Whitepaper Collection

Volume

8

Capability Maturity Model®

An Overview

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Alexander Gola
Gröbenzeller Strasse 37
82178 Puchheim, Germany
phone +49 89 84050934
mobile +49 172 5473831
e-mail alex@alexander-gola.de
web www.alexander-gola.de

Abstract
The Capability Maturity Model® (CMM) and its five levels, has become a standard for software engineering. The model is based on knowledge acquired from software process assessments and extensive feedback from both industry and government. The described maturity framework provides organizations with improvements for establishing effective processes and capability evaluations.
Today it is estimated that over 3000 organizations worldwide are using the model.

Modification History

Version	Date	Author	Description of Changes
0.1	01.03.2004	Alexander Gola	Initial Release
1.0	13.01.2005	Alexander Gola	First Release
1.1	18.01.2005	Alexander Gola	Enhancements, Chapter "Trademarks"
1.2	18.10.2005	Alexander Gola	Publishing Informations
1.3	26.01.2007	Alexander Gola	Changed company address

Table Of Contents

List Of Figures

List Of Tables

1 Capability Maturity Model® (CMM)

The Capability Maturity Model® (CMM) is an integrated model for system and software engineering process improvement, integrated product and process development improvement and supplier sourcing. It integrates best practices from disciplines such as software engineering and management, systems engineering and software acquisition that were typically addressed as separate improvement initiatives in the past.
The actual model release called Capability Maturity Model® Integration (CMMI℠) is the evolution of older, consolidated models (Software CMM, Systems Engineering CMM and Software Acquisition CMM) that provides a refined set of practices based on years of experience.

1.1 History

The Capability Maturity Model® is based on the vision by Watts Humphrey and Philip Crosby. The guideline was developed by the Software Engineering Institute (SEI), funded by Carnegie Mellon University beginning in 1986. This effort was initiated in response to the request of the U.S. Department of Defense to help address the software crisis that existed in the 1980's and to provide a method for assessing the capability of its contractors.
The authors determined that the quality was related directly to the quality of the process used to develop it. To improve application development processes, Humphrey wanted to implement the W. Edwards Deming continuous-improvement cycle "Plan-Do-Check-Act".

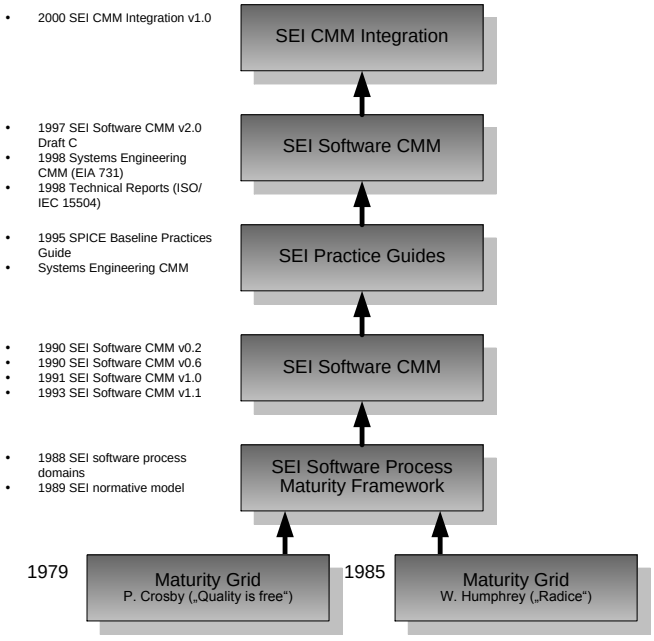

Figure 1 History

The initial release of the model was reviewed and used extensively during 1991 and 1992.
After many improvements the Capability Maturity Model® has become a de facto industry standard for assessing and improving processes. Today the model also covers practices for planning, engineering, managing development and maintenance activities. When followed, these key practices improve the ability of organizations to meet goals for cost, schedule, functionality and product quality.
The current official release, Version 1.1, was made available in February 1993.

1.2 Philosophy and Concepts

The model describes how software engineering practices in an organization evolve under certain conditions, particularly, the work performed is organized and viewed as a process and the evolution of the process is managed systematically.
The structure below describes the model. It shows the maturity levels, which are composed into several key process areas.

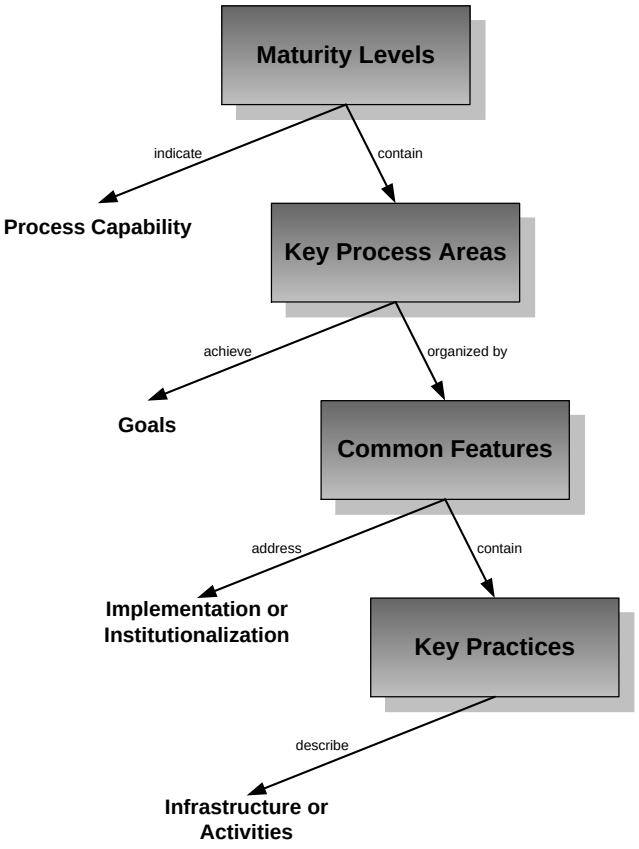

Figure 2 Structure

Each area is organized into five sections called common features. These will specify the key practices.

1.3 Model Types

All existing Capability Maturity Models® are used for several purposes, but the main focus for all is the same. They will help to guide process improvement efforts and help organizations establish and achieve improvement goals, provide a common language for cross-organizational communication and benchmarking, provide an integrating, organizing framework for endeavors and help to understand what specific practices to perform, how to improve its capability in performing those practices and what process areas to focus on next.

Model Type	Description
CMM Integration	The purpose of Capability Maturity Model® Integration is to provide guidance for improving your organizations processes and your ability to manage the development, acquisition and maintenance of products and services. CMM Integration places proven practices into a structure that helps your organization assess its organizational maturity and process area capability, establish priorities for improvement and guide the implementation of these improvements. Parts of this are • SE/SW - Software Engineering and System Engineering • SE/SW/IPPD - Software Engineering and System Engineering with Integrated Product and Process Development (focus on early, continuing stakeholder involvement) • SE/SW/IPPD/SS - Software Engineering and System Engineering with Integrated Product and Process Development (focus on early, continuing stakeholder involvement and supplier sourcing)
Software CMM	The Capability Maturity Model® for Software (SW-CMM) is a model for judging the maturity of the software processes of an organization and for identifying the key practices that are required to increase the maturity of these processes. The Software CMM has become a de facto standard for assessing and improving software processes.
Systems Engineering CMM	The Systems Engineering Capability Maturity Model® (SE-CMM) describes the essential elements of an organizations systems engineering process that must exist to ensure good systems engineering. In addition, the model provides a reference for comparing actual systems engineering practices against these essential elements.
Software Acquisition CMM	The Software Acquisition Capability Maturity Model® (SA-CMM) is a model for benchmarking and improving the software acquisition process. The model follows the same architecture as the Capability Maturity Model® for Software, but with a unique emphasis on acquisition issues and the needs of individuals and groups who are planning and managing software acquisition efforts.
People CMM	The People Capability Maturity Model® is a framework that helps organizations successfully address their critical people issues. Based on the best current practices in fields such as human resources, knowledge management and organizational development, the model guides organizations in improving their processes for managing and developing their work forces. It helps also

	organizations characterize the maturity of their workforce practices, establish a program of continuous workforce development, set priorities for improvement actions, integrate workforce development with process improvement and establish a culture of excellence.

Table 1 Model Types of CMM

The selection of a model is dependent upon the particular discipline or disciplines relevant to the organization within the scope of applicability to the organization.

1.4 Strategic Components

The CMM model consists of several parts. These parts are maturity levels, process capability levels, key process areas, goals, features and practices.

1.4.1 Maturity Levels

A maturity level is a defined platform toward achieving a mature process. The five maturity levels provide the top-level structure.

Maturity Level	Focus	Definition, Goals, Benefits and Characteristics
Initial (performed)	Competent people (and heroics)	The process is characterized as ad hoc and even chaotic. In most cases no required processes exists or few processes are defined and the success of this depends on individual efforts. Goals: • Identify Work Scope • Perform Base Practices Characteristics: • essential activities performed • process unstable and inconsistently performed • cost, schedule, quality objectives may not be met • practices are inconsistent
Repeatable (planned and tracked)	Project management processes	Basic management processes are established to track costs, schedule and functionality. The necessary process discipline is in place to repeat earlier successes. Goals: • establish and maintain organizational policy • plan, track and measure the process • provide resources • assign responsibility • train people • manage configurations • identify and involve relevant stakeholders • monitor and control the process • objectively evaluate adherence

		• review status with higher level management • assist and assure policy compliance Characteristics: • process is planned, documented, performed, monitored and controlled at the local (project/group) level • Process is institutionalized and has become an ingrained part of the way work is performed • Process achieves other objectives that are established, such as cost, schedule and quality objectives
Defined (standard)	Engineering processes and organizational support	The process for management and engineering activities is documented, standardized and integrated into a standard process for the whole organization. All projects use an adjusted version of the organization process for developing and maintaining products. Goals: • establish a defined process • collect improvement information • establish improvement infrastructure • identify and define processes • deploy and manage processes • collect process-level data • provide organization-wide trainings • coordination with other project groups Characteristics: • management establishes process objectives • organizations set of standard • processes is established and improved • standard process and process assets tailored for projects
Managed (measured)	Product and process quality	Detailed measures of the process and product quality are collected, the activities are quantitatively understood and controlled. Goals: • establish quality objectives • establish capability baselines • stabilize subprocess performance • manage processes quantitatively Characteristics: • process is controlled using statistical and other quantitative techniques • quantitative objectives for product quality, service quality and process performance are established and used as criteria in managing the process • people performing the process are directly involved in quantitatively managing the process • statistical predictability is achieved
Optimizing	Continuous process improvements	Continuous process improvements are enabled by quantitative feedback from the process and from piloting innovative ideas and technologies. Goals: • ensure continuous process improvement

		• correct common causes of problems • develop change infrastructure • evaluate and deploy improvements • eliminate causes of defects Characteristics: • process is improved, changed and adapted to meet business objectives • improve performance through technological improvements • quantitative process improvement objectives are established

Table 2 Maturity Levels

1.4.2 Process Capability Levels

Process capabilities describe the range of expected results that can be achieved by following a special process area. These process areas represent a minimum set of processes per level that cover the best practices needed to successfully address the complete life-cycle.

Process Areas	Capability Levels
Process Management	• Organizational Process Focus (OPF) • Organizational Process Definition (OPD) • Organizational Training (OT) • Organizational Process Performance (OPP) • Organizational Innovation and Deployment (OID)

Project Management	• Project Planning (PP)
	• Project Monitoring and Control (PMC)
	• Supplier Agreement Management (SAM)
	• Integrated Project Management for IPPD
	  • Integrated Project Management (IPM)
	  • Risk Management (RSKM)
	  • Integrated Teaming (IT)
	  • Integrated Supplier Management (ISM)
	  • Quantitative Project Management (QPM)

Engineering	• Requirements Development (RD) • Requirements Management (RM) • Technical Solution (TS) • Product Integration (PI) • Verification (VER) • Validation (VAL)
Support	• Configuration Management (CM) • Process and Product Quality Assurance (PPQA) • Measurement and Analysis (MA) • Organizational Environment for Integration (OEI) • Decision Analysis and Resolution (DAR) • Casual Analysis and Resolution (CAR)

Table 3 Process Capability Levels

All of these capabilities improve the power of a process by assuring that the specific goals are achieved and that there is a appropriate planning of the process to assure that it is possible and supported. They also ensure that stakeholders are properly involved in the activities of the complete process.

For a detailed explanation and checklist examples see the spreadsheets "CMM Generic Goal Checklist" and "CMM Specific Goal Checklist".

1.4.3 Key Process Areas

Each maturity level is composed of key process areas. Each of this identifies a cluster of related activities that, when performed collectively, achieve a set of goals considered important for establishing process capability at that maturity level. The key process areas have been defined to reside at a single maturity level.

Key Process Areas in CMM v1.1	Process Areas in CMMI v1.1
• Process Change Management • Technology Change Management • Defect Prevention	• Cause Analysis and Resolution • Organizational Innovation and Deployment
• Software Quality Management • Quantitative Process Management	• Quantitative Project Management • Organizational Process Performance
• Peer Reviews • Intergroup Coordination • Software Product Engineering • Integrated Software Management • Training Program • Organization Process Definition • Organization Process Focus	• Organizational Process Focus • Organizational Process Definition • Organizational Training • Integrated Project Management (for IPPD) • Risk Management • Decision Analysis and Resolution[1] • Integrated Teaming[1] • Requirements Development • Technical Solution • Product Integration[1] • Verification • Validation • Organizational Environment for Integration[1] • Integrated Supplier Management[1]
• Software Configuration Management • Software Quality Assurance • Software Subcontract Management • Software Project Tracking and Oversight • Software Project Planning • Requirements Management	• Requirements Management • Project Planning • Project Monitoring and Control • Measurement and Analysis[1] • Process and Product Quality Assurance • Configuration Management • Supplier Agreement Management[1]

[1] new process area or significant changes

Table 4 Key Process Areas

1.4.4 Goals

The goals summarize the key practices of a key process area and can be used to determine whether an organization or project has effectively implemented the key process area. The goals signify the scope, boundaries and intent of each key process area.

1.4.5 Common Features

The key practices are divided among five common features sections: Commitment to Perform, Ability to Perform, Activities Performed, Measurement and Analysis and Verifying Implementation. The common features are attributes that indicate whether the implementation and institutionalization of a key process area is effective, repeatable and lasting.

1.4.6 Key Practices

Each key process area is described in terms of key practices that, when implemented, help to satisfy the goals of that key process area. The key practices describe the infrastructure and activities that contribute most to the effective implementation and institutionalization of the key process area.

1.5 Strategic Levels

Each key process area comprises a set of goals that stabilize an important component of the process. Achieving each level of the maturity model institutionalizes a different component in the process, resulting in an overall increase in the process capability of the organization.

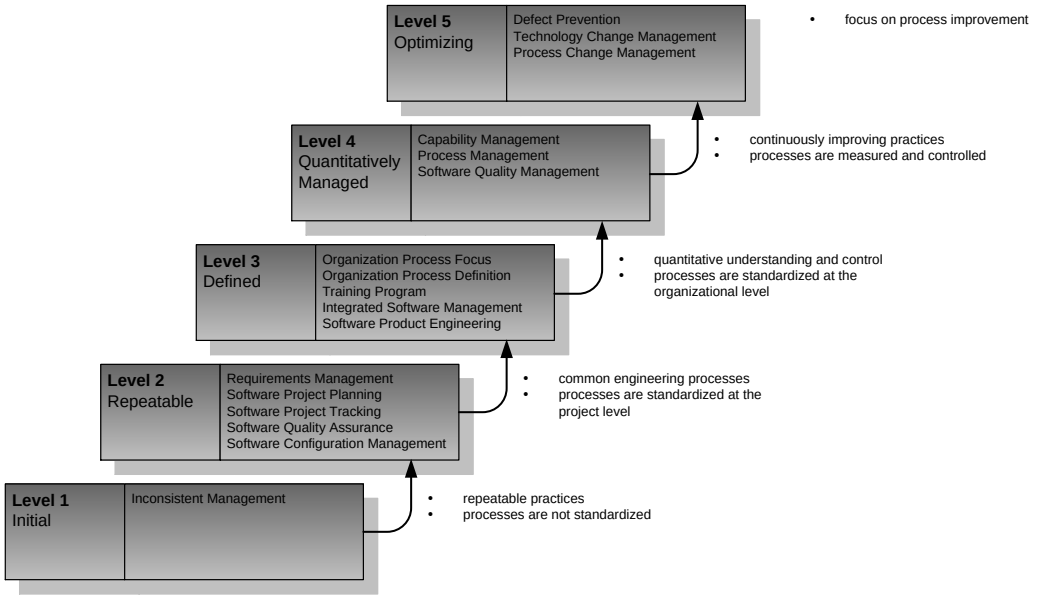

Figure 3 Levels

1.5.1 Initial Level

At this base level, application development practices and results are inconsistent. Development processes rarely are defined and sound practices often are sacrificed to meet unreasonable schedules.
Although developers are capable of performing their assignments, they do so through individualized methods that shows little consistency across the organization.

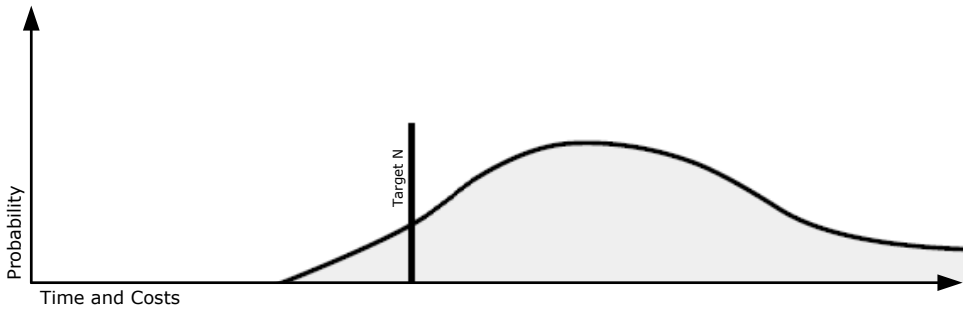

Figure 4 Initial Level

Frequently, project management is weak and does not protect developers from the disruption created by unreasonable commitments or excessive requirements changes. Essentially, the level organization lacks the capability to meet commitments consistently.

1.5.2 Repeatable Level

It is critical first to establish a stable environment that facilitates the repetition of successful practices.
Thus, this level focuses on developing the capabilities of project managers to plan achievable commitments and establish control of requirement baselines and product configurations.

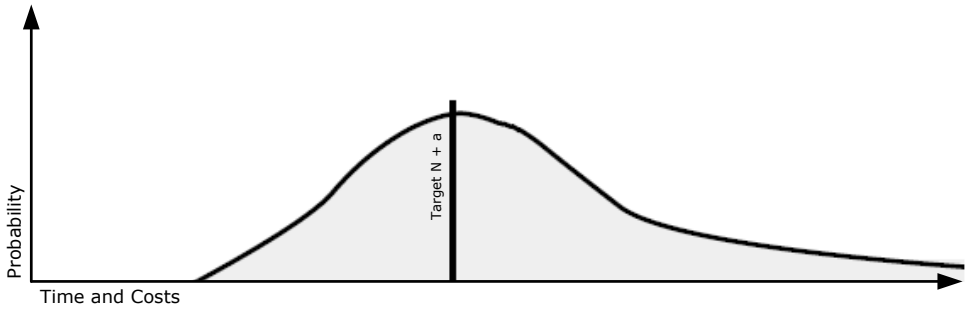

Figure 5 Repeatable Level

Although projects may use different methods or practices, the environment must be stabilized to support their performance. Organizations with these level capabilities deliver their applications on schedule without having to survive on heroes and constant overtime.

Process Areas: Requirements Management, Project Planning, Project Monitoring and Control, Supplier Agreement Management, Measurement and Analysis, Process and Product Quality Assurance, Configuration Management

1.5.3 Defined Level

After projects can repeat successful practices, organizations identify best practices from different projects.
Subsequently, these procedures are integrated into a common process and deployed across the organization. Hence, a strong organizational culture emerges at this level based on a common process that covers all the important elements of this model. Once all projects use tailored versions of a common process, an organization can begin comparing results, sharing lessons learned and transferring people more easily among projects.

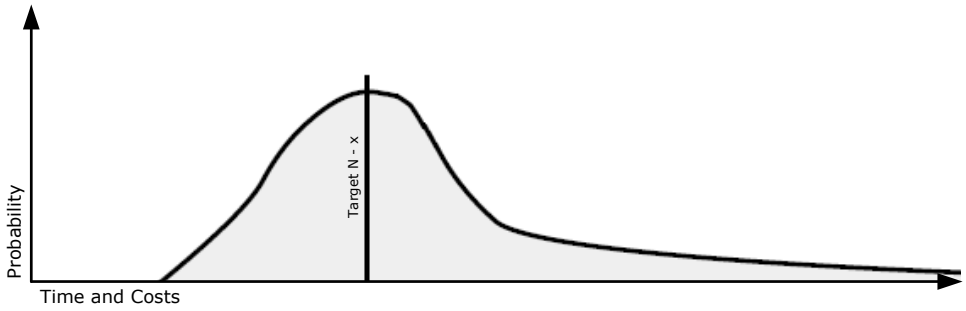

Figure 6 Defined Level

When an organization can begin estimating from historical data resulting from common processes, it is much easier to achieve targets for cost, functionality and scheduling.

Process Areas: Requirements Development, Technical Solution, Product Integration, Verification, Validation, Organizational Process Focus, Organizational Process Definition, Organizational Training, Integrated Project Management, Risk Management, Decision Analysis and Resolution

1.5.4 Managed Level

Having established common processes, an organization then can develop statistical capability baselines that characterize the expected results from performing these procedures.
These baselines provide a profound, quantitative understanding of the capability of development processes and the causes of variation in their performance. By managing the performance of its development processes statistically, an organization can predict and control project outcomes much earlier in the course of a project.

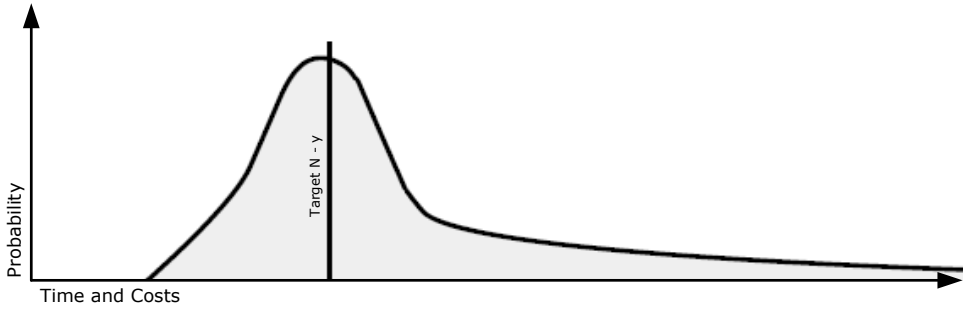

Figure 7 Managed Level

Quantitative management allows greater empowerment of project teams and increased predictability of results for project management.

Process Areas: Organizational Process Performance, Quantitative Project Management

1.5.5 Optimizing Level

Despite the achievement of predictable results, targeted business objectives may not be achieved.
At the highest level of maturity, an organization continuously evaluates the capability of its processes to pinpoint areas requiring the greatest improvement. Continuous improvements can be developed opportunistically by deploying the results of lessons learned, or they can be produced proactively by evaluating new development methods, processes or technologies for potential adoption.

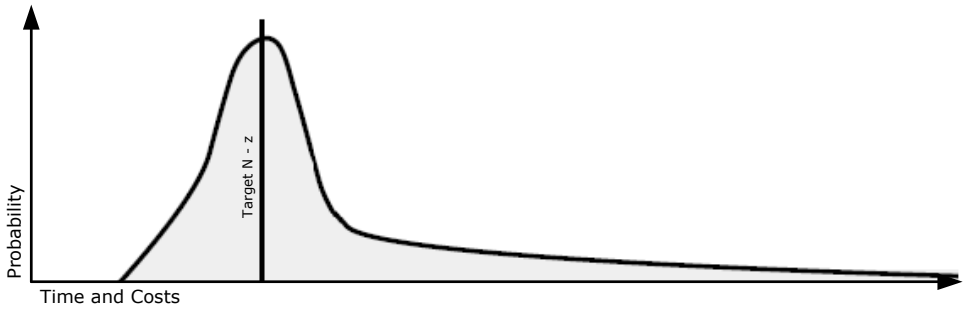

Figure 8 Optimizing Level

Ultimately, an organization at this level establishes an infrastructure for supporting continuous change management as a fundamental, integral component of its overall quality improvement process.

Process Areas: Organizational Innovation and Deployment, Causal Analysis and Resolution

1.6 Responsibilities

The model was developed specifically for those users who are system and product developers and want to improve their processes and products. Recognizing that development usually can be complex and require different players.
The users of the model can include the following person subgroups:

- enterprise executives
- product decision makers
- product developers
- product evaluators
- process owners
- process champions
- process improvement sponsors
- process improvement groups
- process developers
- process implementers
- process improvement consultants
- trainers
- assessors
- discipline specific professional organizations.

Each of these users has a role in the development of a system or product or in the processes that define a system, product or service. Collectively each has a role in determining what the processes will be in product development. The model will provide the tools to make decisions on processes, develop processes or support the process developers.

For a responsibility overview example see the spreadsheet "CMM Responsibility Overview".

1.7 Analyze and Improvements

A company chartered to improve a process area would typically proceed as follows:

- become familiar with the relevant process areas as described in the model
  - analyze the base practices, the goals and the activities performed key practices
  - identify overlaps and relationships between/among the practices
  - derive a combined list of practices
- become familiar with the current state of the relevant process in relation to the life-cycle phases and activity areas where these practices might be performed
  - analyze process information (guidelines, policies, charts, templates)
  - find out who carries out the processes across the life-cycle
- document the current process
  - describe current process
  - measure current process
- analyze current process
  - relate current process to combined list of best practices from the model
  - identify additional practices or missing practices; identify practices essential for success (regardless of practices contained in the model)
  - relate that desired process to generic practices of desired capability level
  - identify and prioritize areas for improvement
  - provide recommendations to chartering group
- improve the process according to agreed recommendations
  - plan for improvement (e.g. pilot strategy, pilot training, etc. or full rollout)
  - carry out selected improvement recommendations
  - measure improved process

1.7.1 Implementation Analysis

The implementation analysis is a qualitative analysis examining the communication, coordination and control processes necessary to insure referrals are made, services are coordinated across the different process areas and data are collected to evaluate the process.

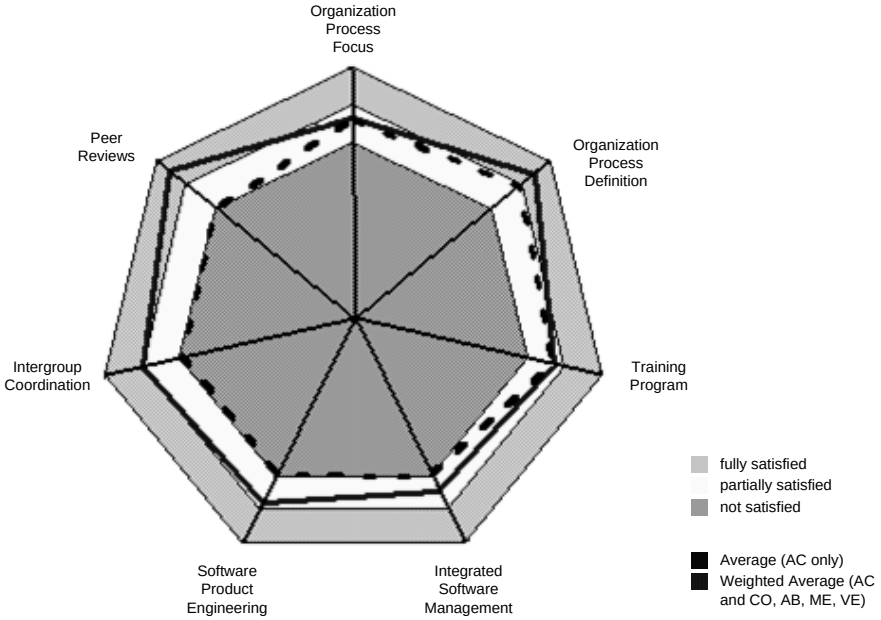

Figure 9 Implementation Analysis

1.7.2 Assessments

Formal and informal assessments are designed to engage the organization and demonstrate commitment to improvement. All assessment types have strict rules about non-attribution and data confidentiality.
To get full value out of an assessment, it is more important for the responsibilities to see management begin to take action with the most actual problems soon after the assessment.

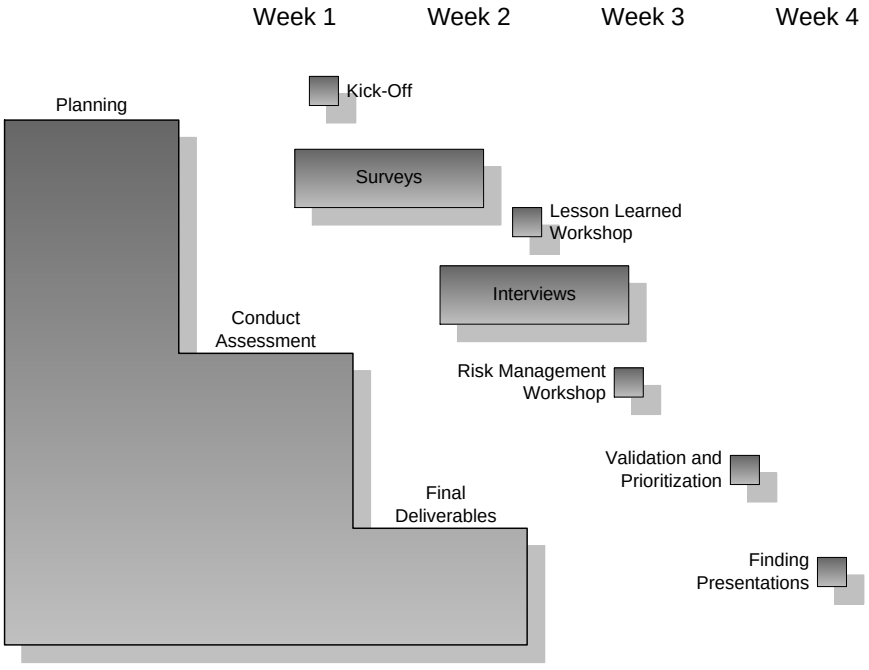

Figure 10 Assessment Timeline

A typical time frame for conducting the organizational assessment is 3 to 4 weeks, including planning, preparation and execution. Before the execution, members of the organization must prepare objective evidence that can be verified by the assessment team during the on-site activities.

Week 1 – Planning
This week initiates the assessment process, forms and educates the assessment team, customizes the assessment approach for client-specific requirements and prepares for the launch. Preparation involves review and potential refinement of the assessment project management survey questions.
The kick-off meeting is conducted at the conclusion of this week, formally launching the assessment process.

Week 2 – Survey Completion and Interviews
This week is reserved for the project team representatives to complete the surveys. The assessment team begins to review the survey responses and prepare and conduct the interviews as the completed surveys are submitted. Concurrently, the team conducts interviews with management and small groups of practitioners. Lessons learned facilitated sessions are conducted to quickly gather as much information about the organization as possible. The team members also review project deliverables and artifacts as pre- and post-interview activities to corroborate findings. All findings must be defensible and based in fact.

Week 3 trough Week 4 – Findings and Recommendations Validation and Prioritization
The assessment team collaborates on findings based on the survey responses, interviews and artifact reviews. The team then drafts findings in terms of strengths and recommendations to advance project performance. The individuals who participated in the assessment validate and prioritize the findings. The assessment team then prepares and delivers the project assessment reports and the executive presentation that presents the current state of project management practices and proposes recommendations for improvement.

1.7.3 Checkpoints

It is recommended managing the improvement activity like a project. There should be project manager and a weekly status meeting to track progress and to take any required corrective actions.
Each quarter, the project team typically performs a project checkpoint. During the checkpoint, the team will interview a subset of practitioners and managers, as well as examine data and analyze metrics collected over the last quarter. This can be used for a planning session covering activities for the next quarter.
Management is briefed on progress relative to the plan and on plans for the coming quarter. The briefing includes progress relative to the schedule, planned and actual costs, planned and actual savings to date and next quarter activities including planned costs and savings.

Typically that last checkpoint includes preparing the staff for the assessment that complete the improvement cycle and sets the stage for the next cycle.

1.7.4 Workshops

Once the management goals are set, the project team facilitates a workshop to build a plan to meet management goals.
The project team typically includes process owners, all members of the staff responsible for the process improvement activity as well as the project managers and some members of the senior technical staff selected for their influence and technical leadership qualities.
The workshop provides a foundation for the introduction and application of measurable process improvement practices within their organization, while helping avoid the typical pitfalls of model-based software process improvement. It also allows the team to identify, prioritize and establish a consensus about the opportunities for improvement that have the best chance at meeting management goals and provide the best overall return on investment.
The project team creates an overall plan for the year and a detailed plan for the next quarter. The plan includes

- clearly defined roles and responsibilities for all participants
- tasks
- required resources
- estimated costs
- detailed schedule
- predicted returns
- risk identification
- cost/benefit analysis
- quarterly improvement targets.

Later the team produces a presentation summarizing the plan. Using this presentation the company management and stakeholders has a good opportunity to review the plan, to ask questions and to define a commitment between all parties.

1.8 Requirements and Tools

Organizations need a way to manage the information, define and execute the general and specific processes and provide a platform for the collaboration and communication elements essential to the quality process. Each of the process areas has requirements and needs specific tools for information management, process management and collaboration.

1.8.1 Infrastructure

Without a common infrastructure, it would become difficult for organizations to fully implement a improvement process. To create a gainful environment, tasks, services and capabilities are required for all process areas.

Tasks
A few of the tasks to organizations in implementing the model are

- publish the generic practices developed, then to review all of the specific derived practices at each project
- measure and incorporate best practices or lessons learned from the specific practices back into the generic practices
- manage the information generated at both the generic level and the specific project level
- foster collaboration between the entire integrated team
- publish the information to all members of the team, including suppliers
- integrate the various tools used at the generic and specific level to ensure adequate information flow
- coordinate, share and get commitment to the establishment of a project plan
- monitor all aspects of the project plan to ensure reactive adjustments to change
- keeping everyone in the integrated team aware of all aspects of change
- providing a way for members of the distributed integrated team to perform and document peer reviews

Services
When looking at infrastructures, organizations should ensure that they have at least a set of services built in to facilitate deployment, e.g. configuration, defect and project management and project planning.

Capabilities
In addition, organizations must provide additional capabilities for implementation, e.g.

- workflow and process templates
- subscription services to work products
- comprehensive and dynamic reporting capabilities

- integration to other tools, e.g. configuration and requirements management and other authoring tools
- peer review support
- collaboration services
- decision and commitment logging
- internet accessible

1.8.2 Framework Integration

The framework is designed to provide an internally consistent set of common elements that apply to any discipline. It builds on and extends the best practices of the Capability Maturity Model® for Software (SW-CMM), the Systems Engineering Capability Maturity Model® (SE-CMM) and the Integrated Product and Process Development Capability Maturity Model® (IPPD-CMM). In summary these models will support process improvement activities, including assessments and training.
The framework currently consists of four parts: the input process, repository, control process and output process. Also the framework sorts, combines and arranges information to make it useful for the user and to tailor the information to the needs.

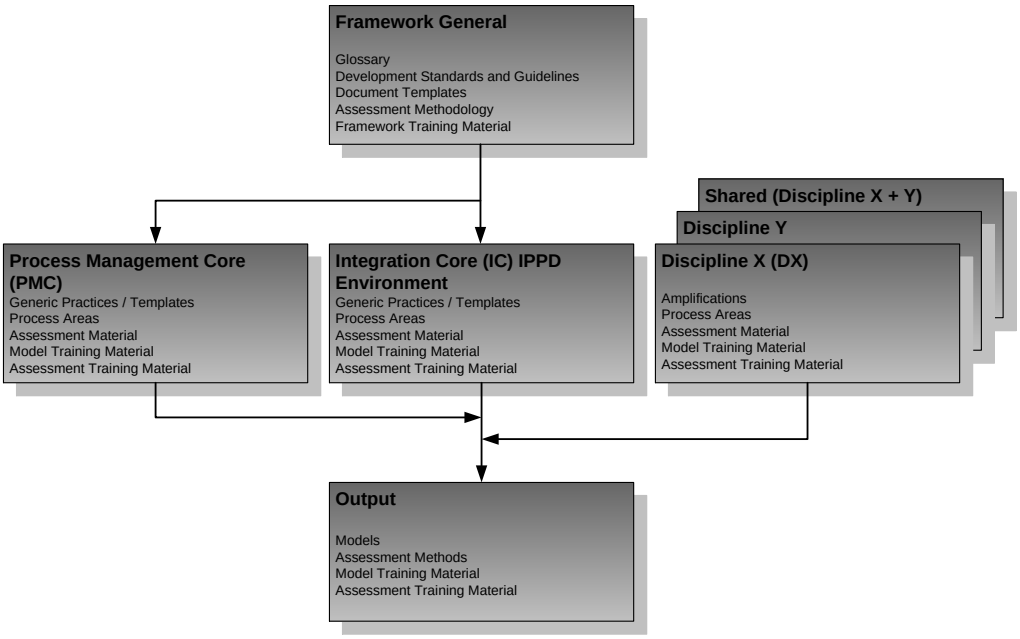

Figure 11 Framework

A user of the framework would specify various options based on the needs of the organization, such as disciplines that need to be covered, staged vs. continuous and inclusion of the IPPD environment.

- The Process Management Core (PMC) contains process management components that apply to all disciplines and all domains. These components are automatically included in the capability model.
- The Integration Core (IC) contains information about IPPD, which can be applied in virtually any discipline or domain.

- The Disciplines represent specific information that the user can select to include in the capability model. The initial model will include only two disciplines: software engineering and systems engineering. However, the framework is being designed so that it can accommodate new disciplines over time.

1.8.3 SCAMPI℠ Assessment Method

The SCAMPI℠ method was developed at the Software Engineering Institute (SEI) and is based on the CBA-IPI method. It was designed to provide benchmark quality ratings relative to CMM models. It is applicable to a wide range of appraisal usage modes, including both internal process improvement and external capability determinations.
The method consists of three phases, called Plan and Prepare for Appraisal, Conduct Appraisal and Report Results.

Plan and Prepare for Appraisal
This first phase includes the activities necessary to define the goals, scope and to obtain the commitment from the sponsor. During this phase a plan will be developed for conducting the appraisal, the appraisal team will be trained and the participants will be briefed about the appraisal process. Finally, members of the appraised organization typically prepare objective evidence, saving time and effort of a "discovery" process.

Conduct Appraisal
In this phase the appraisal team focuses on gathering data from the organization, to judge the extent to which the model is implemented and institutionalized. Appraisal finding ratings may be generated to determine process capability ratings, as well as a process maturity level rating for the appraised organization.

Report Results
During this final phase the appraisal results are presented to the sponsor. Strengths and weaknesses are presented for each process area within the appraisal scope as well as any non-CMM issues that affect the process.

The results of these phases are a formal organization rating, including the following results.

- The rating may be a maturity level that is recognized in the industry as indicating a specific development capability. Government or other customers sometimes require the achievement of certain maturity levels of their software contractors.
- The rating may be a capability level for each process area examined in the appraisal. This rating is used to quantify the capabilities of specific process areas without concern for the levels that are defined in the representation of CMM.
- A detailed report that identifies the strengths and weaknesses of the organizations development processes. The findings include specific practices that contributed to achieving the specified maturity or capability level, specific practices that contributed to not achieving a

higher maturity or capability level and practices that need attention, even though they did not prevent the achievement of a maturity or capability level.
- A list of recommendations for process improvement to identify a starting point.

For a result summary example see the spreadsheet "CMM Assessment Result Summary".

Links

Founded in 1984, the Software Engineering Institute (SEI) provides technical leadership to advance the practice of software engineering. Internationally recognized for its Capability Maturity Model® Integration (CMMI℠) technology and its CERT Coordination Center, the institute works with industry and government communities to help organizations identify and adopt new and improved software practices. The institute is a federally funded research and development center sponsored by the U.S. Department of Defense through the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. The main office is in Pittsburgh, Pennsylvania.

Homepage: http://www.sei.cmu.edu

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