Task/Subtask IA02.4
CDRL Sequence C012-002
23 February 1996

SOFTWARE TECHNOLOGY FOR ADAPTABLE, RELIABLE SYSTEMS (STARS) PROGRAM

Mapping of Cleanroom Against the CMM: Capability Maturity Model for Software Detailed Mapping to Cleanroom Software Engineering Process

Contract No. F19628-93-C-0129

Task IA02 - Process Engineering Support to the AMCCOM Life Cycle Software Engineering Center (LCSEC)

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REPORT DOCUMENTION PAGE

Form Approved
OMB No. 0704-0188

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1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	2/23/96	Initial

4. TITLE AND SUBTITLE
Capability Maturity Model for Software Detailed Mapping to Cleanroom Software Engineering Process

5. FUNDING NUMBERS
F19628-93-C-0129

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C012-002

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Electronic Systems Center/ENS
Air Force Materiel Command, USAF
5 Eglin Street, Building 1704
Hanscom Air Force Base, MA 01731-2116

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
N/A

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Cleared for Public Release, Distribution is Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This document provides the results of an evaluation of the level of compliance of the Cleanroom Software Engineering (CSE) process with the Capability Maturity Model (SW-CMM) for Software, v 1.1. The evaluation of the CSE process for compliance against the SW-CMM was performed using Software Process Framework (SPF) and the source document.

14. SUBJECT TERMS
CMM, Cleanroom

15. NUMBER OF PAGES
27

16. PRICE CODE
N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Capability Maturity Model for Software
Detailed Mapping to
Cleanroom Software Engineering Process

by Paul G. Arnold

Introduction

This document provides the results of an evaluation of the level of compliance of the Cleanroom Software Engineering (CSE) process with the Capability Maturity Model (SW-CMM) for Software, v 1.1.

Basis

The evaluation of the CSE process for compliance against the SW-CMM was performed using Software Process Framework (SPF) and the source document described in this section. A key consideration for this analysis was the quality of the source document that was used for the CSE process.

CSE was conceived at IBM in 1978 with several interpretations of what is included in Cleanroom.

As a result of sponsorship by the STARS (Software Technology for Adaptable, Reliable Systems) program, CSE has been extended and improved to make it current with new technologies and process tools. Part of the effort by STARS was a joint collaboration between STARS and the Software Engineering Institute (SEI) to produce the SEI Process Asset Library (PAL) with the CSE process as one of the key processes. This work was performed at the SEI in the 1991-92 time frame. Part of this effort was also directed at determination of what constitutes a well defined process and what level of detail is required for process execution. The SEI and STARS have made significant improvements in the understanding of these two questions but unfortunately the processes in the PAL have not been improved to keep up with the increased understanding.

The SEI PAL CSE process, hereafter referred to as the CSE process, is still the best public domain description of CSE available. It does not, however, include the full range of technology improvements that have come out of the STARS program nor the improvements in process definition that have come out of both the SEI and the STARS program in the 1992-95 time frame. Using this process description as the basis for this analysis would therefore not provide a true picture of the compliance of CSE with the SW-CMM.

Basis Continued on next page

Basis (Continued)

This problem was solved by the adoption of a mechanism for the analysis that uses the CSE process but also includes a varied compliance grading system. This **Degree of Compliance**, explained below, permits determination of what level of compliance the CSE process has with the SW-CMM including items that would be in a complete, well defined process description, so the CSE process does not get penalized because the process description is not up to date.

Degree of Compliance

The degree to which CSE addresses the recommendations as set forth in the SW-CMM:

Short Description	Level of Compliance with the SW-CMM	Reference Pneumonic
Consistent	The review item is consistent with the defined CSE process. All and/or most details are present in the process definition.	**C**
Consistent But needs Improvement	The review item is consistent with the defined CSE process but needs additional clarification in the process definition. Some details are missing in the process definition.	**CBI**
Consistent But Missing	The review item is consistent with the Cleanroom philosophy but not included in the CSE process definition. Most and/or all details are missing in the process definition.	**CBM**
Precluded, was Alternate Method	The review item is precluded from use by the Cleanroom philosophy. Cleanroom supports an alternate method to achieve the same results.	**PAM**
Outside of Scope	The review item is outside of the scope but not precluded by the Cleanroom philosophy, i.e. not addressed.	**OS**

Summary of Results on next page

Summary of Results

The detailed mapping of the SW-CMM recommendations against the CSE process provided a picture of a well defined process that is highly consistent with the SW-CMM. In areas where CSE is SW-CMM deficient, concerns can be addressed by extending the process definition to include these areas without causing serious compromise of basic CSE principles.

CSE has several consistent SW-CMM deficiencies that are based upon its project centered view with all tasks performed by project teams. This leads to four main areas of non compliance:

- CSE does not include the larger concept of organization. A large amount of the deficiencies in this area are not well addressed by a process description that is geared towards performance at the project level. The project view within CSE is highly developed and provides a strong foundation for building effective organizational processes. CSE compliance with the organizational recommendations of the SW-CMM would not destroy or alter CSE concepts and would be easy to add to the definition. In a number of cases CSE already gathers data required by these organizational level processes. There are a number of Key Practice Areas (KPAs) where the organizational planning/support is deficient because it is not addressed by CSE. It would be most appropriate for the organization to have well developed organizational processes that are available to all projects regardless of whether the projects use CSE or not. These organizational processes would also need to cover the complete range of activities in an organization, not just software development.

- CSE does not include a large amount of the management activities as recommended by the SW-CMM, especially at the senior level. Part of the problem here is the lack of detail in the CSE process definition used as the source document for this analysis but part is also because the CSE process tends to emphasize the Cleanroom techniques used for software development and is less concerned with a lot of the management activities required to support a viable software development project. The SW-CMM is more concerned with management activities and has few specifics about how the processes produce software. This difference in emphasis for CSE and SW-CMM has the interesting effect of making each other's strengths and weaknesses complimentary. The marriage of CSE and SW-CMM would provide a very high quality end product that addresses a range of concerns that is not possible using only one or the other.

Summary of Results Continued on next page

Summary of Results (Continued)

- CSE does not include an independent Software Quality Assurance group since this function is largely performed by CSE project teams. CSE does incorporate to a very high degree the checks, reviews and reports required by the SQA KPA in the form of team reviews. The addition of an independent SQA group that would supply an additional member for team reviews would satisfy most of the SW-CMM recommendations.

- CSE does not define a wide range of metrics important to the improvement of the process, tracking of progress on the project, or improvement of the technology used for the project. The metrics collected for product quality are minimal and limited to error counts, lines of code and classification of errors. Additional metrics are clearly required to build the organizational data base required for future projects and to gain an intellectual control of the process quality. Caution should be taken to not overachieve in this area since most organizations tend to start with lots of measurements and end up collecting meaningless measurements that are never used.

CSE does not address the following KPAs:

- Software Configuration Management (Level 2) concerns in the area of software baselines. However, CSE work products are identified and controlled on an on-going basis within a project by the Certification Team but CSE does not address the issue of how to implement Software Configuration Management. Others areas of control not addressed include specification and development.

- Software Subcontractor Management (Level 2). Use of CSE Black Box specifications could be used as an excellent communications and compliance document with subcontractors. This specification is unambiguous and provides documentation of requirements for statements of work and software development tasks.

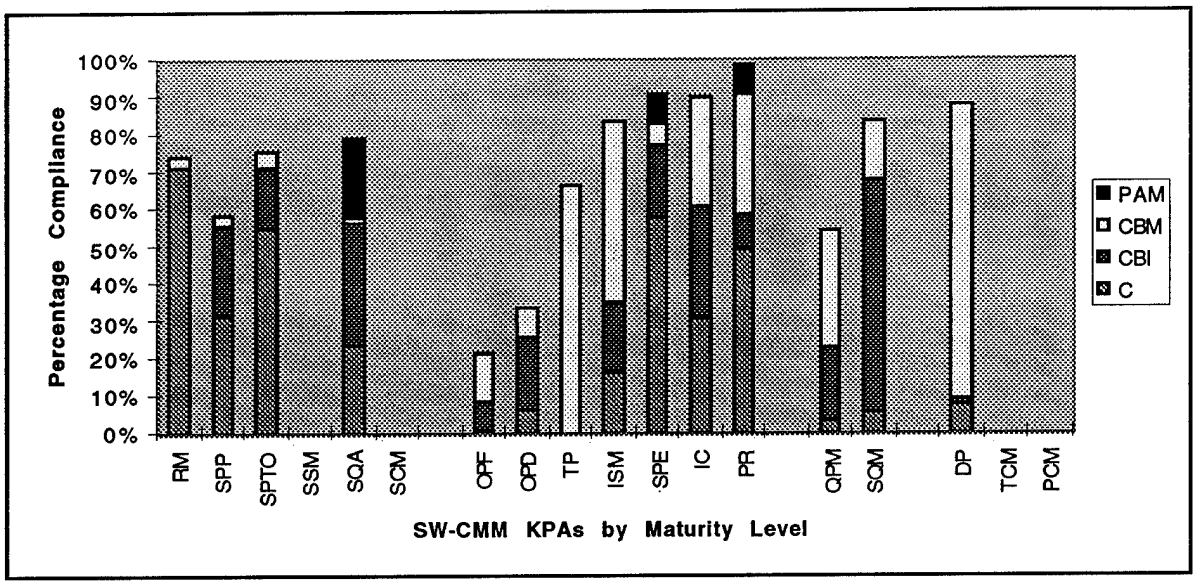
- Technology Change Management (Level 5) is more properly addressed by the organization for the benefit of all projects.

- Process Change Management (Level 5) is more properly addressed by the organization for the benefit of all projects.

Graphical Summary of Results on next page

Graphical Summary of Results

SW-CMM Compliance of Cleanroom Software Engineering



Graphical Chart Interpretation

The above chart reflects the compliance of the CSE process to the recommendations of the SW-CMM. The data is expressed as a percentage (%) of the total number of recommendations for each SW-CMM KPA. The data (expressed as C, CBI, CBM and PAM) is additive to get the complete compliance if the CSE process source document was complete and well defined.

See description of C, CBI, CBM, PAM under section titled ***Degree of Compliance*** on page 2 for detailed explanation.

Source Documents

This analysis used the following as source documentation:

- Cleanroom Process Guide and Model, SEI Process Asset Library, v2, for the Cleanroom Software Engineering (CSE) process
- SEI Software Process Framework, v1, for SW-CMM compliance

Level 2 KPAs start on next page

Detailed Results start on next page

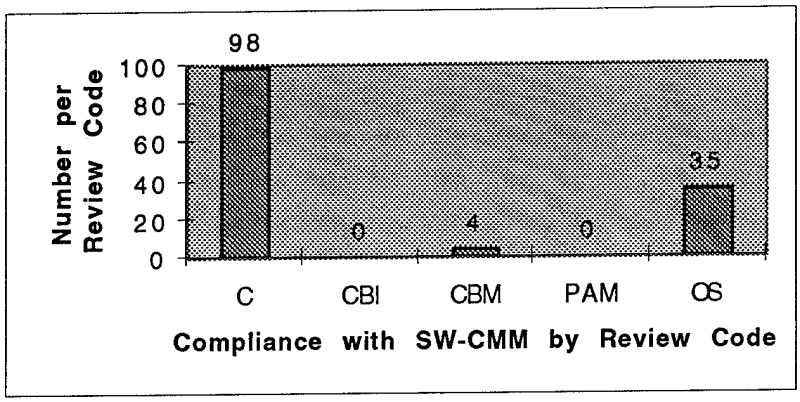
Requirements Management

Purpose

to establish a common understanding between the customer and the software project of the customer's requirements that will be addressed by the software project.

SW-CMM Detailed Compliance

The extent to which the Requirement Management (RM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 137.



Comments

CSE supports this KPA to a high degree with the main deficiencies in the areas of organizational process definition and an independent SQA review of project activities.

CSE requires RM as a fundamental part of the method, whether it is an organizational process or not. Organizational policies, processes and support services are required for full SW-CMM compliance. The team reviews required for all work products for this KPA could easily include an independent SQA monitor.

Level 2 KPAs continued on next page

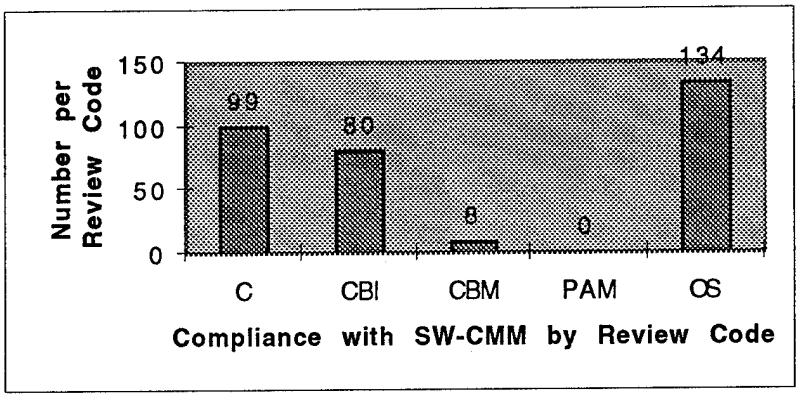
Software Project Planning

Purpose

to establish reasonable plans for performing the software engineering and for managing the software project.

SW-CMM Detailed Compliance

The extent to which the Software Project Planning (SPP) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 321.



Comments

CSE supports this KPA to a partial degree with the main deficiencies in the area of organizational project support, roles (especially at the more senior level), and the lack of documentation for basic size, effort and risk determination.

CSE requires SPP as a fundamental part of the method, whether it is an organizational process or not. CSE projects must be planned, increments must be reviewed, and results considered for planning future increment work.

Level 2 KPAs continued on next page

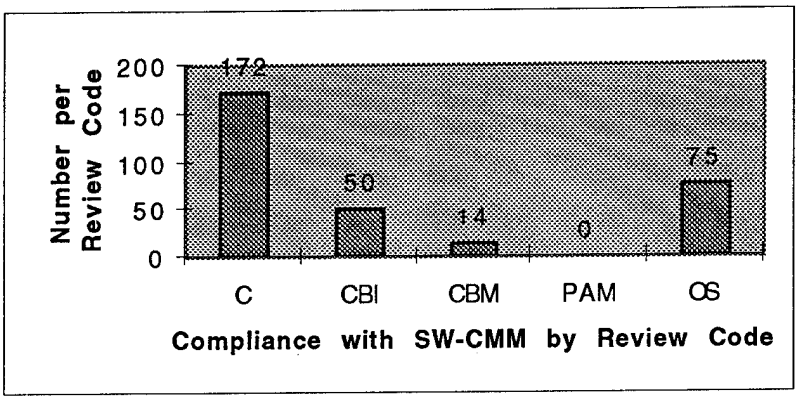
Software Project Tracking and Oversight

Purpose

to provide adequate visibility into actual progress so that management can take effective actions when the software project's performance deviates significantly from the software plans.

SW-CMM Detailed Compliance

The extent to which the Software Project Tracking and Oversight (SPTO) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 311.



Comments

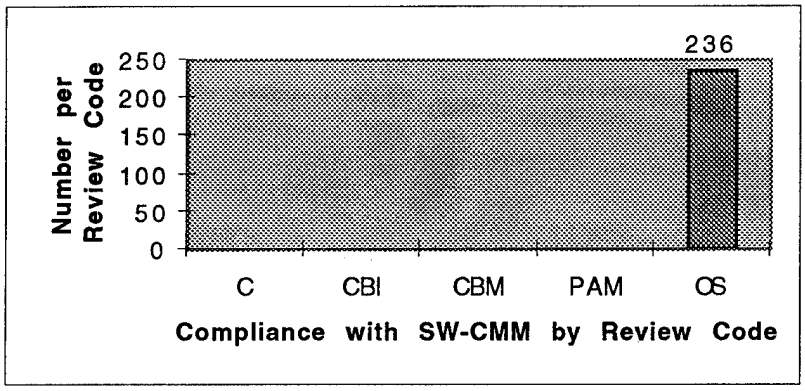
CSE supports this KPA to a high degree with the only deficiencies in the area of SQA review, organizational overview, roles (especially at the more senior level), and the lack of documentation for basic size, effort and risk determination.

Level 2 KPAs continued on next page

Software Subcontractor Management

Purpose to select qualified software subcontractors and manage them effectively.

SW-CMM Detailed Compliance The extent to which the Software Subcontractor Management (SSM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 236.



Comments CSE does not have a process that addresses this area of the SW-CMM.

Use of CSE Black Box specifications could be used as an excellent communications and compliance document with subcontractors. This specification is unambiguous and provides documentation of requirements for statement of work and software development tasks.

Level 2 KPAs continued on next page

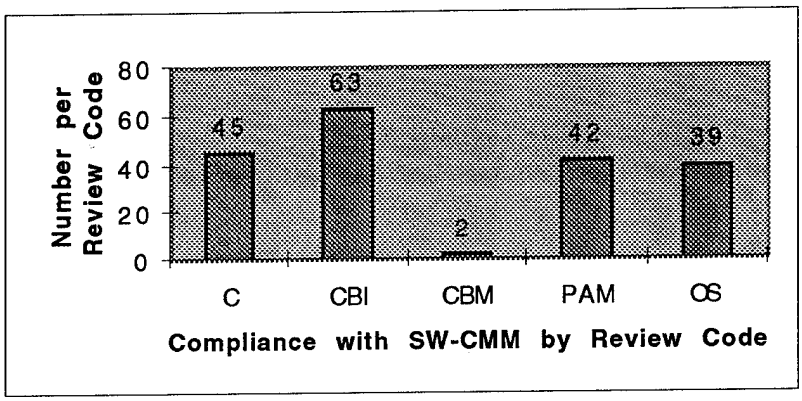
Software Quality Assurance

Purpose

to provide management with appropriate visibility into the process being used by the software project and of the products being built.

SW-CMM Detailed Compliance

The extent to which the Software Quality Assurance (SQA) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 191.



Comments

CSE does not define a separate group whose sole function is SQA activities. CSE does, however, incorporate to a high degree the checks and reports required by this KPA in the form of team reviews. These team reviews do not, however, incorporate the element of independent review of the work performed.

The addition of an independent SQA representative for all CSE team reviews, support for services from the organization, and the addition of roles (especially at the more senior level) would satisfy the SW-CMM recommendations for this KPA.

Level 2 KPAs continued on next page

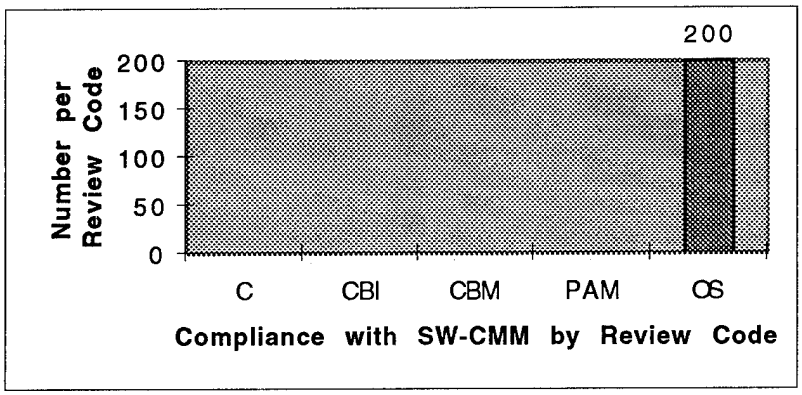
Software Configuration Management

Purpose

to establish and maintain the integrity of the products of the software project throughout the project's software life cycle.

SW-CMM Detailed Compliance

The extent to which the Software Configuration Management (SCM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 200.



Comments

CSE does not have a process that specifically addresses this area of the SW-CMM and does not address software baselines. However, CSE work products are identified and controlled on an on-going basis within the project by the Certification Team. SCM is a required addition for project wide use by all the teams practicing CSE as prescribed by an organizational process. So, while CSE does not satisfy the language expressed in the SW-CMM, the objectives of this KPA are satisfied.

Level 3 KPAs continued on next page

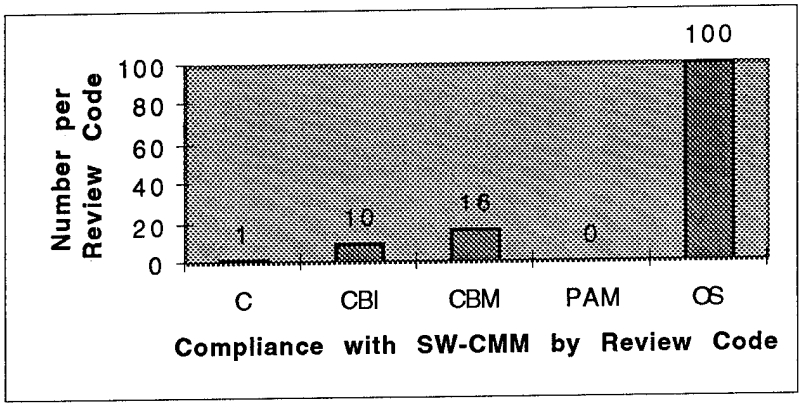
Organizational Process Focus

Purpose

to establish the organizational responsibility for software process activities that improve the organization's overall software process capability.

SW-CMM Detailed Compliance

The extent to which the Organizational Process Focus (OPF) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 127.



Comments

CSE supports this KPA to a low degree with the main deficiencies in the area of generic organizational process support which is the main element of the KPA. CSE already collects data on the quality of products being produced. This data collection would require augmentation with additional process and product quality metrics to produce a more detailed picture of performance. Adding organizational structure to provide for a centralized cross project data collection, analysis and process improvement effort would largely satisfy SW-CMM deficiencies for this KPA.

CSE maintains a project focus that does not preclude the process from being included in the organization process baseline. This KPA is more a recommendation for the organization to implement across all projects rather than a project specific requirement. The organizational process baseline should include CSE processes and practices.

Level 3 KPAs continued on next page

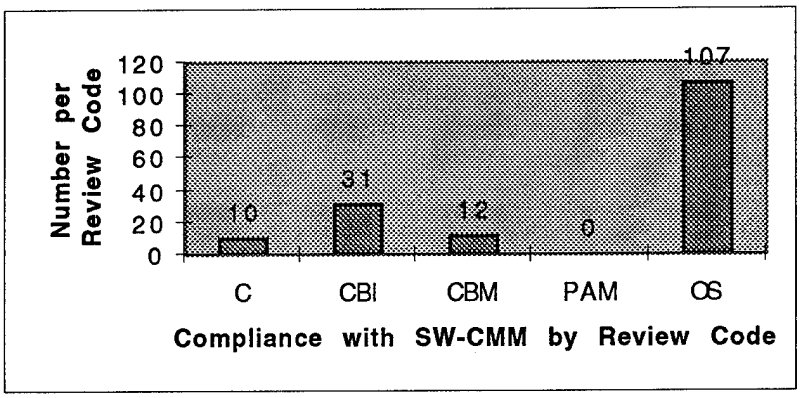
Organizational Process Definition

Purpose

to develop and maintain a usable set of software process assets that improve process performance across the projects and provide a basis for cumulative, long-term benefits to the organization.

SW-CMM Detailed Compliance

The extent to which the Organizational Process Definition (OPD) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 160.



Comments

CSE supports this KPA to a partial degree with the main deficiencies in the area of generic organizational process support. CSE would need the following to satisfy SW-CMM deficiencies for this KPA:

- Organizational adoption of generic process description
- Organizational adoption of measurement/metric collection data store
- Organizational adoption of process improvement based upon experience, lessons learned and analysis of measurement data across the various projects

CSE defines a generic process description that is tailored to a specific project. Tailoring adds project specific information to the generic process description. CSE currently collects, reviews and analyzes data on a project-by-project basis. It is not a goal of CSE to define processes, but to follow them.

Level 3 KPAs continued on next page

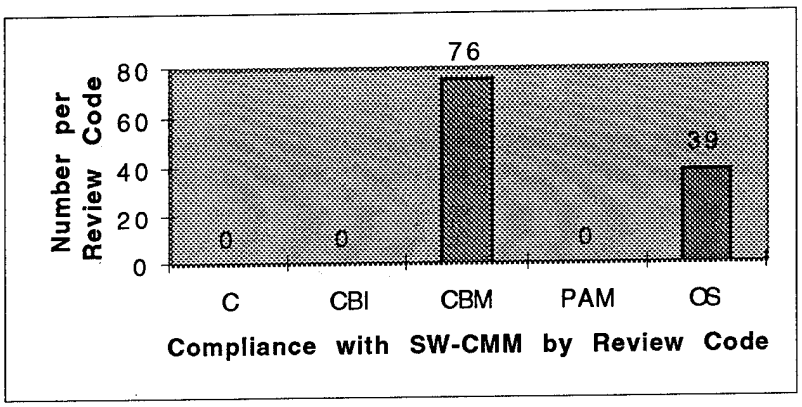
Training Program

Purpose

to develop the skills and knowledge of individuals so they can perform their roles effectively and efficiently.

SW-CMM Detailed Compliance

The extent to which the Training Program (TP) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 115.



Comments

CSE doesn't address the training requirement as part of the defined process but as part of the preparation required before a CSE project could start. The training focus is limited to the area required to perform CSE tasks. CSE has a rather limited defined process for this KPA.

The main area of deficiency is in organizational planning/support and in integrating this training into the defined process. This KPA would be best addressed by an organization process for core competency training, project phase strategy planning and project startup.

Level 3 KPAs continued on next page

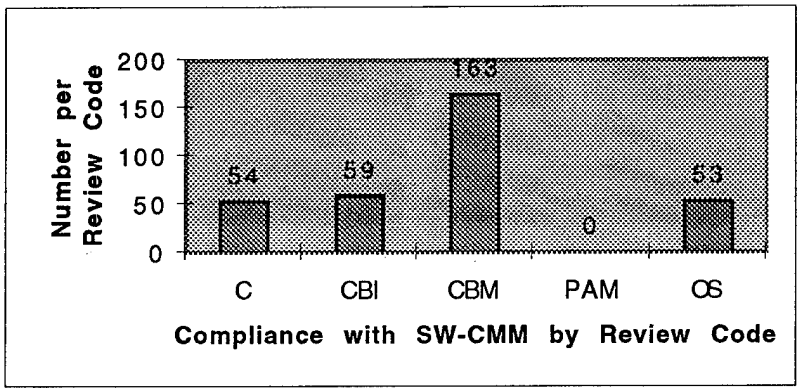
Integrated Software Management

Purpose

to integrate the software engineering and management activities into a coherent, defined software process that is tailored from the organization's standard software process and related process assets, which are described in Organization Process Definition.

SW-CMM Detailed Compliance

The extent to which the Integrated Software Management (ISM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 329.



Comments

CSE supports this KPA to a partial degree with the main deficiencies in the areas of organizational planning/support, general weakness in roles as relates to management, and lack of process monitoring, measurement, and improvement.

ISM is a complex mix of activities best addressed from the organizational level. CSE does not address the organizational level, only the project level.

Level 3 KPAs continued on next page

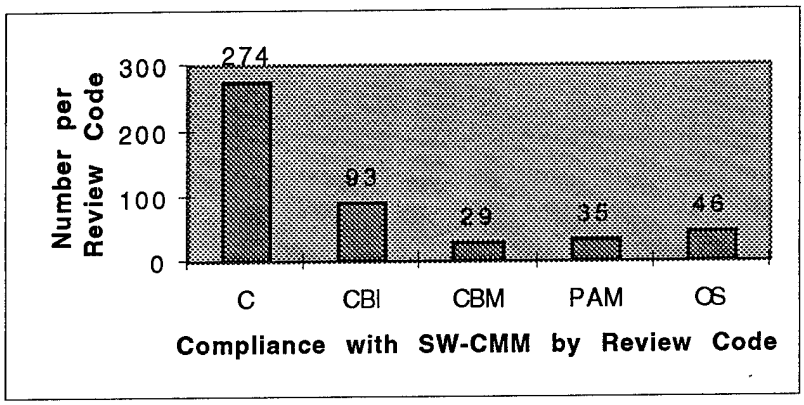
Software Product Engineering

Purpose

to consistently perform a well-defined engineering process that integrates all the software engineering activities to produce correct, consistent software products effectively and efficiently.

SW-CMM Detailed Compliance

The extent to which the Software Product Engineering (SPE) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 477.



Comments

CSE supports this KPA to a high degree with the main deficiencies in the areas of organizational planning/support.

CSE uses stepwise refinement, functional verification, and peer reviews to eliminate the need for debugging. Integration testing and system testing are accomplished through a process called Certification that uses a statistical Usage Profile to focus the "testing". This difference in approach to accomplishing the same end objective, error free software at delivery to the customer, is considered generally compliant with the SW-CMM.

Level 3 KPAs continued on next page

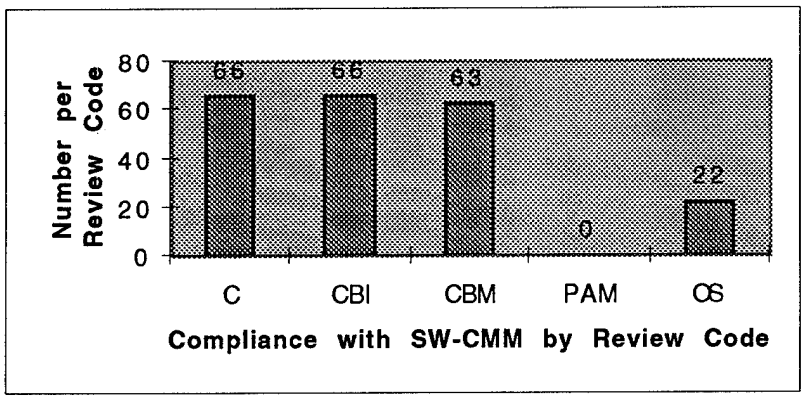
Intergroup Coordination

Purpose

to establish a means for the software engineering group to participate actively with the other engineering groups so the project is better able to satisfy the customer's needs effectively and efficiently.

SW-CMM Detailed Compliance

The extent to which the Intergroup Coordination (IC) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 217.



Comments

CSE supports this KPA to a high degree by the use of the team approach to all reviews. CSE defines a roll for interaction with the customer before the job is accepted to address the questions of clarification of requirements, changes to requirements and accepting responsibility for requirements/changes at each stage of software development.

Compliance would be enhanced by the addition of a coordinator between the CSE teams, systems engineering, test and SQA.

Level 3 KPAs continued on next page

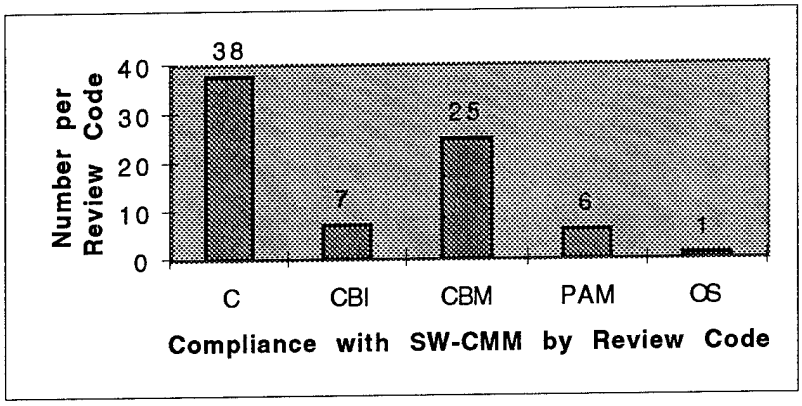
Peer Reviews

Purpose

to remove defects from the software work products early and efficiently. An important corollary effect is to develop a better understanding of the software work products and of defects that might be prevented.

SW-CMM Detailed Compliance

The extent to which the Peer Reviews (PR) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 77.



Comments

CSE supports this KPA to a high degree. There are no deficiencies in SW-CMM compliance for this KPA with the exception of having a written organizational policy to guide peer reviews. This written policy is more appropriately addressed from the organizational level.

Level 4 KPAs continued on next page

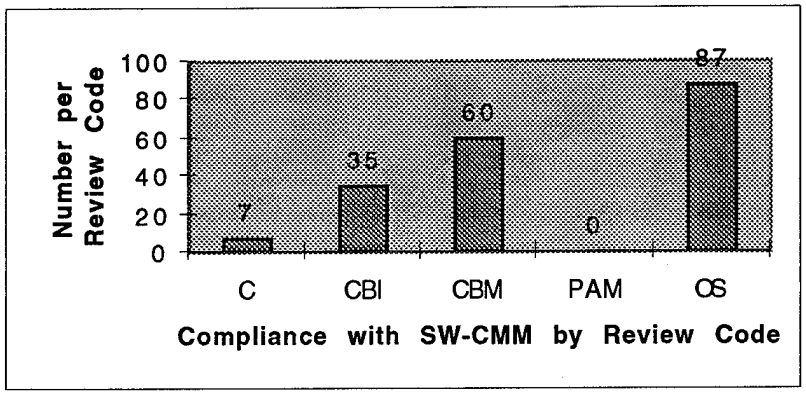
Quantitative Process Management

Purpose

to control the process performance of the software project quantitatively. Software process performance represents the actual results achieved from following a software process.

SW-CMM Detailed Compliance

The extent to which the Qualitative Process Management (QPM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 189.



Comments

CSE supports this KPA to a partial degree and provides a foundation to support this KPA's activities. CSE requires the addition of quantitative and quality standards for assessing process efforts as well as the details for management of the defined process. CSE statistical testing does not address statistical evaluation of the process execution or its results.

Aside from these deficiencies, there is no support for the organizational generic CSE model, passing data collected to an organization based analysis and process improvement group or the setting up of an independent SQA review. These activities, all at the organizational level, are not precluded by CSE but should be included as part of the planning/support services available from the organization.

Level 4 KPAs continued on next page

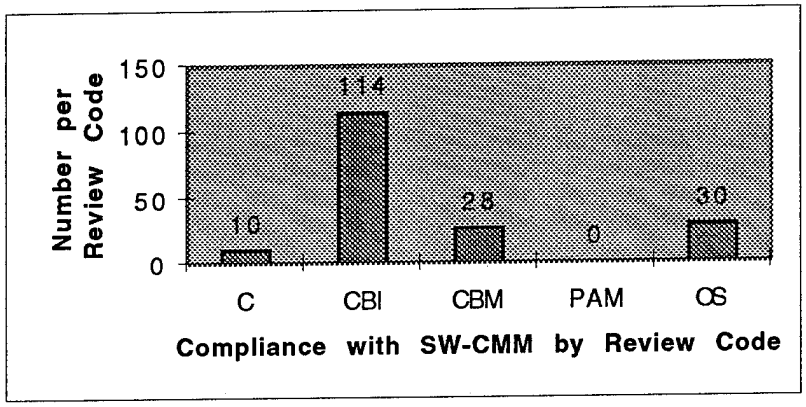
Software Quality Management

Purpose

to develop a quantitative understanding of the quality of the project's software products and achieve specific quality goals.

SW-CMM Detailed Compliance

The extent to which the Software Quality Management (SQM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 182.



Comments

CSE supports this KPA to a high degree and provides a good basic foundation to support this KPA's activities.

The main deficiency is in supporting the organizational generic CSE model by passing data collected to an organization based analysis and process improvement group and the setting up of an independent SQA review. These activities, all at the organizational level, are not precluded by CSE but should be included as part of the planning/support services available from the organization.

Level 5 KPAs continued on next page

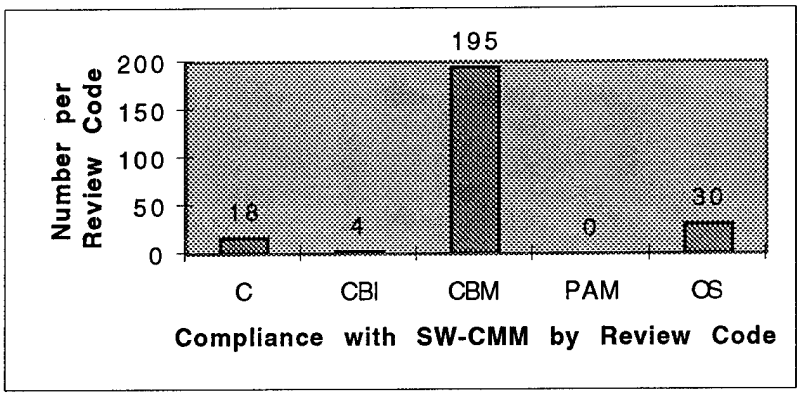
Defect Prevention

Purpose

to identify the cause of defects and prevent them from recurring.

SW-CMM Detailed Compliance

The extent to which the Defect Prevention (DP) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 247.



Comments

CSE supports this KPA to a high degree and provides a good basic foundation to support this KPA's activities. The main deficiency is in organizational planning/support and the setting up of an independent SQA review.

CSE has a strong component in this area to collect, analyze, identify and prevent errors before they happen. In addition, CSE techniques are geared towards developing code that is free of defects during the specification and development phases of software engineering.

Level 5 KPAs continued on next page

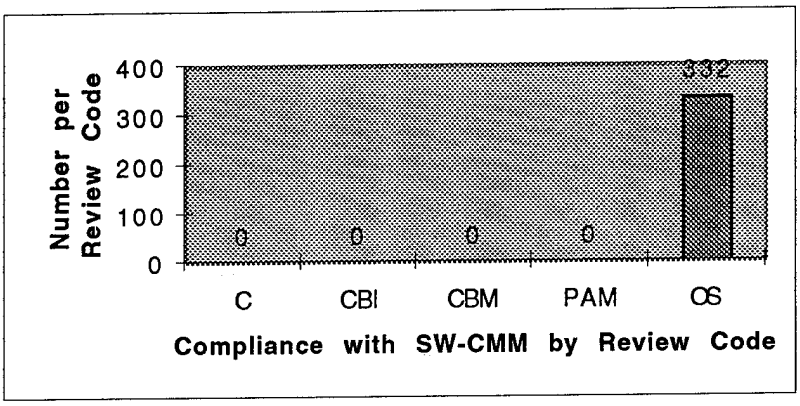
Technology Change Management

Purpose

to identify new technologies (i.e. tools, methods, and processes) and track them into the organization in an orderly manner.

SW-CMM Detailed Compliance

The extent to which the Technology Change Management (TCM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 332.



Comments

CSE does not have a process that addresses this area of the SW-CMM.

This KPA is really not relevant to the practice of CSE. It is an organizational concern and should be supported from that perspective.

Level 5 KPAs continued on next page

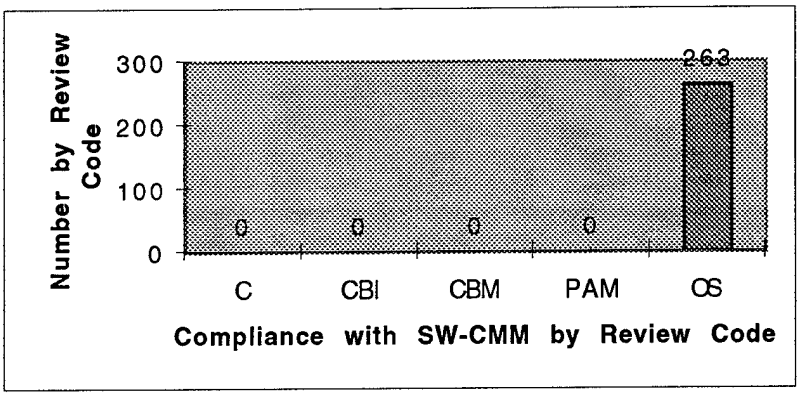
Process Change Management

Purpose

to continually improve the software processes used in the organization with the intent of improving software quality, increasing productivity, and decreasing the cycle time for product development.

SW-CMM Detailed Compliance

The extent to which the Process Change Management (PCM) KPA recommendations are addressed by the CSE process is shown below. The total number of compliance items for this KPA was 263.



Comments

CSE does not have a process that specifically addresses this area of the SW-CMM.

CSE has a strong component to collect, analyze, identify and prevent errors before they happen. This data is used to improve upon the activities of the process at the project level if they are found to be responsible for the introduction of errors or the improvement of efficiency. These activities are primarily related to Defect Prevention and not to process improvement.

This KPA focuses on capturing lessons learned in execution of other processes such as Defect Prevention, Quantitative Process Management and Software Quality Management and expressing them in new/changed processes. Conceptually, CSE satisfies many of the necessary preconditions for compliance. An organizational approach to Process Change Management could be defined using the CSE Processes as s baseline and as sources of metrics for change planning and execution.

Appendix A on next page

Appendix A
Final Results of Detailed Analysis of the Cleanroom Process Guide and Model, SEI Asset Library Process, v2.0, Against the Recommendation of the Capability Maturity Model for Software, v1.1

CMM KPAs	C	CBI	CBM	PAM	% C+CBI+CBM+PAM / TOTALS	OS	Totals
L2-RM	98	0	4	0	74	35	137
L2-SPP	99	80	8	0	58	134	321
L2-SPTO	172	50	14	0	76	75	311
L2-SSM	0	0	0	0	0	236	236
L2-SQA	45	63	2	42	80	39	191
L2-SCM	0	0	0	0	0	200	200
L3-OPF	1	10	16	0	21	100	127
L3-OPD	10	31	12	0	33	107	160
L3-TP	0	0	76	0	66	39	115
L3-ISM	54	59	163	0	84	53	329
L3-SPE	274	93	29	35	90	46	477
L3-IC	66	66	63	0	90	22	217
L3-PR	38	7	25	6	99	1	77
L4-QPM	7	35	60	0	54	87	189
L4-SQM	10	114	28	0	84	30	182
L5-DP	18	4	195	0	88	30	247
L5-TCM	0	0	0	0	0	332	332
L5-PCM	0	0	0	0	0	263	263
Totals	892	612	695	83		1829	4111
%	21.7	14.9	16.9	2.0	55.5	44.5	100