Special Report
CMU/SEI-96-SR-003

Carnegie-Mellon University
Software Engineering Institute

CMM[sm] Version 1.1 Measurement Map

Robert E. Park

October 1996

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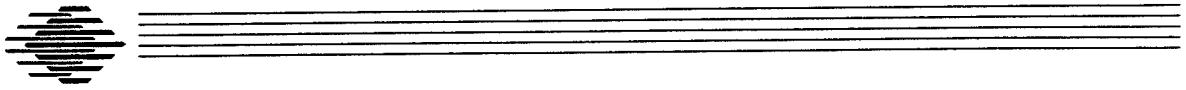

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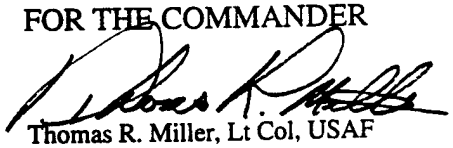

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SEI Joint Program Office

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Table of Contents

CMM v1.1 Measurement Map

Abstract: This report identifies and tabulates all references to software measures and measurement activities that appear in Version 1.1 of the Capability Maturity Model[sm] for Software (CMM[sm]). Each reference is listed in a structured format, and the results are sorted into topic areas in a way that is designed to help organizations plan the evolution of their measurement activities across the key process areas of the CMM. Where the CMM's guidance is unclear or incomplete, opportunities for improving the CMM are noted and explained.

1 Overview

Genesis and Structure

This report is the result of the author's attempt to identify all references to software measures and measurement activities that occur in Version 1.1 of the Capability Maturity Model for Software (CMM) [Paulk 93a, 93b, 95]. It presents a table that sorts the CMM's statements with respect to measurement into related topics and maps the sequencing of measurement activities across the levels of the CMM. The measurement map is presented in three parts, as follows:

The first page of each part lists the topics within that part of the measurement map and shows the page numbers within the map where the topics can be found.

[sm] CMM and Capability Maturity Model are service marks of Carnegie Mellon University.

Prerequisites

Users of this report and of the measurement map are presumed to have a basic familiarity with the CMM.

Objectives

The measurement map of the CMM was prepared with the following objectives in mind:

1. Consolidate and organize the guidance that the CMM provides with respect to software measurement.
2. Provide a systematic listing of measures and measurement activities that can help organizations assess the coverage and effectiveness of their software measurement practices, as they relate to the goals and key process areas of the CMM.
3. Identify and summarize the evolutionary progression of measurement activities that the CMM envisions as organizations progress to higher levels of process maturity.
4. Help organizations introduce software measures and measurement activities in ways that support a smooth progression up the maturity ladder.
5. Help practitioners identify where measures and measurement practices can be used for multiple purposes, so that economies in measurement can be achieved.
6. Identify ways in which the CMM's treatment of software measurement can be improved as the CMM evolves toward Version 2.0.

Current Applications

One major U.S. company with multiple sites and multiple lines of business is using the CMM measurement map in this report to provide a structure for assessing the measurement practices of its various software organizations. Extracts from the map are providing the baselines against which coverage and effectiveness of local measurement activities are being evaluated. The company's first objective is to understand where each operating organization stands with respect to installing and using measures that support their planned progressions to higher maturity levels. Its second objective is to identify opportunities for improving its measurement processes and practices.

Improving the CMM

In pulling the summary table together, numerous opportunities for improving the correctness, completeness, clarity, and consistency of the CMM's treatment of measurement and

statistical methods became apparent. These opportunities have been noted and explained in the comments within the table. The potential areas for improvement include

- making terminology, requirements, and examples of software measures and measurement activities internally consistent
- eliminating impossible or unproductive requirements and examples
- eliminating redundancies
- coordinating measures and measurement activities among key process areas, so that economies in collecting, storing, analyzing, and reporting measurement results can be achieved
- identifying closely related measures and measurement activities, so that opportunities for commonality and sharing can be exploited
- improving the evolutionary path of measurement practices across CMM maturity levels, so that measurement activities that appear useful for Levels 2 and 3 do not turn out to be counterproductive at Levels 4 and 5
- correcting errors and misunderstandings in the CMM's references to statistical methods and in its discussions of the use of control charts and statistical process control for managing and improving software processes
- improving coverage (Some important aspects related to measurement and the use of measurement results were found missing. These are identified and explained.)
- improving the clarity and correctness of the presentation and discussion of measurement issues
- providing guidelines and advice for the quantitative and operational aspects of software process databases, so that the databases may more effectively serve the estimating, planning, and process improvement needs of software organizations

The measurement map, together with and the comments and recommendations it contains, is being used as an input to the development of Version 2.0 of the CMM.

2 The Measurement Map

Format and Notation

Column One of the measurement map lists the actions, measures, indicators, and requirements for measurement that are mentioned in Version 1.1 of the CMM. Bold-faced type highlights specific measures and things to be measured.

Column two identifies the locations in the CMM where the references occur (sometimes there is more than one reference). The notation used is shown below. With this notation, entries such as "PP A7.5, PR Ab3" show that the item was mentioned in Activity 7.5 of the Software Project Planning KPA and in Ability 3 of the Peer Reviews KPA.

Symbol	Key Process Area (KPA)
Level 2	
RM	Requirements Management
PP	Software Project Planning
PTO	Software Project Tracking and Oversight
SM	Software Subcontract Management
SQA	Software Quality Assurance
SCM	Software Configuration Management
Level 3	
OPF	Organizational Process Focus
OPD	Organizational Process Definition
TP	Training Program
IM	Integrated Software Management
PE	Software Product Engineering
IG	Intergroup Coordination
PR	Peer Reviews
Level 4	
QPM	Quantitative Process Management
QM	Software Quality Management
Level 5	
DP	Defect Prevention
TCM	Technology Change Management
PCM	Process Change Management

Symbol	Section of the Key Process Area
G	Goals
C	Commitment to perform
Ab	Ability to perform
A	Activities performed
M	Measurement and analysis
V	Verifying implementation

Column 3 of the measurement map contains notes, observations, clarifications, and recommendations that represent the views of the author.

Columns 4–7 identify the categories into which the measures or activities fall. The notation used is as follows:

Symbol	Category
R	A required measure or action
I	Implied by a required measure or action
T	Classified by the CMM as a typical measure or action (i.e., alternatives are permitted)
E	Cited by the CMM as an example of a representative measure or action
X	Implied by an example measure or action

Users of the measurement map should keep in mind that the CMM contains no requirements. It is purely a descriptive model, not a prescriptive one. The author's use of the term "required" in this report should be interpreted in the sense that the measure or action is required if an organization is to be considered compliant with the CMM.

The CMM's View of Software Measurement

The measurement map is presented on the pages that follow. It consists of three parts, as shown below. The topics in each part are listed on the first page of the part.

CMM v1.1 Measurement Map

Part 1

The Software Process: Measures and Things to Be Measured

CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM	PP	PTO	SM	SQA	SCM	**Level 3** OPF	OPD	TP	IM	PE	IG	PR	**Lvl 4** QPM	QM	**Level 5** DP	TCM	PCM
Size																				
Size (estimated) for software work products	PP A7.5, A9 OPD A5.1, IM A5.3			R						E		E								
Size (estimated) for changes to software work products	PP A7.5, A9			R																
Size (estimated) of generated code	PTO A5.2				I															
Size (estimated) of fully tested	PTO A5.2				I															
Size (estimated) of delivered code	PTO A5.2				I															
Units (estimated) of delivered documentation	PTO A5.3				R															
Size (of the system) (planned)	IM A7.2											E								
Size (estimated/planned)	QPM A4.2	The CMM's slash here is confusing. Three interpretations are possible: "and," "or," and "ratio." A ratio may make sense as a process improvement or process control measure, but only for relatively sophisticated users (not Level 2). If "or" is intended, then it confuses the distinction between estimates and plans. "And" makes sense, but the CMM should not make readers work this hard to deduce its intent.														E				
Size (projected) of software work products (re-estimates based on actuals)	PTO A5.4				R															
Refine, monitor, and adjust on a regular basis.	PTO A5.4				R															
Size (revised estimates)	IM A5.3											E								
Examples of software size measurements (estimated?) include:	PP A9.1	The CMM says "measurement," but the context is estimating.																		
- function points	PP A9.1			E																
- feature points	PP A9.1			E																
- lines of code	PP A9.1			E																
- number of requirements	PP A9.1			E																
- number of pages	PP A9.1			E																
Types of work products for which size estimates are made include:																				
- operational software	PP A9.1			E																
- support software	PP A9.1			E																
- deliverable work products	PP A9.1			E																
- nondeliverable work products	PP A9.1			E																
- software and nonsoftware work products (e.g., documentation)	PP A9.1			E																
- activities for developing, verifying, and validating work products	PP A9.1			E																
Use a documented procedure to estimate size of work products and changes to size of work products.	PP A9			R																
Estimate the sizes of all major software work products and activities.	PP A9.1	Since "major" is undefined, almost any decomposition satisfies. Because granularity is addressed in PP A9.2, the issue here appears to be one of completeness (everything is covered) rather than refinement through decomposition. Perhaps the CMM would be improved if it made its intent clear.		T																
Decompose work products to the granularity needed to meet estimating objectives.	PP A9.2			T																
Use historical data.	PP A9.3			T																
Document all assumptions.	PP A9.4			T																
Document and review estimates.	PP A9.5			T																

Measures and things to be measured are shown in bold face.

R = Required **I** = Implied T = Typical E = Example X = Implied by Example

CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM	PP	PTO	SM	SQA	SCM	**Level 3** OF	OPD	TP	IM	PE	IG	PR	**Lvl 4** QPM	QM	**Level 5** DP	TCM	PCM
Size (actual) of generated code	PTO A5.2	Implies periodic measurement & reporting			R															
Size (actual) of fully tested code	PTO A5.2	Implies periodic measurement & reporting			R															
Size (actual) of delivered code	PTO A5.2	Implies periodic measurement & reporting			R															
Size (actual) for (major) software work products	PTO A5, A5.1 OPD A5.1, IM A5.1, A5.3				R					E		E								
Size (actual) for changes to (major) software work products	PTO A5, A5.1	"Major" = ??			R															
Track the above measures.	PTO A5, A5.1	Implies periodic measurement, reporting, and review			R															
Units (actual) of delivered documentation	PTO A5.3	Implies periodic measurement & reporting			R															
Size (of the system) (actual)	IM A7.2											E								
Size (actual)	QPM A4.2															E				
A group independent of the software engineering group																				
- reviews the procedures for estimating size (and changes to size) of software work products	IM A6.1											T								
- provides guidance in using historical data to establish credible estimates	IM A6.1											T								
(An example of an independent group is a software estimating group.)	IM A6.1											E								
(An example of a method to evaluate size credibility is function-by-function comparison to a completed system.)	IM A6.1											E								
Individuals who prepare size estimates ensure the procedures and data they use are appropriate.	IM A6.1											T								
When the validity of a size estimate is questioned, a team of peers and experts reviews the estimate.	IM A6.1											T								
Apply contingency factors to the size estimates for each software element identified as a software risk.	IM A6.2											T								
Document the rationale for the contingency.	IM A6.2											T								
Assess and document the risks associated with eliminating the contingency.	IM A6.2											T								

Complexity																				
		Presumably data about these go into the software process database. The CMM is silent about this.																		
Complexity (of the system)	IM A7.2	Cantor's theorem suggests that no (single) real-valued measure for complexity is feasible. It is possible, though, to construct ordinal measures for specific attributes of complexity [Fenton 91, pp32-33]. The CMM should be reworded here to avoid setting an impossible standard.										E								
Geographic locations of the project's groups, organizations, and subcontractors	IM A7.2											E								
Host environment (for development)	IM A7.2											E								
Target environment	IM A7.2											E								
The developer's familiarity with the application	IM A7.2											E								
The developer's experience with the application	IM A7.2	This should read "experience with the type of application," not with the application itself.										E								
Availability of resources	IM A7.2											E								
Other special constraints	IM A7.2											E								

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM PP PTO PSM QA SCM	**Level 3** OF OD PTP IM PE IG PR	**Lvl 4** QPM QMM	**Level 5** DP TCM PMM
Reuse		Reuse measurement is closely coupled to size measurement. The CMM errs in deferring reuse measurement to Level 3. Reuse estimates and measures must be used at Level 2 for project planning and project tracking, so that size measures can be interpreted correctly.				
Identify off-the-shelf or reusable components.	IM A6.3			T		
Use this information to manage size and as a basis for reuse measures.	IM A6.3	This Level-3 information is needed for Level-2 KPAs.		I		
Reuse measures	IM A6.3			T		
Account for reuse of requirements, design, code, test plans, & test procedures.	IM A6.3			T		
The effort to modify and incorporate reusable components is factored into the size estimates.	IM A6.3	This doesn't make sense! You can have size=>size, effort=> effort, or size=>effort, but not effort=>size.		T		
Degree of program modification	TCM Ab4					E
Computer resources						
Computer memory capacity (estimated)	PP A11.1		E			
Communication channel capacity (estimated)	PP A11.1		E			
Processor use (estimated)	PP A11.1		E			
Critical computer resource usage (estimated)	PP A7.7	Measures for describing capacities and usages	R			
Use a documented procedure.	PP A11		R			
Relate estimates to size of work products, operational processing load, and communications traffic.	PP A11.2		T			
Estimate usage for each major software component.	PTO A7.1		R			
Base estimates on historical experience, simulations, prototyping, or analysis.	IM A8.1			T		
Record the similarities and differences between the project and the historical data.	IM A8.1			T		
Record the reasoning used to judge the credibility of the estimates.	IM A8.1			T		
Document sources and rationales.	IM A8.1			T		
Document and review estimates.	PP A11.3		T			
Document changes that affect software commitments.	PTO A7.2	Updated projections should be documented too.	R			
Critical computer resource usage (projected)	PTO A7.1	The context implies that "projected" = updated estimates.	R			
Track and compare to plan.	PTO A7.1		R			
Document changes that affect software commitments.	PTO A7.2		R			
Critical computer resource usages (actual)	PTO A7, A7.1		R			
Track and compare to plan.	PTO A7.1		R			
Critical computer resources (available capacities) (actual)	IM A8.3, A8.4			T		
Critical computer resource capacities (planned)	IM A8.4	Planned values can (and often do) differ from estimates.		T		
Critical computer resources (reserve capacities) (planned)	IM A8.4	If estimating and measuring computer resources are so important to Level 2, it seems strange that the CMM defers planning for these issues until Level 3.		T		

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Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM	PP	TO	SM	SA	CM	**Level 3** OF	OD	PP	TM	IE	IG	PR	**Lvl 4** PM	QM	**Level 5** DP	TM	CM
Support Facilities																				
Capacity requirements (estimates) for support facilities	PP A14.1		R																	
Base estimates on estimated sizes of software work products.	PP A14.1		R																	
Examples of support facilities include development computers & peripherals, test computers & peripherals, target computer environment software, and support software.	PP A14.1		E																	
Effort																				
Software effort (estimated) for the project	PP A7.6, A10, PTO A6, IM A5.3		R	R								E								
Use a documented procedure when deriving estimates.	PP A10		R																	
Base estimates on past experience.	PP A10.3		T																	
Use historical data where appropriate.	IM A7.1											T								
Use similar projects when possible.	PP A10.3		T																	
Use productivity data (historical or current).	PP A10.2	For productivity data to be meaningful, there must be mechanisms for normalizing productivities across differing projects and situations. This implies the need for a rationale and structure for attributing cause and effect, so that results can be related to controllable or environmental parameters. Perhaps the CMM should address this. It is unlikely that effective estimating can ever be reduced to simple productivity numbers. The real issues here are cost model use and cost model calibration.	T																	
Relate estimates to estimates for size of work products or changes.	PP A10.1		T																	
Document and review assumptions.	PP A10.4		T																	
Document and review estimates.	PP A10.4		T																	
Document effort estimates in the software development plan.	PTO A6.3			R																
Adapt the models used to estimate effort to the project.	IM A7.1											T								
Update the parameter values of the models used in estimating software effort whenever major changes are made to the software requirements.	IM A7.4											T								
Effort distribution (estimated) over the software life cycle	PP A10.3		T																	
Effort (estimated) for software work products	OPD A5.1									E										
Effort allocated to individually managed tasks or stages	IM A7.3											T								
Effort (estimated) to modify and incorporate reusable components	IM A6.3											T								
Factor effort into the size estimates.	IM A6.3	This doesn't make sense! You can have size=>size, effort=> effort, or size=>effort, but not effort=>size.										T								
Effort (estimated) for preparing for peer reviews	PR Ab3														X					
Effort (estimated) for participating in peer reviews	PR Ab3														X					
SQA effort (planned)	SQA M1						E													
SCM effort (planned)	SCM M1							E												
Effort (planned) for process assessment	OPF M1								X											
Effort (planned) for process development and improvement	OPF M1								X											
Effort (planned) to manage the project	IM M1											E								

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Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2					Level 3							Lvl 4		Level 5		
			RM	PP	PTO	SSM	SQA	SCM	OPF	OPD	PTM	IME	PEG	IGR	PQM	QM	TDP	PCM	PCM
Effort expended (for planning tasks)	PP M1			E															
Effort expended in performing tracking and oversight	PTO M1				E														
Software effort (actual) for the project	PTO A6, A6.1, OPD A5.1 IM A5.1, A7				R					E		R							
Track, over time, against work completed.	PTO A6.1	Implies that the work completed must also be measured and tracked.			R														
Compare to plan.	PTO A6.1, A6.3	Implies periodic measurement & reporting.			R														
SQA effort expended (actual)	SQA M1						E												
SCM effort expended (actual)	SCM M1							E											
Effort (expended) for process assessment	OPF M1								E										
Effort (expended) for process development and improvement	OPF M1								E										
Effort (actual) for software work products	OPD A5.1									E									
Effort (actual) to manage the project	IM M1											E							
Magnitude of replanning effort	IM M1											E							
Effort to analyze each proposed change to a requirement	PE M2												E						
Cumulative effort to analyze proposed changes to requirements	PE M2												E						
Effort (actual) expended by the software engineering group to support other engineering groups	IG M1													E					
Effort (actual) expended by other engineering groups to support the software engineering group	IG M1													E					
Rework effort resulting from peer reviews	PR A3														E				
Effort to fix products and processes	TCM Ab4																E		
Resource expenditures by project, process stage, tools & methods used, program category, degree of program modification, etc.	TCM Ab4																E		
Effort (estimated/revised) for remaining work	IM A5.3, A7.4										ET								
Updated estimates use actual productivity data from the current project where appropriate.	IM A7.4										T								
Use a documented procedure to manage the project's software effort.	IM A7										R								

Staffing																			
Staffing (estimated)	PP A10.3, PTO A6.3			T	R														
Base estimates on past experience.	PP A10.3			T															
Use similar projects when possible.	PP A10.3			T															
Document staffing estimates in the software development plan.	PTO A6.3				R														
Use historical data where appropriate.	IM A7.1										T								
Adapt models used to plan staffing profiles to the project.	IM A7.1										T								
Staffing distribution (estimated) over the software life cycle	PP A10.3			T															
Staffing (actual)	PTO A6.3, IM A5.1				R						E								
Compare to plan.	PTO A6.3	Implies need for periodic measurement & reporting			R														
Document all staffing changes that affect commitments.	PTO A6.4				R														

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2						Level 3							Lvl 4		Level 5		
			RM	PP	PTO	SM	SQA	SCM	OPF	OPD	TP	IM	PE	IG	PR	QPM	QM	DP	TCM	PCM
Schedule																				
Schedule (planned)	PP A7.8																			
Use a documented procedure to derive each project's schedule.	PP A12			R																
Relate schedule to estimates for sizes of work products or changes.	PP A12.1			R																
Relate schedule to software effort and costs.	PP A12.1			T																
Base schedule on experience (use similar projects, if possible).	PP A12.2			T																
Identify milestones and reviews.	PP A7.8			T																
Document assumptions.	PP A12.5			R																
Document and review schedules.	PP A12.6			T																
Account for critical dependencies	IM A9.2			T								T								
- within the software engineering group	IM A9.2											T								
- between the software engineering group and other groups	IM A9.2											T								
Account for critical paths.	IM A9.3											T								
Completion dates (milestones) (planned)	PP A7.8, PTO A8.1			R	R															
Completion criteria	IM A9.1			I	I							T								
Dates of reviews (planned)	PP A7.8			R																
Completion criteria	IM A9.1											T								
Time phasing of activities (planned)	PP A10.3			T																
Dates of imposed milestones (planned)	PP A12.3	Completion criteria should be made explicit.		T																
Critical dependency dates (planned)	PP A12.3			T																
Other constraints (planned)	PP A12.3			T																
Activity durations and times between milestones are appropriate to support accuracy in measuring progress.	PP A12.4			T																
Planned dates for project planning milestones	PP M1			E																
Schedule for work completed (planned)	PTO A6.1				I															
Completion dates (activities) (planned)	PTO A8.1	Completion criteria should be made explicit.			R															
Completion dates (other commitments) (planned)	PTO A8.1	Completion criteria should be made explicit.			R															
Schedule (completion dates) (planned)	PTO A8				R															
- activities	PTO A8.1				R															
- milestones	PTO A8.1				R															
- commitments	PTO A8.1				R															
Document these dates in the software development plan.	PTO A8.1				R															
Schedule revisions																				
Document schedule revisions.	PTO A8.3	Document where? Unless this is in close physical or logical proximity to the dates documented in the development plan, it is unlikely to get used when planning new projects.			R															
Delivery dates (planned) for subcontracted products	SM M1					E														
Dates (planned) for deliveries to the subcontractor	SM M1					E														
Schedule for the project's SQA group's activities	SQA A2.3						R													
SQA milestone dates (planned)	SQA M1						E													
SQA work scheduled (planned)	SQA M1						E													
SCM milestone dates (planned)	SCM M1							E												
SCM work scheduled (planned)	SCM M1							E												

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, Implied requirements, and points needing clarification	Level 2						Level 3							Lvl 4		Level 5		
			R M	P P	P T O	S M	Q A	S C M	O P F	O D	T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	P C M
Schedule milestones (dates) for process development	OPD M1	The CMM says development, but the context is definition.								E										
Schedule milestones (dates) for process maintenance	OPD M1									E										
Schedule (dates?) for risk management	IM A10.1											T								
The schedule for the QPM activities to be performed	QPM A2.4															R				
Schedule milestones for QPM activities (planned)	QPM M1															E				
- milestones for establishing process measurements to be used on the project	QPM M1															E				
- milestones for determining how process data will be collected	QPM M1															E				
- milestones for collecting the project's process data	QPM M1															E				
Schedule for software process development	PCM A9.3																			E
Schedule for software process improvement	PCM A9.3																			E
Schedule (estimated)	QPM A4.2															X?				
Completion dates (actual) for project planning milestones	PP M1			E																
Schedule (actual)	PTO A8.1, IM A5.1, PCM A9.3, QPM A4.2			R								E				E				E
Completion dates (activities) (actual)	PTO A8.1			R																
Completion dates (milestones) (actual)	PTO A8.1			R																
Completion dates (other commitments) (actual)	PTO A8.1			R																
Schedule (completion dates) (actual)	PTO A8			R																
- activities	PTO A8.1			R																
- milestones	PTO A8.1			R																
- commitments	PTO A8.1			R																
Compare these dates to those documented in the software development plan.	PTO A8.1			R																
Delivery dates (actual) for subcontracted products	SM M1				E															
Dates (actual) for your deliveries to the subcontractor	SM M1				E															
SQA milestone dates (completed)	SQA M1					E														
SQA work completed (actual)	SQA M1					E														
SCM milestone dates (completed)	SCM M1						E													
SCM work completed (actual)	SCM M1						E													
Task completion dates (actual) for software engineering (SE) support to other engineering groups	IG M1													E						
Milestone completion dates (actual) for SE support to other engineering groups	IG M1													E						
Task completion dates (actual) for support by other engineering groups to the software engineering group	IG M1													E						
Milestone completion dates (actual) for support by other engineering groups to the software engineering group	IG M1													E						

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2						Level 3							Lvl 4		Level 5		
			R M	P P	P T O	S S M	Q A	S C M	O P F	O P D	P T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	P C M
Schedule milestones for QPM activities (actual)	QPM M1															E				
- dates when process measurements are established for use on the project	QPM M1															E				
- dates when the procedures for collecting process data have been determined	QPM M1															E				
- dates when the project's process data are collected	QPM M1															E				
Compare the actual dates to those in the approved plan.	QPM M1															E				
Schedule (estimated/planned versus actual)	QPM A4.2	This statement is unclear. Does the slash imply "and," "or," or a ratio? A better way to say it would be "Plot all three (estimated, planned, and actual) on the same chart."														E				
Schedule time (actual) by project, process stage, program category, program size, degree of program modification, etc.	TCM Ab4																		E	
Schedule performance	PCM A9.3																			E
Expected cycle-time benefits from process improvement proposals	PCM A5.3																			E

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
			RM	**PP**	**PTO**	**SM**	**SQA**	**SCM**	**OPF**	**OPD**	**TP**	**IM**	**PE**	**IG**	**PR**	**QPM**	**QM**	**DP**	**TCM**	**PCM**
Cost																				
Costs (estimated) for the project	PP A7.6, OPD A5.1, IM A5.3			R					E			E								
Use a documented procedure.	PP A10			R																
Relate estimates to estimates for size of work products or changes.	PP A10.1			T																
Include direct labor, overhead, travel, computer costs, etc.	PP A10.2			E																
Use productivity data (historical or current).	PP A10.2			T																
Base estimates on past experience.	PP A10.3			T																
Use similar projects when possible.	PP A10.3			T																
Use historical data where appropriate.	IM A7.1											T								
Adapt models used to estimate cost to the project.	IM A7.1											T								
Adjust the referenced cost data to incorporate project variables.	IM A7.2											T								
Update the parameter values of the models used in estimating software costs whenever major changes are made to the software requirements.	IM A7.4											T								
Document and review assumptions.	PP A10.4			T																
Document and review estimates.	PP A10.4			T																
Document in the software development plan.	PTO A6.2				R															
Cost distribution (estimated) over the software life cycle	PP A10.3			T																
Costs (estimated) for software work products	OPD A5.1								E											
Costs allocated to individually managed tasks or stages	IM A7.3											T								
Cost (initial estimate) for implementing and testing each incorporated product engineering change	PE M2												E							
Cost data (estimated/planned) used to control the project's defined software process	QPM A4.2	The slash does not appear to mean division. Whether it means "and" or "or" is not clear.														E				
Costs (planned) for managing each subcontract	SM M1					E														
Cost over time for QPM activities (planned)	QPM M1															E				
Projected cost of planned defect prevention activities	DP V1.6																	R		
Costs (actual) for the project	PTO A6, A6.1, OPD A5.1, IM A5.1, A7				R				E		R									
Track, over time, against work completed.	PTO A6.1	Work completed must be measured and tracked.			R															
Compare to plan.	PTO A6.1, A6.2	Implies periodic measurement & reporting.			R															
Document all cost changes that affect commitments.	PTO A6.4				R															
Costs (actual) for managing each subcontract	SM M1	Implies periodic measurement & reporting.				E														
Costs (actual) for software work products	OPD A5.1								E											
Costs for process definition activities	OPD M1								E											
Cost (actual) for implementing and testing each incorporated product engineering change	PE M2												E							

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2 RM PP TO PM SA QM SC	Level 3 OF OD PP TM IE PG IR	Lvl 4 QPM QM	Level 5 DPM TCM PCM
Cost over time for QPM activities (actual)	QPM M1				E	
Compare actual costs to those in the plan.	QPM M1				E	
Cost (actual) for achieving software quality goals	QM A4.5				R	
Cost for achieving quality goals	QM M1				E	
Cost of poor quality	QM M1	There is a mismatch here. The data needed for computing this are not addressed until Level 5. See the entries for DP A5.2 that follow.			E	
Cost for identifying each defect	DP A5.2					E
Cost for correcting each defect	DP A5.2, M1	Estimated or actual? The CMM is not explicit here.				E
Estimated cost of not fixing each defect	DP A5.2					E
Cost of holding causal analysis meetings	DP M1					E
Cost of completed defect prevention activities	DP V1.6					R
Cost of software process development	PCM A9.3					E
Cost of software process improvement	PCM A9.3					E
Costs (estimated) for remaining work	IM A7.4			T		
Updated estimates use actual productivity data from the current project where appropriate.	IM A7.4			T		
Use a documented procedure to manage the project's software costs.	IM A7			R		

Productivity						
Productivity data	PP A10.2, OPD A5.1, QPM A4.2, PCM A9.3	It would be helpful if the CMM issued a cautionary note or two about productivity numbers— most software productivities are unnormalized. Hence they cannot be compared and are often misleadingly misused.	T	E	E	E
Productivity						
- by project	TCM Ab4, PCM A9.3					E E
- by process stage	TCM Ab4					E
- by tools and methods used	TCM Ab4					E
- by program category	TCM Ab4					E
- by degree of program modification	TCM Ab4					E
Productivity goals	PCM A5.1					E
- for the organization's software processes	PCM M1					E
- for each project's software processes	PCM M1					E
Productivity (actual)						
- for the organization's software processes	PCM M1					E
- for each project's software processes	PCM M1					E
Productivity trends for each project	PCM M1	Making productivity trends meaningful within individual projects is likely to be difficult.				E
Organizational productivity trends	PCM A9.3	Normalization mechanisms are needed.				E
Productivity of software process development	PCM A9.3	?? This seems like an excessive requirement.				E
Productivity of software process improvement	PCM A9.3	?? This seems like an excessive requirement.				E
Expected productivity benefits of process improvement proposals	PCM A5.3					E

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
			R M	P P	T O	S M	Q A	C M	O P F	O D	P P	T M	I E	P G	P R	Q P M	Q M	T D P	P C M	C M
Risk																				
Risks associated with cost, resource, schedule, and technical aspects	PTO A10				R															
- priorities	PTO A10.1				R															
- contingencies	PTO A10.1				R															
Risks are tracked.	PTO A10				R															
Risks are identified, assessed, documented, and managed according to a documented procedure.	IM A10											R								
Risk priorities (initial)	PTO A10.1				R															
Risk priorities (revised)	IM A10.6											T								
Estimated loss for each identified risk	IM M1											E								
Adverse impact (realized) for each identified risk	IM M1											E								
Number of unanticipated adverse impacts	IM M1											E								
Track over time.	IM M1											E								
Magnitude of unanticipated adverse impacts	IM M1											E								
Track over time.	IM M1											E								
Staff resources required for risk management (includes staff & tools)	IM A10.1	These data go into the plan, so in this case "required" and "planned" seem to be identical.										T								

Testing																				
Test efficiency	OPD A5.1									E										
Test coverage	OPD A5.1									E										
Test coverage (to be achieved)	PE A5.3												R							
Statement coverage	PE A5.3												E							
Path coverage	PE A5.3												E							
Branch coverage	PE A5.3												E							
Usage profile	PE A5.3												E							
Technical staff receive training in measuring test coverage.	PE Ab2												E							

Scrap and Rework																				
Rework effort resulting from peer reviews	PR A3	Measuring and reducing resources expended for scrap and rework have historically been key elements of process improvement. This is recognized in MIL-STD-498 and in the emerging IEEE-1498 standard. The only place that v1.1 of the CMM addresses this issue is in the Peer Review KPA. It probably should receive more attention. One of the Level-4 KPAs would seem to be an appropriate place.													E					

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
			R M	**P P**	**P T O**	**S M**	**S Q A**	**C M**	**O P F**	**O P D**	**P T P**	**I M**	**P E**	**I G**	**P R**	**Q P M**	**Q M**	**T D P**	**P C M**	**C M**
Quality (organizational focus)																				
Measurements are made and used to determine the status of the software quality management activities.	QM M1															R				
Cost of poor quality	QM M1															E				
Cost for achieving quality goals	QM M1															E				
Organizational quality trends	PCM A9.3																			E
Quality goals for the organization's software processes	PCM M1																			E
Quality (project focus)																				
Quality measurements	OPD A5.1, QPM A4.2 PCM A9.3								E							E				E
Number of defects in software requirements	OPD A5.1, QPM A4.2								E							E				
Number of defects in software code	OPD A5.1, QPM A4.2								E							E				
Quality of the software products	PE M1												R							
Number of defects in software products	PE M1												E							
Track cumulatively by life-cycle stage.	PE M1												E							
Types of defects in software products	PE M1, TCM Ab4												E							E
Track cumulatively by stage.	PE M1, TCM Ab4												E							X
Length of time the problem has been open	PE M2												E							
Number of product defects related to each life-cycle stage	QM A3.5, TCM Ab4															E				E
Post-delivery defects (predicted values)	QM A1.2															E				
Post-delivery defects (target values)	QM A1.2															E				
Post-delivery defects (measured values)	QM A1.2															X				
Percent of predicted defects found by the end of the test cycle	QM A3.5	Over what set of predicted defects? Percentages are meaningless without a well-defined denominator.														E				
Product and process defect data that relates	TCM Ab4																			R
Stage introduced	TCM Ab4																			E
Stage removed	TCM Ab4																			E
Type	TCM Ab4																			E
Cause	TCM Ab4, PCMA5.1																			E E
Severity	TCM Ab4																			E
Time to fix	TCM Ab4																			E
Effort to fix	TCM Ab4																			E
Data on activities to fix product and process defects	TCM Ab4																			E
Defect ID	TCM Ab4																			E
Product version where fix was implemented	TCM Ab4																			E
Identification of defects introduced in implementing each fix	TCM Ab4																			E
Density of defects	TCM Ab4																			E
By project	TCM Ab4																			E
By product type	TCM Ab4																			E
For each product	TCM Ab4																			E
For subproducts (e.g., modules)	TCM Ab4																			E

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2						Level 3							Lvl 4		Level 5		
			R M	P P	T O	P S M	S Q A	S C M	O P F	O P D	T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	P M
Quality goals for each project's processes	PCM M1																			E
Each program's defect history	PCM A9.3																			E
Quality trends for each project	PCM M1	Examining quality trends within a project is likely to be difficult and less meaningful than examining them across projects. Perhaps the CMM should focus on project-to-project trends here. Alternatively, it should illustrate ways in which quality trends within projects might be meaningful and useful.																		E
Software reliability measures	OPD A5.1, QPM A4.2									E						E				
Severity of defects in software requirements	OPD A5.1, QPM A4.2 TCM Ab4									E						E			E	
Severity of defects in software code	OPD A5.1, QPM A4.2									E						E				
Severity of problem	PE M2, TCM Ab4												E						E	
Severity of defects in software products	PE M1, TCM Ab4												E						E	
Track cumulatively by stage.	PE M1, TCM Ab4												E						X	
Quality goals for each life-cycle stage	QM A3.5, PCM A5.1																R			X
Quantitative goals for each identified quality characteristic	QM A3, A3.3 PCM A5.1																R			X
Measurable values (required to be achieved) for each identified quality characteristic	QM A3.3																R			
Measurable values (desired levels) for each identified quality characteristic	QM A3.3																R			
Quality measures (actual values) for each life-cycle stage	QM A4.2																R			
Software mean time between failures (MTBF) specified by requirements	QM A3.3																E			
Software MTBF (planned)	QM A3.3																E			
Software MTBF that must be achieved, as determined by analysis & experiment	QM A3.3																E			
Cost (actual) for achieving software quality goals	QM A4.5																R			

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	Level 2						Level 3							Lvl 4		Level 5		
			RM	PP	PTO	SM	SQA	SCM	OPF	OPD	TP	IM	PE	IG	PR	QPM	QM	DP	CM	PCM
The organization has a written policy for measuring and quantitatively controlling each project's defined software process.	QM C1																I			
The organization has a documented procedure for developing and maintaining software quality plans for each project.	QM A1																I			
The project follows the written organizational policy for managing software quality.	QM C1																R			
Each project's software quality management activities support the organization's commitment to improve the quality of software products.	QM C1.1																T			
Each project defines and collects the measurements used for quality management based on its defined software process.	QM C1.2																T			
Each project defines quality goals for its software products.	QM C1.3																T			
Each project monitors its progress towards its quality goals.	QM C1.3																T			
Each project's responsibilities for software quality management are defined and assigned.	QM C1.4																T			
Projects establish criteria to enable its groups to determine their success in achieving the quality goals of their software products.	QM C1.4																T			
Each project has a software quality plan.	QM A1																I			
Each project's software quality plan is developed and maintained according to a documented procedure.	QM A1																R			
Each project measures and understands the software quality needs of its organization, customer, and end users. Examples of ways to measure include surveys, focus groups, and product evaluations.	QM A1.1																X			
Characteristics of product quality (how well it will perform, how well it can be developed and maintained) are identified.	QM A3.1																R			
Measurements are used to quantify the characteristics of software product quality.	QM A3.2																R			
Quality goals for software products are documented in each project's software quality plan.	QM A3.4																R			
Quality goals are defined and documented for each software life-cycle stage.	QM A3.5																R			
Each project's quantitative quality goals are monitored and revised throughout the software life cycle.	QM A3																R			
Quality goals for the product and its life-cycle stages are revised as understanding of the product and of the organization's, customer's, and end user's needs evolve.	QM A3.6																R			
Predicted values for the number of post-delivery defects are tracked and updated as the product matures.	QM A1.2																E			
Product quality is measured, analyzed, and compared to goals.	QM A4 & A4.3	The CMM appends "...on an event-driven basis." This appears to have no semantic content.															R			

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CMM v1.1 Measurement Map

Part 2

Key Process Areas and Activities

CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
			R M	P P	T O	S M	Q A	S C M	O P F	O P D	T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	C M
Requirements Management																				
Measurements are made and used to determine the status of activities for managing the allocated requirements.	RM M1		R																	
Status of each allocated requirement	RM M1, PE M2	Implies that a list of states must be defined.	E										E							
Change activity for allocated requirements	RM M1, PE M2 TCM Ab4	Implies that entry and exit dates for states must be recorded.	E										E						X	
Cumulative number of changes to allocated requirements	RM M1		E																	
- number proposed	RM M1		E																	
- number open	RM M1		E																	
- number approved	RM M1		E																	
- number incorporated into system baseline	RM M1		E																	
Measurements are made and used to determine the functionality of the software products.	PE M1	In the sense of allocated requirements both by category and traced to software requirements and test cases.											R							
Number of allocated requirements, summarized by category	PE M1												E							
- number that are security requirements	PE M1												E							
- number that are system configuration requirements	PE M1												E							
- number that are performance requirements	PE M1												E							
- number that are reliability requirements	PE M1												E							
Number of allocated requirements traced to the software req'ts	PE M1												E							
Number of allocated requirements traced to system test cases	PE M1												E							
Other requirements measures and actions																				
Number of requirements for each major work product (estimated)	PP A9.1			E																
Number of requirements for each major work product (actual)	PP A9.1, IM A6.3			E								X								
Number of defects found in software requirements	OPD A5.1, QPM A4.2									E						E				
Severity of defects found in software requirements	OPD A5.1, QPM A4.2									E						E				
Stability of the requirements	IM A7.2											E								
Number of reused requirements	IM A6.3											X								
Size (initial estimate) for each incorporated change	PE M2												E							
Size (actual) for each incorporated change	PE M2												E							
Effort to analyze each proposed change to a requirement	PE M2												E							
Cumulative effort to analyze proposed changes to requirements	PE M2												E							
Cost (initial estimate) for implementing and testing each incorporated change	PE M2												E							
Cost (actual) for implementing and testing each incorporated change	PE M2												E							
Total number of requirements	QPM A5.6															X				
Compare the expansion ratio of software requirements (e.g., number of "shalls") into the number of SLOC to upper and lower limits determined by analyzing historical data.	QPM A5.6	To get usable ratios, models or categories should be used to account for the fact that things like programming languages, application classes, and system support environments can all affect the values observed. The focus on upper and lower limits here seems a bit too strong. This is an estimating issue, not a process control situation. It would be better to look at the error distribution or scatter plot obtained when the historical data are fitted or otherwise mapped to the new situation.														E				

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM	PP	PTO	SM	SQA	SCM	**Level 3** OPF	OPD	TP	IM	PE	IG	PR	**Lvl 4** QPM	QM	**Level 5** TDP	PCM	PCM
Planning																				
Measurements are made and used to determine the status of software planning activities.	PP M1			R																
Planned dates for project planning milestones	PP M1	Implies the need for completion criteria. These should be stated explicitly.		E																
Completion dates for project planning milestones	PP M1			E																
Work completed (for planning tasks)	PP M1			E																
Effort expended (for planning tasks)	PP M1			E																
Funds expended (for planning tasks)	PP M1			E																
Planning data are recorded. These include	PP A15	Recorded where? Since this is part of a Level-2 KPA, this appears to ask only that the data and estimates be recorded at the project level, in some project artifact.		R																
- estimates	PP A15.1			R																
- information needed to reconstruct estimates	PP A15.1			R																
Planning data are archived.	PTO A11.3	Archived where? In what form? How does archived differ from recorded? What ensures that data 'archived' at Level 2 are available for (and get inserted into) the software process database at Level 3? "Recorded" and "archived" are not defined in the CMM's glossary. Perhaps they should be, so that notes stuffed in a desk drawer or stored in a box in the basement are not viewed as satisfying this requirement.			R															
Each project provides appropriate software planning data for storage.	IM A5.3	Are storage and archiving the same things?										R								
Size of code (estimated)																				
- generated	PTO A5.2				R															
- fully tested	PTO A5.2				R															
- delivered	PTO A5.2				R															
Document these estimates in the software development plan.	PTO A5.2				R															
Effort (estimated)	PTO A6				R															
Document these estimates in the software development plan.	PTO A6.1, 6.3				R															
Staffing (estimated)	PTO A6.3				R															
Document these estimates in the software development plan.	PTO A6.3				R															
Costs (estimated)	PTO A6				R															
Document these estimates in the software development plan.	PTO A6.1, 6.2				R															
Units of delivered documentation (estimated)	PTO A5.3				R															
Document this estimate in the software development plan.	PTO A5.3				R															
Work completed (estimated) versus time and/or estimated effort and costs	PTO A6.1				I															
Critical computer resources for each major component	PTO A7				R															
Document these estimates in the software development plan.	PTO A7.1				R															
Schedule (completion dates) (planned)	PTO A8				R															
- activities	PTO A8.1				R															
- milestones	PTO A8.1				R															
- commitments	PTO A8.1				R															
Document these dates in the software development plan.	PTO A8.1				R															
Release contents for successive builds (planned)	PTO A9.2				R															

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
			R M	P P	P T O	S M	S Q A	C M	O P F	O P D	T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	C M
Replanning data are recorded. These include	PTO A11				R															
- estimates	PTO A11.1				R															
-information needed to reconstruct and verify estimates	PTO A11.1				R															
Replanning data are archived.	PTO A11.3	Where? How does archived differ from stored?			R															
Each project provides appropriate software replanning data for storage.	IM A5.3	"Appropriate" begs definition. What are the criteria for appropriate? Who determines them? If it's all arbitrary, then any data suffices.										R								
Each project has a measurement plan.	OPD A6								E											
Project measurement plans are included in the organization's library of process-related documentation.	OPD A6								E											
Frequency of replanning	IM M1											E								
Magnitude of replanning effort	IM M1											E								
Causes of replanning effort	IM M1											E								

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2 RM	PP	TO	SM	SA	SQM	Level 3 OF	OD	PP	TM	IE	PG	IR	Lvl 4 PM	QM	Level 5 DP	TCM	PCM
Tracking		Tracking implies periodic measurement & reporting.																		
Size of (major) software work products	PTO A5, A5.1	"Major" is not defined.			R															
Size of changes to software work products	PTO A5				R															
Size of code	PTO A5				R															
- generated	PTO A5.2				R															
- fully tested	PTO A5.2				R															
- delivered	PTO A5.2				R															
Compare these sizes to estimates documented in the software development plan.	PTO A5.2				R															
Units of delivered documentation	PTO A5.3				R															
Compare this measure to estimates documented in the software development plan.	PTO A5.3				R															
Projected size of software work products (estimates plus actuals)	PTO A5.4				R															
Refine, monitor, and adjust on a regular basis.	PTO A5.4				R															
Effort	PTO A6				R															
Track over time.	PTO A6.1				R															
Compare against work completed.	PTO A6.1				R															
Compare against estimates documented in the software development plan.	PTO A6.1, 6.3				R															
Staffing	PTO A6.3				R															
Track over time.	PTO A6.3				I															
Compare against estimates documented in the software development plan.	PTO A6.3				R															
Costs	PTO A6				R															
Track over time.	PTO A6.1				R															
Compare against work completed.	PTO A6.1				R															
Compare against estimates documented in the software development plan.	PTO A6.1				R															
Work completed	PTO A6.1				R															
Track over time.	PTO A6.1				I															
Compare to work planned.	PTO A6.1				I															
Critical computer resources (actual use)	PTO A7.1				R															
Compare to estimates for each major component documented in the software development plan.	PTO A7.1				R															
Critical computer resources (projected use)	PTO A7.1				R															
Compare to estimates for each major component documented in the software development plan.	PTO A7.1				R															
Schedule (completion dates) (actual)	PTO A8				R															
- activities	PTO A8.1				R															
- milestones	PTO A8.1				R															
- commitments	PTO A8.1				R															
Compare these dates to those documented in the software development plan.	PTO A8.1				R															
Software engineering technical activities	PTO A9				R															
- technical status	PTO A9.1				R															
People report their status to first line managers on a regular basis.	PTO A9.1				R															
Release contents for successive builds (actual)	PTO A9.2				R															
Compare these to the plans documented in the software development plan.	PTO A9.2				R															
Problem reports	PTO A9.4				R															
Track to closure	PTO A9.4				R															
Risks associated with cost, resource, schedule, and technical aspects	PTO A10				R															
- priorities	PTO A10.1				R															
- contingencies	PTO A10.1				R															

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2						Level 3							Lvl 4		Level 5		
			RM	PP	PTO	SM	SQA	SCM	OPF	OPD	TP	IM	PE	IG	PR	QPM	QM	DP	TCM	PCM
Risk																				
- number of unanticipated adverse impacts	IM M1											E								
- magnitude of unanticipated adverse impacts	IM M1											E								
Actual measurement data are recorded.	PTO A11	Recorded where? This should be spelled out.			R															
Actual measurement data are archived.	PTO A11.3	How does archived differ from recorded?			R															
Measurements are made and used to determine the status of software tracking and oversight activities	PTO M1				R															
Effort expended in performing tracking and oversight	PTO M1				E															
Other resources expended in performing tracking and oversight	PTO M1				E															
Change activity for the software development plan:	PTO M1, TCM Ab4				E														X	
Size estimate change activity	PTO M1, TCM Ab4				E														X	
Cost estimate change activity	PTO M1, TCM Ab4				E														X	
Critical computer resource estimate change activity	PTO M1, TCM Ab4				E														X	
Schedule change activity	PTO M1, TCM Ab4				E														X	
Number of defects in software products	PE M1												E							
Track cumulatively by life-cycle stage.	PE M1												E							
Types of defects in software products	PE M1, TCM Ab4												E						E	
Track cumulatively by stage.	PE M1, TCM Ab4												E						X	
Severity of defects in software products	PE M1, TCM Ab4												E						E	
Track cumulatively by stage.	PE M1, TCM Ab4												E						X	
Number of changes incorporated into the software baseline by category	PE M2												E							
- number of interface changes	PE M2												E							
- number of security changes	PE M2												E							
- number of system configuration changes	PE M2												E							
- number of performance changes	PE M2												E							
- number of usability changes	PE M2												E							
Number of action items	QPM A4.2															E				
Rate of closure of action items	QPM A4.2															E				
Change activity for software products and work processes:	TCM Ab4																		E	
Amount of code produced	TCM Ab4																		E	
Amount of documentation produced	TCM Ab4																		E	

Subcontract Management Measurements are made and used to determine the status of activities for managing the software subcontract.	SM M1	Implies separate measurements for each subcontractor.				R														

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2 RMP PP TO PM SA SM	Level 3 OPF OD PP TM IE PG IR	Lvl 4 QPM QM	Level 5 TDP CP CM
Software Quality Assurance						
Resource requirements for the project's SQA group	SQA A2.2		R			
- staff	SQA A2.2		R			
- tools	SQA A2.2		R			
- facilities	SQA A2.2		R			
Schedule for the project's SQA group's activities	SQA A2.3		R			
Funding for the project's SQA group's activities	SQA A2.3		R			
Measurements are made and used to determine the cost and schedule status of the SQA activities.	SQA M1		R			
SQA milestone dates (planned)	SQA M1		E			
SQA milestone dates (completed)	SQA M1		E			
SQA work scheduled (planned)	SQA M1		E			
SQA work completed (actual)	SQA M1		E			
SQA effort expended (planned)	SQA M1		E			
SQA effort expended (actual)	SQA M1		E			
SQA funds expended (planned)	SQA M1		E			
SQA funds expended (actual)	SQA M1		E			
Audits	—	The CMM does not explicitly address quality assurance audits or measures dealing with audits (counting them, tracking action items, etc.). Perhaps it should.	—			

Software Configuration Management						
Measurements are made and used to determine the status of the SCM activities.	SCM M1		R			
Number of change requests per unit time	SCM M1	Processing completion dates must be recorded.	E			
The date each change request is processed	SCM M1	Completion criteria must be defined.	X			
SCM milestone dates (planned)	SCM M1		E			
SCM milestone dates (completed)	SCM M1		E			
SCM work scheduled (planned)	SCM M1		E			
SCM work completed (actual)	SCM M1		E			
SCM effort expended (planned)	SCM M1		E			
SCM effort expended (actual)	SCM M1		E			
SCM funds expended (planned)	SCM M1		E			
SCM funds expended (actual)	SCM M1		E			

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CMM v1.1 Measurement Map

Issue **Action, measure, Indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RMP PPO TMS PQA SCM	**Level 3** OPF OPD TP IME PEG IR	**Lvl 4** QPM QM	**Level 5** TDP PCM CM
Process Development and Improvement						
Measurements are made and used to determine the status of the organization's process development and improvement activities.	OPF M1			R		
Work (planned) for process assessment	OPF M1			X		
Work (completed) for process assessment	OPF M1			E		
Effort (planned) for process assessment	OPF M1			X		
Effort (expended) for process assessment	OPF M1			E		
Funds (planned) for process assessment	OPF M1			X		
Funds (expended) for process assessment	OPF M1			E		
Results of process assessments	OPF M1			E		
Recommendations from previous assessments	OPF M1			E		
Work (planned) for process development and improvement	OPF M1			X		
Work (completed) for process development and improvement	OPF M1			E		
Effort (planned) for process development and improvement	OPF M1			X		
Effort (expended) for process development and improvement	OPF M1			E		
Funds (planned) for process development and improvement	OPF M1			X		
Funds (expended) for process development and improvement	OPF M1			E		
Process Definition (organizational focus)						
Measurements are made and used to determine the status of the organization's process definition activities.	OPD M1			R		
Schedule milestones (dates) for process development	OPD M1	The CMM says development, but the context is definition.		E		
Schedule milestones (dates) for process maintenance	OPD M1			E		
Costs for process definition activities	OPD M1	Costs for process maintenance activities are not listed. It seems strange to track milestone dates for process maintenance but not costs.		E		
Process Definition (project focus)						
Each project's defined software process typically specifies that						
Provisions are made for gathering, analyzing, and reporting measurement data needed to manage the software project.	IM A4.1			T		
Activities for estimating and tracking are tied to the key tasks and work products of the defined process.	IM A4.2	This implies that key tasks and work products are distinguished somehow from ones that are not "key."		T		
Readiness criteria are established, documented, and used for each key task.	IM A4.3	But if the rules are arbitrary, then the distinction adds		T		
Completion criteria are established, documented, and used for each key task.	IM A4.3	little value. The CMM would avoid a red herring and be more to the point if it dropped the word "key."		T		

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Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM	PP	TO	SM	QA	SM	**Level 3** OF	OD	PP	TM	IE	PG	IR	**Lvl 4** PM	QM	**Level 5** DP	TM	PM
Training																				
Measurements are made and used to determine the status of the training program activities.	TP M1										R									
Attendance (projected) at each course	TP M1	"Projected" seems to mean something different here than when used to describe size measures.									E									
Attendance (actual) at each course	TP M1										E									
Number of training waivers approved (over time)	TP M1										E									
Progress in providing training courses compared to project's plan	TP M1										E									
Progress in providing training courses compared to organization's plan	TP M1										E									
Quality of the training program	TP M2										R									
Course reviews from students	TP M2										E									
Results of post-training tests	TP M2										E									
Feedback from software managers	TP M2										E									
The individuals who develop a project's defined software process receive training in using the software process database.	IM Ab2											E								
Software managers receive training in software estimating.	IM Ab3											E								
Software managers receive training in software tracking.	IM Ab3											E								
Technical staff receive training in measuring test coverage.	PE Ab2												E							
Individuals implementing or supporting quantitative process management receive the training needed to perform these activities.	QPM Ab4	Since a distinction was made earlier between supporters and performers, this statement (taken literally) seems to imply that performers do not need training. This was not the intent of the authors of the CMM.														R				
Examples of training include																				
- modeling and analyzing the software process	QPM Ab4															E				
- selecting, collecting, and validating process measurement data	QPM Ab4															E				
- applying basic quantitative methods and analysis techniques, such as estimation models, Pareto diagrams, and control charts	QPM Ab4															E				
All members of the software engineering group and related groups receive orientation on the value and goals of quantitative process management.	QPM Ab4	"Orientation" is not defined.														R				
Individuals implementing and supporting software quality management receive training in measuring product and process quality.	QM Ab2																E			

Integrated Software Management																				
Measurements are made and used to determine the effectiveness of the integrated software management activities.	IM M1											R								

Software Product Engineering																				
Measurements are made and used to determine the functionality of the software products.	PE M1	Examples of functionality measures are listed in the "Requirements" section of this mapping.										R								
Measurements are made and used to determine the status of software product engineering activities.	PE M2	The examples the CMM gives for status measures are listed with their related items in preceding sections.										R								

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Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2						Level 3							Lvl 4		Level 5		
			R M	P P	P T O	S M	S Q A	S C M	O P F	O P D	P T P	T M	I P E	P I G	P R	Q P M	Q M	T D P	C M	P C M
Intergroup Coordination																				
Measurements are made and used to determine the status of the intergroup coordination activities.	IG M1													R						
Effort (actual) expended by the SE (software engineering) group to support other engineering groups	IG M1													E						
Other resources expended by the SE group to support other engineering groups	IG M1													E						
Effort (actual) expended by other engineering groups to support the software engineering group	IG M1													E						
Other resources expended by other engineering groups to support the software engineering group	IG M1													E						
Task completion dates (actual) for SE support to other engineering groups	IG M1													E						
Milestone completion dates (actual) for SE support to other engineering groups	IG M1													E						
Task completion dates (actual) for support by other engineering groups to the software engineering group	IG M1													E						
Milestone completion dates (actual) for support by other engineering groups to the software engineering group	IG M1													E						

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			RM	**PP**	**PTO**	**SM**	**SQA**	**SCM**	**OPF**	**OPD**	**PTP**	**IM**	**PE**	**IG**	**PR**	**QPM**	**QM**	**DP**	**TCM**
Peer Reviews																			
Coverage	OPD A5.1, QPM A4.2									E						E			
Efficiency	OPD A5.1, QPM A4.2 TCM Ab4									E						E			E
Data on defects identified in peer reviews and testing	PE A9												R						
Collect and analyze according to the project's defined process.	PE A9												R						
Provide resources and funding to collect and report data from peer reviews.	PR Ab1														R				
Peer review leaders receive training in collecting and reporting peer review data.	PR Ab2														E				
Defect description	PE A9												E						
Defect category	PE A9												E						
Severity of each defect	PE A9												E						
Units containing the defect	PE A9	The names, not the number of units.											E						
Units affected by the defect	PE A9	The names, not the number of units.											E						
Activity where the defect was introduced	PE A9												E						
Peer review or test cases that identified the defect	PE A9												E						
Description of the scenario being run that identified the defect	PE A9												E						
Expected result that identified the defect	PE A9												E						
Actual result that identified the defect	PE A9												E						
Data on conduct and results of peer reviews	PR A3. TCM Ab4														R				E
Defect data	TCM Ab4																		E
The data are recorded.	PR A3	Recorded where? Perhaps the CMM should distinguish between formal and informal recording.													R				
Work product ID	PR A3														E				
Size of work product	PR A3														E				
Size of review team	PR A3														E				
Composition of review team	PR A3														E				
Preparation time per reviewer	PR A3														E				
Length of review meeting	PR A3														E				
Types of defects found	PR A3														E				
Types of defects fixed	PR A3														E				
Number of defects found	PR A3														E				
Number of defects fixed	PR A3														E				
Rework effort	PR A3														E				
Effort (estimated) for preparing for peer reviews	PR Ab3														X				
Effort (estimated) for participating in peer reviews	PR Ab3														X				
Measurements are made and used to determine the status of the peer review activities.	PR M1														R				
Number of peer reviews (planned)	PR M1														E				
Number of peer reviews (actual)	PR M1														E				
Effort expended on peer reviews (planned)	PR M1														E				
Effort expended on peer reviews (actual)	PR M1														E				
Number of work products reviewed (planned)	PR M1														E				
Number of work products reviewed (actual)	PR M1														E				
Compare the peer review hours per KSLOC to the upper and lower limits determined by analyzing historical data.	QPM A5.6															E			

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Issue **Action, measure, Indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM PP TO PM SM QA SM	**Level 3** OF OD PP TM IE PG IR	**Lvl 4** QP QM	**Level 5** TD PC PM CM
Process Management (project focus)						
The organization has a written policy for measuring the performance of each project's defined software process.	QPM C1	The CMM's statement here combines measuring with controlling. These are distinct actions that are probably best separated, especially if measuring for process improvement is also a goal.			**R**	
The organization has a written policy for quantitatively controlling the performance of each project's defined software process.	QPM C1				**R**	
Each project implements a documented plan to bring the project's defined software process under quantitative control.	QPM C1.1	This statement is imprecise and inadequately informative. The term "quantitative control" is open to so many possible interpretations that it is effectively meaningless. If statistical control is what is wanted, then the CMM should say so. If something else is intended, then the meaning should be made clear, and references that guide users toward achieving the goal should be provided. If statistical control is what is intended, then the CMM should probably point out that achieving statistical control means identifying and eliminating all assignable causes and demonstrating sustained performance within the natural limits of the process.			T	
Each project's plan for quantitative process management is developed according to a documented procedure.	QPM A1				**R**	
Each project's plan for QPM is based on						
- the organization's strategic goals for product quality, productivity, and development time	QPM A1.1				T	
- the organization's measurement program	QPM A1.1				T	
- the organization's standard software process	QPM A1.1				T	
- the project's goals for product quality, productivity, and development time	QPM A1.1				T	
- the measured performance of other projects' defined software processes	QPM A1.1				T	
- the description of the project's defined software process	QPM A1.1				T	
Each project's QPM plan covers						
- the goals and objectives of the QPM activities	QPM A2.1				**R**	
- the software tasks and activities that will be measured and analyzed	QPM A2.2				**R**	
- the instrumentation of the projects defined software process	QPM A2.3				**R**	
- the QPM activities to be performed and the schedule for these activities	QPM A2.4				**R**	
(This includes not only project needs, but also current organizational needs and measurements that may be useful to future efforts.)	QPM A2.4				E	
- the groups and individuals responsible for the QPM activities	QPM A2.5				**R**	
- the staff, tools, and other resources required to perform the QPM activities	QPM A2.6				**R**	
- the procedures to be followed in performing the QPM activities	QPM A2.7				**R**	

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Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RMP PP TO PM SA SQM CM	**Level 3** OPF OD PP TM IE PG IR PR	**Lvl 4** QPM QM	**Level 5** TPM CM PM CM
Each project's QPM plan undergoes peer review.	QPM A1.2	"Peer" is not defined. What criteria should be used to determine "peer?" Without this clarification, the statement is meaningless. While peer review may be helpful, what is really needed hear is review by someone (or a group) that is well-versed in statistical process control principles and methods. These may well be people from the hardware part of an organization. Unfortunately, it is all to easy for semi-knowledgeable people to have erroneous views of statistical principles associated with successful SPC. Important points will then be missed, and illogical and unworkable methods can easily get embedded in the plan.			T	
Each project's QPM plan is reviewed by the group responsible for the organization's software process activities (e.g., the SEPG).	QPM A1.3	Apparently the SEPG review is in addition to the peer review. Is this so?			T	
Each project's QPM plan is managed and controlled.	QPM A1.4	"Managed and controlled" are defined in QPM A1.4.			T	
Sensitive data relating to performance of individuals are protected.	QPM C1.2	"Protected" is not defined. What constitutes adequate protection?			T	
Access to sensitive data relating to performance of individuals is controlled.	QPM C1.2	"Controlled" (in this context) is not defined.			T	
The organization's process capability baseline is used in establishing each project's process performance goals.	QPM C2.2	Note that establishing such a baseline requires first that the process be brought under statistical control.			T	
Managers and task leaders of the software engineering groups and related groups perform the project's quantitative process management activities. (Related groups include software engineering, SQA, SCM, and documentation support.)	QPM Ab2.1	Cost estimating should probably be included too.			R E	
Adequate resources and funding are provided for quantitative process management activities.	QPM Ab2	Adequate training is needed too, if success with statistical methods is desired.			R	
Each project's QPM activities are performed according to the project's QPM plan.	QPM A2				R	
The strategy for data collection is based on the project's defined software process.	QPM A3				R	
The analyses to be performed are based on the project's defined software process.	QPM A3				R	
The data collection and analyses strategies consider these attributes of the project's defined software process:						
- the tasks, activities, and their relationships to each other	QPM A3.1				R	
- the software work products and their relationships to each other and to the project's defined software process	QPM A3.2				R	
- the process control points and data collection points	QPM A3.3				R	
The measurement data used to control each project's defined software process are collected according to a documented procedure.	QPM A4	The implication is that the procedure is defined by the project. If this is the intent, perhaps it could be stated more clearly.			R	
The measurement data used to control each project's defined software process support the organization's goals and objectives.	QPM A4.1				T	
The measurement data used to control each project's defined software process support the project's goals and objectives.	QPM A4.1				T	

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Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2** RM PP PTO PSM SQA SCM	**Level 3** OPF OPD PTP ITM PEE PIG PPR	**Lvl 4** QPM QPM	**Level 5** TPD PCM PCM
Each project documents precise definitions for the measurement data to be collected to control its defined software process.	QPM A4.2	This requirement seems to preempt QPM A5.8.			T	
Each project defines and documents the intended use and analysis of each measurement used to control its defined software process.	QPM A4.2				T	
Each project predefines the data analysis activities it will use to control its defined software process.	QPM A5.1				T	
Each project's predefined description of data analysis activities covers						
- input data required	QPM A5.1				E	
- tools used	QPM A5.1				E	
- data manipulations performed	QPM A5.1				E	
- information to be derived	QPM A5.1				E	
- decision criteria to be used in (a) performing each analysis and (b) deciding what actions to take	QPM A5.1				E	
Each project's predefined data analysis techniques include						
- Pareto diagrams	QPM A5.1				E	
- control charts	QPM A5.1	It would be helpful if the CMM could provide examples of where and how control charts might be useful to software projects. Without examples of control charts that work for software, this statement leaves users of the CMM grasping at straws. Alternatively, a pointer to [Wheeler 92] would be helpful.			E	
- trend diagrams	QPM A5.1				E	
- scatter diagrams	QPM A5.1				E	
Each project defines and documents the process control points at which its process control data will be collected.	QPM A4.2				T	
Each project's process control measurements are chosen from the entire life cycle (including post-development stages).	QPM A4.3				T	
The measurements used to control the project's defined software process appropriately characterize the process.	QPM A5.3	The CMM appends "they represent." This seems redundant.			T	
The measurements cover the properties of the key software process activities.	QPM A4.4				T	
The measurements cover the properties of the major software work products.	QPM A4.4	"Major" is not defined.			T	
The measurements to be controlled are a natural result of the software activities where possible.	QPM A4.6	The CMM is not clear here. What are "controlled measurements"? What is a "natural result"?			T	
The measurements are selected to support predefined analysis activities.	QPM A4.7				T	
Measurements that are research oriented should be explicitly identified as such.	QPM A4.7				E	
The validity of the measurement data is independently assessed.	QPM A4.8	Validity of a measure is a different issue from that of correctness of the data. The CMM needs to be clearer here as to which it is asking for. Perhaps it should ask for both. Perhaps the CMM should point out that validity of data (or measurement definitions) can only be judged in the context of intended use. Furthermore, if predictive validity is desired, this can only be verified with empirical evidence that the predictions work. Also, "independently assessed" should be defined.			T	

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			R M	P P	P T O	S M	S Q A	C M	O P F	O P D	T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	C M
Each project establishes a process performance baseline.	QPM A5.5	Process performance baseline is defined in the CMM's glossary.														T				
When new software projects are substantially different from past projects, new process performance baselines are established for those projects as part of tailoring the organization's standard software process.	QPM A7.6	Should perhaps a distinction be made between a baseline based on needs (requirements) and a baseline based on extrapolations from demonstrated process performance. There is great danger when the two are confused.														T				
Examples of substantial differences include																				
- new application domains	QPM A7.6															E				
- use of radically different technologies	QPM A7.6	"Radical" may be too strong a word here.														E				
- significant change in the size of the application	QPM A7.6	"Change" is not a good word here. The issue is whether the new project differs significantly in size from projects for which the organization's standard software process was designed. This is different from change in size since the start of the project.														E				
Changes to the organization's standard software process are tracked and analyzed to assess their effects on the process capability baseline.	QPM A7.7	Excellent! But to avoid confusing the innocent, it should be pointed out that process capability cannot be established until the process is brought under statistical control (i.e., is operating stably).														T				
Specify the expected values for the mean and variance of each measurement.	QPM A5.4	This is statistically erroneous. Expected values are never "specified." The data determine SAMPLE means and variances, which are often used to estimate the true means and variances. Perhaps the CMM means to say "target values." But SW process measures will seldom have stationary process means. Instead, we will usually be dealing with trajectories, such as cumulative effort, cost, work completed, problems reported, or problems fixed. Mean and expected value are concepts that seem more applicable to end-of-project data. But then they are not very useful for control purposes in the classical sense. Perhaps a better analogy when trajectories are being tracked is that of navigation (flight planning) and course correction.														T				
Each project defines acceptable limits for the measurements it uses to control its defined software process.	QPM A5.5	Be very careful here. Limits defined arbitrarily lead to overcontrolling and to destabilized processes. It would be wise to distinguish between the "voice of the customer" and the "voice of the process" if intelligent and effective actions are to be taken on the basis of these limits. See [Wheeler 92] and [Wheeler 95].														T				

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			R M	P P	P T O	S M	S Q A	S C M	O P F	O P D	T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	P M
An example of establishing acceptable limits is to calculate the historical deviation from the mean performance of the process.	QPM A5.5	This is confused and confusing. The preceding statement implies that limits for controlling project parameters such as size, effort, schedule, cost, and defects are what are wanted. These usually involve profiles over time (i.e., trajectories). What is needed are prediction intervals for these profiles, set according to some criteria that permits rare events to be identified. The profiles can be estimated only with a model that accounts for differences among projects. Except in the simplest of situations, calculating "the historical deviation from the mean performance of the process" will be both impossible and useless. Also, this kind of wide ranging variation is NOT what one should use to construct control limits [Wheeler 92].													E				
Each project compares the actual values of its measurements to the expected values of the means and variances.	QPM A5.6	Projects will never know what the "expected" values are (in the probabilistic sense). The best they will ever have is the organization's estimates for these values. But even this presumes either that the project follows exactly the same process and that the product has exactly the same characteristics (size, reuse, language, application, etc.) as all others in the set used to develop the estimates, or that competent cost models are competently used to account for these differences. Today's cost models ATTEMPT (but don't necessarily succeed) to estimate expected "means," but few (if any) address variances in any realistic way. It would be more reasonable to require use of a model that estimates expected values and variances based on extrapolations from past projects. What is really needed is not estimates at completion, but estimates of the trajectories one expects to see over time. Perhaps the real issues the CMM should address here are (a) comparison of actual values to planned values, and (b) comparison of the plan to historical experience.													T				
Projects adjust their processes to bring performance in line with the defined acceptable limits.	QPM A5.7	Limits that are too narrow cause overcontrolling, instability, and degradations in performance. The advice the CMM gives here should be accompanied by guidance that makes this clear. Also, adjustment alone is unlikely to help. It is almost always more effective to focus on identifying assignable causes and removing them, then work on process improvement.														T				

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When the project's defined software process is controlled quantitatively, baselines are established for	QPM A5.8	From the context, the intent appears to be, "To control its defined SW process quantitatively, each project should establish (statistically derived?) baselines for:..."														T					
- the definition of measurements	QPM A5.8	Since "definition" is singular here, this appears to say that each process is to establish a baseline for its definition process. The context, though, suggests that each project is to establish baseline definitions for the measures it uses to control its SW process. But that requirement is already stated in QPM A4.2. Is QPM A5.8 redundant here?														T					
- the actual measurement data	QPM A5.8	The intent here is not clear. In what sense are baselines established for actual measurement data?														T					
- the acceptable limits for the measurements	QPM A5.8	How does establishing baselines for acceptable limits differ from simply establishing acceptable limits? Perhaps the CMM should point out that there are statistically valid ways for doing this (i.e., Shewhart's control charts). This may be important, since in practice invalid limits seem rampant.														T					
Manage and control the process performance baseline for each software project.	QPM A5.9															T					
The data collected to control each project's defined software process is stored in the organization's software process database, if appropriate.	QPM A4.9															T					
Each project's defined software process is analyzed and brought under control according to a documented procedure.	QPM A5															**R**					
Identify, collect, and analyze measurement data on process activities throughout the project's defined software process.	QPM A5.2	Are there any activities that are not "process" activities?														T					
Prepare and distribute reports that document the results of each software project's activities.	QPM A6	This is not always the smart thing to do. In some instances it is best to leave control charts in the hands of the people who operate and manage the process. Otherwise they become a "big brother is watching you" club that is used to beat people around the shoulders.														**R**					
The results of data analysis (of the project's QPM activities) are reviewed with those affected by the data before they are reported to anyone else.	QPM A6.1															**R**					
Software managers, task leaders, and senior managers receive regular reports (of the project's QPM activities) appropriate to their needs.	QPM A6.2	For this to be a testable requirement, each organization or project should establish definitions for "appropriate" and "regular."														**R**					
The project manager, senior managers, software managers, and software task leaders receive specialized reports (of the project's QPM activities) on request.	QPM A6.4															**R**					
The software quality assurance group receives regular reports (of the project's QPM activities) appropriate to its needs.	QPM A6.3	For this to be a testable requirement, each organization or project should establish definitions for "appropriate" and "regular."														**R**					

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Measurements are made and used to determine the status of the activities for quantitative process management.	QPM M1	The context makes it appear that this applies to the project's QPM activities rather than to those of the organization. Should there not also be an organizational focus?															R				
Cost for QPM activities (over time) (planned)	QPM M1																E				
Cost for QPM activities (over time) (actual)	QPM M1																E				
Schedule milestones for QPM activities (planned)	QPM M1																E				
- milestones for establishing process measurements to be used on the project	QPM M1																E				
- milestones for determining how process data will be collected	QPM M1																E				
- milestones for collecting the project's process data	QPM M1																E				
Schedule milestones for QPM activities (actual)	QPM M1																E				
Each software project's activities for quantitative process mgt are reviewed with the project manager on both a periodic and event-driven basis.	QPM V2																R				

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Process Management (organizational focus)																					
An organization-wide measurement program exists.	QPM Ab2.2	It's not at all clear that an organization-wide "program" is a prerequisite for successful process management. What's needed is organization-wide use of measurement practices that guide and motivate process management toward productive directions and that enable decisions to be based on factual information. A "program" is only one way to get there, and maybe not the best way at that.														R					
The organization-wide measurement program includes		Perhaps organization-wide measurement "practices" would be better?																			
- definition of organization-wide measurements	QPM Ab2.2															E					
- collection of organization-wide measurements	QPM Ab2.2	It's not clear what "organization-wide measurements" might be. Perhaps "measures that address organization-wide issues" would be more accurate.														E					
- analysis of organization-wide measurements	QPM Ab2.2															E					
- quantitative measurement goals for the organization	QPM Ab2.2															E					
A written policy for analyzing the process capability of the organization's standard software process exists.	QPM C2															R					
A process capability baseline for the organization's standard software process is established and maintained.	QPM A7	This may not be easy. Establishing a process's capability requires that the process be brought under statistical control (shown to be stable). What variables does the CMM perceive should be measured to demonstrate its concept of stability? Without some elaboration here, this may be an impossible requirement.														R					
Measurements of process performance are analyzed to establish and maintain a process capability baseline.	QPM C2.1	Excellent! But is this intended to apply to software subprocesses, or just to the overall software process?														T					
The process capability baseline for the organization's standard software process is documented.	QPM A7.3	The meaning of "documented" is unclear here. For example, what constitutes acceptable documentation? The customary way to document process capability is to use control charts and performance histograms, sometimes supplemented by capability ratios. If this is what the CMM means, it should say so. If not, it should make its intent clear.														T					
A documented procedure is used to establish and maintain the process capability baseline.	QPM A7															R					
The process capability baseline for the organization's standard software process is managed and controlled.	QPM A7.5															T					
The process capability baseline includes standard definitions and expected ranges for the measurements used.	QPM C2.1	This may be neither realistic nor practical. Perhaps the CMM should instead require standardized reporting and recording of definitions used for measurements. Note that "expected ranges" presuppose data about the future that are not yet in evidence. Assurances that a process will continue to operate in the same fashion and in the same environment in the future as in the past are the responsibility of the project or process manager, not of any statistical methods that might be used for baselining. The distinctions between analytic and enumerative studies are important here.														E					

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The process performance baseline for each project's defined software process is incorporated (as appropriate) into the process capability baseline for the organization's standard software process.	QPM A7.2	The purpose is to update the organization's baseline. Actual performance data should be used, not the project's "process performance baseline" established at the start of the project. The CMM uses the term "process performance baseline" in both an anterior and a posterior sense. This introduces confusion. (Compare QPM A5.5, 5.8, and 7.2) This may be an impossible requirement. When a project's actual software process differs from the organization's standard process (and it invariably will), there may be no completely valid way to aggregate the measured values with those of other projects. At best, it will require the use of models to normalize the data.															T				
Process capability trends for the organization's standard software process are examined to predict likely problems or (and?) opportunities for improvements. Examples of using capability trends include	QPM A7.4	"And" seems to convey the intent better (i.e., why not do both?) The examples that follow are misplaced. They have nothing to do with QPM A7—establishing and maintaining a baseline according to a documented procedure.															T				
- predicting software defects and comparing predictions to actuals	QPM A7.4	Is this example misplaced? It seems to deal with project issues, not organizational issues.															E				
- predicting the distribution and characteristics of defects remaining based on data from peer reviews and/or testing	QPM A7.4	This example is misplaced. It deals with project issues, not organizational issues.															E				
A group exists to coordinate the quantitative process management activities for the organization.	QPM Ab1	Does "group" imply at least two individuals? If so, why not say so? Alternatively, if one person might suffice in a small organization, say so.															**R**				
This group is either part of the group responsible for the organization's software process activities (e.g., the software engineering process group), or its activities are closely coordinated with that group.	QPM Ab1.1																**R**				
Adequate resources and funding are provided for quantitative process management activities.	QPM Ab2	"Adequate" is undefined. Without criteria for "adequate," this requirement has no semantic content.															**R**				
Support exists for collecting, recording, and analyzing data for selected process and product measurements. ("Product" data refers to product measurements used for analyzing the software process.)	QPM Ab3	"Support" is not defined—little semantic content here.															**R**				
Individuals implementing or supporting quantitative process management receive the training needed to perform these activities.	QPM Ab4																**R**				
Examples of training include																					
- modeling and analyzing the software process	QPM Ab4																E				
- selecting, collecting, and validating process measurement data	QPM Ab4																E				
- applying basic quantitative methods and analysis techniques, such as estimation models, Pareto diagrams, and control charts	QPM Ab4																E				
All members of the software engineering group and related groups receive orientation on the value and goals of quantitative process management.	QPM Ab4																**R**				
The activities for quantitative process mgt are reviewed periodically with senior mgt.	QPM V1																**R**				

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Process Management (enterprise focus)		The CMM does not address the use of software measurements for enterprise management. For example: How much software do we have? How much in each language? How many programmers? Designers? Systems engineers? What is our inventory of software tools? What is our annual investment in CASE and other software tools? What are our trends related to these measures? Etc. Mature organizations address these questions—but at what level? And which KPAs should they be tied to?				
Tools						
Tools to support software project planning activities are provided. - estimating models	PP Ab3.2 PP Ab3.2		**R** E			
Tools to support quantitative process management are made available. - source code analyzers - test coverage analyzers - database systems - quantitative analysis packages - problem-tracking packages	QPM Ab2.3 QPM Ab2.3 QPM Ab2.3 QPM Ab2.3 QPM Ab2.3 QPM Ab2.3				**R** E E E E E	
Support exists for collecting, recording, and analyzing data for selected process and product measurements. ("Product" data refers to product measurements used for analyzing the software process.)	QPM Ab3	"Support" is not defined—little semantic content here.			**R**	
Tools to support predicting, measuring, tracking, and analyzing software quality are made available. - data collection tools - database systems - spreadsheet programs - software life-cycle simulators - quantitative analysis tools - code audit tools	QM Ab1.2 QM Ab1.2 QM Ab1.2 QM Ab1.2 QM Ab1.2 QM Ab1.2 QM Ab1.2				**R** E E E E E E	
The organization's software process improvement plan covers the tools needed to implement the plan.	PCM A4.1					**R**

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Defect Prevention						
Action proposals identified in causal analysis meetings are documented.	DP A5.1					
Originator	DP A5.1					R
Description of the defect	DP A5.1					E
Description of the defect cause	DP A5.1					E
Defect cause category	DP A5.1	Implies that the organization (or perhaps the project?) has established a formal list of defect categories. At Level 5, there should be some standardization of categories across projects to make trend analyses possible. The CMM may want to address this.				E
Stage when the defect was injected	DP A5.1					E
Stage when the defect was identified	DP A5.1					E
Description of the action proposal	DP A5.1					E
Action proposal category	DP A5.1	Implies that the organization (or perhaps the project?) has established a formal list of action proposal categories.				E
Status	DP A4.9					R
Action items resulting from action proposals are documented.	DP A5.2					
Person responsible for implementing the action item	DP A5.2					R
A description of the areas affected	DP A5.2					E
The individuals who are to be kept informed	DP A5.2					E
The next date its status will be reviewed	DP A5.2	"Next" implies that previously scheduled review dates need not be documented. Is this the CMM's intent?				E
The rationale for key decisions	DP A5.2	Implies a formal classification into key and non-key decisions.				E
A description of the implementation actions	DP A5.2					E
The time for identifying the defect	DP A5.2					E
The time for correcting the defect	DP A5.2	Estimated or actual? The CMM is not explicit here.				E
The cost for identifying the defect	DP A5.2					E
The cost for correcting the defect	DP A5.2, M1	Estimated or actual? The CMM is not explicit here. (Actual costs must be recorded somewhere if the requirements of DP V1.6 [below] are to be met.)				E
The estimated cost of not fixing the defect	DP A5.2					E
Status	DP A4.9					R

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Number of action items proposed	DP V1.4																	R		
Number of action items open	DP V1.4																	R		
Number of action items closed	DP V1.4																	R		
Profiles of the numbers of action items proposed, open, and closed	DP M1																	E		
Number of defects																				
Number of defects injected in each stage (cumulatively for each project)	DP M1																	E		
Number of defects injected in each stage over releases of similar products	DP M1	It is unlikely that raw totals are useful for comparing across projects. They certainly need to be collected, but normalizing for factors like size and reuse is needed to make comparisons valid.																E		
Summary of major defect categories	DP A8, V1.1																	R		
Frequency distribution of defects in major defect categories	DP A8, V1.1																	R		
Summary of action categories, for actions related to defects	DP V1.2																	R		
Frequency distribution of major action categories related to defects	DP V1.2																	R		
Summary status of action proposals	DP A8																	R		
Summary status of action items	DP A8																	R		
A summary of the effectiveness and savings attributable to defect prevention activities	DP V1.5																	R		
Cost of holding causal analysis meetings	DP M1																	E		
Cost of completed defect prevention activities	DP V1.6																	R		
Projected cost of planned defect prevention activities	DP V1.6																	R		
Defect prevention data are tracked across the teams coordinating defect prevention activities.	DP A5																	R		
Members of the software engineering group and other software-related groups receive feedback on the status and results of the organization's and project's defect prevention activities on a periodic basis.	DP A8																	R		
Compare time and cost for identifying and correcting defects with estimated cost of not correcting the defects.	DP M1	It's not clear how one compares time to estimated cost. Perhaps estimated times should be recorded as well.																E		

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Technology Change Management																				
Experienced staff members with expertise in software measurement are available to help evaluate, plan, and support initiatives for technology change management.	TCM Ab2.1																		E	
Support exists for collecting and analyzing data needed to evaluate technology changes:	TCM Ab3																		**R**	
- Support for recording selected product and process data automatically	TCM Ab3.1																		**R**	
- Support for data analysis	TCM Ab3.2																		**R**	
- Support for displaying selected data	TCM Ab3.3																		**R**	
- Results of data analysis are presented in formats that appropriately convey the information content, e.g., graphical displays	TCM Ab3.3																		E	
Data on software processes and work products that support selecting and evaluating technology changes	TCM Ab4																		**R**	
The group responsible for technology change management receive training in																				
- the analytical and support facilities available to the organization	TCM Ab5																		E	
- principles of statistical quality control	TCM Ab5																		E	
Measurements are made and used to determine the status of the organization's activities for technology change management.	TCM M1																		**R**	
Number of technology changes	TCM M1																		E	
Types of technology changes	TCM M1																		E	
Sizes of technology changes	TCM M1																		E	
Goals of technology changes	TCM M1																		E	
Effects of technology changes, compared to the goals	TCM M1																		E	

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Process Change Management						
The organization has quantitative, measurable goals for software process improvement.	PCM C1.1					T
The organization tracks performance against process improvement goals.	PCM C1.1					T
Tools are made available to support statistical analysis of process improvement.	PCM C1.3					E
Changes to the organization's standard software process are tracked.	PCM A2.7					R
The strategy for collecting data to measure and track the change in process performance when transferring a software process improvement into normal practice is documented, reviewed, and agreed to by individuals responsible for implementing the processes affected by the change.	PCM A8.2					T
Support tools are instrumented, as appropriate, to record the desired performance data automatically.	PCM A8.2	Presumably, "instrumented" means "used." The CMM could be clearer here.				T
The organization's software process improvement plan covers the resources needed to implement the plan.	PCM A4.1					R
Staff	PCM A4.1					R
Tools	PCM A4.1					R
Each proposal						
Expected benefits of each software process improvement proposal	PCM A5.3					T
Priority of software process improvement proposals selected for implementation	PCM A5.4					T
Initiation (date?)	PCM A9.1	The wording in the CMM leaves a bit to be desired. It seems to be asking for a date, but whether this is the initiation date for the proposal of for the implementation is not clear. It would make sense to record both.				I
Status of each software process improvement proposal	PCM A5.7 PCM A9.1					T R
Defined goals for implementing each process improvement	PCM M1					E
The actual effect of implementing each process improvement	PCM M1					E
Response time for each software process improvement proposal	PCM A5.8	The CMM is not clear whether this is the response time for the action or for the benefit.				I
Aggregate process improvement activities						
Measurable short-term goals for process improvement	PCM A4.3					R
Measurable long-term goals for process improvement	PCM A4.3					R
Measured effectiveness of activities within the software process	PCM A5.1					E
Accomplishments of process improvement activities	PCM A2.6					R
Participation in process improvement activities	PCM A2.6					R
Customer satisfaction indicators	PCM A3.1					T
Status of process improvement activities	PCM A2.6, A10.3					R
Number of proposals submitted	PCM A10.3					R
Number of proposals open	PCM A10.3					R
Number of proposals completed	PCM A10.3					R

Measures and things to be measured are shown in bold face.

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CMM v1.1 Measurement Map

Issue Action, measure, indicator, or requirement	References	Notes, implied requirements, and points needing clarification	Level 2						Level 3							Lvl 4		Level 5		
			R M	P P	P T O	S S M	S Q A	C M	O P F	O P D	P T P	T I M	I P E	P I G	P R	Q P M	Q M	T D P	C M	P C M
Measurements are made and used to determine the status of the software process improvement activities.	PCM M1																			R
Number of proposals submitted for each process area	PCM M1	"Process area" is not defined in the CMM.																		E
Number of proposals implemented for each process area	PCM M1																			E
Number of proposals submitted for each project	PCM M1																			E
Number of proposals submitted for each group	PCM M1																			E
Number of proposals submitted for each department	PCM M1																			E
Number and types of awards and recognitions received by each project	PCM M1																			E
Number and types of awards and recognitions received by each group	PCM M1																			E
Number and types of awards and recognitions received by each department	PCM M1																			E
Response time for handling software process improvement proposals	PCM M1																			E
Percentage of software process improvement proposals accepted per reporting period	PCM M1																			E
Overall change activity	PCM M1	These are changes to the software process, not changes to products. The CMM should make this explicit.																		E
- number	PCM M1																			E
- type	PCM M1																			E
- size	PCM M1	Size units (other than dollars or staff hours) are likely to be different for each proposal. It is not clear that size measures can be aggregated.																		E
Process measurements that relate to indicators of the customer's satisfaction	PCM M1																			E
Goals for the performance of the organization's software processes	PCM M1																			E
- effectiveness	PCM M1																			E
- quality	PCM M1																			E
- productivity	PCM M1																			E
Actual performance of the organization's software processes	PCM M1																			E
- effectiveness	PCM M1																			E
- quality	PCM M1																			E
- productivity	PCM M1																			E
Goals for the performance of each project's software processes	PCM M1																			E
- effectiveness	PCM M1																			E
- quality	PCM M1																			E
- productivity	PCM M1																			E
Actual performance of each project's software processes	PCM M1																			E
- effectiveness	PCM M1																			E
- quality	PCM M1																			E
- productivity	PCM M1																			E

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
			R M	P P	T O	P S M	Q A	S C M	O P F	O P D	T P M	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	C M
Pilot installations of process improvements																				
Measured benefits	PCM A7																			T
Measured effectiveness	PCM A7																			T
Estimated benefits for each improvement	PCM A7.3	Presumably one would measure and track actual benefits and impacts as well. The CMM does not presently include measuring benefits or impacts as requirements for Level 5.																		T
Estimated risks for each improvement	PCM A7.3																			T
Estimated impacts for each improvement	PCM A7.3																			T
Uncertainty in the estimated benefits for each improvement	PCM A7.3																			T
Uncertainty in the estimated risks for each improvement	PCM A7.3																			T
Uncertainty in the estimated impacts for each improvement	PCM A7.3																			T
Historical records are maintained and reports are produced on software process improvement activities.	PCM A9.3																			R
Productivity for each project	PCM A9.3																			E
Quality for each project	PCM A9.3																			E
Schedule performance for each project	PCM A9.3																			E
Defect history for each program	PCM A9.3	Presumably this means "software" program.																		E
Software quality trends (organizational)	PCM A9.3																			E
Productivity trends (organizational)	PCM A9.3	The need for normalizing productivity measures to make trend analysis possible is not mentioned.																		E
Cost of software process development	PCM A9.3																			E
Cost of software process improvement	PCM A9.3																			E
Schedule for software process development	PCM A9.3																			E
Schedule for software process improvement	PCM A9.3																			E
Productivity of software process development	PCM A9.3	?? This seems like an excessive requirement.																		E
Productivity of software process improvement	PCM A9.3	?? This seems like an excessive requirement.																		E
The organization's software process database is a possible mechanism for maintaining these records.	PCM A9.3																			E
The degree to which software process improvement activities are consistently measured and tacked	PCM V2.5																			R
The degree to which software process improvement performance achieves the plans and goals	PCM V2.6																			R

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CMM v1.1 Measurement Map

Part 3

The Software Process Database

CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
			R M	P P	T O	S M	Q A	S C M	O P F	O P D	T P	I M	P E	I G	P R	Q P M	Q M	T D P	P C M	P C M
Data Storage & Use																				
There is a software process database	OPF A4								R											
The database is coordinated at the organizational level.	OPF A4								R											
The database is established.	OPD A5									R										
The database is maintained.	OPD A5									R										
The database is managed and controlled.	OPD A5.3									R										
User access to the database is controlled to ensure completeness, integrity, and accuracy of the data.	OPD A5.4									R										
Access is limited to those who have a need to enter, change, view, analyze, or extract data.	OPD A5.4	Rules for determining "need" should be made explicit, else this statement has little operational content. Limiting access implies that an access authorization list be maintained, some form of read-only access mechanism be used, and authorization be checked before change access is granted. The CMM would be more helpful if it mentioned these issues.								R										
Sensitive data are protected.	OPD A5.4									R										
Access to sensitive data is appropriately controlled.	OPD A5.4									R										
The individuals who develop a project's defined software process receive training in using the software process database.	IM Ab2												E							
The organization's standard software process provides the ability to define and aggregate a standard set of process measurements from the projects at the organization level.	OPD C1.1									R										
The standard software process documents the product data to be collected.	OPD A2.2									T										
The standard software process documents the process data to be collected.	OPD A2.2									T										
Data entered into the database is reviewed to insure integrity of database contents.	OPD A5.2									R										
The database contains or references the actual measurement data.																				
The database contains the data needed to understand and interpret the measurement data.	OPD A5.2									R										
The database contains the data needed to assess the measurement data for reasonableness and applicability.	OPD A5.2									R										
Each project provides appropriate software planning data for storage.	IM A5.3											R								
Each project provides appropriate software replanning data for storage.	IM A5.3											R								
Each project provides appropriate measured data for storage.	IM A5.3											R								
Each project collects and stores project measurement data in the database.	IM C1											T								
Each project collects and stores process measurement data in the database.	QPM A4.9															T				
Each project's software process measurements that relate to the organization's standard software process are collected uniformly across all projects.	QPM A4.5															T				
																T				
The organization's software process database is used for planning and estimating.	IM A5											R								
The database is used as a source of data to estimate, plan, track, and replan projects.	IM A5.1											R								
Data from similar projects are used when possible.	IM A5.1											R								
Parameter values used for estimating are compared to those of other projects.	IM A5.2											R								
Similarities and differences to other projects are assessed.	IM A5.2											R								
Similarities and differences to other projects are recorded.	IM A5.2											R								
Rationales for similarities and differences between parameter values are recorded.	IM A5.2											R								
The reasoning used to judge the credibility of the project's estimates is recorded.	IM A5.2	The SEI cost-estimating checklists can be helpful here [Park 95].										R								

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CMM v1.1 Measurement Map

Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**								**Lvl 4**		**Level 5**		
			R M	P P	P T O	S S M	Q A	C M	O P F	O P D	P T P	I M	P E	I G	P R		Q P M	Q M	T D P	P C M	P C M
The software process database contains																					
Process measures collected from projects	OPD C1.4									E											
Product measures collected from projects	OPD C1.4									E											
Lessons learned	OPD C1.4									E											
Size estimates	OPD A5.1, IM A5.3									E		E									
Effort estimates	OPD A5.1, IM A5.3									E		E									
Cost estimates	OPD A5.1, IM A5.3									E		E									
Revised estimates	IM A5.3											E									
Size data (actual)	OPD A5.1, IM A5.3									E		E									
Size of software work products	IM A5.1											E									
Effort data (actual)	OPD A5.1, IM A5.1									E		E									
Cost data (actual)	OPD A5.1, IM A5.1									E		E									
Productivity data	OPD A5.1, PCM A9.3									E											E
Organizational productivity trends	PCM A9.3																				E
Quality measurements	OPD A5.1, PCM A9.3									E											E
Organizational quality trends	PCM A9.3																				E
Peer review coverage	OPD A5.1									E											
Peer review efficiency	OPD A5.1									E											
Test coverage	OPD A5.1									E											
Test efficiency	OPD A5.1									E											
Software reliability measures	OPD A5.1									E											
Number of defects found in the software requirements	OPD A5.1									E											
Severity of defects found in the software requirements	OPD A5.1									E											
Number of defects found in the software code	OPD A5.1									E											
Severity of defects found in the software code	OPD A5.1									E											
Defect histories for each program	PCM A9.3																				E
Schedule	IM A5.1											E									
Schedule performance	PCM A9.3																				E
Staffing	IM A5.1											E									
Technical activities	IM A5.1	Should be "descriptions of technical activities." You can't put activities into a database!										E									
Task descriptions	IM A5.3											E									
Assumptions	IM A5.3											E									

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Issue **Action, measure, indicator, or requirement**	**References**	**Notes, implied requirements, and points needing clarification**	**Level 2**						**Level 3**							**Lvl 4**		**Level 5**		
					P		S	S	O	O						Q			T	P
			R	P	T	S	Q	C	P	P	T	I	P	I	P	P	Q	D	C	C
			M	P	O	M	A	M	F	D	P	M	E	G	R	M	M	P	M	M
Parameter values used to derive estimates for size, effort, cost, schedule, and use of critical computer resources	IM A5.2											**R**								
	IM A7.4											T								
Updated parameter values	IM A7.4											I								
Associated information needed to reconstruct estimates, assess reasonableness, and derive estimates for new work	IM A5.3											E								
Similarities and differences to other projects	IM A5.2											**R**								
Rationales for similarities and differences between parameter values	IM A5.2											**R**								
The reasoning used to judge the credibility of the project's estimates	IM A5.2	The SEI cost estimating checklists can be helpful here.										**R**								
Each project's software process data, as summarized in its process performance baseline	QPM A7.1															T				
Cost of software process development	PCM A9.3																			E
Cost of software process improvement	PCM A9.3																			E
Schedule for software process development	PCM A9.3																			E
Schedule for software process improvement	PCM A9.3																			E
Productivity of software process development	PCM A9.3	?? This seems like an excessive requirement.																		E
Productivity of software process improvement	PCM A9.3	?? This seems like an excessive requirement.																		E

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References

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This report identifies and tabulates all references to software measures and measurement activities that appear in Version 1.1 of the Capability Maturity Model℠ for Software (CMM℠). Each reference is listed in a structured format, and the results are sorted into topic areas in a way that is designed to help organizations plan the evolution of their measurement activities across the key process areas of the CMM. Where the CMM's guidance is unclear or incomplete, opportunities for improving the CMM are noted and explained.

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