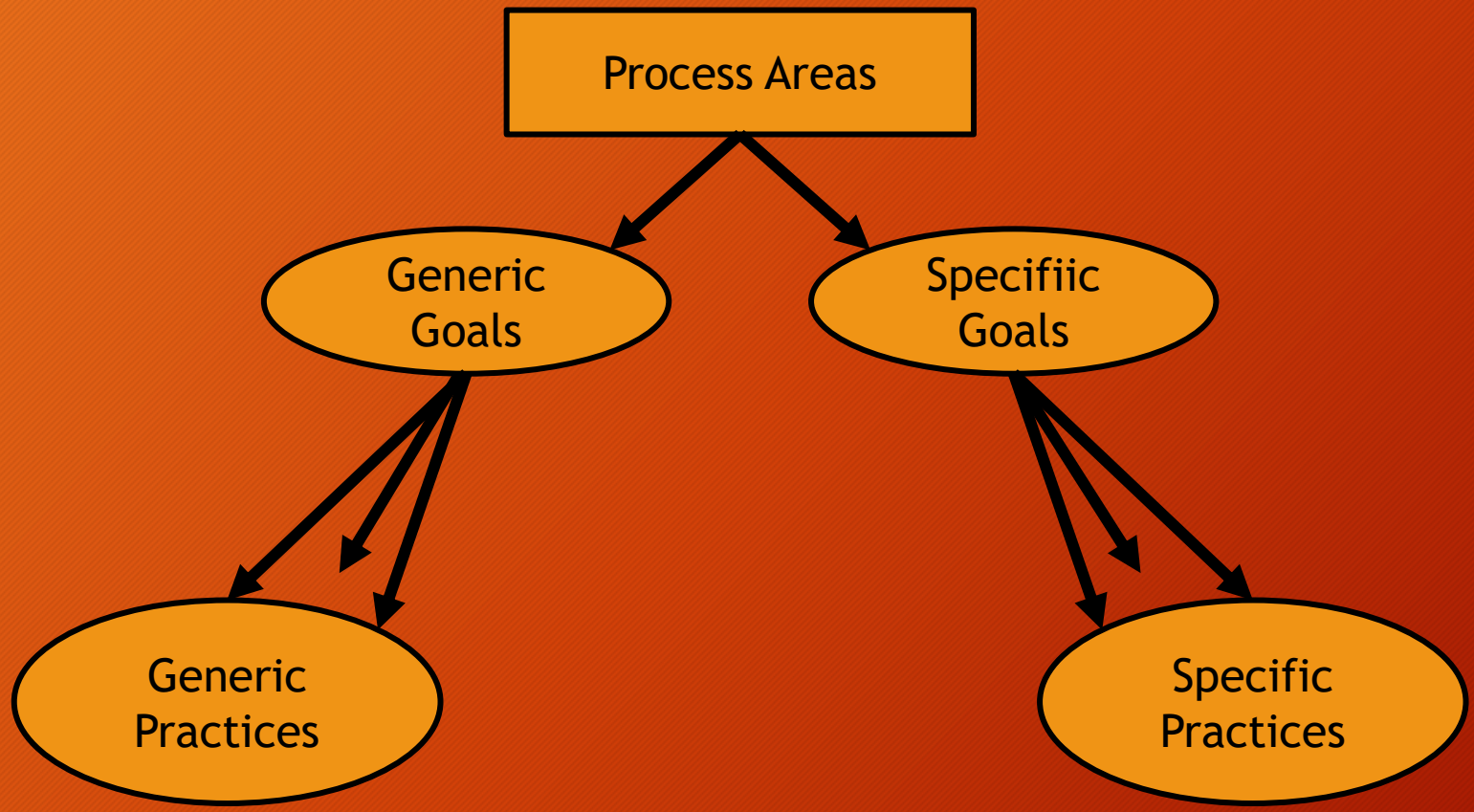
Specific Goals

- Describes the unique characteristics that must be present to satisfy the process area
- Is a required model component and is used in appraisals to help determine whether a process area is satisfied

Specific Practices

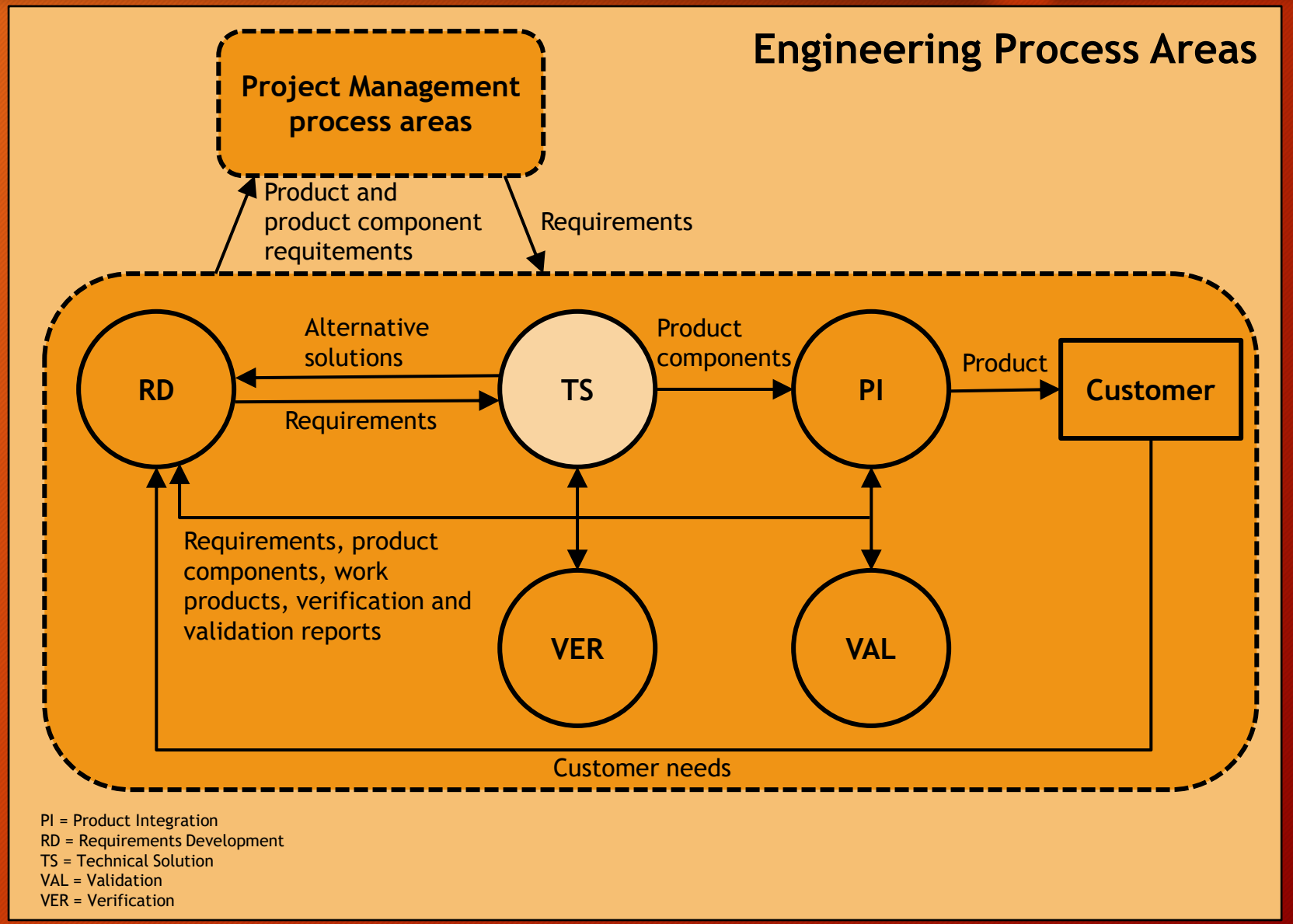
- A specific practice is the description of an activity that is considered important in achieving the associated specific goal
- The specific practices describe the activities that are expected to result in achievement of the specific goals of a process area
- A specific practice is an expected model component

CMMI Goals and Practices Structure



Engineering Process Areas

- The Engineering Process Areas integrate the processes associated with different engineering disciplines into a single product development process, supporting a product oriented process improvement strategy
- Such a strategy targets essential business objectives rather than specific technical disciplines
- The Engineering process areas apply to the development of any product or service in the development domain
  - Software products
  - Hardware products
  - Services
  - Processes



Generic Goals and Practices

Generic Goal 1 (GG1)

- **GG 1: Achieve Specific Goals**
  - **The specific goals of the process area are supported by the process by transforming identifiable input work products into identifiable output work products**

- GP 1.1: Perform Specific Practices
  - Perform the specific practices of the process area to develop work products and provide services to achieve the specific goals of the process area

Generic Goal 2 (GG2)

- **GG 2: Institutionalize a Managed Process**
  - **The process is institutionalized as a managed process**

- GPs are elaborated for all Process Areas
- Only the Elaboration for the TS Process Area is shown in this document

- GP 2.1: Establish an Organizational Policy
  - Establish and maintain an organizational policy for planning and performing the process

TS Elaboration:
This policy establishes organizational expectations for addressing the iterative cycle in which product or product component solutions are selected, designs are developed, and designs are implemented

In the form of company policies for performing these practices

- GP 2.2 Plan the Process
- Establish and maintain the plan for performing the process.

TS Elaboration:
This plan for performing the technical solution process can be part of (or referenced by) the project plan as described in the Project Planning process area

In the form of the company or program Architecture Management Plan

CMMI statements applicable to the System Architecture Definition Process are highlighted in yellow

Generic Goal 2 (GG2) (continued)

- GP 2.3: Provide Resources
  - Provide adequate resources for performing the process, developing the work products, and providing the services of the process

TS Elaboration:

Special facilities may be required for developing, designing, and implementing solutions to requirements

When necessary, the facilities required for the activities in the Technical Solution process area are developed or purchased

Examples of resources provided include the following:

- Design specification tools
- Simulators and modeling tools
- Prototyping tools
- Scenario definition and management tools
- Requirements tracking tools
- Interactive documentation tools

Described in the Architecture Management Plan

Generic Goal 2 (GG2) (continued)

- GP 2.4 Assign Responsibility
  - Assign responsibility and authority for performing the process, developing the work products, and providing the services of the process

TS Elaboration:

Appointing a lead or chief architect that oversees the technical solution an has authority over design decisions helps to maintain consistency in product design and evolution

Described in the Architecture Management Plan

- GP 2.5: Train People
  - Train the people performing or supporting the process as needed

TS Elaboration:

Examples of training topics include the following:

- Application domain of the product and product components
- Design methods
- Architecture methods
- Interface design
- Unit testing techniques
- Standards (e.g., product, safety, human factors, environmental)

Generic Goal 2 (GG2) (continued)

- GP 2.6 Control Work Products
  - Place selected work products of the process under appropriate levels of control

TS Elaboration:

Examples of work products placed under control include the following:

- Product, product component, and interface designs
- Technical data packages
- Interface design documents
- Criteria for design and product component reuse
- Implemented designs (e.g., software code, fabricated product components)
- User, installation, operation, and maintenance documentation

- GP 2.7: Identify and Involve Relevant Stakeholders
  - Identify and involve the relevant stakeholders of the process as planned

Described in the Architecture Management Plan

TS Elaboration:

Examples of activities for stakeholder involvement include the following:

- Developing alternative solutions and selection criteria
- Obtaining approval on external interface specifications and design descriptions
- Developing the technical data package
- Assessing the make, buy, or reuse alternatives for product components
- Implementing the design

Generic Goal 2 (GG2) (continued)

- GP 2.8 Monitor and Control the Process
  - Monitor and control the process against the plan for performing the process and take appropriate corrective action

TS Elaboration:

Examples of measures and work products used in monitoring and controlling include the following:

- Cost, schedule, and effort expended for rework
- Percentage of requirements addressed in the product or product component design
- Size and complexity of the product, product components, interfaces, and documentation
- Defect density of technical solutions work products
- Schedule for design activities

Described in the Architecture Management Plan

Generic Goal 2 (GG2) (continued)

- GP 2.9: Objectively Evaluate Adherence
  - Objectively evaluate adherence of the process and selected work products against the process description, standards, and procedures, and address noncompliance

TS Elaboration:

Examples of activities reviewed include the following:

- Selecting product component solutions
- Developing product and product component designs
- Implementing product component designs

Examples of work products reviewed include the following:

- Technical data packages
- Product, product component, and interface designs
- Implemented designs (e.g., software code, fabricated product components)
- User, installation, operation, and maintenance documentation

- GP 2.10 Review Status with Higher Level Management
  - Review the activities, status, and results of the process with higher level management and resolve issues

Process Area-Specific Goals and Practices

Only the TS Process Area is covered here

Technical Solution (TS) Description

- The purpose of Technical Solution (TS) is to select, design, and implement solutions to requirements
- Solutions, designs, and implementations encompass products, product components, and product related lifecycle processes either singly or in combination as appropriate
- SG 1 Select Product Component Solutions
  - SP 1.1 Develop Alternative Solutions and Selection Criteria
  - SP 1.2 Select Product Component Solutions
- SG 2 Develop the Design
  - SP 2.1 Design the Product or Product Component
  - SP 2.2 Establish a Technical Data Package
  - SP 2.3 Design Interfaces Using Criteria
  - SP 2.4 Perform Make, Buy, or Reuse Analyses
- SG 3 Implement the Product Design
  - SP 3.1 Implement the Design
  - SP 3.2 Develop Product Support Documentation

CMMI statements applicable to the System Architecture Definition Process are highlighted in yellow

Specific Goal 1 (SG1)

- SG 1: Select Product Component Solutions
  - Product or product component solutions are selected from alternative solutions
- SP 1.1: Develop Alternative Solutions and Selection Criteria
  - Develop Alternative Solutions and Selection Criteria

- Alternative solutions should be identified and analyzed to enable the selection of a balanced solution across the life of the product in terms of cost, schedule, performance, and risk
- These solutions are based on proposed product architectures that address critical product quality attribute requirements and span a design space of feasible solutions
- Specific practices associated with the Develop the Design specific goal provide more information on developing potential product architectures that can be incorporated into alternative solutions for the product

  - Subpractices
    - Identify screening criteria to select a set of alternative solutions for consideration
    - Identify technologies currently in use and new product technologies for competitive advantage
    - Identify candidate COTS products that satisfy the requirements
    - Identify re-usable solution components or applicable architecture patterns
    - Generate alternative solutions
    - Obtain a complete requirements allocation for each alternative
    - Develop the criteria for selecting the best alternative solution

CMMI statements applicable to the System Architecture Definition Process are highlighted in yellow

Specific Goal 1 (SG1) (continued)

- SP 1.2: Select Product Component Solutions
  - Select the product component solutions based on selection criteria

    - Selecting product components that best satisfy the criteria establishes the requirement allocations to product components
    - Lower level requirements are generated from the selected alternative and used to develop produc component designs
    - Interfaces among product components are described
    - Physical interface descriptions are included in the documentation for interfaces to items and activities external to the product

  - Subpractices
    - Evaluate each alternative solution/set of solutions against the selection criteria established in the context of the operational concepts and scenarios
    - Based on the evaluation of alternatives, assess the adequacy of the selection criteria and update these criteria as necessary
    - Identify and resolve issues with the alternative solutions and requirements
    - Select the best set of alternative solutions that satisfy the established selection criteria
    - Establish the functional and quality attribute requirements associated with the selected set of alternatives as the set of allocated requirements to those product components
    - Identify the product component solutions that will be reused or acquired
    - Establish and maintain the documentation of the solutions, evaluations, and rationale

Specific Goal 2 (SG2)

- SG 2: Develop the Design
  - Product or product component designs are developed
- SP 2.1: Design the Product or Product Component
  - Develop a design for the product or product component

> - Product design consists of two broad phases that can overlap in execution: preliminary and detailed design
> - Preliminary design establishes product capabilities and the product architecture, including architectural styles and patterns, product partitions, product component identifications, system states and modes, major intercomponent interfaces, and external product interfaces
> - Detailed design fully defines the structure and capabilities of the product components

  - Subpractices
    - Establish and maintain criteria against which the design can be evaluated
    - Identify, develop, or acquire the design methods appropriate for the product
    - Ensure that the design adheres to applicable design standards and criteria
    - Ensure that the design adheres to allocated requirements
    - Document the design

Specific Goal 2 (SG2) (continued)

- SP 2.2: Select Product Component Solutions
  - Select the product component solutions based on selection criteria

    - Selecting product components that best satisfy the criteria establishes the requirement allocations to product components
    - Lower level requirements are generated from the selected alternative and used to develop product component designs
    - Interfaces among product components are described
    - Physical interface descriptions are included in the documentation for interfaces to items and activities external to the product

  - Subpractices
    - Determine the number of levels of design and the appropriate level of documentation for each design level
    - Determine the views to be used to document the architecture
    - Base detailed design descriptions on the allocated product component requirements, architecture, and higher level designs
    - Document the design in the technical data package
    - Document the key (i.e., significant effect on cost, schedule, or technical performance) decisions made or defined, including their rationale
    - Revise the technical data package as necessary

Specific Goal 2 (SG2) (continued)

- SP 2.3 Design Interfaces Using Criteria
  - Design product component interfaces using established criteria

    - The criteria for interfaces frequently reflect critical parameters that should be defined, or at least investigated, to ascertain their applicability
    - These parameters are often peculiar to a given type of product (e.g., software, mechanical, electrical, service) and are often associated with safety, security, durability, and mission critical characteristics

  - Subpractices
    - Define interface criteria
    - Identify interfaces associated with other product components
    - Identify interfaces associated with external items
    - Identify interfaces between product components and the product related lifecycle processes
    - Apply the criteria to the interface design alternatives

Specific Goal 2 (SG2) (continued)

- SP 2.4 Perform Make, Buy, or Reuse Analyses
  - Evaluate whether the product components should be developed, purchased, or reused based on established criteria

    - The determination of what products or product components will be acquired is frequently referred to as a “make-or-buy analysis”
    - It is based on an analysis of the needs of the project
    - This make-or-buy analysis begins early in the project during the first iteration of design; continues during the design process; and is completed with the decision to develop, acquire, or reuse the product

  - Subpractices
    - Develop criteria for the reuse of product component designs
    - Analyze designs to determine if product components should be developed, reused, or purchased
    - Analyze implications for maintenance when considering purchased or nondevelopmental
      - e.g., COTS, government off the shelf, reuse) items

Specific Goal 3 (SG3)

- **SG 3: Implement the Product Design**
  - **Product components, and associated support documentation, are implemented from their designs**
- SP 3.1: Implement the Design
  - Implement the designs of the product components

    - Once the design has been completed, it is implemented as a product component
    - The characteristics of that implementation depend on the type of product component
    - Design implementation at the top level of the product hierarchy involves the specification of each of the product components at the next level of the product hierarchy
    - This activity includes the allocation, refinement, and verification of each product component. It also involves the coordination between the various product component development efforts

  - Subpractices
    - Use effective methods to implement the product components
    - Adhere to applicable standards and criteria
    - Conduct peer reviews of the selected product components
    - Perform unit testing of the product component as appropriate
    - Revise the product component as necessary

Specific Goal 3 (SG3) (continued)

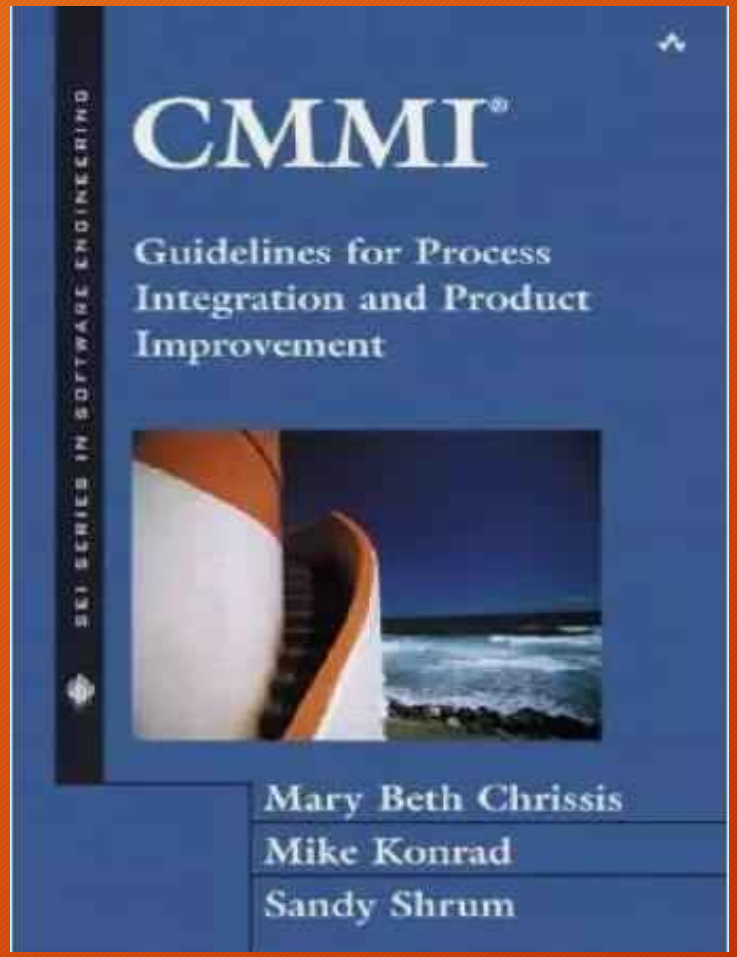
- SP 3.2: Develop Product Support Documentation
  - Develop and maintain the end-use documentationSelect the product component solutions based on selection criteria

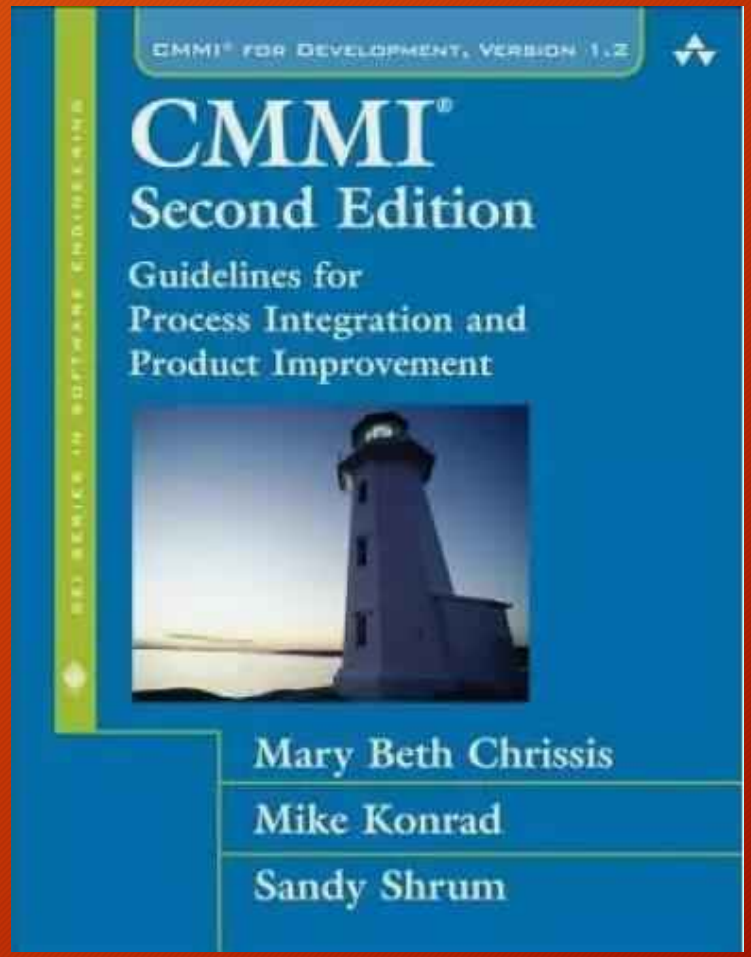
    - This specific practice develops and maintains the documentation that will be used to install, operate, and maintain the product

  - Subpractices
    - Conduct peer reviews of the installation, operation, and maintenance documentation
    - Revise the installation, operation, and maintenance documentation as necessary

CMMI v1 Textbook Availability

- Hardback textbooks covering CMMI Versions 1.1 and 1.2 are still available on eBay for as little as $5 US





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