

Can You Trust Software Capability Evaluations?

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SCEs are widely used to determine an organization's Capability Maturity Model rating, but their results can be misleading. The authors reveal how certain practices distort results and waste time and money and suggest ways to improve the process.

In the early 1980s, the US Department of Defense (DoD) suffered many monetary, schedule, and performance costs because it misjudged the ability of its contractors to develop software. Recognizing that this was less a reflection on the organizations themselves than on the immaturity of the software industry in general, the DoD helped create the Software Engineering Institute with the aim of studying ways to help the software industry grow responsibly.

In 1987, the SEI established the software capability evaluation (SCE) as a formal way to determine an organization's software process maturity framework and generally measure its software development competence. The primary motivation was to help ensure that the DoD awarded a software development contract to a qualified contractor. One of the SEI's first major results was the Capability Maturity Model (CMM), a mechanism it introduced in 1991 that ranks a potential DoD contractor's software maturity. The CMM rating is along five levels, with Level 1 being the lowest. By defining a development process and then satisfying requirements in key process areas within subsequent levels, an organization advances its maturity rating.

Although the DoD continues to use the SCE as protection against immature organizations, there are problems.¹ On the DoD side, the software acquisition process is too broadly defined, the schedule is too tight to do any meaningful and comprehensive evaluation, and results are often taken out of context.

On the contractor side, there is the potential for stretching the truth. A single large contract can sustain a software development organization, so contractor organizations are highly motivated to achieve a high CMM ranking. Contractors have been known to coach interviewees and provide misleading documentation. Unless the evaluation team is very perceptive, they can be deceived into recommending a contractor that will not deliver.

In 1998, we conducted a formal study to explore the practices that evaluation teams observed on the sites being rated and the processes and attitudes reflected in evaluation interviews. Although our experience relates to the DoD's application of the SCE, we firmly believe that the problems apply to most industries striving to ensure the maturity of their software contractors.

HOW THE SCE WORKS

The SCE fits into the DoD software acquisition process in the following way: The DoD releases a request for proposal (RFP) that describes the work to be performed (statement of work) and the contract's terms. The statement of work generally contains the work's objective, scope, and background, as well as a description of the technical requirements. The contract terms include instructions, conditions, and notices to the bidder (candidate contractor), such as policies about using subcontractors, patented software, and cost accounting. The

terms also include the offeror's (government agency's) requirements, such as the proposal due date and rules for submitting cost and pricing information.

The RFP typically requires a minimum CMM ranking and requires the candidate contractor to undergo an SCE. The contractor then submits a proposal, answering the RFP's terms. The contractor typically provides information about its management practices, contract costs, software processes, and technical eligibility (including staff resumes and organizational knowledge). The proposal also includes a technical response to specific tasks in the statement of work.

The DoD reviews each response, selects candidate contractors, and begins creating and training the SCE team. The team conducts its evaluations and provides its findings and recommendations to the DoD's Source Selection Advisory Council. After reviewing the SCE results and aspects of the contractor such as cost and past performance, the Council awards the contract.

The SCE is important to the acquisition process because it provides empirical evidence of the contractor's ability to create a software product that meets technical requirements, as well as the desired schedule and budget. The idea is to determine the weaknesses, strengths, and improvement activities in the contractor's software development process and use these to judge the risk associated with using that supplier for a particular acquisition.

Preparation

The SCE team reviews the qualifications and materials the contractor supplies. These include the contractor's responses to a maturity questionnaire and profiles of its software projects. It may also include other relevant artifacts such as software development processes and company policies. The team selects a subset of projects to evaluate on the basis of their similarity (cost, scope, subject matter, size, and so on) to the contracted project. The team then reviews the questionnaire responses and uses them as the SCE's foundation, aiming to prove or disprove them. The contractor submits a maturity questionnaire for each project the team will evaluate. By comparing answers on each questionnaire, the team identifies possible weaknesses and inconsistencies and establishes a basis for interviews during the site visit.

The team also reviews the contractor's software process improvement plan, which describes how the contractor will improve its software process maturity and thus its CMM rating. Although this step is not mandatory, the SEI recommends it because it reflects the contractor's enthusiasm for proactively identifying problems and improving performance.

Finally, the team determines the personnel to be interviewed. The interviewees should represent all primary functions within the sample project (program manager,

configuration management, quality assurance, developers, testers, and so on). The team provides an evaluation agenda to the contractor.

Site visit

The site visit helps the team understand how the contractor performs at a working level. The team members begin by familiarizing themselves with the contractor's organizational policies, standards, and procedures. They then conduct exploratory interviews with project personnel—one of the most important parts of the SCE. The SEI recommends that exploratory interviews focus more on how the technical staff perform their jobs. Interviews with personnel at higher levels should aim to identify how well-rounded management skills are to support each project.

The next step is for the team to review project documentation so that it can see the consistency of software practices and confirm personnel statements. The SEI suggests that each project should have a project trail that includes software development folders, meeting minutes, peer review results, and other evidence of a design progression. The series of documents should show how the contractor implements its processes.

After the documentation review, the team may tour the project environment. Although the SEI does not mandate this activity, the team may use the tour to help confirm or deny what it found in previous steps.

The team may also conduct consolidation interviews with project personnel to clarify any ambiguities from the exploratory interviews.

These steps help the team determine if the contractor consistently follows a defined software process and if that process is effective. When it completes these steps, the team must think beyond the scope of the project being evaluated, considering events that might occur on the contracted project. It must ultimately decide if the contractor can respond to this particular contract's needs. The team's recommendation includes a CMM rating of the contractor and profiles its strengths, weaknesses, and potential for growth.

WHAT'S WRONG: DOD SIDE

There are several significant pitfalls to the SCE process on the DoD side.

Evaluation tool application

The DoD uses a variety of evaluation tools. The US Air Force alone uses the SCE, Air Force Aeronautical System Center (ASC) Software Development Capability Evaluation (SDCE), ISO-9001 certification, Mil-Std-498, EIA/IEEE J-Std-016, and ISO/IEC-12207. Unfortunately, government agencies tend to apply evaluation tools without discrimination. The SEI rec-



The SCE determines the weaknesses, strengths, and improvement activities in the contractor's software development process.

TASKS/TECHNICAL REQUIREMENTS:

4.1 The contractor shall enhance an existing software middleware capability to include the test and delivery of a software toolset that incorporates numerous duplicate requirements from one or more DODIIS migration systems. The enhanced middleware capability will provide an insulation layer between applications, new version releases of software, and changes to the database (i.e. changes to data elements, field lengths and schema). Upon government approval, integrate the existing software middleware capability within the approved growth areas. The enhancement/integration of an existing middleware capability will provide as a minimum the following features:

4.1.1 A single Application Programmer Interface (API) and database service to at least a Sybase Database Management System (DBMS).

4.1.2 An API to Motif.

4.1.3 An API/map graphic to a standard military MAP application toolset.

4.1.4 A capability to get to shared or common utilities or application services.

4.1.5 A standard Data Dictionary.

4.1.6 The middleware will be capable of operating with the appropriate DOD infrastructure, including DOD User Environment (DUE) and DIICOE.

From Section L: Instructions, Conditions, and Notices to Contractors:

Ref. No. 34: TECHNICAL LIBRARY.

A technical library relating to the area of this acquisition is available for review by Offerors during proposal preparation period. The library consists of the following relevant documents:

- (1) Software Requirements Specification for the AAA System (AAAS).
- (2) BBB System (BBBS) Security Requirements and Analysis.
- (3) Software Design Document for DOD User Environment (DUE).
- (4) Interface Control Document (ICD) for DUE.
- (5) MiddleTool Support Requirements.
- (6) MiddleTool Software and Developer User Manual.

Figure 1. Extract from a 1998 DoD Request for Proposal statement of work. The middleware tool, MiddleTool, is a product offered by one of the candidate contractors. It is not trivial to build or acquire. This means that other contractors are not likely to qualify and that the MiddleTool developer will probably get the contract, which turned out to be the case. Even worse, the same contractor wrote the documents in section L. This type of bias is not uncommon and makes an SCE hardly worth the time and money.

ognizes this and has stated that the results of one evaluation tool should not be considered interchangeable or directly comparable with those from another tool.²

Thus, it seems that the DoD has no immediate plans to dictate when certain evaluation tools should be used. David Maibor, principal author of DoD-Std-

2167 (a DoD standard that defines requirements used during software acquisition, development, and product support for mission-critical systems), views the DoD's acquisition process as "a state of free fall; there's no telling where each RFP will land with respect to proposal requirements, contractor evaluation methods, and contractual requirements."³

Wasted resources

This lack of an established selection procedure can cost time and money. Too often, an SCE is used when it is not necessary, or it isn't used when it is necessary. In 1993, a single SCE was estimated to take about two weeks and \$10,000 to prepare and conduct. Considering that the DoD must evaluate multiple candidate contractors, SCEs can cost tens of thousands of dollars.

An example of wasted resources is the SCE conducted for a 1995 Air Force contract, in which the winning contractor, rated at CMM Level 3, became integrated with an Air Force software development team. The integrated team was tasked to create a simple database that maintained information on the security clearances of approximately 1,000 contractors, civilians, and Air Force personnel. Because the Air Force developers were also the customer, they imposed their development processes on the contractor team—even though the Air Force team had only a Level 1 rating. With the less mature processes, the integrated team missed deadlines, rewrote requirements during development, and turned out a low-quality product. The DoD eventually gave the contractor full responsibility for correcting the problems and fielding the application, but less than a year after the product was finally baselined, the DoD approved a commercial product to replace it. In the end, an SCE hardly seemed necessary, given the decisions that clearly minimized the importance of process maturity.

Lack of oversight

Another way the DoD misuses SCEs is to mandate one when it has already decided who should get the contract. The lack of oversight in applying evaluation tools makes it hard to watchdog any bias toward a particular contractor or product. Such bias does exist, however—often quite obviously. Theoretically, the DoD's acquisition regulations require that competition for new work be unbiased, which is the whole point of releasing an RFP. The DoD follows these regulations by releasing an RFP, but it can also add specific requirements to the statement of work that weaken the eligibility of contractors other than the one it wants.

Figure 1 shows an extract from a 1998 RFP statement of work that clearly illustrates this type of bias. The middleware tool required, MiddleTool, was the product of one of the candidate contractors. The same contractor wrote the documents listed in section L.

Entries 5 and 6 relate to MiddleTool, which satisfied every requirement in the statement of work. In fact, the statement of work contained some of the same text and a diagram from the contractor's documents. In this case, an SCE was unnecessary, since the MiddleTool developer would be the only one who would pass the technical requirements. The DoD did, however, conduct an SCE, and, predictably, the MiddleTool developer won the contract.

In an interview with Emilie O'Connell, a DoD acquisitions manager stated that the inconsistent and improper use of the SCE was only a small piece of the software acquisition problem. Cut-and-paste mistakes or ambiguities in RFPs, monetary influences, the participation of contract incumbents, and the tolerance of requirements creep are more examples of why the acquisition process is "such a mess."

SCE team selection and policies

The SEI provides the following guidance to an acquirer (the DoD, for example) in selecting an evaluation team:²

The evaluation team should have four to six members, preferably five ... Team members should have a cross-section of seven or more years of experience in software engineering, software management, or contract acquisition. The team should include at least one senior, knowledgeable individual and no more than two junior personnel.

As you might imagine, this guidance is loosely applied. The evaluation team frequently lacks any individual with sufficient depth in software engineering or development to evaluate a contractor. During one SCE evaluation in which O'Connell participated, the SCE team consisted of two newly assigned Air Force personnel who were trainees in the acquisition office, a moderator who was a representative from an SEI-licensed evaluation organization, and three individuals employed by the acquisition office. No one had an obvious software engineering or development background. Despite this, team members were expected to interview personnel classified as software engineers. When we examined the interview topics with this particular team, we found that they tended to ask software engineer interviewees questions related more to time sheets, performance reviews, and project schedules than to technical matters. When one such interviewee began to discuss his organization's intricate software baseline management strategy, which met the requirements of many key process areas, the team asked questions that redirected him to administrative topics. The same was true of other projects the team evaluated. It did not ask the software engineer interviewees any of the more technical key process area questions.

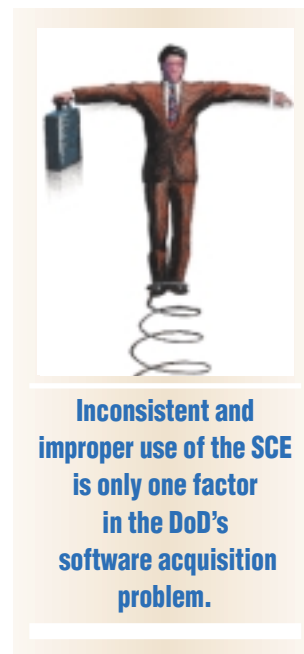
A solution to unqualified evaluation teams doesn't appear to be forthcoming. The DoD's A-76 study, conducted in the early 1990s and now in effect in different areas of the DoD, mandated the downsizing and elimination of most software development and maintenance personnel within the DoD. Thus, many such positions have already been contracted out, and it is difficult for SCE teams to include team members with relevant, current experience in software development. Although the SEI is now licensing third parties as SCE teams, there is always the problem of conflicting interests and biased evaluations.

Another problem is that the SCE team rarely represents the end customer, many of whom are small military units who understand the technical requirements but have insufficient knowledge about product acquisition. These units rely on a DoD-wide contracting office to understand their requirements well enough to find an appropriate contractor. Unfortunately, the contracting offices are staffed largely by administrative personnel, who are often ill qualified to interpret and understand technical requirements.

Scheduling. An SCE team typically has one week to evaluate a candidate contractor. During that time, the team must

- review all project artifacts,
- conduct exploratory interviews,
- compile findings,
- conduct consolidation interviews,
- determine the contractor's CMM rating, and
- present findings to the DoD's Source Selection Advisory Council.

In version 3.0 of the SCE, the SEI gave evaluators the flexibility to perform group interviews—the entire evaluation team interviews a group of representatives (programmers, testers, quality inspectors, and so on) from multiple projects. This contrasts with version 2.0, in which the evaluation team interviewed one representative at a time from each project. In a recent SCE, the team interviewed six software engineers representing three projects in only an hour. In the original interview format, the interviewee first describes his job and fills in as many key process areas as possible before the team begins asking precise questions. In this SCE, the evaluation team began asking questions immediately, and each interviewee had only a small part of the hour to represent his project's maturity. If the team did not get all the information it needed from the interviewee group, it held a second



Inconsistent and improper use of the SCE is only one factor in the DoD's software acquisition problem.

interview, which then defeated the goal of saving time with a group interview. An SCE coordinator for a contractor noted:

You can't tell a coherent story ... We also think that the interviewers would resent it, because if one project has a point of weakness, it is pretty easy for [project personnel] to nod and smile [and let the complying project personnel answer] and it doesn't get noticed. Frankly, gaming the evaluation [presenting artificial results to look good] becomes much easier, which is bad for everybody in the long run. The primary reason for the group interviews is to save time. As it was, [by the third day], the interviewers were obviously approaching mental toasthood.

Judgment calls. In most SCEs, a weakness within a key process area does not cause the contractor to fail that area. The SEI deliberately made the rating process subjective, allowing evaluators to rationalize the importance of a particular weakness. However, as an SCE coordinator notes:

Without much training or experience in the functional area being evaluated, the SCE team typically falls back on treating the CMM as a regulation, where each item in a key process area must be satisfied whether reasonable or not.

Additionally, when the contractor does fail a key process area, it may still accomplish that area's goals through an alternative practice. The SEI also expects the evaluation team to consider alternative practices

It is unlikely that an appraised entity will implement all CMM key practices and subpractices on all projects all the time. Weaknesses in the implementation of CMM practices may or may not be significant when looking at the appraised entity as a whole.

Yet as a senior acquisitions manager for a contractor stated, "My experience is that SCE teams do not like to have to use insight and judgment. They prefer to check off items from their lists."

Maturity questionnaire

The SCE is based on contractor responses to the maturity questionnaire. The questionnaire consists of 101 questions and covers 13 key process areas. Of those 101 questions, 85 are graded. Not every question is relevant to a given contract, but the same questionnaire is used regardless. Terry Bollinger and Clement McGowan stated⁴:

Just as no government agency would think of using a single test to accredit lawyers, civil engineers, and doc-

tors to do government work, it would seem comparably unwise to try to use a single 85-question yes/no test to accredit organizations for developing all the many types of application software used by the Defense Department.

In describing an SEI workshop, David Card noted that, of the five speakers from the government and Mitre Corp., no two speakers described the same way of conducting SCEs.⁵ The Air Force has drafted policies about how to do future SCEs, in which it hopes to derive contractor data from earlier ones, saving time and money. However, given the current inconsistencies in SCE application, these results may not provide meaningful, reusable information for future acquisitions.

Use of SCE results

The DoD tends to take the SCE results out of context. In some cases, it views the CMM ranking with too much importance. Bollinger and McGowan note that at conferences and meetings to review SCE audits, the level grades are usually the only topic discussed.⁴ In other cases, the DoD overlooks the CMM rating in favor of political and monetary concerns. In an interview with O'Connell, a DoD acquisitions manager stated that, more often than not, a contract is awarded to the lowest bidder, regardless of the contractor's CMM-related merits. Inevitably, the government suffers.

During the early 1990s, the DoD awarded a contract worth approximately \$500,000 to the lowest bidder—even though the SCE results identified many risks, and the evaluation team did not recommend this contractor. The contractor was to develop a tape reader interface to a particular piece of tape drive hardware. After the first development phase, the product failed testing when the tape reader did not consistently read the tapes. The contractor could not resolve the error, the project schedule doubled, and development was reduced to code and fix. The customer was so dependent on this system that it was forced to provide additional funding and accept significant schedule slips. As one government program manager stated, "The contractor knew they had us." The contractor had no reason, at that point, to change its methods as long as the government continued to provide funding. Eventually, the DoD added a third-party organization to the contractor team, which determined almost immediately that the tape drive's read heads were worn out and simply needed to be replaced.

WHAT'S WRONG: CONTRACTOR SIDE

In the acquisition process, a contractor uses the proposal and SCE to demonstrate its process maturity and management and technical skill. There is considerable pressure to perform well: A high CMM rating is good

publicity and may result in follow-on business. If the contractor is a mature software development organization, the SCE process is simple, and a mature rating is easy to get. A less mature organization must work harder to sell itself. There is the temptation to skew presentations and information to appear more qualified. When a contractor's acquisitions manager was asked how his organization might game an SCE (provide data that makes a contractor appear more mature or compliant than it actually is), he responded:

The idea is one, to swamp the evaluators with all the good stuff we're doing to make us look as good as we can look; two, to offer evidence, no matter how meager, that we're doing the other stuff; and three, to make it very easy for the evaluators to fill in their checklists. This will often provoke them into giving us the benefit of the doubt on stuff we're really not doing very well in.

Contractors have four main strategies in gaming an evaluation.

Intentional vagueness

The maturity questions tend to take a coarse-grained approach to evaluation, which means that the contractor can scale up its responses. Unless the SCE team specifically examines them, the overblown answers go unchallenged. The contractor uses the evaluation team's weaknesses—little time and limited understanding—to its advantage. There are many ways to inflate qualifications. For example, many SCEs require that all project documentation be available on the Internet. Converting information affords the contractor an opportunity to improve documentation and create an eye-catching display.

Proposals are also a good vehicle. A standard part of the proposal is the blackball chart, a matrix of key personnel and their technical and managerial qualifications. For each qualification, the contractor puts a black dot in a corresponding cell. However, the chart does not specify the degree of qualification. For example, entries may indicate that an individual has C, Ada, HTML, and Motif skills, but it doesn't provide any insight into the type of knowledge. There's a great deal of difference between working knowledge, as in X years of experience, and reading knowledge, as in the individual manages a project that uses these tools.

Intentional detail

Contractors can also overwhelm SCE teams by providing too much information. The idea is to provide so much complex data that the SCE team has no choice in their limited time frame but to scan it and assume that because it appears intricate, the contractor must be compliant. In one SCE, the contractor provided the diagram in Figure 2a to the evaluation team to demon-

strate its peer review process, but it actually used the process in Figure 2b, which it had not even formally defined. In reality, there was no enforcement, no follow-up, and no tracking, as the submitted diagram had indicated.

Inappropriate sample projects

The SEI states that the contractor should choose projects for the SCE that represent its typical software process implementation, and include attributes such as application domain, language, and estimated size.⁶

These qualifications leave the contractor much leverage. For a large contractor, the guidance becomes meaningless because it can choose from dozens, or even hundreds, of projects. The contractor will always submit its most mature projects and choose the most qualified people to represent them. In one organization, the same team participated in four SCEs but represented the same technical position on the same project for each one. The acquisitions staff called them "The Golden Team." In two SCEs, the only relationship between the project and the work to be performed was that each contract fell under the same contract procurement category. Granted, the software processes were also similar, but they were corporate-level processes that the project used only indirectly.

Staff coaching

We extracted the following information from an organization's SCE participant's guide:

For us to put our best foot forward, then, it is up to us to bring out, clearly and distinctly, all the relevant information that the person interviewed should know ... We are trying to help the participant organize his thoughts to discuss all of the things that we are doing to comply with the CMM requirements ... We are ensuring that the SCE team does not make assumptions of noncompliance.

This illustrates that, although interviewees are sometimes coached to help them provide correct information to the evaluation team, this practice can be taken to an extreme. In one situation we observed, an interviewee's notepad, which consisted of pseudocode for an algorithm he was developing, was defined as a "software development folder," and he was asked to mention it during the interview.

In the days before the SCE, the same person was given a CMM reference manual, with the company logo on the cover, to take with him into the interview room. The manual included all the corporate-level soft-



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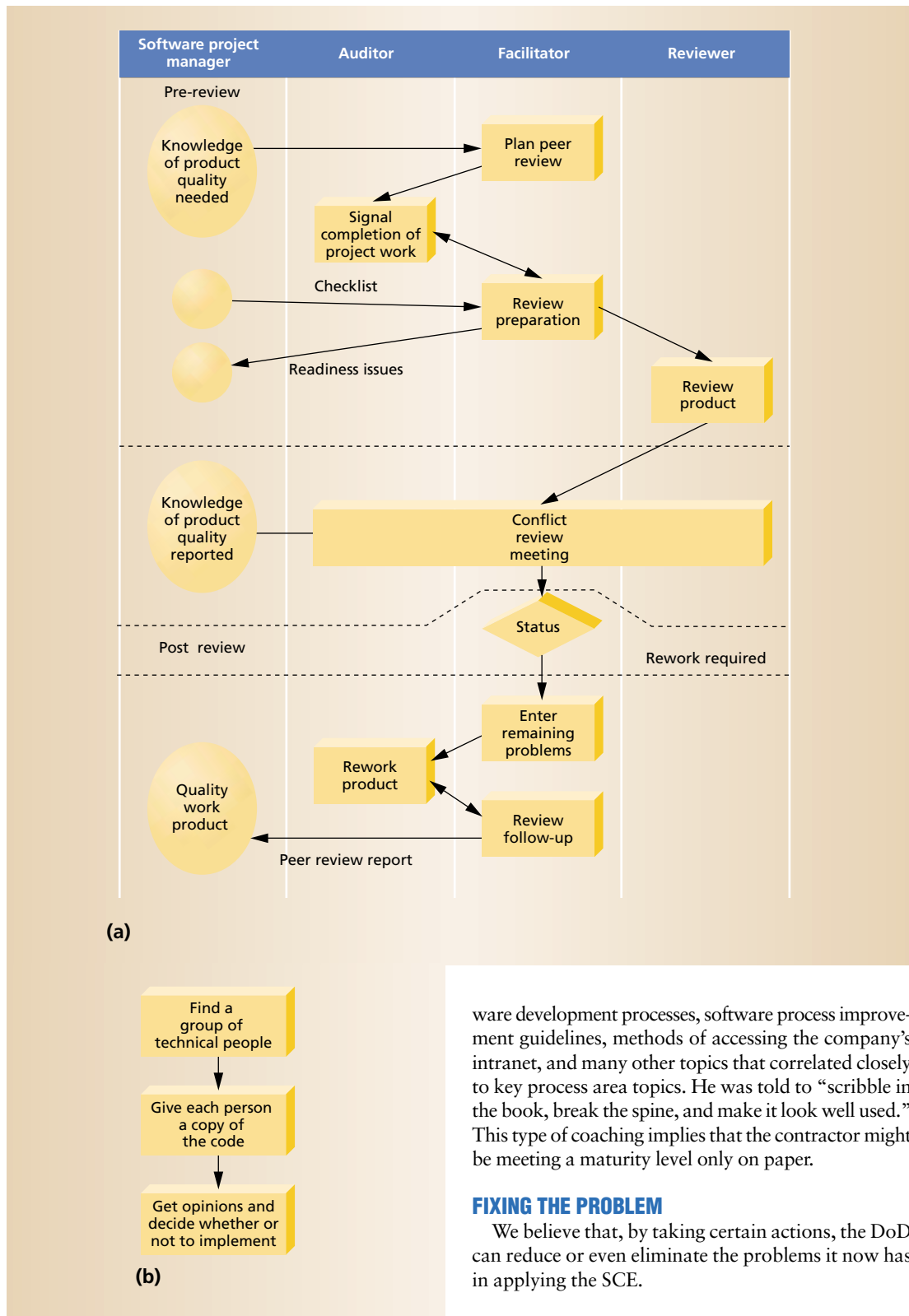


Figure 2. Documented versus actual peer review processes. (a) What the contractor gave the SCE team to demonstrate its peer review process. (b) The process the contractor actually followed. The first diagram illustrates a technique contractors use to sidestep SCE requirements: Overwhelm the team with information that looks so official that the team will assume you comply with that key process area.

ware development processes, software process improvement guidelines, methods of accessing the company's intranet, and many other topics that correlated closely to key process area topics. He was told to "scribble in the book, break the spine, and make it look well used." This type of coaching implies that the contractor might be meeting a maturity level only on paper.

FIXING THE PROBLEM

We believe that, by taking certain actions, the DoD can reduce or even eliminate the problems it now has in applying the SCE.

- *Use the SCE consistently.* Base use on the amount of risk associated with the software development part of the contract and the cost of conducting the SCE. The SEI determines the risk of a software development contract by the size of the end system (contract length, product size, and monetary cost), its complexity (number of interfaces, security classification, and so on), and its uniqueness.² On cost,

the SEI advises that the government agency be “sensitive to the difficulties of the contractor if it wants to encourage true process improvement rather than a bureaucratic response to a requirement.”

- *Choose a representative SCE team.* The team must include personnel who represent all major contract aspects. The team must understand the goals of each key process area and be able to identify how they are satisfied. It must also be able to identify and appreciate alternative practices. Further, it must bear in mind that the evaluation is based on projects the contractor has selected, and it must examine any areas of concern closely.
- *Don't base SCE results solely on the CMM rating.* The team should evaluate all information with equal importance. As the SEI states, “Feedback from SCE teams has demonstrated that maturity level scores alone are not useful indicators of actual process capability because they are abstractions of the underlying process strengths and weaknesses observed by the SCE team.” Instead, the team should use maturity scores as high-level classifiers and review all sources to cross-check scores.
- *Conduct technical evaluations (on-sites).* Observing the work accomplished is much different from hearing or reading about it. A technical evaluation is a spontaneous way to gain technical information, and it complements the current SCE version's managerial focus. It also means the contractor has less opportunity to game the evaluation.
- *Require two sources to confirm information.* The evaluation team should not conclude that a contractor has complied with a key process area on the basis of a single interview or artifact. Compliance should be based on a hard-copy artifact and personnel confirmation that it is used.
- *Track contractor performance after the SCE and contract award.* This way, the DoD can collect data about the effectiveness of the SCE as an evaluation mechanism.
- *Require existing contractors to periodically assess themselves.* The self-assessments could replace SCEs or provide proof that a contractor is implementing a software process improvement plan.
- *Monitor contractor performance.* Each DoD contract should require periodic status reviews, status reports, and evaluations from customers. The DoD will then be able to recognize problems and risks in early stages. The status checks then become the basis of data for future procurements.

We have not written this article to highlight the lack of integrity of particular DoD contractors but rather to provide insight into the weaknesses of the DoD's software acquisition

process, specifically how it uses the SCE. Regardless of contractor behavior, the burden is on the DoD to ensure that it awards a contract properly. Contractors will continue to stretch the truth in their efforts to please the evaluators. The problem lies not in this natural tendency but in the lack of procedures for controlling it. It is not the CMM's fault either, as some believe. We are confident that the CMM is robust enough to provide the assurance of maturity that the DoD needs. ♦

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