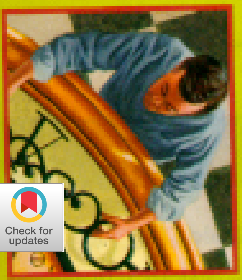

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# Combining Quality and Software Improvement

*A fascinating case study depicts how CMM and other improvement programs are used at PRC, Inc.*

**Selecting a process improvement paradigm that fits the culture of an organization can provide dramatic results. This article describes how PRC based its software process improvement (SPI) program on an integration of its corporate quality improvement (QI) program and the model-based initiatives of the Software Engineering Institute (SEI). The commitment to QI throughout PRC nurtures a culture characterized by rapid problem-solving, strong senior management support, a common process definition language, visible process improvement, and a network of process-related teams. PRC's SPI has leveraged this QI culture to mature rapidly to Level 3 and to establish a foundation for Levels 4 and**

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5 of the Capability Maturity Model (CMM) for software.

PRC, a subsidiary of Litton Industries, is a systems and software integrator whose primary customers are national government agencies. PRC has 5,600 employees in criminal justice/public safety, defense, document imaging, education/training, electronic commerce, global command and control, health/medical, intelligence, legacy systems, transportation, and weather/energy/space markets. PRC maintains four core competencies: open systems, program management, software engineering, and multimedia/imaging. The SPI program spans all PRC business units and worldwide locations. Prior to 1993, PRC approached SPI in the traditional fashion—a group within our Technology Center was responsible for "getting PRC to Level 3." This group performed assessments on two pilot projects, designed corporate processes, and wrote manuals that defined software engineering and SPI practices; yet no significant institutionalization beyond the pilot projects occurred.

In 1991, PRC investigated Total Quality Management (TQM) programs, selected a TQM vendor, and initiated pilot programs. This manufacturing-based program failed to take hold in PRC's services environment. Under strong new senior leadership, PRC tried again, this time using the QI process developed by Florida Power & Light (FPL). At that time, FPL was the only U.S. company to win the Deming Award for Quality. This approach is supported by a FPL spin-off—Qualtec Quality Services—and has three basic components: quality teams, quality in daily work (QIDW), and priority management. Currently, over 75% of PRC's senior management team are formally trained in QI, with over 100 process management (QIDW) systems in place company-wide. Quality management boards (QMB), consisting of managers and their direct reports, oversee the implementation of QI at corporate and business unit levels. The QMB initiates and acts as a steering committee for QI teams.

*Quality teams* use a 7-step problem solving process called the "QI story." Many of these teams cross functional areas. A QI lead team follows particular QI teams in the execution of their QI story or in the definition of processes, and facilitates the teams' recommended problem solutions.

*Quality in daily work* (QIDW) identifies, controls, and improves key work processes. We first identify our top-priority work processes and determine which need improvement. For those, we identify customers, determine what satisfies our customers (their valid requirements), and document the process to meet requirements using flowcharts and text. Next, we add targets and indicators to measure the process and the quality of its outcome. Using these indicators according to statistical process control principles, we monitor and modify our processes until they are stable and capable of meeting customers' needs. Then, we standardize and replicate them elsewhere in the business.

*Priority management* focuses on achieving breakthrough improvements in the highest priority areas. PRC's executive team conducts "voice of the customer" analysis to determine what is most important to customers, and "voice of the business" analysis to determine what is most important to employees and other key stakeholders.

## Applying QI to SPI

In early 1993, the U.S. Air Force released an RFP requiring a software capability evaluation. As a result, PRC senior management created the Phoenix team in March 1993 as a cross-project quality improvement team chartered to apply QI to SPI, to perform CMM-based assessments on 10 major software projects, and to produce a SPI plan to effect improvements at project and corporate levels. The team was to exist regardless of the outcome of the RFP (which was eventually retracted). Meanwhile, PRC could see the Phoenix team mechanism was working.

Phoenix team projects represented a range of size and a variety of clients and application domains, but shared a common element: a desire to improve their software processes. Team representatives were those who were "so key to their projects that they could not be spared;" they became local SPI champions.

Each project initiated two QI teams: a QMB and a Software Engineering Process Group (SEPG). The SEPGs are QI lead teams and report to their QMBs. This ensures that SEPGs are integrated into our continuous improvement program. As lead teams, SEPGs and QMBs initiate QI teams. Supporting the SPI program at the corporate level are several full-time staff positions—including the Technology Center SEPG, which derives its tasking from the PRC SEPG and the Director of the Software Engineering Core Competency. The combination of line

**Table 1.** QI and SPI tools and techniques used in the quality improvement story

| Quality Improvement Story | | |
|---|---|---|
| **Step:** | **QI Tools and Techniques** | **SEI Tools and Techniques** |
| 1. Reason for improvement | Graph, flowchart, control chart | CMM |
| 2. Current situation | Pareto chart, checksheet, histogram, control chart | CMM-based assessment |
| 3. Analysis | Cause and effect analysis (Ishikawa/Fishbone Diagram), Pareto chart, scatter diagram | Assessment report |
| 4. Countermeasures | Cost estimation, action plan, countermeasures matrix, barriers and aids | Software process Improvement plan |
| 5. Results | Pareto chart, checksheet, histogram, control chart | CMM-based assessment (PRC's radar chart) |
| 6. Standardization | Control chart, procedures, training | Process definition, training |
| 7. Future plans | Action plan, plan-do-check-act | Software process Improvement plan |

personnel involved in SPI and Technology Center full-time SPI resources has been critical to PRC's success.

The Phoenix team used the QI story as its methodology, but it supplemented freely with the tools and techniques provided by the SEI. The team found the two methodologies complemented each other; the SEI CMM methodology had a strong and well-established model that provides specific criteria, targets, and measurements, whereas the QI story provided a thorough problem-solving technique and set of tools. Table 1 shows where the SEI tools and techniques were inserted into the QI story.

In 1994, PRC initiated Phoenix II, beginning improvements on another set of 12 projects. Representatives from these projects learn QI and SPI tools and techniques, assess their projects using the PRC maturity questionnaire, build software process improvement plans, encourage each other, and broadcast their results within the company. A Phoenix III team began in September 1996; and PRC plans additional Phoenix teams in the near future to coordinate selected SPI efforts within other Litton divisions.

## Measuring Results

We performed a second set of assessments in January 1994, and have perform them annually ever since. We analyze the findings from the assessments to focus our plans each year (see Figure 1). Project and company objectives and priorities are incorporated into the SPI plans so they maintain a business case for SPI while countering weaknesses from the assessment, institutionalizing strengths, and progressing toward higher maturity levels.

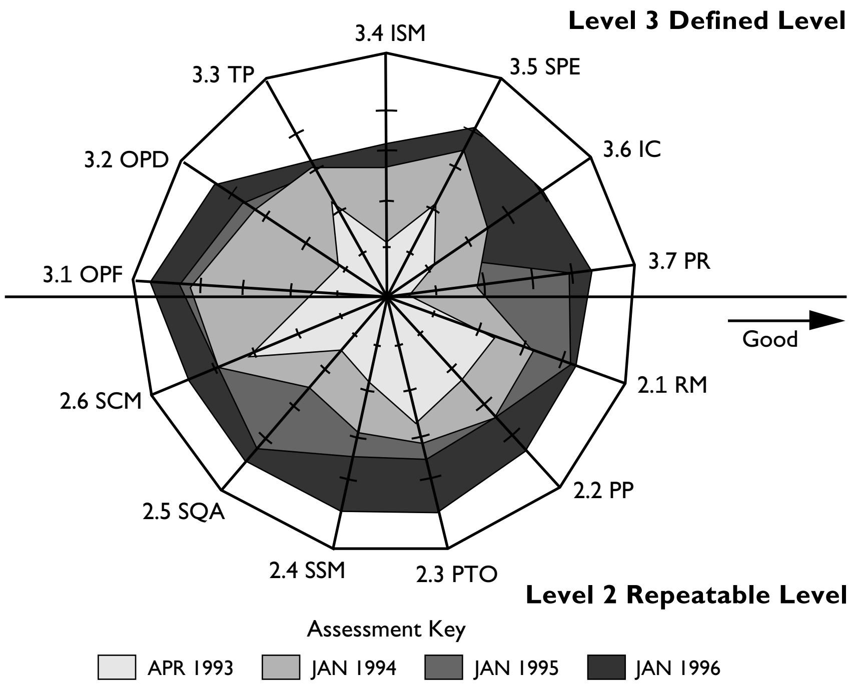
Since our goal is not just project but organizational maturity, we continue to reexecute the QI story each year. Our assessments have continued to show marked improvement in process maturity, which translates to achievements like a reduction in critical defect density of 49.9% between releases, and a time-to-market reduction of 28.6%.

A case study reporting the experience of 11 software projects in reusing 120 processes from 1991–1995 indicated the time to develop a project-specific process was dramatically lower through reuse, showing up to a 10 to 1 decrease in time to tailor a process [3].

In July 1996, PRC's Systems Integration business unit contracted an outside firm to conduct a Software Capability Evaluation, an independent assessment of PRC's progress in achieving CMM maturity. The firm certified the business unit and the six evaluated projects at CMM Level 3. It took them 39 months to move from Level 1 to Level 3, well below the mean of 55 months [1].

## Costs and Lessons Learned

The cost of SPI is shared within PRC as an overhead cost by the four business units, which invest in SPI based upon their organizational SPI commitments, goals, and customer needs. PRC has been engaged in QI/SPI for four years, spending




**Level 2 Repeatable Level**

| | |
|---|---|
| Requirements Management | RM |
| Software Project Planning | PP |
| Software Project Tracking and Oversight | PTO |
| Software Subcontract Management | SSM |
| Software Quality Assurance | SQA |
| Software Configuration Management | SCM |

**Level 3 Defined Level**

| | |
|---|---|
| Organization Process Focus | OPF |
| Organization Process Definition | OPD |
| Training Program | TR |
| Integrated Software Management | ISM |
| Software Product Engineering | SPE |
| Intergroup Coordination | IC |
| Peer Reviews | PR |

**Figure 1.** Results of PRC CMM-based assessments from 1993 to 1996

about $1 million a year, an average of $470 per software engineer annually. Table 2 compares PRC SPI cost data with those from 13 organizations representing a variety of maturity levels [2].

Top management commitment to both QI and SPI has been essential to achieving accelerated maturity. The CEO enforces and rewards SPI involvement, advocates the program at the PRC QMB, and hosts a semiannual Executive Sponsor Status Review. SEPG representatives, program managers, and senior managers, up to and including the CEO, attend the status review, where results and issues are shared company-wide, project success stories are showcased, and every project displays their "CMM poster," detailing current status and progress. To meet middle managers' need for planning information, a "Managing Software Process Improvement" course is offered.

The biggest challenge to continued progress in SPI is maintaining momentum and visibility. Key countermeasures are the status review, lead team briefs, PRC-wide SPI symposia, internal technical articles, capability evaluation readouts, SEI visits, and wide participation by line organizations.

Top down organizational goals drive business unit objectives; SPI goals are included in personal objectives of key management. We consider QI and SPI as the "way we do business." It is not optional. This has required a substantial cultural change both for PRC and, in some cases, for our customers.

We have found that the things that are measured are the ones that improve, but PRC experienced early difficulty in institutionalizing measurement. Keys to our current success are:

- Active management involvement
- Trained project champions
- A full-time metrics advocacy function

**Table 2.** Comparison of PRC and industry SPI costs

| CATEGORY | INDUSTRY RANGE | INDUSTRY MEDIAN | PRC |
|---|---|---|---|
| Total yearly cost of SPI activities | $49,000 – $1,202,000 | $245,000 | $1,112,000 |
| Years engaged in SPI | 1–9 | 3.5 | 4 |
| Cost of SPI per software engineer | $490 – $2004 | $1375 | $470 |

• Higher project maturity, which motivates measurement

Training courses were developed for PRC corporate processes, including how to tailor them for specific projects. A cadre of SPI instructors is maintained to teach the "PRC way." As individuals move among projects, the basic processes, procedures, methods, and tools are familiar, and are the product of continuous improvement.

In 1994, the PRC SEPG converted its electronic Process Asset Library, a collection of SPI-related assets, to web-based technologies. The number of assets now totals over 1,000, including the corporate SPI processes, training materials, and related artifacts. When project "Best of Breed" processes failed to take hold, we used domain engineering techniques to build reusable processes.

The PRC Phoenix SPI Reference Manual provides information to every software engineer about PRC's software engineering policies, the CMM, the asset library, PRC's SPI Training Program, and other PRC-developed SPI tools. These tools include a CMM poster that displays a project's maturity, the Process Asset Library, and the PRC Maturity Questionnaire, which automates analysis and reporting of an expanded SEI questionnaire.

## Plans for the Future

In the near term, PRC plans to replicate our Phoenix process, reaching more projects and sites. We also expect to support SPI for small projects, expand our use of measurement, assess the personal software process, and support and extend our web-based asset library. Moreover, we will establish Level 4/5 "potential maturity" through process definition, documentation, and training of all Level 4 and 5 key process areas.

Each of these plans relies on elements of the QI infrastructure. Of particular value to certain Level 4/5 processes (for example, quantitative process management, process change management, defect prevention, and technology change management) is the requirement embedded in our QI/QIDW system for quality and process indicators. Therefore, improved measurement activities and use of statistical control techniques will result in additional maturity gains. The synergy between PRC's QI and SPI programs enables us to plan aggressively for Level 4 and 5 maturity at selected divisions, sites, and projects. C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