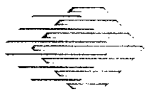

Carnegie Mellon
Software Engineering Institute

The 2001 High Maturity Workshop

Mark C. Paulk
Mary Beth Chrissis

January 2002

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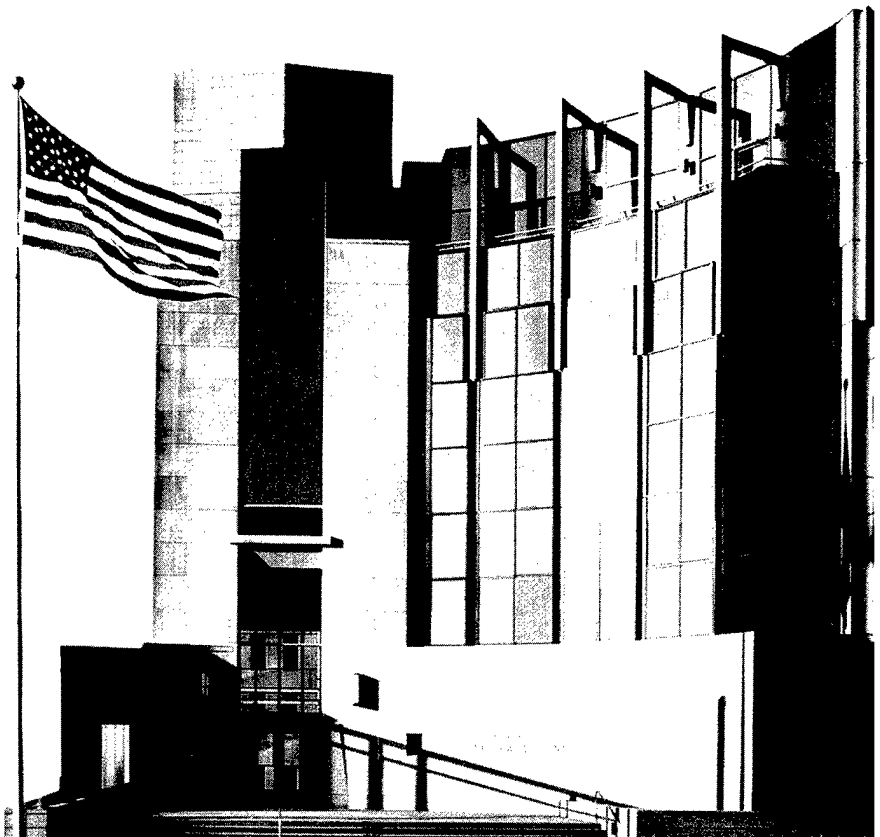

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The 2001 High Maturity Workshop

CMU/SEI-2001-SR-014

Mark C. Paulk
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January 2002

Software Engineering Process Management

This report was prepared for the

SEI Joint Program Office
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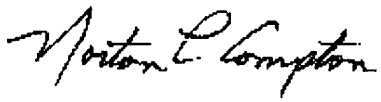

Norton L. Compton, Lt Col., USAF
SEI Joint Program Office

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Table of Contents

List of Figures

List of Tables

Abstract

In March of 2001, the Software Engineering Institute (SEI) in Pittsburgh, PA, hosted a workshop for high maturity organizations to better understand practices that characterize Capability Maturity Model® for Software (Software CMM®) Level 4 and 5 organizations. Topics of discussion included practices described in the Software CMM as well as other practices that have a significant impact in mature organizations. Important themes included statistical process control for software, the reliability of Level 4 and 5 assessments, and the impact of the CMM Integration℠ effort. Additional topics solicited from the participants included measurement, Six Sigma, Internet speed and process agility, and people and cultural issues. This report contains overviews of more than 30 high maturity organizations and the various working group reports from the workshop.

® Capability Maturity Model and CMM are registered in the U.S. Patent and Trademark Office.
℠ CMM Integration is a service mark of Carnegie Mellon University.

1 Introduction

A workshop for high maturity organizations was held on March 27-29, 2001, hosted by the Software Engineering Institute (SEI) in Pittsburgh, PA. The purpose of this workshop was to better understand practices that characterize the Capability Maturity Model® for Software (Software CMM®) Level 4 and 5 organizations. This workshop was by invitation only. The SEI invited representatives from all known Level 4 and 5 organizations and Lead Assessors/ Evaluators who had reported assessing a Level 4 or 5 organization. There were 48 participants, representing 35 high maturity organizations. The individuals participating are listed in Appendix A. The organizations represented are listed in Appendix B.

Previous high maturity workshops were held in 1996 [Paulk 99] and November 1999 [Paulk 00a]. Previous surveys of high maturity organizations were held in 1998 [Paulk 99] and 1999 [Paulk 00b].

Topics of discussion included both practices described in the Software CMM and other practices that have a significant impact in mature organizations. Themes that were anticipated to be important to the workshop participants included statistical process control for software, the reliability of Level 4 and 5 assessments, and the impact of the CMM Integration effort. Additional topics solicited from the participants included measurement, Six Sigma, Internet speed and process agility, and people and cultural issues. This report contains overviews of more than 30 high maturity organizations and the various working group reports.

The workshop began with a welcome by Clyde Chittister, Chief Operations Officer of the SEI. This was followed by an overview of the workshop agenda. The proposed working group sessions were revised by the attendees to make the most effective use of the time available.

A survey on high maturity practices was distributed in February 2001 to all known Level 4 and 5 organizations[1]. Participants in the workshop were briefed on the preliminary results of that survey to inspire discussion within the working groups. For representatives from Level 4 and 5 organizations, completing the survey was a prerequisite for attending the workshop, as was providing an organizational summary for this report. Lead Assessors/ Evaluators were asked to provide a working paper on their insights into high maturity practices.

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[1] Paulk, Mark C., Goldenson, Dennis, and White, David M. *The 2001 Survey of High Maturity Organizations* (CMU/SEI-2001-SR-013).

Working group sessions were run as afternoon plus morning discussions, with briefings on working group conclusions after lunch. A general workshop debriefing was held on the last day. Steve Cross, Director of the SEI, closed the workshop by thanking participants.

The high maturity organizations invited were identified as the result of appraisals that were conformant with the CMM Appraisal Framework (CAF). These are usually CMM-based assessments for internal process improvement (CBA IPI), or, less frequently, software capability evaluations (SCE). In both of these methods, the appraisal team should be led by, respectively, an SEI-authorized Lead Assessor or Lead Evaluator. There are also a few instances of CAF-conformant appraisals in the list, where the appraisal method has been reviewed and approved by the SEI. Appendix B notes those cases where the appraisal was not a CBA IPI.

2 Preliminary Results of the 2001 Survey of High Maturity Practices

The preliminary results of the 2001 survey of high maturity practices briefed to the workshop participants were based on 41 responses from 132 organizations reported as being assessed or evaluated at Level 4 or 5. The preliminary results are summarized below; the final results will be published as an SEI special report[2].

According to the preliminary results, high maturity organizations typically:

- have an independent software quality assurance (SQA) organization
- use domain-specific software architectures
- have a centralized measurement program
- have required training in management skills

Most high maturity organizations:

- are ISO 9001 certified
- have a Total Quality Management (TQM) program for the assessed organization or some higher corporate level
- embed SQA in the process
- use incremental or evolutionary life cycles
- do user interface prototyping
- have independent test groups
- measure code coverage of testing
- have product lines or families
- do other forms of systematic reuse
- use Pareto analyses
- use control charts in code, test, design, and requirements
- have required training in software engineering skills, team building, domain knowledge, interpersonal skills, and change management

[2] Paulk, Mark C., Goldenson, Dennis, and White, David M. *The 2001 Survey of High Maturity Organizations* (CMU/SEI-2001-SR-013).

Many high maturity organizations:

- use Balanced Scorecard
- use CMM Integration[SM] (CMMI[SM])
- use Six Sigma
- use the People CMM
- use Delphi methods for estimating
- use parametric cost models
- use chief architects and chief engineers
- do integrated process and product development
- use earned value
- use defect prediction, reliability, and/or release readiness models
- use formal methods
- use cost of quality
- use orthogonal defect classification or other defect taxonomies
- use control charts in operations
- use structured English (or another natural language) for process definition
- use ETVX (entry criteria, task, verification, and exit criteria) process modeling notation
- have a formal mentoring program
- have required training in meeting management

Some high maturity organizations:

- use ISO/IEC 12207 (Software Life Cycle Processes)
- use Malcolm Baldrige National Quality Award criteria
- use Systems Engineering CMM
- use ISO/IEC 15504 (Software Process Assessment)
- use EIA/IS 731 (Systems Engineering Capability Model)
- use critical chain
- use PSP[SM] (Personal Software Process[SM]) and/or TSP[SM] (Team Software Process[SM])
- use Quality Function Deployment
- use regression analysis
- use analysis of variance

[SM] CMM Integration, CMMI, PSP, Personal Software Process, TSP, and Team Software Process are service marks of Carnegie Mellon University.

- use process modeling
- use confidence intervals
- use prediction intervals
- use hypothesis testing
- do designed experiments
- do quasi-experimental design
- use other multivariate techniques
- use EITVOX (entry criteria, inputs, task, verification, outputs, and exit criteria) process modeling notation
- use IDEF0 (function modeling method)
- use SADT (structured analysis and design technique)
- have required training in principled negotiation

All of the responding organizations began their software process improvement programs before 1998. Ten of the respondents were DOD or other government contractors, two were government agencies, two were commercial shrinkwrap organizations, and 14 were custom software developers. Most of the respondents build embedded systems, many build real-time applications, and some develop management information systems.

3 Working Papers from Lead Assessors

Lead Assessors and Evaluators were asked to provide a working paper on assessing high maturity organizations. A template was provided with five sections suggested.

First, the Lead Assessors were asked to include any desired supplemental information, e.g., an ISO 9001 auditor, an ISO 15504 assessor, etc.

Second, with respect to assessing high maturity organizations: What were some of the difficult questions they had to answer in determining whether an organization was Level 4 or 5? How were the questions resolved? Why was the decision made as it was? What are the issues seen for reliable and consistent high maturity assessments? Should Level 5 organizations continue to reassess using CMM-based appraisals for internal process improvement (CBA IPI) or the standard CMMI assessment method for process improvement (SCAMPI[SM]) every 2-3 years? Are there more effective assessment methods for high maturity organizations?

Third, in characterizing high maturity: What are some of the things that characterize high maturity, i.e., a low maturity organization would not be expected to do this, but it is an important contributor to high maturity capability? What practices are high maturity organizations abandoning, or radically changing, as they move to Levels 4 and 5? For example, are there measures that might be useful at Level 2 that are either abandoned or significantly modified in moving to Levels 4 and 5? What are some of the people issues that high maturity organizations have to deal with that may be different or addressed differently? Is there anything special about team building? About change management? About skills building? Formal mentoring programs? Extensive induction training for new hires? Is turnover an issue? Growth? Has employee morale improved as a result of the process improvement activities?

Fourth, with respect to continuing improvement: What are the priorities that high maturity organizations need to work on next? What are the improvement objectives? The practices that they are adopting or refining? What are the biggest barriers they are currently facing? Are there other models or standards they are using (or moving to)?

Fifth, to summarize: What does it mean to be maturity level 4 or 5? What is different? What are the effects on the organization?

Only one of the participating Lead Assessors provided the working paper requested. Several of the participating Lead Assessors did so as representatives of their organization and may

[SM] SCAMPI is a service mark of Carnegie Mellon University.

have provided feedback on the issues above as part of the organizational summaries in the next section of this report. The following section in this chapter of the report was written by the Lead Assessor and has been lightly edited.

3.1 Judah Mogilensky, Process Enhancement Partners, Inc.

In my paper for the 2001 SEPG Conference, entitled "Behavioral Clues to Organizational Process Maturity," I described my approach to using observable behaviors of managers, participants, and assessment team members as a way to increase or decrease confidence in assessment results. Specifically, I discussed observable behaviors that help confirm that an organization really deserves a rating of Level 4 or Level 5.

The perspective that leads to this approach comes from my training in the family therapy techniques of Virginia Satir. In family therapy, everything is relevant data, not just the transcripts of the "official sessions." Examples of other types of data include:

- who first calls the therapist; what do they say
- who shows up for sessions
- in what order do they enter the room
- where do they sit, what body postures do they assume
- who calls between sessions, how are commitments for future sessions made

All of these items are considered relevant data because they all demonstrate and reveal the relationships and interactions going on within the family. In the same sense, people in the software process improvement community have long recognized that maturity levels are not just unconnected groups of practices, but they are cultural patterns that extend across the organization. (As a aside, one of my concerns with the continuous representation used in the CMMI models is precisely that it does encourage viewing process areas as separate, unconnected, and independent, not as part of an organization-wide pattern of behavior.)

In my work with organizations, especially performing assessments based on the Software CMM, I began to notice recognizable behavior patterns that characterized the different maturity levels. I realized that these patterns could be used informally to confirm, or to raise doubts about, the "official" assessment data. This is not to suggest that formal assessment ratings should be based on anything but the official data, i.e., maturity questionnaires, document reviews, interviews, draft findings feedback, etc. However, useful confirming (or disconfirming) data can be observed from several sources, including:

- management behavior during contracting phase and delivery phase
- participant behavior during on-site period

- team member behavior during training and on-site period

Rather than discuss my indicators of low (Level 1) and moderate (Levels 2 and 3) maturity, I will restrict myself to indicators of high (Levels 4 and 5) maturity in this section of the report.

Indicators of high maturity derived from observing management behavior include:

- The organization has collected duration and effort data from previous assessments. This information is offered to the Lead Assessor, with the clear expectation that it will be used in planning the current assessment.
- Senior managers (including senior management sponsors) are generally not included in interviews as assessment participants. In planning the current assessment, organization members point out that senior managers are so involved in the process that failing to include them would risk missing crucial data about the process. They may or may not, in the end, be included, but there is substantial discussion about including them.

Indicators of high maturity derived from observing assessment participant behavior include:

- Across the different interview sessions, there is widespread awareness among the participants of what measurements are used on projects, and how. When invited to bring materials that they find helpful to the interview sessions, several participants bring tables and charts with them, which they can explain in detail.
- In virtually every discussion group, participants tell new stories about process improvement suggestions that were made and implemented. There may be some duplication of the examples cited, but there are enough instances of process improvement suggestions accepted that almost all the ones cited are new.
- During at least one group discussion session, as participants from different projects are discussing some problem or issue they have encountered, the rough equivalent of a causal analysis session spontaneously "breaks out." Typically, the session facilitator must intervene to stop the discussion and bring the discussion session back to the planned topics.

Indicators of high maturity derived from observing the assessment team members (assuming that they are largely drawn from the organization being assessed) include:

- The typical assessment team provided by a high maturity organization has substantial prior assessment experience, enough to put an experienced team member on every mini-team. Assessment team members are very well prepared for their roles, even before team training.
- The team routinely completes the work of each day on that day. While catch-up efforts are done if they are needed, such efforts are rarely needed.
- At least one or two mini-teams look for opportunities to get ahead of the scheduled team work plan (e.g., by starting to prepare draft findings early).

- My only instance of giving a team a scheduled work day off during an assessment on-site period was for a Level 5 rated organization, when the team completed all its work but the senior executive sponsor did not want to hold the Final Findings briefing a day early.

Again, it must be emphasized that no single instance of these, or other, behaviors, is decisive. Rather, what I am looking for is a consistent pattern of behavior as a way of increasing (or decreasing) confidence in the results indicated by the normal, "official" assessment data.

4 Organizational Summaries of High Maturity Organizations

Members of any high maturity organization, whether they planned to participate in the workshop or not, were invited to provide an organizational summary. These descriptions were intended to be brief, on the order of 1-3 pages, although summaries were allowed. Organizations were asked to provide their name, city, and U.S. state or country. They were asked to provide the summary data listed in the table below.

Maturity Level	4 or 5
Date of Assessment	month year
Lead Assessor(s)	(or Lead Evaluators) as authorized by SEI (or company if CAF-conformant assessment rather than CBA IPI)
Point of Contact	name and email address of contact person
Web Page	if one exists for the organization
Size of the Organization	number of software professionals (full-time employees, not including temporary staff)
Typical Program Size	number of people per typical project
	number of lines of code or function points per typical program
Primary Application Domain(s)	product lines, domain-specific architectures, etc.

This could be followed by any desired supplemental information about the organization as a whole. Examples from the previous high maturity workshop included ISO 9001 certification, PSP/TSP training, history of the software process improvement program, or a description of assessment variants (CAF-conformant corporate assessment).

They were asked to provide return-on-investment (ROI) and improvement trend data. This included how much had been invested in software process improvement (total and per software engineer) and what kind of business benefit had been obtained in terms of cost, schedule, quality, etc., i.e., the return on investment. It also included the primary business objectives that the improvement program was measured against, e.g., decrease post delivery defects by 50% within one year, increase customer satisfaction to 94% within one year, etc. Graphics showing improvement trends over time against the business objectives were requested.

They were asked to describe the barriers to achieving high maturity that they had encountered. These barriers could be process, measurement, cultural, business environment, or customer relation. The intent was to identify the things that had to be done differently to transi-

tion to Level 4 or 5 (or the issues that were problems before but became dominant problems that had to be solved to become Level 4 or 5). Particularly useful would be any things that the organization tried and abandoned because they did not help.

They were asked to describe any unique or distinguishing practices that they considered characteristic of high maturity, i.e., a low maturity organization would not be expected to do this, but it is an important contributor to the high maturity capability of the organization.

They were asked to describe any people and cultural issues that high maturity organizations have to deal with that may be different – or addressed differently. Is there anything special about team building? About change management? About skills building? Has the organization established a formal mentoring program? Extensive induction training for new hires? Is turnover an issue? Growth? Has employee morale improved as a result of the process improvement activities?

They were asked to describe their continuing improvement activities. What do they need to work on next? What were the improvement objectives? What were the practices being adopted or refined? What were the biggest barriers the organization was currently facing? Did they plan to reassess using the Software CMM? Were there other models or standards they were using (or moving to)?

To conclude, they were asked to summarize what it means to be maturity level 4 or 5. What is different? What are the effects on the organization?

The following sections in this chapter of the report were written by representatives of the various high maturity organizations. They have been lightly edited.

4.1 Atos Origin India, Mumbai, India

Maturity Level	5
Date of Assessment	November 2000
Lead Assessor(s)	Cyril Dyer
Point of Contact	Darayus S. Desai, darayusdesai@atosorigin.com
Size of the Organization	~ 350 at the time of the assessment
Typical Program Size	Average project size is ~15 persons (ranges from 5 to 40 persons)
Primary Application Domain(s)	Commercial custom-built software Embedded software Information systems software, for business information Enterprise resource planning (ERP) packages

Atos Origin India is part of Atos Origin, a top tier, global IT consulting and services company, with operations in more than 30 countries. Atos Origin India primarily focuses on pro-

viding the full range of software engineering and ERP-related services to clients in India and across the globe.

Atos Origin India started its quality journey in 1993, soon after its inception, and achieved the first quality milestone with the ISO 9001 certificate in July 1994. After evaluating various quality models, we decided to adopt the Software CMM. An informal CMM assessment in January 1996 found us to be close to Level 3. During that period we were growing very rapidly and undergoing substantial change in terms of the service portfolio and nature of business. Consequently, the Quality System went through several evolutions, until it reached a stage where it had to be completely revamped. This meant a major improvement initiative, led by the P&Q (Processes and Quality) function with help from a number of task forces consisting of seasoned practitioners.

After a number of informal mini assessments along the way, we underwent a formal assessment in October 1999, when we were assessed at Software CMM Level 4, followed by another formal assessment in November 2000 for Level 5.

4.1.1 ROI and Improvement Trend Data

While we have realized returns in various areas, one of the major benefits has been the constant upward trend in customer satisfaction. While no customer rated us at 5 (on a scale of 0 to 5) until 1997, today we have 40% of the customer satisfaction surveys with a rating of 5, and we have built strong long-term partnerships with our customers.

We have also seen a significant improvement in the defect-free deliveries and achievement of planned schedules.

The bottom line has also shown a positive trend over these years, although there are various other factors too, besides process improvement, that have contributed to that.

4.1.2 Barriers to Achieving High Maturity

Some customers have a misconception about processes and the Software CMM; they perceive these as overheads, both in terms of time and cost. Further, some customers themselves are at a very low maturity level and convincing them to follow at least some basic processes is also a tough job. This barrier was overcome by educating and convincing them about the benefits of a structured process approach and assuring them that it was not going to affect their costs and schedules.

Several employees also felt that their job was "software engineering," and Software CMM or ISO did not seem to fit into their scheme of things. They had to be educated and convinced about the reasons why we were doing this and the benefits. This was done through regular awareness programs, quality forums and actual case studies. Furthermore, the Quality System

was written based on our business model, avoiding any Software CMM or ISO specific orientation.

Initially, we had the tendency to take too many measurements, many of which were not being subsequently used. People also felt that there were too many forms. So these were reviewed critically and several forms were merged, and some forms and measurements were dropped to avoid duplication and remove the extraneous ones.

4.1.3 Unique or Distinguishing Practices

These include

- high level of senior management commitment—not just in terms of statements and funding, but also demonstrated by *actual participation* in process improvement activities
- usage of tools—preferably ones with the workflow integrated into them
- higher level of sharing knowledge and experiences across the organization (not just within business units)
- stronger focus on proactive improvements
- in-depth understanding of our processes

4.1.4 People and Cultural Issues

Some of the people issues have already been described in the section on barriers.

Since we get new recruits with varied backgrounds from diverse organizations, it is crucial to get them into the Atos Origin quality culture. Specific awareness programs and refresher courses are held regularly to build and sustain this culture. Creating process action teams with people across different business units helped in team building, as well as greater sharing of experiences across the entire organization, thus reducing "compartmentalization."

Involving practitioners in process improvement initiatives helped build a better sense of ownership and disseminate the culture further into the organization.

During the initial stages of the Software CMM initiative there was a certain amount of resistance and the morale even went down slightly, but as people started to see the results and benefits over a period of time, it improved substantially.

Software CMM does not address people issues adequately, and that gap has to be filled in by other practices.

4.1.5 Continuing Improvement

We are currently working on ISO 9001:2000 and also starting with the People CMM initiative. The objective is to excel in whatever we do; not just to achieve business goals set by ourselves, but also perform well by benchmarking against other best-in-class organizations.

4.1.6 Summary

Level 5 provides the basic foundation of well-understood processes and a strong culture oriented towards process and quality improvement. We intend to use it as a launching pad, for aiming for greater heights such as business excellence, and ensuring that besides achieving our business goals, we are able to benchmark ourselves with other best-in-class organizations.

Customer satisfaction has gone up tremendously and so has repeat business.

Overall, it has enhanced our image greatly, in the eyes of our customers, other sister organizations, as well as our employees, who feel proud to be part of a Level 5 organization.

4.2 Boeing's Reusable Space Systems (RSS) and Satellite Programs (SP) in Downey and Seal Beach, CA

Maturity Level	5
Date of Assessment	October 1999
Lead Assessor(s)	Jeff Facemire
	Andreas R. Felschow
Point of Contact	D. Dillehunt, Donald.Dillehunt@west.boeing.com
Web Page	Boeing Space & Communications Group (overview):
	http://www.boeing.com/defense-space/sc-back/index.html
	Commercial Information Systems (formerly Satellite Programs):
	http://www.boeing.com/defense-space/sc-back/index.html#cis
	Reusable Space Systems:
	http://www.boeing.com/defense-space/sc-back/index.html#rss
Size of the Organization	350
Typical Program Size	Number of people per typical project is around 100
	Number of lines of code or function points per typical program is about 500,000 SLOC
Primary Application Domain(s)	Military software, adhering to DoD standards, and systems software, used to control physical devices

In 1984, Rockwell's Space Systems Division (SSD) became a technology transfer site for Southern California, and SSD's Software Engineering Directorate was formed. A Software Methods group was created in 1986, a precursor to the Software Engineering Process Group

(SEPG). An informal self-assessment was performed in 1989 and again in 1991. At this time, SSD had projects supplying products to DoD, NASA, and commercial customers, where each customer used its own terms and required different reviews and products. We included all customer types in our March 1992 self-assessment (through SEI Software CMM Level 3). In April 1992, Rockwell had the Software Productivity Consortium (SPC), an authorized SEI assessment organization, validate revisions to our improvement plan, and our CMM-based self-assessment.

In September 1994, another internal process improvement appraisal was held in which we evaluated ourselves as meeting the criteria for a Level 3 organization. The four largest software projects participated in this appraisal, sampling our entire customer base. In 1995, we received our ISO 9001 certification. In 1997, the scope of our Software CMM effort was expanded to five projects and self-evaluation through Level 4 as our business grew. In 1998, our division joined The Boeing Company, and the following reorganization effort was focused on three remaining projects. In 1999, we were assessed that we were operating at an SEI Software CMM Level 5. A CBA IPI was performed on Reusable Space Systems (RSS) and Satellite Programs (SP). Three projects representing over 70% of the embedded flight software staff were evaluated. We are the third and largest Boeing organization to receive a Level 5 rating.

4.2.1 ROI and Improvement Trend Data

We were involved in two Software Capability Evaluations and one Software Development Capability Evaluation, the results of which contributed to multimillion-dollar contract awards. Additionally, process improvements have lowered our development costs as shown in Figure 1 (development costs are normalized to the year 1989's hours / SLOC values). We have reduced our defect rates to such an extent that one project has had no defects reported in its delivered software products since 1997. Our investment in process improvement has remained stable during this time, with an average of nine personnel per year working on organizational process activities from 1992 to 1999. Additional personnel on each project were assigned project process activities.

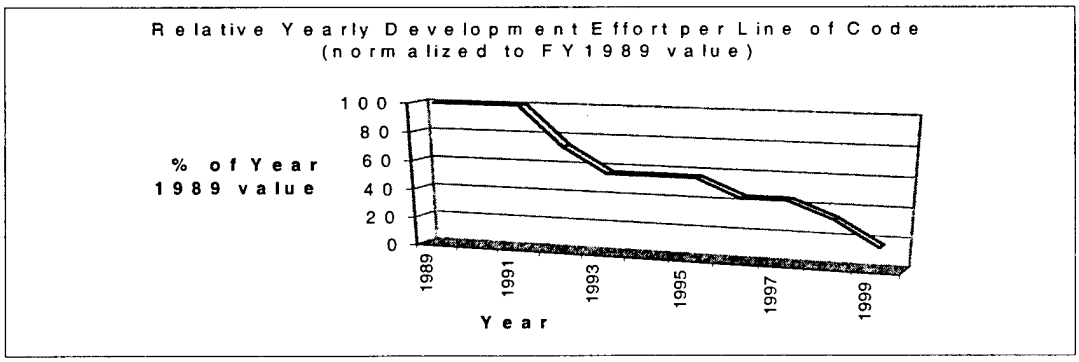

Figure 1: Boeing Process Improvements Lower Development Effort per Line of Code

Figure 2 represents the training performed on a yearly basis. Attendees shown in the chart reflect the number of personnel attending classes; personnel attending multiple classes are counted for each class attended. Note that more training is required each time the organization strives to reach a new level. Once the level is reached, and most personnel are trained, training drops off during the next improvement planning cycle. Level 3 was attained in 1994 and Level 5 appraised in October 1999.

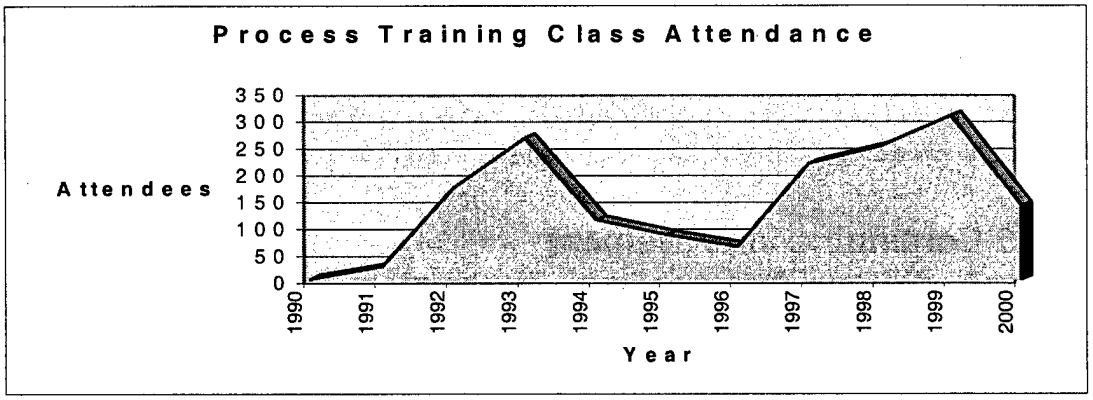

Figure 2: Significant Process Training Needed To Reach Software CMM Level 5

4.2.2 Barriers to Achieving High Maturity

Level 4 required additional personnel training on the application of a form of statistical control process to be used across the organization. Due to the merger of Boeing and McDonnell Douglas, we were able to leverage pre-existing McDonnell Douglas Malcolm Baldrige training, reducing the investment cost for Level 4 training activities.

Being a Level 4 organization means projects must be convinced that investing in this type of statistics will provide benefits over the course of the program. Having been a Level 3 organization for a significant time, our projects saw that the benefits in customer satisfaction, reduced errors, and on-time deliveries were worth the project management and peer review effort expended. Level 4 was a leap of faith for projects that did not have previous experience to provide assurance that the new efforts would benefit them. The organization needs to provide support to assist projects until the benefits are realized and processes internalized.

There are added project costs to provide data if it is a test project for a new technology or process. Acquiring that data is probably one of the hardest obstacles that must be overcome to become a Level 5 organization. If a project has traveled the Software CMM path from a lower level, it is more likely that it may feel an obligation to the organization for benefits derived from the long association. Obtaining data from new and especially short-term projects is more difficult and can require persistence from SEPG personnel.

4.2.3 Unique or Distinguishing Practices

As a Level 5 organization, we provide consistency across all projects regarding availability of tools and processes, the collection of metrics through our integrated tool set, and project setup and defect prevention activities. Continued organizational investment in mechanisms for cross-project dissemination of lessons learned also is a critical factor in maintaining open lines of communication between projects.

4.2.4 People and Cultural Issues

The Space Beach Host Engineering Mentorship Program began in 1990 and has had more than 300 participants. This program is used as an adjunct to the more formal software process training program, and has proven to be very valuable in transferring skills from experts to new personnel. The goal of the mentorship program is to capture critical skills within engineering by providing training in meta-cognitive skills and mentoring strategies.

4.2.5 Continuing Improvement

Our most significant challenge is business consolidation, with the associated reorganization and restructuring of our financial resources. In December 1999, our business unit from Downey, CA, was consolidated with the business unit at a former McDonnell Douglas facility in Huntington Beach. As of January 2001, our core engineering function now hosts four separate business units: Human Space Flight and Exploration (HSF&E), Expendable Launch Systems (ELS), Integrated Defense Systems (IDS), and Phantom Works (PW).

These groups are located mainly at three sites in California: Huntington Beach, Seal Beach, and Long Beach. Our near-term challenge continues to be the consolidation of McDonnell Douglas, Rockwell, and Boeing procedures and personnel within a Boeing structure, including a reallocation of funding, project and core responsibilities, and personnel. Additionally, the president of Space and Communications has challenged all business units to reach Software CMM Level 5. In addition to achieving higher maturity levels, we are now working to address changes as a result of last year's release of the new system and software integrated CMM, i.e., the CMMI, as well as changes associated with moving from ISO 9001 to AS9100.

4.2.6 Summary

Being a Level 5 organization means investment in the future. Our organization funds research into new processes and technologies, verifies usefulness, and provides this data to projects. Our organization recommends best practices. As projects, business thrusts, and customer bases change, our process needs to evolve to reflect the current situation. Our motto has been "a race without a finish" which requires our continued commitment to meet the needs of both our organization's projects and their customers for us to remain successful. Continued investment and vigilance in assessment of future goals is needed to stay at the top.

4.3 CG-Smith Software, Bangalore, India

Maturity Level	5
Date of Assessment	October 1999
Lead Assessor(s)	Richard. F. Storch
Point of Contact	Raghavendra Swamy
Web Page	www.cg-smith.com
Size of the Organization	260
Typical Program Size	0.17 KSLOC–350 KSLOC
Primary Application Domain(s)	Commercial software in real-time embedded systems: automotive electronics and aerospace, data communications and telecommunications, process control and instrumentation, medical electronics, language processing, and electronic design automation (EDA)

4.3.1 ROI and Improvement Trend Data

On average, productivity has tripled in the last five years.

4.3.2 Barriers to Achieving High Maturity

Some of the barriers that we have faced include

- resistance to new process change
- middle management buy-in
- working with customers who are at different process maturity

4.3.3 Unique or Distinguishing Practices

The unique practices at CG-Smith (CGS) that characterize the high maturity of the organization and that distinguish CGS from low maturity organizations are:

- CGS has a proven proprietary software development methodology that has delivered outstanding results to more than 175 projects executed. The methodology is based on the Uniphase model.

  Uniphase: the process model that is followed at CGS. Uniphase is composed of four basic elements, the process, the screen, the store, and Management and Control (M&C).

  Process: defines the transformation activities of the Uniphase.

  Screen: identifies the techniques that verify and validate products produced by the process elements.

Store: identifies the input and output products of the software process element as well as their source and destination. It configures, manages, and controls the software products produced by the process element.

Management and Control (M&C): identifies the resources and the mechanisms required to monitor and control the process, screen, and store elements within the Uniphase. It describes the measurements to be taken and the reports to be generated, as well as identifies all persons responsible for managing the Uniphase.

- *SPN (Structured Process Notation)*: identifies the work breakdown structure (WBS) and is used to define the transformation activities of the Uniphase process element. It identifies the sequence of activities as well as the linkage of activities.
- *Quantitative Process Management*: similar to how the CEO of the company decides on the performance of the company by just two numbers, i.e., debit / credit and profit / loss, projects at CGS are managed effectively and more predictably only by six numbers. They are:
  - *Engineering Effort (WE):* total engineering effort for the product.
  - *Rework Effort (RE):* total rework effort for the product. This includes rework due to additional customer requirements and defect correction.
  - *Pre-Release Defects (DF):* defects found before the product gets stored.
  - *Post-Release Defects (DE):* defects found after the product has been stored.
  - *Changes from Customer (FC):* changes initiated to incorporate additional requirements from the customer.
  - *Changes Due to Defects (UC):* Changes initiated due to post release defects.
- Process automation: a high level of process automation has been done at CGS. The tool consists of seven modules:
  - *Process Definition:* allows the user to define the WBS for the project. It gives the user enough flexibility to separate a huge activity or integrate two small ones, divide the project as per the products that are to be delivered, etc.
  - *Project Management:* helps manage project estimation, project tracking and analysis, and organizational performance analysis.
  - *Defect Management:* helps manage defect recording, defect tracking and analysis, and defect prevention.
  - *Change Management:* helps in version management, managing change requests, and change implementation tracking and analysis.
  - *Knowledge Management:* helps to manage the knowledge capture at the personal, project team, and organizational level. The knowledge thus captured is available online to each engineer in an organization.
  - *Process Improvement:* helps to record process suggestions and monitors new process implementation.
  - *Resource Management:* helps to populate and maintain human resource skill repository, logs and maintains equipment history, and matches project needs with suitable resources.

This unique Process Automation tool provides process, project, and knowledge management solutions. It focuses on the intricacies involved in process definition, project estima-

tion and tracking, management of defects and changes, and helps build a continuously improving organization.

- *Process Improvement:* CGS has a very active process improvement program in place. For the last five years, we have received close to 600 process improvements from the engineers in the organization, testimony to the fact that CGS is a learning and improving organization.

4.3.4 People and Cultural Issues

We have developed procedures and practices in line with the requirements of the People CMM, which addresses issues such as training, mentoring, skills building, and career growth. All these are at different levels of institutionalization in the company. Training has been identified for all levels of people in the organization, which includes training on process, engineering, domain, and technology. Induction training for new recruits is very comprehensive and covers all areas of software development and the soft skills required. Mentoring is being done by the managers.

Further we have a very good process improvement program in place with a reward mechanism associated. Employees are reaping the benefits, and the morale of the engineers is very high as they see a distinct difference and benefits from process improvement. However, growth of the organization calls for a more dedicated and focused effort to sustain the above program.

We are maintaining a very comprehensive skill database, which details the complete skills that engineers have acquired to date, including the competencies and expertise that he/she has acquired at CGS. The skill database is part of our Process Automation tool, which gives instant information to the line managers about the skills acquired. This helps managers plan for the training to build skills of the engineers.

4.3.5 Continuing Improvement

The biggest barrier facing us is with respect to changing the attitude of people towards creating new processes, dismantling processes, or changing existing processes, as the tendency is "If it's working, why change it?" However, CGS management has strengthened its Process Improvement initiative by substantially enhancing the reward program and also has tied process improvement initiatives to the employee appraisal system. This has yielded results to a greater extent in changing the attitude regarding continuous improvement. Since being assessed at Level 5, we have received 282 process improvement proposals.

The main objective of improvement has been to improve productivity, reduce delivered defects, and reduce schedule slippage further, ultimately to achieve our goal of total customer satisfaction. This desire has allowed us to look towards CMMI for further improvement.

We plan to reassess using the Software CMM in 2001 or assess with CMMI in 2002.

4.3.6 Summary

CGS was assessed at Level 5 in October 1999. CGS has gotten exposure worldwide as being one of the few companies who have got Level 5.

Some of the noticeable differences have been in the areas of:

- Process improvement—newer process and improvement to the existing process are defined resulting in better software development.
- Focus on customer satisfaction—survey results have helped to focus on issues perceived by the customer in turn helping to fine tune our process to serve customers better.
- Control of project schedule overruns—because of well laid out planning, tracking and working with anticipation, project schedule overruns have been controlled to a greater extent.
- Reduction in delivered defects—because of the increased focus through out the life cycle of project development.
- Estimation has become more realistic and software development has become more predictable.

4.4 Cognizant Technology Solutions, Chennai, India

Maturity Level	5
Date of Assessment	September 2000
Lead Assessor(s)	V. Kannan
Point of Contact	Emani Sarathy, esarathy@chn.cognizant.com
Web Page	http://www.cognizant.com
Size of the Organization	3245
Typical Program Size	Number of people per project ranges between 3–50, depending on the type of project. Projects at CTS are categorized as small and large projects depending on the duration and effort required.
Primary Application Domain(s)	Financial services, health care, information-defined services, diversified, insurance, government, hospitality, IT services, retailer, telecom, travels, and utilities.

Cognizant's road map to quality:

- ISO 9001 certified in 1996
- assessed at Level 4 of the Software CMM in December 1998
- re-certified ISO 9001 in March 1999
- assessed at Level 5 of the Software CMM in September 2000

The following are some of the key initiatives of Cognizant Academy:

- Personal Software Process (PSP) :
  - Personal Software Process course offered by Carnegie Mellon University

- Cognizant Certified Professional (CCP) Program:
  - introduced the concept of internal certification in Cognizant in February 2000
  - topics were finalized based on the competency and requirements at Cognizant and wherever external certifications were not available
  - IBM Mainframe, IBM Web Technologies, AS400, S/W Engineering, Quality and Process Management, Business Development, Client Management

- Congregation@Cognizant:
  - to create a common platform for Cognizant Associates to showcase best practices, technologies, and tools

4.4.1 ROI and Improvement Trend Data

Improvements in effort, schedule variation, and the rework effort have resulted in achieving the business objectives of the organization. Effort variation % has reduced from 21.67 to 8.69. Variation spread has reduced from ± 14.74 to ± 7.78. Schedule variation % has reduced from 23.37 to 11.39. Variation spread has reduced from ± 13.51 to ± 7.60. Rework % has reduced from 9.19 % to 5.19 % of the total effort.

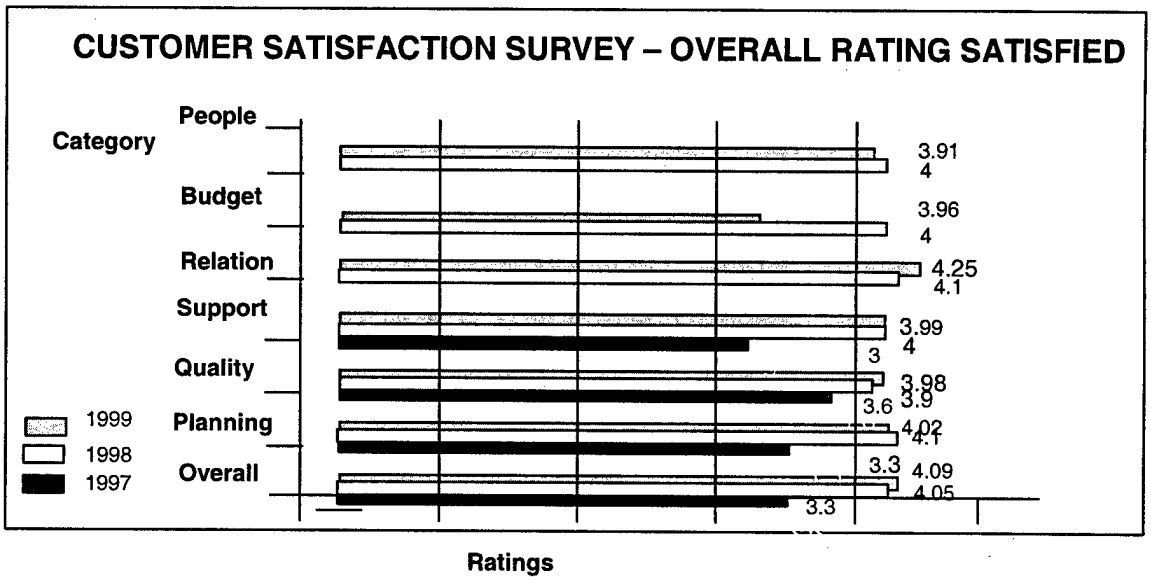

Figure 3: Cognizant Customer Satisfaction

As shown in Figure 3, customer satisfaction has improved.

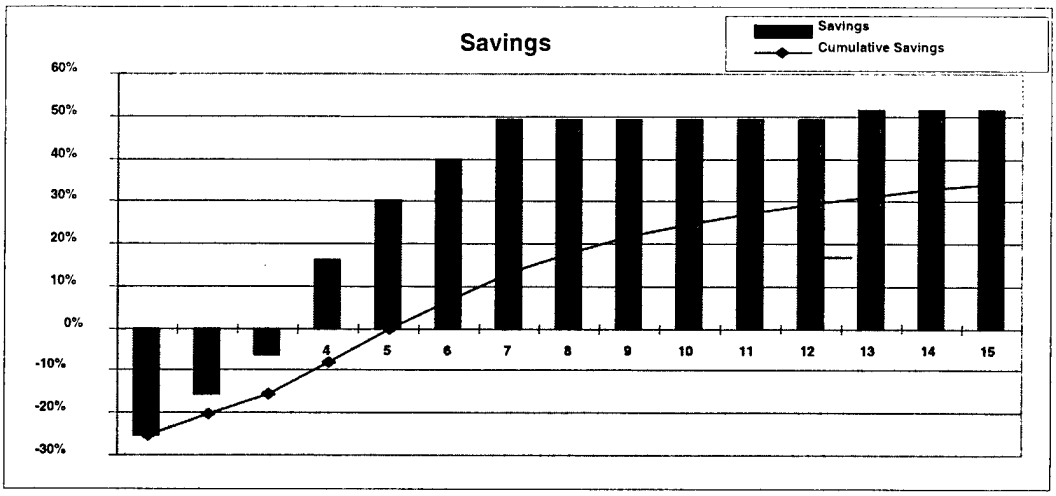

Figure 4: Cognizant Benefits to Customers – Cost Advantage

As illustrated in Figure 4, there are significant cost savings for the customer.

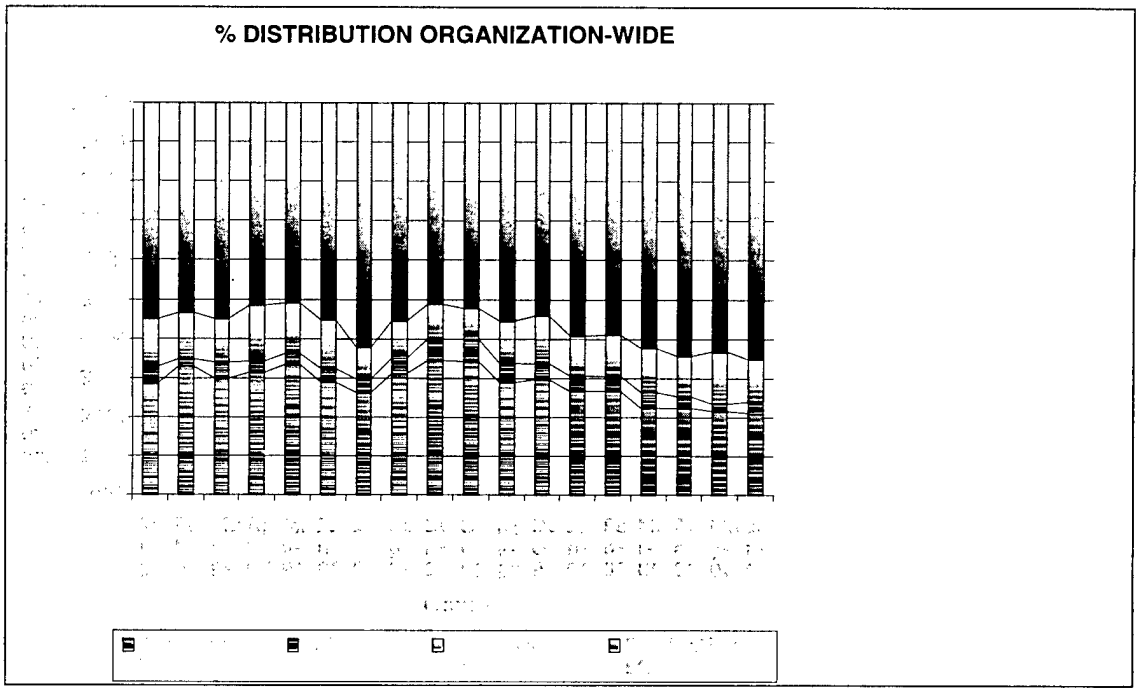

Figure 5: Cognizant Cost of Quality Analysis for Cognizant

Figure 5 illustrates the cost of quality analysis at Cognizant, while Figure 6 compares Cognizant performance with industry standards as published by Krasner.

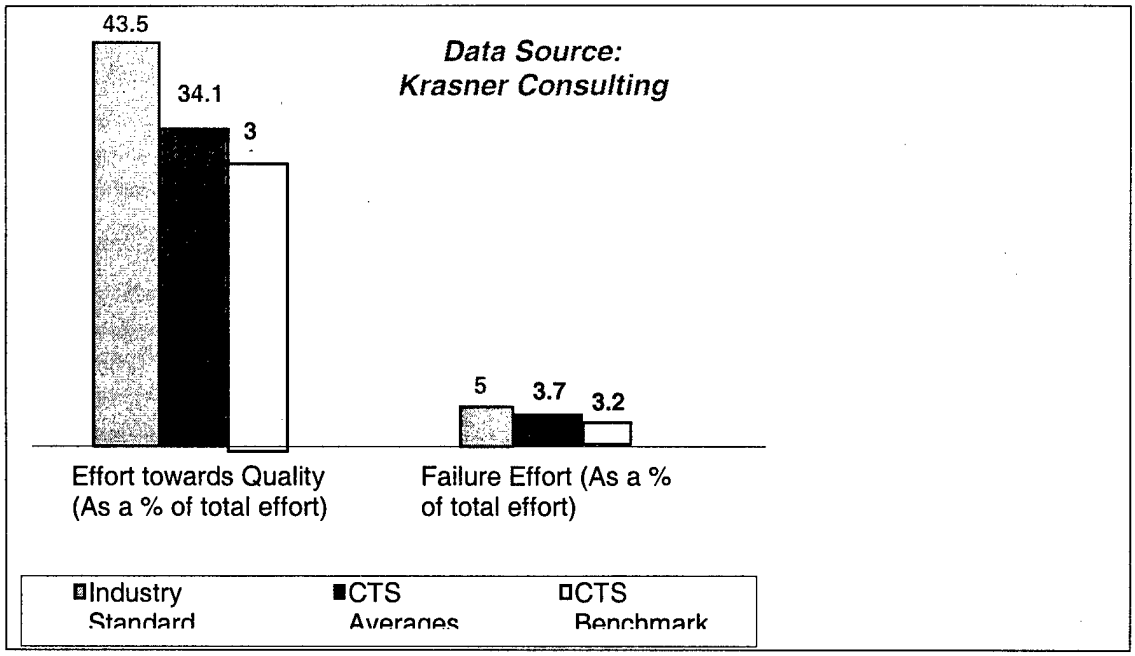

Figure 6: Industry Norms for Cost of Quality Compared to Cognizant

4.4.2 Barriers to Achieving High Maturity

The following were found to be difficult while transitioning from maturity level 4 to maturity level 5:

- Defect Prevention: creating a defect database from over 150 projects of different platforms and different operational models
- Technology Change Management: quantitatively measuring the impact of upcoming technologies

4.4.3 Unique or Distinguishing Practices

Practices related to people:

- training on domain specific areas
- practicing 3Ps: Positive attitude, Passion, Perseverance
- availability of pool of personnel on various applications
- equal opportunities to all associates
- availability of internal mentors for projects
- frequent location change at Cognizant Academy

Practices related to process:

- internal quality reviewers for large projects
- accessibility to project-specific intranet
- judicious use of central / group review
- sharing of Lotus Notes database with clients
- Resource Management Group—each one takes care of one location
- Human Resources—quarterly reviews against targets
- harmonization of quality reviewer audits
- sharing of risk management plan with customer
- having an independent delivery coordinator
- case study approach to training
- checklist for joint requirements planning
- documents organized stage-wise, as in Project Software Process Handbook, enabling quality reviewers to do audits from their desktops
- having assessment centers away from office
- adopting use case point technique for effective estimation
- close-to-real estimation using Extended-FP

Practices related to technology:

- effective use of knowledge repository
- accessibility to component repository
- availability of SQA ROBOT, Winrunner – testing and eraser tool customized from Y2K tool
- development and use of referral management tool
- use of standards checking tool for Java
- metrics-based status reporting system
- Web-based issue tracking system
- paperless office RAMS tool has been piloted and intranet-based travel request system
- eZCreator for automating SPP and PSPH preparation and automatic CV generator
- Rational Rose for analysis and design

Practices related to business:

- existence of Business Vision Group for an account
- pioneering initiatives at CA giving social visibility
- positioning process as role model to client
- creating brand equity in campuses

QSmart is a comprehensive tool with the complete Software Quality Assurance function automated through powerful built-in workflow mechanisms. Key features are online review and approval of project activities, meticulous audit planning, and reporting activities with provision to display and monitor all SQA-related metrics that reflect project health. It maintains a complete knowledge repository for project management activities and graphically displays key profile parameters of projects.

4.4.4 People and Cultural Issues

Cognizant strongly believes that its associates form the crux of its competitive advantage in the market. Therefore there is a very strong people-centric orientation in the organization with emphasis on continuous training and competency building.

In a techno-centric software environment, associates grow rapidly in terms of responsibility without much time or opportunity to gain the required skills needed to lead teams, manage projects, and network with customers. This is addressed by providing a strong support system to help associates enhance their behavioral skills and competencies. Several innovative interventions such as role-transition workshops, team-building programs, cross-cultural adaptability workshops, and leadership modules are conducted throughout the year to address this need. Intranet sites on various areas, including behavioral skills, bring such competencies to the desktops of the associates and allow a widely dispersed workforce ample opportunity to acquire these competencies. This, coupled with technical training on all the frontier technology areas, helps associates manage change and transition smoothly. Every associate undergoes a mandatory ten days of training in a year.

Assessment centers are also conducted every year. These help identify the competency levels of individuals and provide a clear developmental plan. Comprehensive induction programs (spanning nine weeks) held on a continuous basis, combine a detailed business, technical, soft-skill orientation, and on-the-job induction, which every new entrant needs to undergo at the time of joining.

A special "fast-track" program identifies the high performers, who are then mentored and groomed to help them maximize their potential and grow into future leaders. Mentoring also exists at very senior levels, where managers are in turn mentored and guided by the senior management team throughout the year.

Several "togetherness" events such as "Annual Days" and excursions help foster strong bonds between the employees and the organization. Other forums such as "Open Houses" provide a platform for associates, irrespective of hierarchy, to pose questions to the management.

Retention rates in Cognizant are among the highest in the country. The attrition rate at middle and senior management levels is almost zero. High retention is the direct outcome of competitive compensation packages, attractive employee benefit schemes, participation in employee stock option plans, and an assimilative work culture.

4.4.5 Continuing Improvement

The enhancements to the Quality Systems are through research, senior management directives, analysis of internal audit findings, project's feedback, internal support services survey, customer satisfaction survey, gap analysis, and effectiveness of the enhancement measured through metrics.

4.4.6 Summary

- Process benefits: processes continuously and systematically improved, and common sources of problems understood and eliminated
- Technology benefits: new technologies proactively pursued and deployed
- People benefits: strong sense of teamwork across the organization, and all involved in process improvement
- Measurement benefits: data used to evaluate and select process improvements

While these are the benefits achieved by CTS being at maturity level 5, the following areas could be looked into by the SEI:

1. The Software CMM model, and in particular the CBA IPI, must have a surveillance type model / requirement to ensure continued compliance to the KPAs at the assessed level.
2. The SEI should strongly recommend the delinking of the marketing focus of the Software CMM assessment and advocate on internal benefits to an organization with respect to process improvement.
3. The SEI should conduct and authorize training in India of the courses that are currently being done in Pittsburgh, such as the Software CMM Lead Assessor Course, PSP, etc.
4. The SEI should enforce through their qualified assessors a very stringent assessment at Level 5. Unless companies adequately demonstrate, both during assessment and on a continuous basis, the KPAs at Level 5 such as Technology Change Management, Defect Prevention, and Process Change Management, such companies must not be declared to be at Level 5. Often teams that worked for these Level 5 KPAs are disbanded once the assessment is through.
5. The Software CMM model may also have to look into the emerging trends in new technology areas where cycle times are constantly shrinking. Industry is looking forward for "CMM for lightweight processes."

4.5 Computer Sciences Corporation (CSC), Aegis Program, Moorestown, NJ

Maturity Level	5
Date of Assessment	March 2001
Lead Assessor(s)	Kathryn Gallucci (Lead Evaluator)
Point of Contact	Wendy Irion Talbot, wirionta@csc.com
Web Page	www.csc.com
Size of the Organization	~400 software professionals
Typical Program Size	Projects range in size from 50 to 200 individuals Project size varies, but frequently ranges 2-3 million SLOC
Primary Application Domain(s)	These are DoD real time combat systems in the C4I and weapons domains. Specific product lines include: radar, weapons control, command and control, and interactive displays.

This program, with many upgrades and follow-on increments, has been in place since 1969. This legacy has resulted in an organizational environment that has required strong, disciplined management and software practices for nearly 30 years. Formal, model-based process improvement efforts were begun in 1993, Level 2 was achieved in 1994, Level 3 in 1996, Level 4 in 1998, and Level 5 in 2001. The organization has undergone CBA IPIs, source selection SCEs, various internal assessments and has commissioned SCEs.

4.5.1 ROI and Improvement Trend Data

We have viewed ROI from a variety of perspectives. We have invested a full-time core staff, augmented by a part-time network that spans the program, in our process improvement program. We monitor the resources applied to process improvement activities against measurable changes in performance, as well as the intangible value-added effects including employee morale. Investments are linked to specific business goals which range at a high level from client satisfaction on contract performance, or Software CMM rating required for a new business opportunity, to the project implementation activities, such as specific performance improvement of our code inspection process. The process improvement activities are managed and subjected to the same rigorous business management practices as the product development activities.

4.5.2 Barriers to Achieving High Maturity

Our initial barrier to pursuing high maturity practices in a formal, model-based form rested in making the business decision that there would likely be return on the investment if this were pursued. After achieving a Level 3 capability in 1996, there was a period of research and reflection to support this decision process. We recognized that there were many elements of the Level 4 and 5 process areas in place already as a function of the standard program processes. However, some elements of the key practices were not in place. In particular, the advanced analytical techniques (e.g., statistical process control) were only used in specific areas and

instances in the program as needed, and were not part of a defined overall quantitative management strategy. We needed to determine whether furthering the maturity of these practices would be advantageous to the program. Management needed to understand and buy-in, realizing that some high maturity practices require significant investment in terms of both resources and lead time before results can be observed (e.g., defect leakage reduction over time). In addition to reviewing other organizations' successes and reports on ROI, the market was also taken into consideration. Not surprisingly, as more organizations achieved the Level 3 rating, Levels 4 and 5 became competitive discriminators. The decision to proceed was made and recognized as a strategic initiative, rather than a short-term tactical objective.

Once the decision was made to continue to advance rather than just maintain Level 3, obvious barriers included process change management issues: process modification investment, training, resistance to change, competing program vs. process improvement priorities, and a lack of understanding of the true value of institutionalized advanced maturity processes. In retrospect, the cultural issues were probably the largest hurdle, and are addressed below. Another barrier which we did not recognize as such early on, but became extremely obvious as we tackled it, was truly understanding which components of our development cycle were appropriate for quantitative management using statistical process control versus other quantitative methods. There was a lack of readily available guidance on alternate quantitative management mechanisms that were both useful and would satisfy model criteria, other than SPC.

4.5.3 Unique or Distinguishing Practices

After having institutionalized Level 5 throughout the projects on the Aegis program, it was evident that there were unique activities in place that distinguished this organization from itself in earlier years, and other projects / programs not yet at Level 5.

Senior Leadership: In the Level 5 organization, the highest level of senior leadership executes commitment by being personally involved and holding the organization at each level responsible for performing in an advanced maturity manner. The implementation of "commitment" changes from only ensuring sufficient budget and resources, to also being *involved* on a personal level. They "walk the walk" and apply advanced maturity practices in their daily activities. In addition, process improvement and project goals were de-conflicted; these goals were aligned in a way that made business sense for the project and supported the process improvement objectives.

Process Management Approach: Process management activities were distributed and supported by a larger segment of the population. While the SEPG remained the focal point for process improvement, a wider "network" of working groups and committees responsible for specific processes not only directly involved more people in the process change and management activities but also helped to ease the cultural issues and aided further institutionalization.

Listen to the People: Today during meetings, regardless of subject and participants, we hear talk about needing even more and better documented processes, should the Defect Prevention Committee be represented in the discussion, what type of analysis is appropriate, are the right data elements being analyzed for statistical relationships, etc. The level, depth and content of daily activities with respect to advanced maturity concepts has changed. "Statistical thinking" is common rather than the exception.

4.5.4 People and Cultural Issues

We found that we really needed to address moving to Level 5 in a holistic fashion, that is ensuring that the entire process infrastructure was considered and developed as an integrated whole and that the staff understood the context of the overall efforts in relationship to their individual activities. As noted earlier, the cultural issues were probably the largest barrier to advancing our maturity. It was rapidly evident that moving to Level 5 was not just a matter of implementing the mechanics of process change – the cultural implications needed to be identified, planned for, and addressed. Appropriate training, updated formal mentoring, regular focus group discussions and an improved, self-sustaining process infrastructure facilitated the culture changes required.

In operating at Level 5, we've found that a broader segment of the population becomes involved in process (and technology) improvement, from suggesting change to participating in various initiatives. There is now a stronger belief that the individual can initiate effective change.

The single cultural factor that most directly affected our path to success was the sustained personal involvement of our program manager (PM). In addition to supplying resources and funding as needed, the PM participated in training sessions, focus group discussions, and adjusted his management techniques and formal review content to include the advanced process maturity initiatives. This not only signaled that he was fully committed to achieving the Level 5 goal, but that this wasn't just a mark in the sand – the practices were applied and performed at the highest levels of the organization on a daily basis. This enlightened leadership was and remains visible to the entire organization.

4.5.5 Continuing Improvement

Our efforts remain focused on continuing to improve performance in all aspects of our program in a cost-effective manner – essentially to "do more for less." Our process improvement program applies not only to the mainstream software development activities, but also to the infrastructure and functional support areas such as human resource management, finance and administration, etc. Some specific initiatives include:

- investigating new tools to support qualitative and quantitative analysis
- identifying and testing other areas in the development cycle and in the infrastructure processes where quantitative management may be beneficial

- strengthening and extending our quantitative analysis skills, knowledge and resources
- enhancing defect prevention, and particularly reducing defect leakage, in both the development cycle and our business management strategy
- assessing the impact of transitioning to CMMI
- migrating our process management approach to an integrated knowledge management environment

In addition, now that we have impacted our business culture, we are challenged to strengthen and reinforce our holistic "Level 5" view so that it withstands and continues to support our increasingly dynamic business environment.

The bottom-line remains the positive return on investment. Initiatives must be tied to clearly defined business objectives to which measurable value can be assigned. We must remain vigilant and resist the common practice of jeopardizing long-term growth for the sake of short-term profit. Developing and deploying continuing improvement initiatives is a front-end loaded expense, both in dollars and human resources. Management must remain steady and supportive, and staff must be motivated to participate and develop a heightened awareness of the strategic benefit of process improvement to the organization, to the roles they perform, and to themselves as individuals.

4.5.6 Summary

Now that we've moved to Level 5, it is increasingly our belief that the advanced maturity practices are actually essential to effective, enlightened and ultimately successful project management. This is particularly true in today's market where rapid technology change is the norm, innovative process and technology strategies are the requirement, and management of those strategies will determine survival and success.

4.6 Computer Sciences Corporation (CSC), Civil Group, Greenbelt, MD

Maturity Level	4 (Civil Group) 5 (SEAS Program within Civil Group)
Date of Assessment	Civil Group—January 2001 SEAS Center—November 1998
Lead Assessor(s)	Paul Byrnes
Point of Contact	Mel Wahlberg, mwahlber@csc.com
Web Page	www.csc.com
Size of the Organization	Civil Group includes approximately 2100 software professionals
Typical Program Size	Size varies so widely that it is almost impossible to define "typical." Individual projects range from less than one person up to about 200.
Primary Application Domain(s)	Again this information varies widely and includes probably most major architectures and systems. Major application domains include air traffic control, NASA spacecraft control systems, and tax systems modernization.

Civil Group was formed in June 1998 from a reorganization of CSC's former Systems Group. Civil Group includes all of CSC's Federal Government business with Civil agencies. Civil Group was independently assessed at Level 3 in May 1999 and at Level 4 in January 2001. The SEAS organization within Civil Group was assessed at Level 5 in November 1998 and is also ISO 9001 registered.

As we are maturing as an organization, we believe, increasingly, that "high maturity" practices—especially those involving measurement—are actually basic to effective management. Without these types of metrics, an organization cannot assess the actual quality of the products it produces (software or otherwise), or determine how well its management processes are working. Ultimately, these high maturity practices also become a rallying point for personnel and a motivational force for measuring the organization's performance.

4.7 IBM Global Services India, Bangalore, India

Maturity Level	5
Date of Assessment	November 99
Lead Assessor(s)	Richard Storch
Point of Contact	Dr Asha Goyal, gasha@in.ibm.com
Web Page	www.ibm.com/in
Size of the Organization	2400 software professionals (full-time employees)
Typical Program Size	Any number from 5 to 30 people per typical project
	300-400 Function Points or parts of very large products
Primary Application Domain(s)	Systems software, firmware and chip design
	Commercial software products
	Information systems software for business processes
	Contract or outsourced software development
	End user software, such as Office Suite

IBM Global Services India – Software Export Group has been ISO 9001 certified since 1994 when it was a small group. At that time it was more focused on system software and operating systems. Since then it has grown much larger, has been re-certified with multi-location extension and is moving to ISO 9001:2000 now. The organization started a PSP initiative using internal faculty and has 50 PSP-trained people currently. PSP is now being introduced in basic training. The organization was assessed at maturity level 4 in November 1997 and at maturity level 5 in November 1999 by SEI authorized Lead Assessors.

The organization's primary business objective is to meet commitments made to the customer. This implies that better predictability, adherence to service level agreements, and defined processes are important. The organization-wide baselines have been defined, and every project has to meet them. The baselines are enhanced on the basis of trends. Individual projects can take specific targets to improve. ROI currently has been observed at 4 to 5 times the investment in SPI activities.

4.7.1 Barriers to Achieving High Maturity

Customer satisfaction is very important. The customers appreciate the maturity practices. Customers do look for specific measures and alignment in technology. This is not exactly a barrier to maturity, but requires continuous pursuit in the right direction. Processes and documentation are sometimes perceived as overhead, and the customer may look for immediate return and may not be satisfied with a long-term view in the early part of the project. This barrier is crossed with the right culture and senior management commitment.

As a culture in IT industry, the creative activity of code writing is associated more with analytical and less with numerical, whereas project management uses more quantitative analysis. Team members at junior levels are more intuitive and less oriented towards measurements.

When high maturity culture prevails, a change happens to this thinking and a balance in quantitative and analytical can be seen. Practitioners also have to change their role as they move from activities of prototype to development and to support. As this happens, the attitudes have to change, and awareness for appropriate measures is to be created. There are always a lot of change elements in the environment. All these cannot be addressed by automated systems. These have to be addressed as part of process maturity.

In the published literature, very clear information on investment and corresponding activities related to SPI as well as ROI is not available at the desired granularity. This makes it difficult to justify investments in business environment other than as culture building. On the subject of ROI, we are working on a special model so that all practitioners can have a mind share in any ROI framework.

4.7.2 Unique or Distinguishing Practices

We have an automated process change management tool available to all practitioners. The change requests are systematically analyzed, prioritized, and processed. The quality group very often pilots concepts in training, tools and processes, makes recommendations for organizational changes, and moves on to other activities. The audit reporting process includes reporting on best practices in different groups and gives quantitative performance so that groups can benchmark with each other.

Every project accesses a database containing learnings from various projects before starting each phase to avoid recurrences of similar defects. Defect prevention activities are taken up using effective statistical tools to analyze data, arrive at root causes, and measures to be implemented to eliminate these root causes and minimize their occurrence. There is an extensive process assets library (tools, reusable artifacts, and learnings) that makes information available on a shared server. There is extensive focus on training, resources, and tracking.

An integrated measurement framework covering all relevant levels in the organization (senior management, support functions, and projects) has been created. Quality policy is related to operational measures at project and department level. Capability baselines for in-process quality are available to practitioners. A measurement program is supported by close interaction with academicians and enables practitioners to appreciate the "concepts" and their "implementation" in industry. A dedicated group for measurement provides guidance and support to practitioners.

4.7.3 People and Cultural Issues

A useful cultural aspect is that of team building and close working of the quality group with practitioners. They work together and help recognize innovations that can come up as process changes. One issue that comes up is that of regular measurements. Practitioners often make the measurements but may not submit them. Very generalized automated systems for data collection sometimes only give gross measurements. In depth specialized measurement

analysis studies with the help of QA managers or SQAs are done to bring out many aspects of data. The change management is handled with the help of groupware and by communicating with practitioners.

Very often employee turnover is the only resource change aspect that gets attention. However, what also needs attention is the people movement upwards, laterally and to different locations as they grow and as business grows. We have taken some specific measures to keep people involved in process changes and to keep them aware of changes as far as the quality management system is concerned. These measures also help in process-related skill building. In our formal and extensive training programs for new hires, we have introduced quality-related topics for awareness. We have a formal mentoring program. But mentoring also works better with clear objectives and confidentiality. Employee morale definitely improves as a result of the process improvement activities and is associated with active participation of practitioners, middle and senior management in process improvement activities (internal assessments, workshops, industry interactions through paper submissions, presentations) apart from just the quality group.

A good practice called "Buddy System" is in practice, in which each new joinee is associated with a senior person from the same team. Buddy prepares a plan for induction and makes sure that the joinee goes through full cycle of induction and covers all related departments activities. It is a clearly defined process and is not just an open concept. It also defines how many hours we expect buddy to spend and how long the relationship is expected to be active. Morale of the employee has increased considerably because of the structured processes as well as well defined roles and responsibilities.

4.7.4 Continuing Improvement

We have been working extensively with Software CMM model. We do see that it helps the group in a techno-cultural manner to move ahead with one model (like one shared language for practitioners), a well-defined goal, and "something new" to achieve. We do intend to explore CMMI and plan an assessment in early 2002. We are also continuing our process model integration with ISO and going for ISO 9001:2000 certification. We have started our initiatives on People CMM. The biggest barrier to maturity is the flip side of growth itself, that is, keeping an ever-growing manpower resource operating with mature processes. It is not only time-to-market that needs to be reduced but also the time-to-understand-process and become competent in using processes and process models. The main improvement objective is to enhance processes to work with organizational initiatives of competency development, training and technology induction while incorporating SDLC innovations to address business scenarios.

4.7.5 Summary

Market forces make an organization aware of where it stands and it shows up in business growth. What the organization has to do itself is to find out how to improve and then make

the improvement happen. We have observed that being at maturity level 4 fosters a culture of measurement appropriate to the problem at hand and hence close to a practical usable level. It helps the management and those who are not involved at a certain level of technical detail, to see the trends in delivery. Then the management can get a feel for what is happening and lead the directions in an overall manner. This also allows everyone to understand how different parts of the organization are doing and enables a culture of improvement. If the measurement framework has the right granularity then one can see where the roadblocks are. The same people who are facing the roadblocks also create the innovations to remove them because they can see the picture clearly.

Being at maturity level 5 helps one in being proactive in the areas addressed by Process Change Management (PCM), DP, and TCM. PCM helps in understanding where the change is coming from. Then the change management can be looked at in a holistic manner and organizational action can be taken. It can almost help giving a direction for organization development activities. DP is by far the most important activity due to changes that are happening at any point of time and how one can hardly cope with them. Probably, more academic work needs to be done in this area. One can analyze the problems, but are we able to reduce the repetition of those problems? Are we able to use technology to solve those problems? Can we create measures that help us make decisions to solve those problems? It does help in making people aware of the forthcoming problems and also makes them confident that something can be done.

TCM has been well appreciated by management because it is one of the highest concern areas and involves very visible costs. It gives the middle managers a way to mold the organizational thinking, process, and planning to move in the desired direction.

4.8 i-flex solutions limited, Mumbai and Bangalore, India

Maturity Level	5
Date of Assessment	Dec 1995—CITIL, Mumbai, Level 4
	Dec 1995—CITIL, Bangalore, Level 4
	Oct 1999—CITIL Data Warehouse Center of Excellence, Bangalore, Level 5
	Dec 2000—IT Services Division, Mumbai, Level 5
	Dec 2000—IT Services Division, Bangalore, Level 5
Lead Assessor(s)	Dec 1995—Cynthia Wise and Ken Dymond
	Oct 1999—Ken Dymond, S Santhanakrishnan, Anand Kumar
	Dec 2000—S Santhanakrishnan, Atul Gupta, Anand Kumar
Point of Contact	Anand Kumar, Anand.Kumar@iflexsolutions.com
Web Page	www.iflexsolutions.com
Size of the Organization	1400
Typical Program Size	10-40 people per project
	50-1000 KLOC per project
Primary Application Domain(s)	Banking products and services—retail, corporate, investment, brokerage, data warehouse, Internet

i-flex solutions limited was earlier known as Citicorp Information Technology Industries Limited (CITIL). The organization was assessed at Level 4 through two back-to-back assessments carried out in December 1995, one for each of its sites, Mumbai and Bangalore. The CITIL Data Warehouse Center of Excellence, Bangalore was assessed at Level 5 in December 1999. The IT Services Divisions at Mumbai and Bangalore were assessed at Level 5, once again through two back-to-back assessments, in December 2000.

4.8.1 ROI and Improvement Trend Data

The following are some ROI trends that the organization has been able to establish over the years that it has implemented a metrics program:

- mean annual growth in productivity of 5% over the last 6 years
- mean annual reduction in defect density of 15% over the last 6 years
- percentage rework effort halved over the last 5 years
- price of non-conformance down by 50% over the last 5 years
- ROI of 100% in the first year; now stable at about 300%

4.8.2 Barriers to Achieving High Maturity

The following are some areas that the organization had to grapple with, in its journey on the path of the Software CMM:

- non-repetitive nature and scope of work coming from hundreds of customers. This is an outcome of being a products company in the area of banking and financial software, where the market is very aggressive.
- high growth rate, in terms of revenue, geographical dispersion of operations, as well as manpower.
- a large inflow of new practitioners, who need to be quickly assimilated into the organization's process culture.
- reducing life spans for methodologies and technologies.
- business pressures to improve further even before the full benefits of current process improvement initiatives have accrued.

4.8.3 Unique or Distinguishing Practices

Some practices that we have, which we believe would be common to several high maturity organizations:

- managing continuous inflow of requirements, without adversely impacting delivery capability
- release cycles as low as 4-6 weeks
- evolutionary life cycles piloted, evaluated, and found effective in meeting time-to-market requirements
- centralized-cum-dispersed SEPG responsibilities
- planned reuse of design and code components across the organization
- software rating using an empirical model
- intranet as the primary communication vehicle for process improvement activities and results e.g., process changes, process pilots, Process Change Control Board
- high level of automation of software engineering and management activities
- end-to-end automation for data capture

4.8.4 People and Cultural Issues

An important challenge is to maintain and improve the process culture of the organization despite the rapid manpower induction.

There is a well-established and focused induction training program for all new joinees, lateral and freshers.

Process adherence needs to be constantly emphasized through suitable rewards and punishments linked to this area.

Participation in process initiatives and programs is valued by the organization.

We have a rotation policy that facilitates movement of people between SQA and SEPG on the one side and delivery on the other.

A clear organizational policy that makes a term in SEPG or SQA mandatory before promotions to senior management cadre can be considered.

4.8.5 Continuing Improvement

The Software CMM will continue to guide us in our process framework. We now plan to also focus on knowledge management as an organizational initiative. We have been working on this for the last 18 months, and have already seen some very positive results. In addition, we are currently in the process of holding discussions with senior management on the next quantum jump in our process and quality initiatives. Some options being discussed are: Six Sigma, PSP and TSP, People CMM, CMMI, and Balanced Scorecard.

4.8.6 Summary

What does it mean to be maturity level 4 or 5? Well, to start with it means that the SEI classifies you under the umbrella of "High Maturity Organizations." But what it really means is that you start seeing, and therefore believing in, the real benefits of implementing the Software CMM. Levels 2 and 3 of the Software CMM can be considered to be the sowing and growing phases of cultivation, where you do all the hard work and lay the foundation for a great harvest. Levels 4 and 5 are where you really reap the benefits of all that hard work, in quantitative terms. You know your process capability, and you are able to use the DP, TCM, and PCM infrastructure to make significant enhancements to that capability in order to meet the needs of the marketplace. In fact, while the Software CMM stresses the need to align process improvement goals to business goals across levels, the alignment becomes so natural at Level 5. From the SEPG point of view, "selling" processes to senior management and project teams in a Level 5 organization is so much easier than doing the same in a Level 2 organization, for example.

4.9 Litton/PRC, McLean, VA

Maturity Level	5
Date of Assessment	March 2000
Lead Assessor(s)	Joseph Morin
Point of Contact	Al Pflugrad, pflugrad_al@prc.com
Web Page	www.prc.com
Size of the Organization	5500 employees, 2500 are within the scope of Software CMM efforts
Typical Program Size	6 people per project, where the typical project is a single-year or annualized task order. 50-200 KSLOC/year
Primary Application Domain(s)	Litton/PRC spans two major domains: • software and services for National Defense Systems • software and services for Civil Government Systems

In March 2000, PRC received a PRC-wide Level 5 rating in which the assessment team rated at the practice level for all process areas in the Software CMM v1.1 model. This major milestone is the last of many. PRC initiated model-based process improvement in 1993. PRC sites attained Level 2 in December 1995, and PRC sectors achieved Level 3 in June 1996. PRC developed a combined SE/SW model-based program in June 1997 and secured its initial ISO 9001/9002 registrations in May 1998. In addition to other ISO registrations, PRC received a PRC-wide Level 3 rating in June 1999.

PRC has integrated many different quality approaches into one multi-faceted quality infrastructure: CMM-based process improvement, quality improvement (Qualtec TQM), ISO 9000, quality assurance, customer satisfaction, and employee satisfaction. The quality improvement facet contains the foundational principles, teams, and methods upon which all other facets are built. PRC has pioneered the integration of the Systems Engineering CMM, SECM, and Software CMM and has participated in the development of the CMMI framework and associated models and representations.

4.9.1 ROI and Improvement Trend Data

PRC's budget for engineering process improvement has exceeded $1M per year since 1993. This figure is supplemented by various line expenditures. The following characterize the business benefit PRC has received since its first process capability baseline (September 1999):

- defects in delivered documentation are down 78%
- defects in delivered code are down 70%
- defects found operationally are down 60%
- PRC's ability to estimate costs on a monthly basis has increased 32%

- PRC's ability to meet monthly cost goals increased by 40% (CPIm is 0.977; 1.000 is where planned monthly costs equal actual monthly costs)
- PRC's ability to meet monthly schedule goals increased by 7% (SPIm is 0.980; 1.000 is where planned monthly schedule equals actual monthly schedule)

4.9.2 Barriers to Achieving High Maturity

To achieve Level 4, PRC had to overcome several barriers.

First, PRC needed to resist applying Level 4 only to software-related activities. Instead, we adopted the Level 4 requirements to the broader business issues of profitability and business development based on past and present performance. These business issues transcended software development and yet still could be applied to it. PRC worked to select the few goals and measures that were most meaningful to all projects and that had a sufficient stream of continuous data.

Secondly, PRC needed to resist applying only organizationally mandated goals and measures on projects. Through pre-assessment consultation, PRC realized that quantitative management should be applied to a project's "points of pain." When projects discovered that quantitative management could address the very real problems they were facing, resistance to implementation changed to enthusiasm.

Thirdly, PRC needed to think quantitatively – to value quantitative management and to see applications of it to existing problems. While this ability comes with practice, it was difficult to envision the end result during initial implementation of Level 4 principles.

4.9.3 Unique or Distinguishing Practices

Some distinguishing practices of high maturity organizations include:

- performing process improvement for business reasons, not just process maturity goals
- managing by fact
- respecting people
- applying process improvement principles to non-model areas
- reducing and simplifying processes and process assets for widespread use
- leveraging corporate infrastructure, past improvements, and best practices

4.9.4 People and Cultural Issues

On one hand, PRC has historically maintained that the principles of quality organizations can be applied regardless of the organizational process maturity. That is why PRC implements respect for people, managing by fact, continuous improvement, and customer satisfaction as foundational principles for all projects and teams.

On the other hand, as PRC's process improvement program has matured, it has had to maintain momentum and move from a program targeted to innovators to one targeted at the majority of managers and staff. Process improvement personnel are now assigned to various levels of management, much as contract and HR personnel are.

4.9.5 Continuing Improvement

PRC is actively pursuing improvements to increase project performance within its major business areas. First, PRC is implementing widespread use of quantitative management within all organizational units. PRC management has begun rollout and review of PRC-wide quantitative project management initiatives for given types of projects and values during monthly operational reviews. Second, PRC is adding processes and process improvement support for non-model process areas such as information assurance, COTS integration, network management, transition planning, database administration, etc. PRC believes that the CMMI is a process framework flexible enough to add support for these engineering processes, and therefore, PRC is actively transitioning to full CMMI implementation. Third, PRC is pre-tailoring corporate processes to program units to reduce or eliminate the amount of tailoring necessary at the task order or small project level within our business domains. Finally, PRC is refining its internal assessment methods to include: 1) targeted assessments using a subset of CMMI process areas within the continuous representation, and 2) informal interim assessments based upon periodic QA process audits.

4.9.6 Summary

To adapt Winston Churchill, Level 5 is not the end; it is not even the beginning of the end; but it may be the end of the beginning. Level 5 gives an organization the tools it needs to independently and continuously address and resolve its own business issues. Specifically, Level 5 gives PRC the ability to manage by fact, to quantitatively increase performance, and to provide process power to each employee.

4.10 Lockheed Martin Aeronautics Company, Fort Worth, TX

Maturity Level	4
Date of Assessment	December 1999
Lead Assessor(s)	Leia Bowers White
Point of Contact	Phil Gould philip.c.gould@lmco.com
Web Page	http://sepg.insite.lmtas.lmco.com/home/index.htm is inside the LM firewall http://www.lmaeronautics.com/ is outside the firewall, but no process information is there
Size of the Organization	1200 during the assessment, approximately 2000 now after the merger
Typical Program Size	20-30 people, approximately 500KSLOC, however, our projects do range from very small (2 people and 2 KSLOC to 100 people and 1+ MSLOC)
Primary Application Domain(s)	Military software • avionics • flight controls • vehicle management systems • stores management systems • test stations • mission planning

We started our software process improvement activities in early 1991. We were then General Dynamics. We achieved Level 3 in 1993, ISO 9001 certified in 1996, and ISO TickIT in 1997. We achieved our Level 4 rating in December 1999 as Lockheed Martin Tactical Aircraft Systems. We are currently merging three Lockheed Martin companies (see the "Barriers" section below) into one.

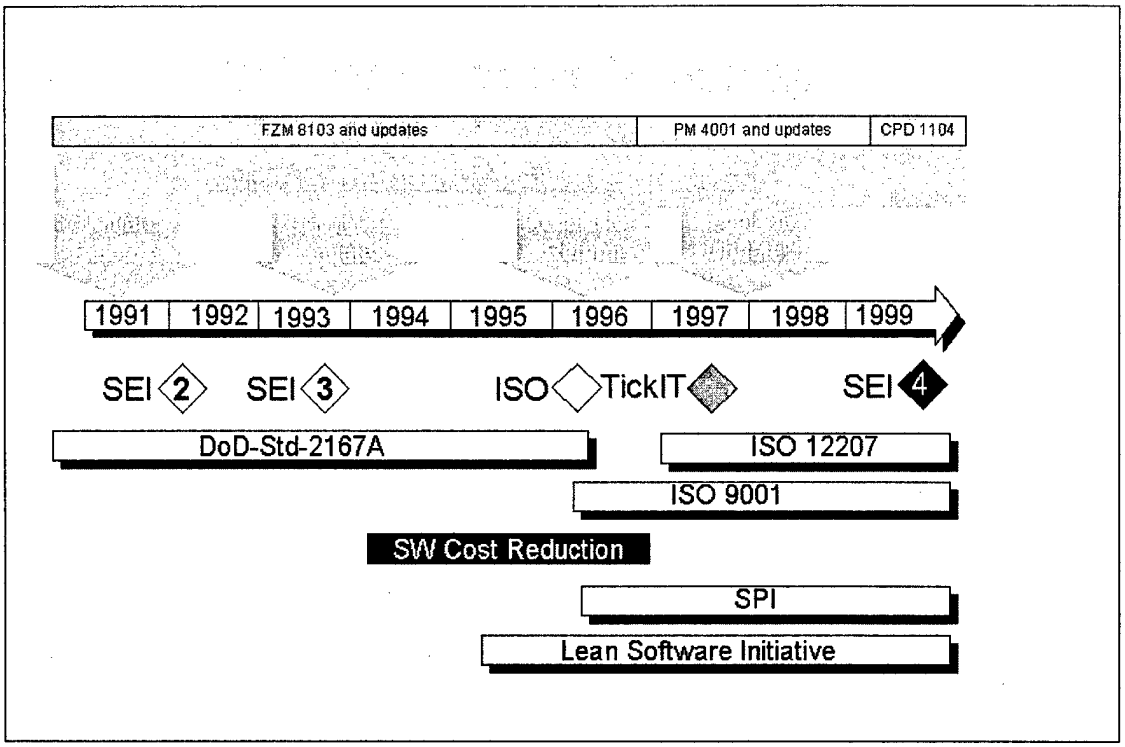

Figure 7: LMAero Software Process Roadmap

4.10.1 ROI and Improvement Trend Data

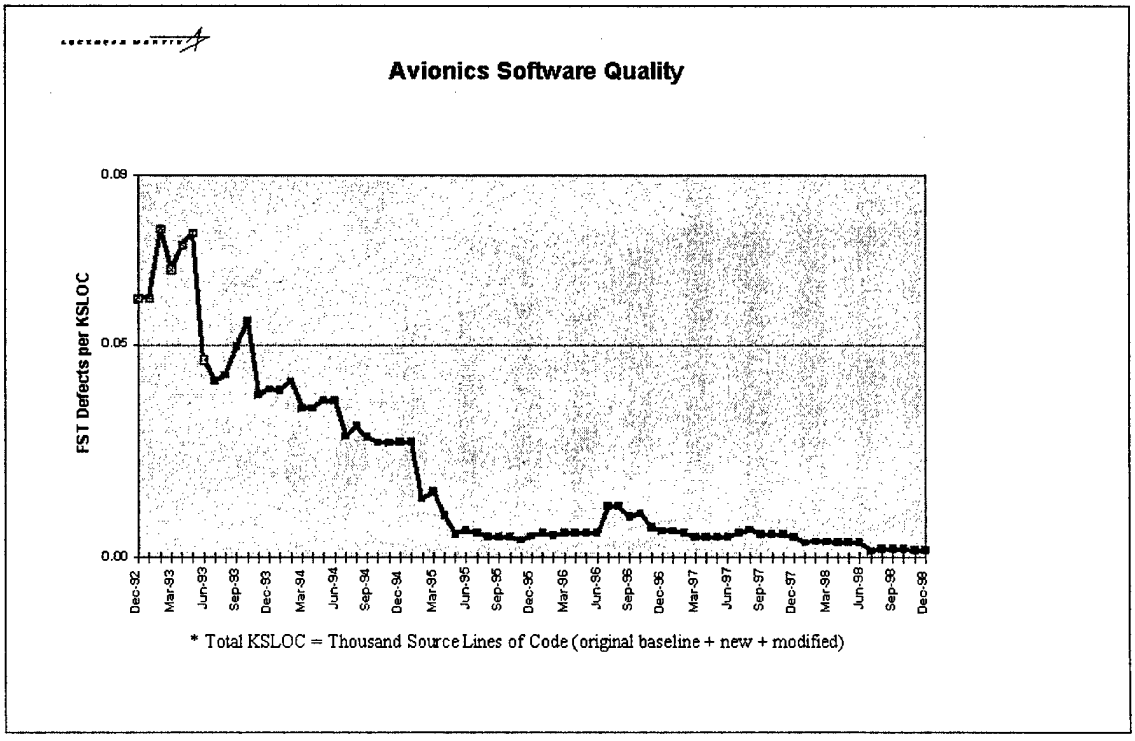

Figure 8: LMAero Avionics Software Quality

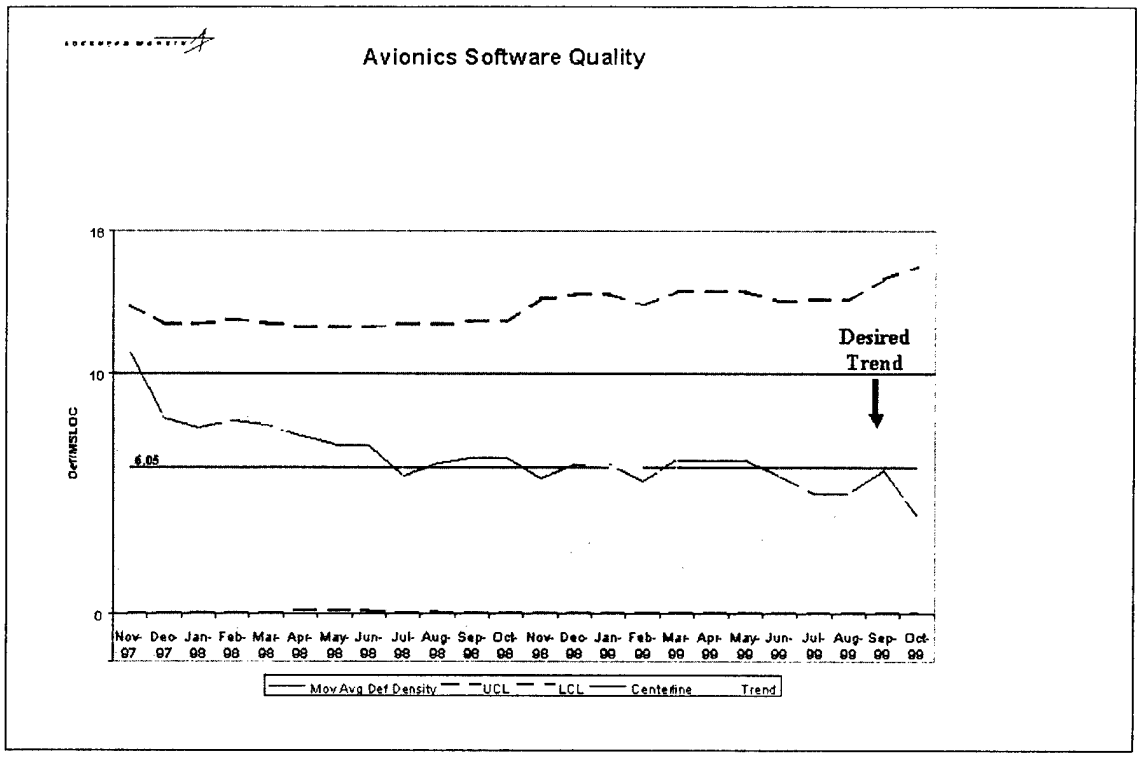

Figure 9: LMAero Avionics Software Quality

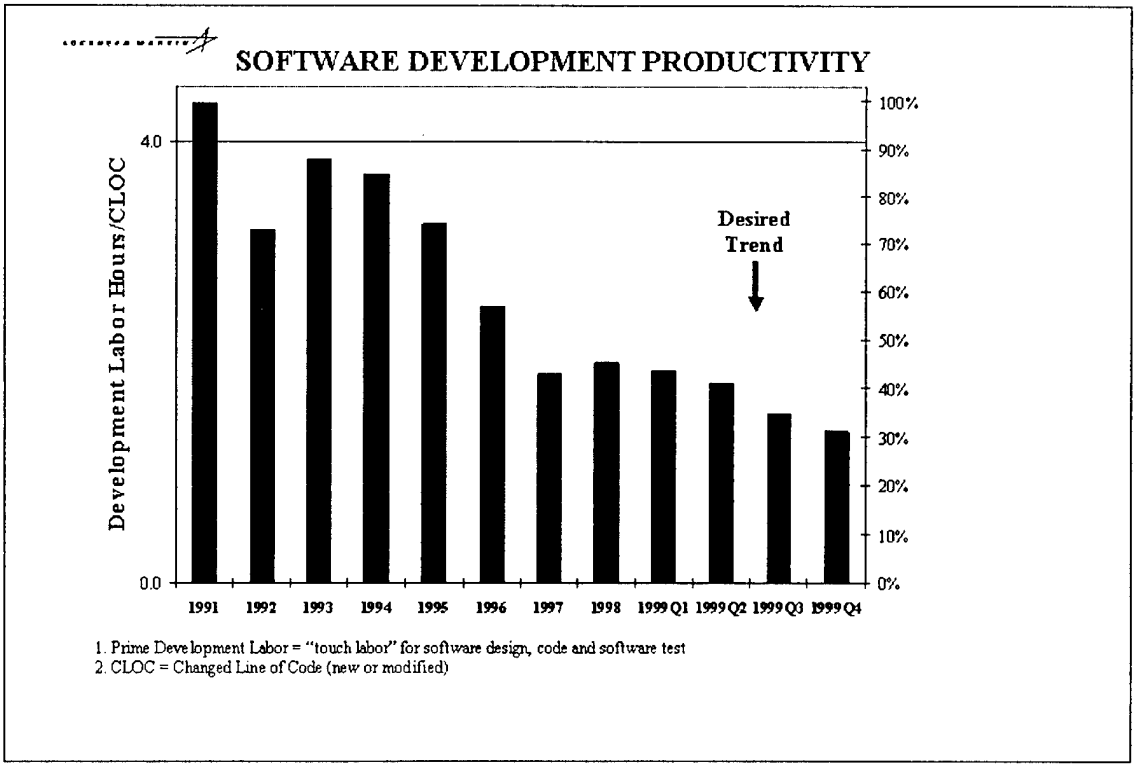

Figure 10: LMAero Software Development Productivity

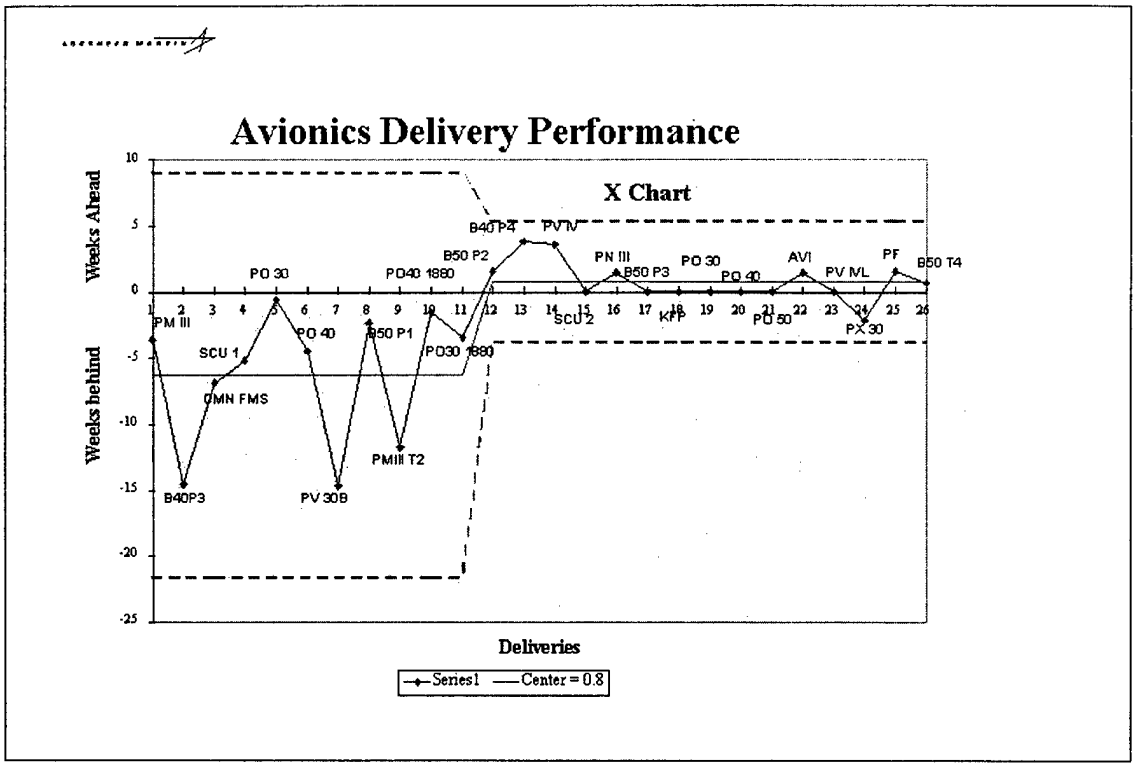

Figure 11: LMAero Avionics Delivery Performance

The above charts show the history of the Lockheed Martin Aeronautics Company, Fort Worth, software process improvement efforts. Our early efforts were strictly cost and schedule focused, while maintaining the existing quality.

4.10.2 Barriers to Achieving High Maturity

Our most significant barriers to achieving and maintaining high maturity are the continued education and re-education of senior management. Senior management believes (and rightly so) that this plant is a builder of aircraft (F16s, etc.) Software is only a part of the airplane and thus must be managed as such. Software is approximately 25% of our total business base.

We successfully achieved our Level 4 assessment in December 1999, after a struggle of three concentrated years of effort. When we started our Level 4 effort (it was customer driven), our internal assessment was that we had slipped back from our Level 3 rating. We completely rebuilt our data collection system, we had to re-educate a lot of people, and we had a significant management hill to climb. We are now getting a lot of management pull for information that can only be provided by the efforts put in place for the Level 4 assessment.

The biggest barrier we now have is the consolidation of three large Lockheed Martin companies, and the move to a consolidated, single set of processes. Right at the time of our Level 4 assessment, we received word that what was Lockheed Martin Tactical Aircraft Systems (Fort Worth, TX), Lockheed Martin Aeronautical Systems (Marietta, GA), and Lockheed Martin Skunkworks (Palmdale, CA) would be merged into one company with one president and one

set of processes. We are a year into this merge of three different mindsets, three different process sets, three different cost accounting systems, three different metrics systems, three different maturity levels, etc. One of the requirements of the merger is that one "site" would not dominate the new company. The best of each site was to be brought forward. The plan is for a formal assessment in late 2002, probably using the SCAMPI as our assessment method with the CMMI approach as the model.

4.10.3 Unique or Distinguishing Practices

We have a single database (our internal built AutoMet) that is the single repository of organization data. It allows us to pull and look at data through multiple filters and to "roll-up" data from a project view through a program view to an organization view, along with getting a domain view across projects / programs.

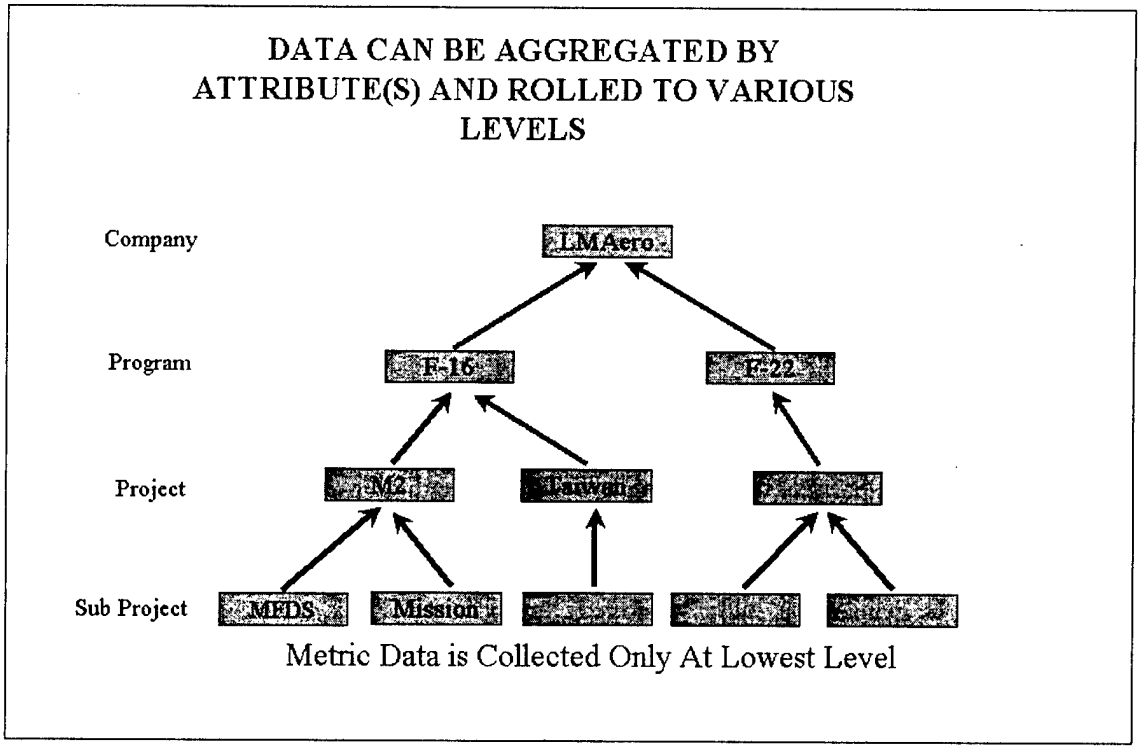

Figure 12: LMAero Data Aggregation

Another area is in our defect predictions. As can be seen from the charts in the "Trends" section, our cost, quality, and schedule performance are very much under control and repeatable. Our next step was to be able to predict quality as we progress through the development life cycle. Below are two slides from the presentation we gave at SEPG 2001, which show our defect processing model and the profile that we developed. This profile is updated monthly as the project continues through the life cycle. We have seen an ability to predict the amount of test (and in some cases actually decrease our test time) by understanding how this model and the resultant profile affect a given project.

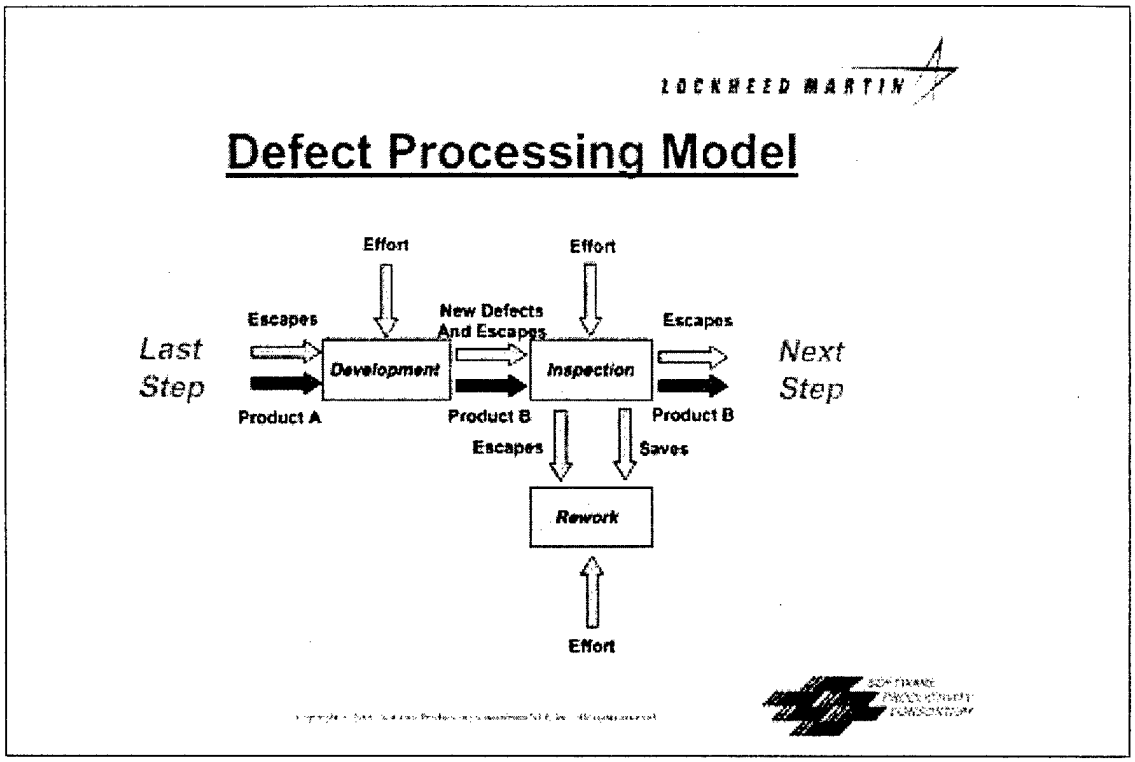

Figure 13: LMAero Data Processing Model

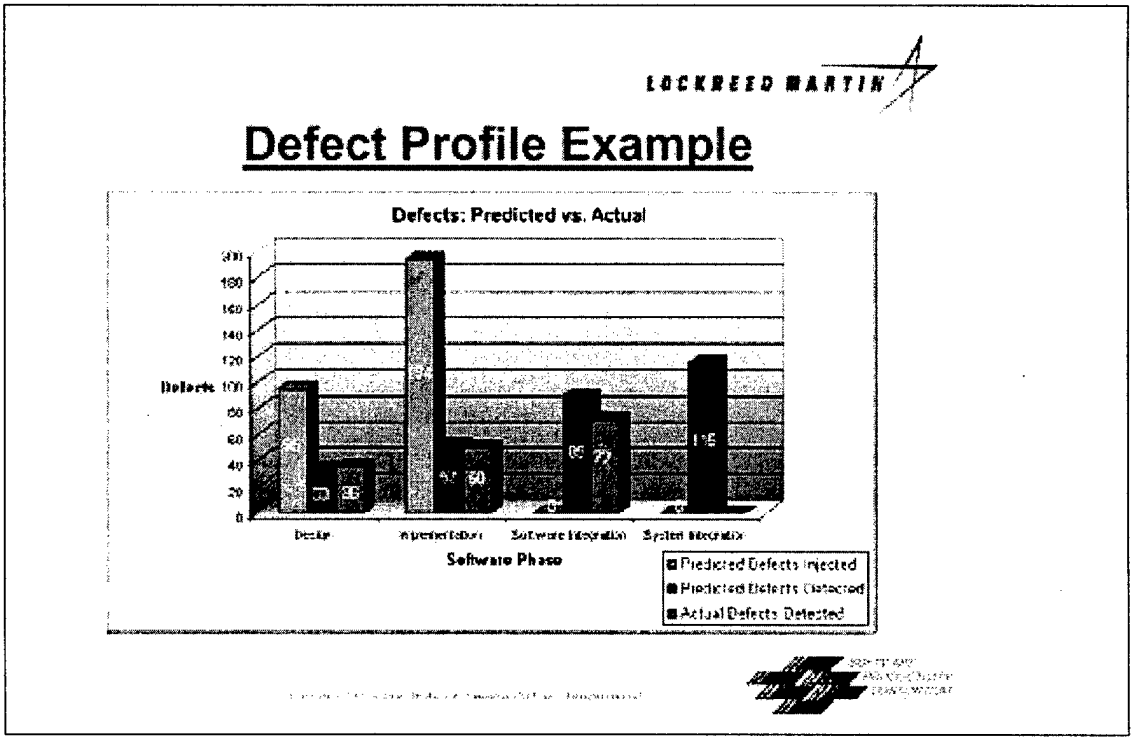

Figure 14: LMAero Defect Profile Example

4.10.4 People and Cultural Issues

One thing we learned during our journey to Level 4 was that management buy-in is absolutely critical. Even through we have a very "vocal" and motivated process improvement team, without the management buy-in, our efforts to get projects to collect data differently, more data, training on SPC, etc., would not have succeeded.

4.10.5 Continuing Improvement

Our next (continuing) effort is the merger of the three companies. We need to bring our other processes (systems engineering, hardware / electrical, etc.) along with the software process to give a complete product development process view to us, our senior management and to our customers. We will be performing an assessment across the three sites within the next year or so.

4.10.6 Summary

LMAero is moving ahead on a path of continuous process improvement. We are developing and deploying an integrated product development process that will join together all disciplines that work towards actual product development. Our emphasis will be on "other" engineering disciplines while maintaining our software process maturity, and using our knowledge of process improvement in software to "speed up" the process improvement in our other engineering disciplines.

4.11 Lockheed Martin Management & Data Systems, King of Prussia, PA

Maturity Level	5
Date of Assessment	December 2000
Lead Assessor(s)	Andy Felschow
	Carol Granger-Parker
	Dennis Ring,
Point of Contact	M. Lynn Penn, Mary.lynn.penn@lmco.com
Web Page	http://www.lockheedmartin.com
Size of the Organization	4500 organization software engineers
Typical Program Size	9-1500 engineers per project
	100M lines of code

Assessed at maturity level 5 in December 2000, at maturity level 4 in December 1998, at maturity level 3 in August 1996, at maturity level 2 in May 1995. ISO 9001 certified and assessed against the Systems Engineering CMM at Level 5, November 2000. Total employees at M&DS are 8500 and nine different geographic locations, not including customer sites. We are currently adopting the People CMM.

4.11.1 ROI and Improvement Trend Data

For a number of years, Lockheed Martin Management & Data Systems (LM-M&DS) has had long-term goals for improving software productivity and quality. Productivity is tracked in terms of lines of code / hour, while quality is tracked in terms of defects / KLOC detected during independent testing activities. The latter was regarded as a predictor of defect density in the field. Various strategies were employed to address these goals including increased process discipline and use of quantitative management during our Software CMM Level 4 period. However, the emphasis on early defect detection via increased use of work product inspections and defect prevention driven by causal analysis during our Software CMM Level 5 efforts seems to have had the most impact. LM-M&DS believes there is still much additional benefit to be obtained as we become better at such activities.

The solid lines in the following chart provide Rayleigh-curve based models of our baseline performance for defect detection over the life cycle as well as our recent performance.

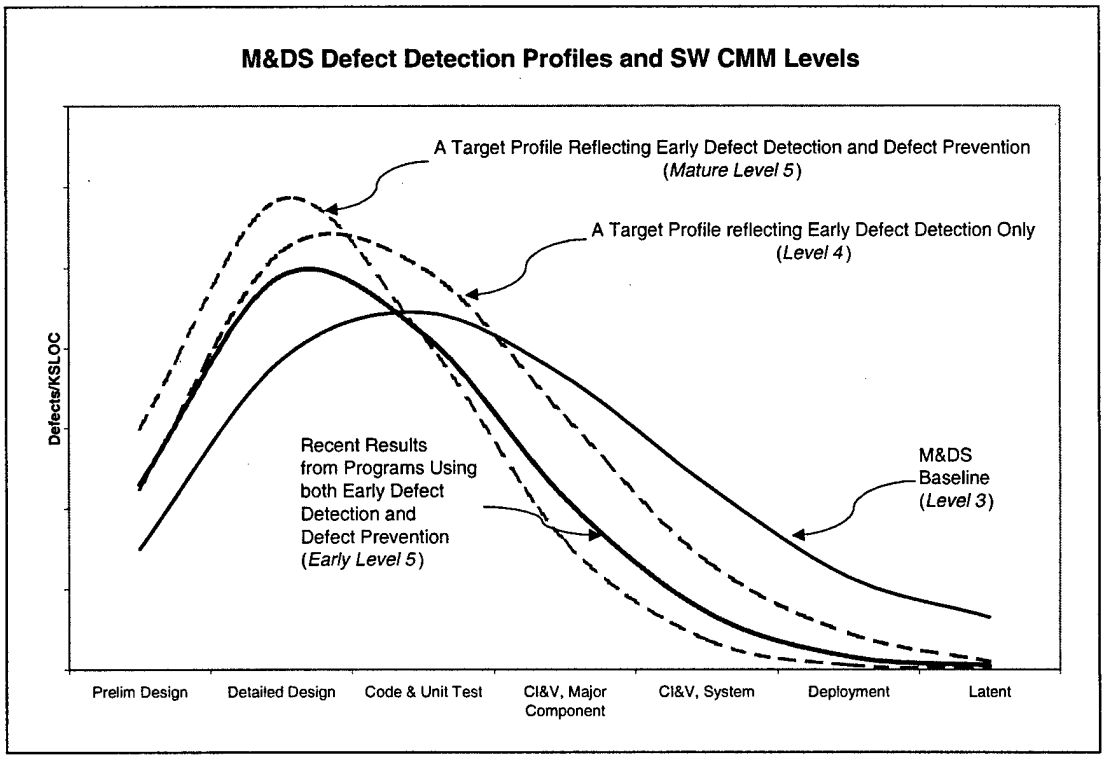

Figure 15: LM M&DS Defect Detection Profiles and Software CMM Levels

The dashed lines are target profiles derived from the baseline model. One profile reflects just the impact of improved early defect detection and the other profile reflects early defect detection and defect prevention. The use of such target profiles enabled programs to set realistic goals for defect detection during early phases and, as they utilized wider use of inspections

and performed defect detection, they grew more confident in the techniques and more anxious to achieve the most ambitious profile.

Our bottom-line results against our productivity and quality goals are reflected by the charts in Figure 16 and Figure 17.

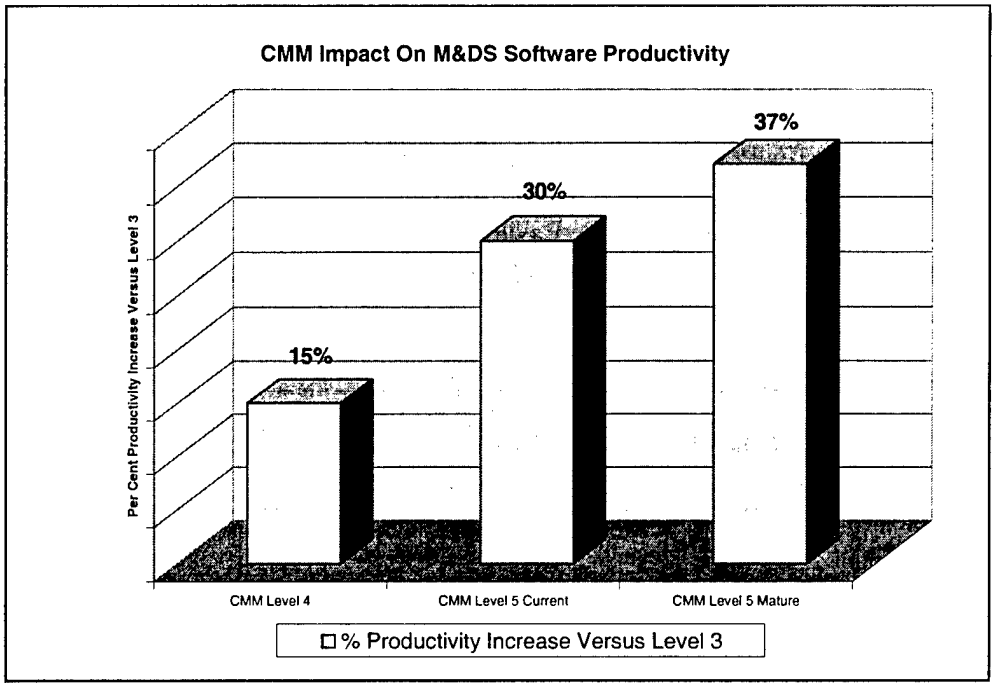

Figure 16: Software CMM Impact on LM M&DS Software Productivity

The mature Software CMM Level 5 column in each chart reflects our future target as we continue to employ rigorous defect prevention across all our disciplines. M&DS recognizes that even Level 5 is a journey and that maturity within the level is a reality.

4.11.2 Barriers to Achieving High Maturity

The biggest challenge for M&DS was the acquisitions made. We found ourselves acquiring different groups with different product lines, different maturity, and different geographic locations. This challenge forced us to re-evaluate our mandatory level of compliance. Where we had taken a standard process and through years of maturing that process had made it quite specific, we were required to raise it back up and allow for more tailoring. This level of compliance issue was for processes, metrics, and analysis methods.

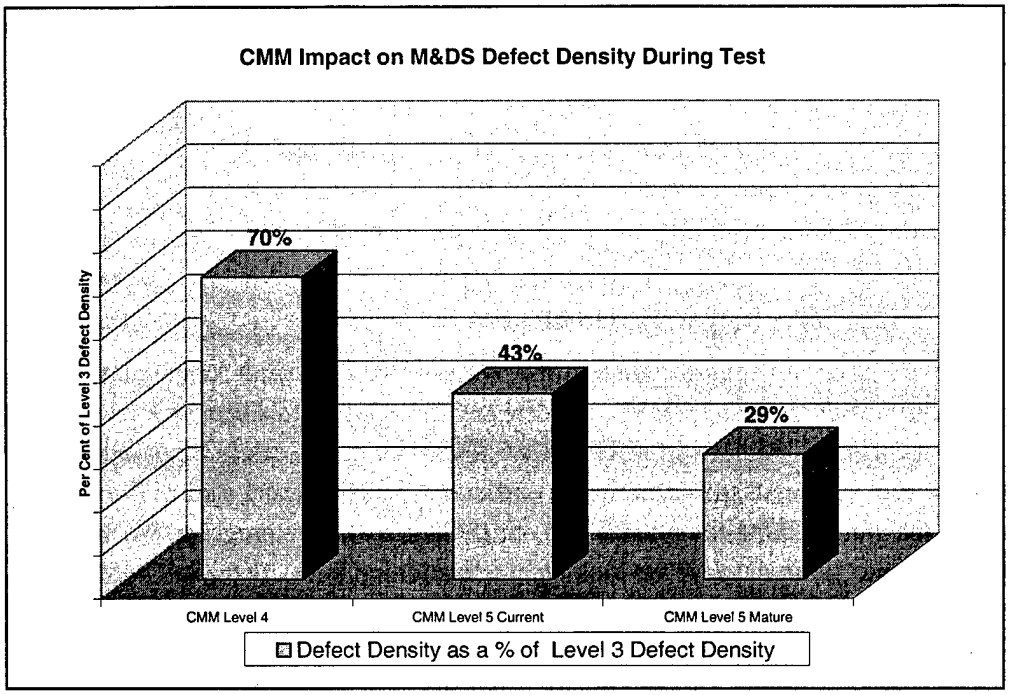

Figure 17: Software CMM Impact on LM M&DS Defect Density During Test

4.11.3 Unique or Distinguishing Practices

In Process Quality (IPQ) is a way of looking at quality throughout the whole process and product development not just at defined points. As we state in our introductory training "IPQ enhances M&DS' ability to produce quality products by emphasizing a focus on quality throughout *all* stages of development. It enables a process of defect analysis and corrective action to be implemented earlier in the development cycle." The four basic elements of IPQ are

- Discipline – defects do not pass through to next phase
- Quality Awareness – quality goal setting in each process phase
- Quality Inspection – inspection of each product and defect in each process phase
- Root Cause Analysis and Corrective Actions

This process, its definition, discipline, and execution, were critical to our achievement of Level 5. IPQ has been responsible for a major shift in our Defect Detection Profile to a much earlier detection rate. Defects have dropped in test by 30%.

4.11.4 People and Cultural Issues

Similar to our challenge above based on the diversity in regions and product lines, people and cultures were also very different. Once the alignment of the organization came together we could proceed with maturing. We have adopted the People CMM to put more structure in our workforce practices. We have formally adopted structured Integrated Product Development Teams on most large projects. We have a formal mentoring program and have structured our

core competencies to both our strategic plan and our technology plan. We have adopted a skills database that is product and function oriented. Orientation training has remained a very focused formal process, which it has always been. Our process orientation training is now a mandatory compliance module every year for *all* employees—discussing the latest in process improvements at M&DS. Employees are excited about the process environment and actually are very responsive now to customer evaluations to show their "stuff."

4.11.5 Continuing Improvement

There are numerous initiatives at the current time. We have put together a formal plan on maintaining Systems Engineering CMM and Software CMM Level 5s since we know sliding back is always very easy. We have a formal one-week activity that we do in each region once a year to make sure we are all still operating as expected—benchmarking against the CMMs. We have also integrated CMM compliance into our ISO internal audit program. We are adopting the People CMM. Also we are looking at transitioning formally to the CMMI in 2002 and the new ISO 9001:2000 standard in 2003.

4.11.6 Summary

The true benefit is in the setting of expectations. We know what we can do. We know our process capability as it relates to today and we can show management how a new process will relate to tomorrow. We prevent programs from turning "red" —going bad versus reacting after the fact. We know where we are and how we are doing, based on data not judgment.

4.12 Lockheed Martin Naval Electronics and Surveillance Systems-Undersea Systems (Manassas, VA)

Maturity Level	5
Date of Assessment	February, 1999
Lead Assessor(s)	Judah Mogilensky John Travalent Donald White
Point of Contact	Dana Roper, dana.roper@lmco.com
Web Page	http://www.lockheedmartin.com/manassas/
Size of the Organization	Approximately 190 software engineers
Typical Program Size	Average number of software engineers per program = 7 Average number of delivered source statements per program = 1.2 million
Primary Application Domain(s)	• Military software, adhering to DoD or MoD standards • Systems software, used to control physical devices

Lockheed Martin Naval Electronics & Surveillance Systems – Undersea Systems (LM NE&SS-USS) Manassas achieved the following certifications:

1. ISO 9001:1994 in September, 1995
2. AS 9000:1997 in November, 1997
3. ISO 14001:1996 in December, 1998
4. ISO 9001:2000 in December, 2000

LM NE&SS-USS Manassas has been involved in process assessments for quite some time, as illustrated in Table 1.

Table 1: LM NE&SS-USS Assessment History

Date	Activity	Results	Evaluator(s)
September 1990	Process Assessment (SPA)	Level 3	Internal; multiple divisions plus SEI personnel
September 1990	Capability Evaluation (SCE)	> Level 2; Awarded contract	US Navy
May 1992	Capability Evaluation (SCE)	Unknown; Awarded contract	US Army
August 1992	Capability Evaluation (SCE)	Level 3; Awarded contract	US Navy
October 1992	Process Assessment (SPA)	Level 3	Internal, multiple divisions
November 1992	Process Assessment (SPA)	Level 1-2	Internal pilot using Software CMM v1.0
October 1994	Capability Evaluation (SCE)	Unknown; Awarded contract	US Army
February 1995	Capability Evaluation (SCE)	Unknown; No contract	US Air Force
June 1995	Process Assessment (CBA IPI)	Level 4	External with three authorized Lead Assessors
February 1999	Process Assessment (CBA IPI)	Level 5	External with three authorized Lead Assessors

4.12.1 ROI and Improvement Trend Data

The 3.5 person group responsible for process improvement at LM NE&SS-USS Manassas is concerned with all processes. Therefore, it is difficult to cleanly define the amount invested in software process improvement. However, the results of software process improvement are easier to measure and determine. Some of the results are delineated below:

1. 350% increase in software productivity
2. variance of both actual cost and schedule about target values decreased

3. 87% decrease in the number of delivered defects (graphic shown at 1999 High Maturity Workshop)

4.12.2 Barriers to Achieving High Maturity

The biggest barrier was gaining an understanding of what is truly meant by the two Level 4 Key Process Areas (KPAs). The first impression one comes away with after reading Quantitative Process Management is a description of *mature* management by metrics. The intended rigor of statistical tools and particularly statistical process control (control charts) does not come through.

Once this understanding has been achieved, the next barrier becomes one of determining which (sub)processes should be measured and controlled. All too often companies measure what is easiest or convenient and not what is important. As with most changes, you have to have both the will to change and a person or group willing to work to get the change made part of the organization.

4.12.3 Unique or Distinguishing Practices

For many years, LM NE&SS-USS Manassas has used a software reliability growth model (SRGM) to produce a latent defect projection (LDP). The SRGM is a home grown tool based on how software engineering is performed at LM NE&SS-USS Manassas. The LDP is one tool to help determine the effectiveness of our software processes.

Data from all inspections are rolled up to provide a composite profile for a program. From this data, an SRGM is run to provide a LDP. The LDP is an estimate of the software quality (number of defects) of the product after delivery. The LDP is an early indicator of possible problems with either a product or process(es).

4.12.4 People and Cultural Issues

All new hires, college or professional, receive a core set of required training. Even with this training, we have found that some new hires coming from a less structured environment may resist the imposition of processes. Usually, once they have observed the benefit gained from process adherence, these same people become process advocates.

4.12.5 Continuing Improvement

Having achieved Level 5, we see our next jobs as two parts: maintain and improve our software processes and extend process maturity to the related engineering disciplines, especially systems engineering. Toward that end, LM NE&SS-USS Manassas is moving toward the CMMI model. The biggest barrier currently seen is the existence of the two representations of the model.

4.12.6 Summary

The effects on the organization vary depending on the view one takes. If you look at the organization as being made up of groups of engineers, the effect is almost nonexistent. Most engineers are simply doing their jobs and not worrying about the maturity of the processes they are following.

To the organization as a whole, being a high maturity organization is a very nice recognition of the many years of continual process improvement.

4.13 Mastek Limited, Mumbai, India

Maturity Level	5
Date of Assessment	September 2000
Lead Assessor(s)	Ronald Radice
Point of Contact	Rajshekharan P
Web Page	www.mastek.com
Size of the Organization	Total 1100 professionals, of which offshore professionals are approximately 600
Typical Program Size	20-30 people for a typical project
Primary Application Domain(s)	**Product:** Supply-chain management (GOLDMINE) **Domain-specific:** Insurance, Securities, Education, Finance, Telecom **Platform**: Backend: Oracle SQL server, Informix, Ingres, Sybase Front end: VB, ASP, Java, C, VC++, C++, Open Road **Tools**: Oracle Apps, CRM, Site-server, Work flow Mobile application, Wireless application

ISO certification since 1994. Assessed at Software CMM Level 4 in 1999. Assessed at People CMM Level 3 in 2000.

4.13.1 ROI and Improvement Trend Data

The performance of our improvement program is measured through the following parameters:

- overall customer satisfaction
- quality (% rework and % defect leakage to customer)
- efficiency (estimation efficiency and productivity)
- timeliness (delivery slippage)

Some graphical representation of the trends on these above parameters is given below for the time period of one year.

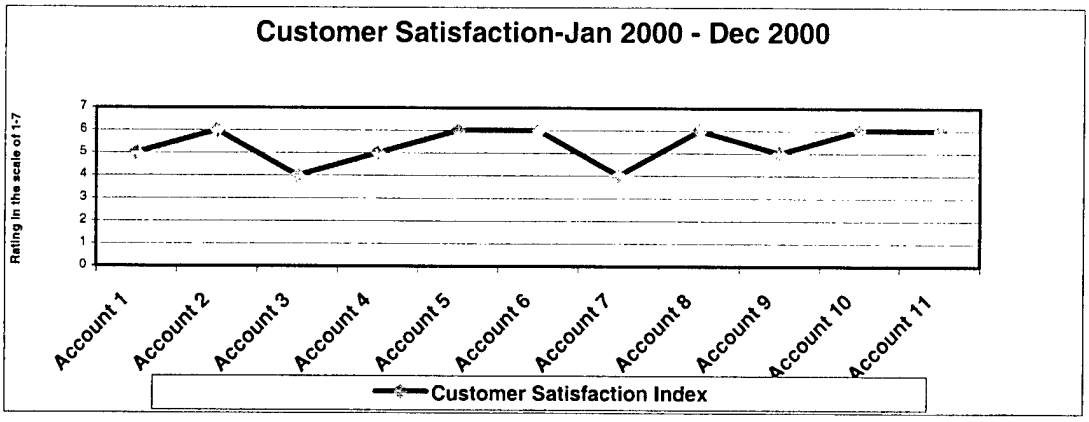

Figure 18: Mastek Customer Satisfaction

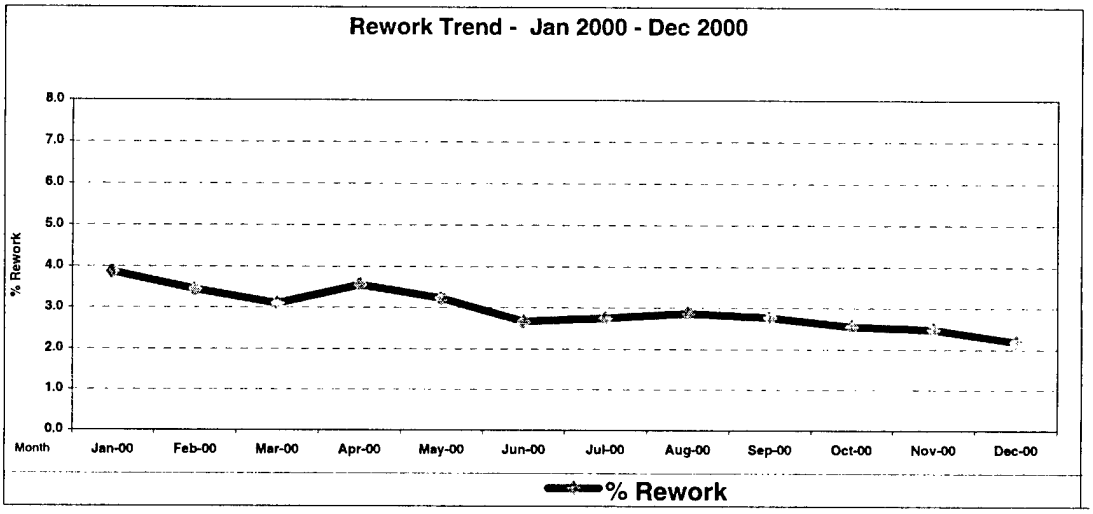

Figure 19: Mastek Rework Trend

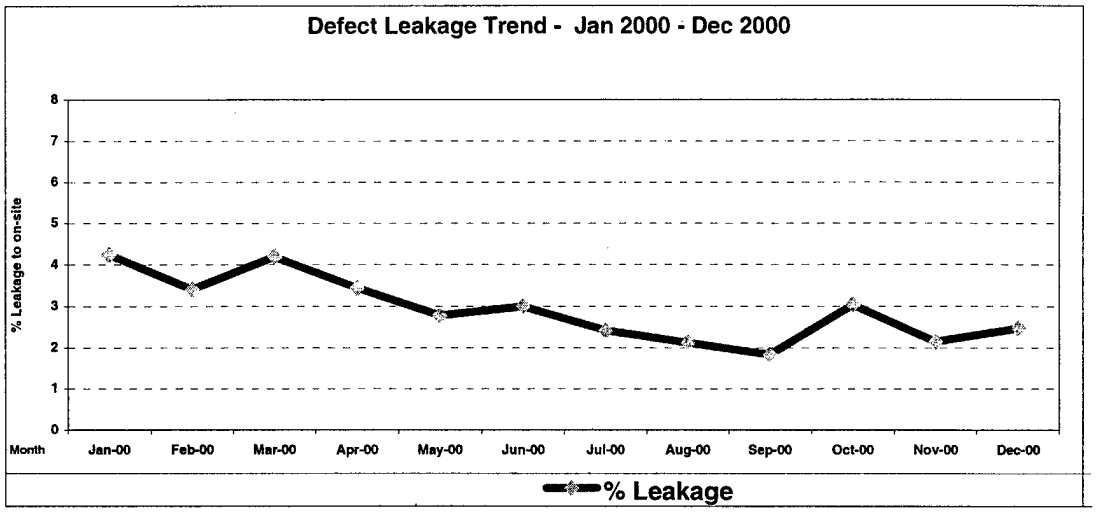

Figure 20: Mastek Defect Leakage Trend

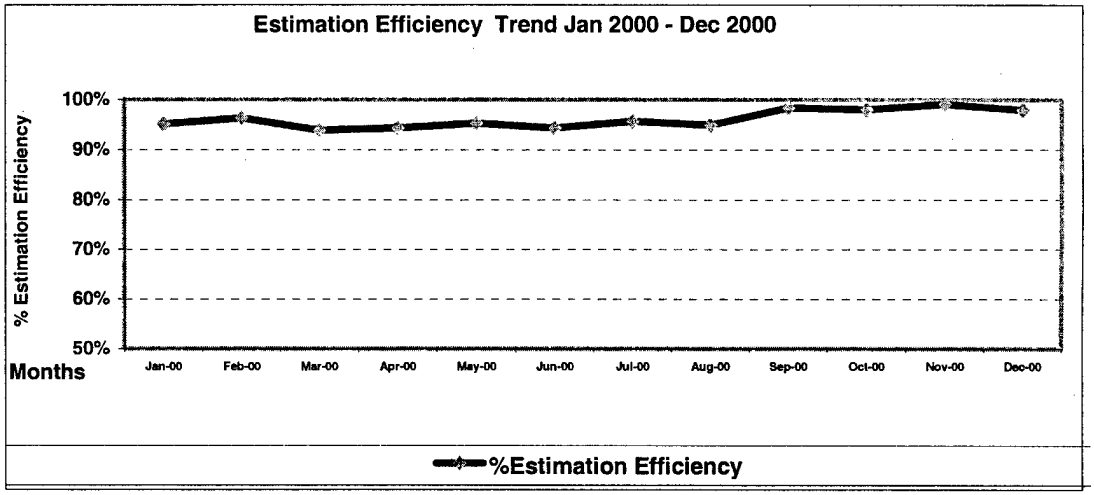

Figure 21: Mastek Estimation Efficiency Trend

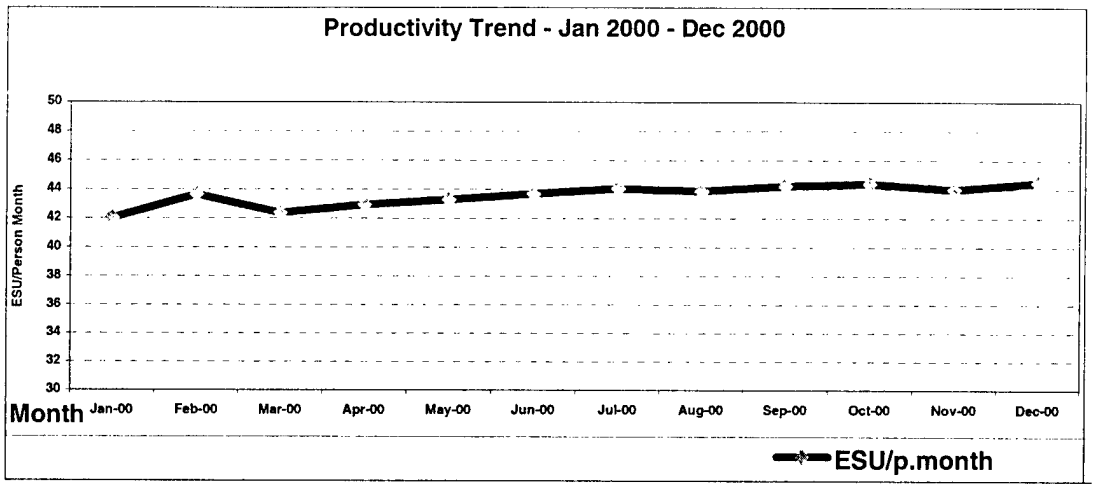

Figure 22: Mastek Productivity Trend

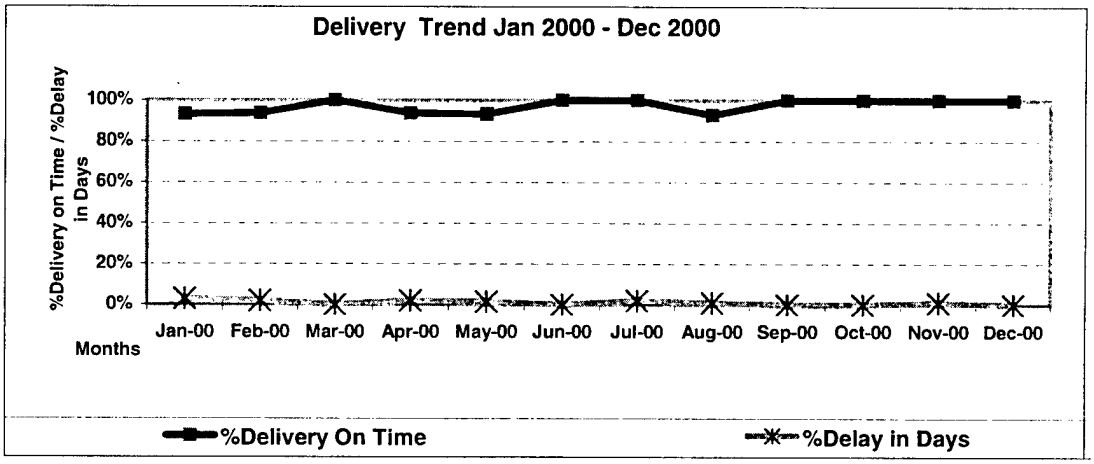

Figure 23: Mastek Delivery Trend

4.13.2 Barriers to Achieving High Maturity

Main difficulties faced while practicing Levels 4 and 5 were

1. Implementing Metrics Program, in terms of
   - finalizing required measurement parameters at different levels of review
   - data collection methodology
   - appreciating the benefit of data analysis and applying SPC

   Action taken for smooth transition

   - finalization of metrics program through Quality Improvement Team (QIT) consisting of experts from process group, corporate functions and project managers and heads from line functions

- automation of data collection and reporting through project tracking tools (ARTS) developed in-house
- training of SPC at different levels, such as process group, senior management, project managers, and team members
- proper stratification of data for analysis and defining measurement parameters distinctly as review parameters and controlling parameters through SPC

2. Implementing Process Change Management (PCM) in the organization, in terms of
   - creating the awareness and involving *all* practitioners in PCM drive
   - handling suggestions from different directions and implementing in the organizational procedure and guidelines

Action taken for smooth transition

- defining proper work flows for process improvement suggestions coming from different directions
- campaigning on PCM, regular updates with implementation status, and rewarding practitioners for good suggestions

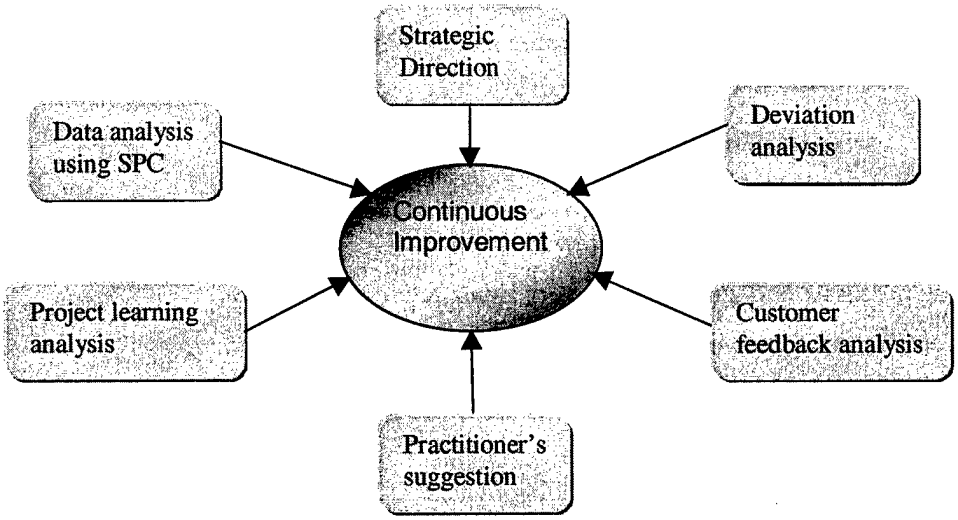

Figure 24: Mastek and Continuous Improvement

4.13.3 Unique or Distinguishing Practices

Three important contributors and characteristics of the company in the current situation are:

1. Evolution of SQA role with higher maturity level
   - SQA's activity and audits mainly focus on the data validation, project review with quantitative data analysis
   - SQAs play a major role in defect prevention, early detection through peer reviews, and helping practitioners for contributing in process improvement

- automation of routine SQA activities, so that SQA can devote more time in effective process improvement

2. Process change suggestion at almost all levels are data driven
   - at project level, SQAs and project members analyze project performance data and come out with project action items and organization-wide process changes
   - at organization level, corporate process groups analyze trends across projects, calculate capability bands, and come out with process change suggestions

3. Project management and review is fully data driven with the help of on-line Dash Board giving charts for all measurement parameters.
   - Mastek uses e-PMO as a project management tool, which is an in-house customized solution. This solution is Web-enabled and provides support for various activities in project management like request or service call registration, work planning, time and defect tracking, and various MIS reports for project's progress review. These reports are available for internal project mangers as well as the customer's review.

4.13.4 People and Cultural Issues

After attaining high maturity in the existing processes, the main challenges are to

- maintain consistent ROI
- align and educate customers, who are at lower maturity levels

4.13.5 Continuing Improvement

Current improvement objectives are

- productivity improvement at individual level
- fine-tuning processes and guidelines for very small deliveries / projects
- carrying on process improvement programs through self-managed teams

4.13.6 Summary

The benefits seen in the organization can be categorized as

Internal benefits:

1. a disciplined and consistent way of managing projects
2. smooth transitioning of newcomers into organization and projects
3. predictability of deliverables improved substantially
4. continuously evolving processes and ability to adapt them quickly across similar projects
5. customer confidence and increase in businesses share from existing customers. Repeat business grew to 83% from 76% last year.
6. process improvement ownership moved from SEPG to practitioners

Business and Customer benefits:

1. ability to meet demands of a dynamic industry
2. transparency for customer through integrated project management tool – e-PMO
3. higher return to customer due to improved productivity, reduction in waste and meeting the timelines

4.14 Applied R&D Center, Asia Pacific Telecom Carrier Solutions Group, Motorola, Beijing, China

Maturity Level	5
Date of Assessment	December 2000
Lead Assessor(s)	Motorola QSR SS10 (Quality System Review Subsystem 10)
Point of Contact	Graham Hu, qch1422@email.mot.com
Size of the Organization	250 in 2001
Typical Program Size	20 engineers per typical project 40,000 lines of code per typical program
Primary Application Domain(s)	Systems software, used to control physical devices

- Assessed at maturity level 4 in 1999, Motorola QSR Subsystem 10
- Assessed at maturity level 5 in 2000, Motorola QSR Subsystem 10
- Strong SPI sponsorship from senior management
- SPI participation is organization-wide
- Conduct the SPI effort based on the data analysis
- Use of automated software process measurement system
- Use of statistical process control
- Quality prediction and control
- Use of ODC
- Extensive process training program

4.15 Motorola China Software Center, Beijing/Nanjing/ Chengdu, China

Maturity Level	5
Date of Assessment	September 2000
Lead Assessor(s)	Dan Weinberger Patricia McNair
Point of Contact	John Junan Yu, A14810@email.mot.com
Web Page	
Size of the Organization	350
Typical Program Size	Number of people per typical project: 15-30 persons Number of lines of code or function points per typical program: 20.5 Function Points per staff month or 6.56 KAELOC / staff month[3]
Primary Application Domain(s)	Wireless communication – GSM / CDMA / 3G infrastructure and subscriber software developmentCommon test platform (SDL, MSC, TTCN, SW simulation) and test automation Embedded system and software tools – Real time OS and embedded system – Device drivers – Voice recognition and synthesis, digital audio / video – DSP applications, simulation and algorithm – Compiler, IDE tools, modeling and simulation tools – Audio / video processing Network management – CDMA / GSM network management system Internet and eCommerce

Established in 1993, Software Center, Motorola China (SCMC) is an integral part of Motorola Global Software Group. SCMC is the first organization in mainland of China with business development based on the Capability Maturity Model for Software (Software CMM). SCMC is the first SEI Software CMM Level 5 organization in Great China. There are three locations in Great China; they are Beijing, Nanjing, and Chengdu.

Motorola China Software Center was assessed as

- Software CMM Level 5 in September 2000 by SEI-authorized Lead Assessors in CBA IPI
- Software CMM Level 4 in January 1999 by Motorola assessors in CBA IPI / QSR SS10

4.15.1 ROI and Improvement Trend Data

In SCMC, there are more than 5% of total engineering staff working in the area of software process improvement, quality assurance, new technology induction and software engineering

[3] We use 1 function points = 320 lines of assembly code.

training. There is a dedicated software quality engineer in each project (product) development.

Total customer satisfaction in past two years: 9 points (range from 0-10, 6=good, 8=very good, 9=excellent, 10=world class)

Productivity in typical domain: 6.56 KAELOC / staff month, which is much higher than the industry average

Post-release defects: 0.0032 defect / KAELOC (6 sigma)

In-process fault is under control limit

4.15.2 Barriers to Achieving High Maturity

The following barriers were overcome during our Software CMM Level 5 implementation

- Process culture building, how to balance the long-term investment and short-term benefit. The local (Chinese) culture sometimes is the barrier. We set up the international culture step by step.
- We introduced new measurement technology, new tools and environment. We set up a Software CMM expert team to lead the development team from Level 3 to Level 4 and Level 5.
- We got strong senior management commitment

4.15.3 Unique or Distinguishing Practices

Two of our distinguishing practices are culture building and strong commitment from senior management.

4.15.4 People and Cultural Issues

There are a lot opportunities from outside to experienced Software CMM practitioners in China; how to keep them is a big issue.

Chinese culture and English language are two big barriers in China.

Any changes in process and technology should be business oriented.

4.15.5 Continuing Improvement

Continue to improve our process and introduce new technology to meet our business needs.

Fine tune our current process and combine CMMI into our current practice.

Because many engineers in China are emigrating to U.S. and Canada, how to train their replacements is a key issue.

4.15.6 Summary

Levels 4 and 5 make high expectation from customer.

Levels 4 and 5 mean high quality, on-time delivery, high cost efficiency.

Level 4 and 5 organizations can fine-tune their organization infrastructure, management style. Most of their activities can be presented quantitatively.

4.16 United Space Alliance, Houston, TX

Maturity Level	5
Date of Assessment	November 1989
Lead Assessor(s)	Donald Sova
Point of Contact	Julie Barnard, Julie.r.barnard@usahq.unitedspacealliance.com
Web Page	www.unitedspacealliance.com
Size of the Organization	300 software professionals (full-time employees, not including temporary staff)
Typical Program Size	100 people per typical project 500,000 lines of code or function points per typical program
Primary Application Domain(s)	Real Time Applications

The Space Shuttle Onboard Software project is a part of the United Space Alliance Limited Liability Company based in Houston, TX. The project was previously a part of the IBM, Loral, and Lockheed Martin corporations before joining United Space Alliance on July 4, 1998. The project (under IBM at the time) was assessed at Level 5 in November of 1989 by an SEI-trained NASA team, led by Donald Sova of NASA Headquarters Code Q.

The project was initially registered to ISO 9001 in 1994 and has maintained its ISO 9001 compliance for the last six years. Additionally the project was awarded the IBM Best Software Laboratory at the time IBM was using the Malcolm Baldrige National Quality Award criteria as an internal assessment method.

The Space Shuttle Software project is responsible for the software executed onboard during all phases of the Shuttle flight. In addition, the project also maintains the application tools that support configuration management, test and simulation, verification, and flight reconfiguration.

To satisfy NASA's requirement for software that meets the highest safety and reliability standards, the project evolved a software process that yields a highly predictable quality result.

By executing the process faithfully to specified process standards, the software produced by the process is predictably near zero defects. The processes have been modified and refined over two decades to create an optimized process suitable for producing software meeting the desired expectations.

The project size fluctuates around 250-300 people. The project resides within a larger software organization of approximately 600 people that includes a major subcontractor assessed at Software CMM Level 5 in October 1999.

4.16.1 ROI and Improvement Trend Data

NASA's overriding concern is for the quality and safety of the Shuttle software at the time it is certified ready to fly a specific mission. Accordingly, the customer specifies defect density thresholds applicable to the software at this delivery milestone. One of the objectives of process improvement is to minimize the remaining errors in the delivered software.

During the period of process improvement leading up to the Software CMM Level 5 rating, the defect density improved significantly. This demonstrated a correlation between the maturation of the processes and the improvement in delivered product quality. As the process activity turned more to the nature of process refinements, rather than massive process overhauls, the defect density continued to improve but at a slower pace. Excellent product quality has been sustained in a predictable zone for the number of years since.

4.16.2 Barriers to Achieving High Maturity

The project began early with high maturity practices due to the life criticality of the software and the quality expectations levied by the customer. A driving expectation of zero defect software made the move to Level 5 a natural path.

Because the project was assessed at a high maturity level some time ago, the current barriers facing the project relate more to the sustainment of high maturity at an organizational level, rather than to achieving high maturity.

One of the challenges facing the project over the more than ten-year period since its Software CMM Level 5 assessment has been to sustain its practices across the company changes and reorganizations. Through corporate transitions, reorganizational growing pains, expansion, etc., the project has encountered a need to periodically assess itself against the Software CMM. These internal CMM-based assessments are done to ensure there is no backsliding of existing practices, to fold newer parts of the organization into high maturity practices, and to ensure continuity in infrastructure across organizational transitions. By leaving intact the basic organization structure, core management, and process infrastructure, the best practices have continued successfully across the corporate boundaries.

The organization is expanding to include groups who were not a part of the original project and who are striving for improving their process maturity. Integrating lower maturity groups into an existing project steeped in tradition, a high maturity mentality, and a culture focused on zero defects has been the latest challenge. Groups from a variety of corporate genealogies that are accustomed to diverse cultures, methods, toolsets, and terminology are being joined together to blend the best of each area.

4.16.3 Unique or Distinguishing Practices

Some of the distinguishing practices the project is recognized for include:

- rigorous application of formal inspections, including software requirements inspections
- in-depth defect prevention process, including robust root cause analysis performed on each software defect that is a detailed examination to determine causes for process escapes
- matrixed program management and control board structure
- long-term continuous process improvement
- reliability analysis and prediction modeling based upon historical data
- senior manager reviews of project key processes (e.g., inspection, requirements evaluation, development test, etc.) to examine process escapes, process changes, and process metrics
- use of process enactment type tools to facilitate process handoffs

4.16.4 People and Cultural Issues

Aside from some expected fallout of personnel across three corporate transitions, the project has benefited from the retention of core skills in key functional areas. There has been a fairly large amount of hiring in the past couple of years, which is partially due to expanding work opportunities. The attrition rate is typically quite low, as many employees remain long term on the project.

The mentoring program and new hire orientation have been used for many years to indoctrinate new employees into the complex software domain. Due to the amount of time it takes to prepare an employee before taking on active assignments, the project relies on these programs heavily. The mentoring program includes a documented formal process that establishes assigned mentor / mentee relationships and conducts surveys periodically to monitor progress. It allows for a no-fault termination of mismatched mentor / mentee pairs in situations where the assignments just did not work out. The new hire orientation includes general project overviews, detailed process presentations by owners of each process, domain specific training, and other required training specific to the organization. This supplements the company provided new hire topics.

The high maturity culture is fostered by ongoing and visible senior management commitment, involvement, and sponsorship. The senior manager conducts periodic project all hands meetings including VIPs, reinforces accomplishments and achievements with ample recognition, and communicates strategic direction for the organization—outlining future opportunities for project growth. In addition, process team empowerment and employee ownership of processes is the norm.

Recently, a prospective employee approached one of the project managers and inquired about the background of our high maturity organization. He indicated that he was tired of dealing with a Level 1 environment (e.g., working extensive overtime and always being schedule driven). He had come to the project looking for an oasis of work refreshment.

4.16.5 Continuing Improvement

The project has been working on process improvement for over two decades, beginning with major changes in fundamental process approaches and then evolving to refinements of processes with less extensive changes. A current focus is on research-oriented prototyping of techniques for potential process improvement identification. Within the project there are planned research activities to investigate the applicability of certain techniques / models to improve prediction of remaining defects at delivery. Because this ties closely to the objectives of end product delivered quality, the project continues to pursue improved methods for examining data, early indicators, and analysis techniques that will provide varied insight into its existing processes.

Future improvement activities also include transferring mature practices from within the project to other parts of the company. The corporate software process owner and company SEPG serve as the primary mechanism for advancing the software process maturity of the overall company software process. The project is contributing its process expertise to review software processes in other parts of company and to aid in the development of mature processes.

The corporate software process goals include plans for formal company-wide assessment against Software CMM v1.1. This assessment will include at least some part of the current flight software organization. There is a long-term expectation of evolving the corporate software and systems engineering processes towards CMMI. An assessment against CMMI of the software process would be a longer-term objective.

Similarly, the use of ISO 9001 will evolve from the 1994 version of the standard to the more current version. The project will be assessed against the revised 9001 at the time the company registration scope is modified to step up to the newer version of the approved standard.

The NASA Software Working Group is developing an agency-wide software standard that incorporates the requirements of IEEE/EIA 12207 for development of mission critical software. As this standard is deployed to NASA projects, it is likely that the applicable software projects will also assess compliance to 12207.

4.16.6 Summary

A built-in part of a mature process is to change the process and assure continuous improvement. Even a project that has operated over two decades with success has continued to improve and change. Skilled people and a continuously improving process produce quality products. Process changes are identified from both detailed introspective analysis and metric analysis with a goal of process optimization. Process changes are prioritized then tracked by program management to ensure attention is paid to critical changes. Appropriate process changes are tied to customer commitments. Modeled and predicted product quality and reliability are compared to actual quality and reliability for tracking overall product objectives.

There are some mandatory organizational attitudes that prevail in the high maturity organization:

- management and employee obsession
- discipline
- perfection expectation
- long-term commitment
- employee empowerment and ownership

4.17 Philips Software Centre, Bangalore, India

Maturity Level	5
Date of Assessment	July 2000
Lead Assessor(s)	Richard Knudson
Point of Contact	Bob Hoekstra, bob.hoekstra@philips.com
Web Page	http://www.philipssoftwarecentre.com
Size of the Organization	About 500+ during assessment
Typical Program Size	About 8-10 persons / project (there are bigger as well as smaller projects than this). In PSC, "Program" is used to mean LOB, and these are 50-100 persons in size.
Primary Application Domain(s)	Embedded software used in TVs, DVDs, adhering to internal Philips standards.

Philips Software Centre is a fully owned subsidiary of Royal Philips Electronics NV, Netherlands. This company was inaugurated in September 1996. PSC, Bangalore was assessed at Software CMM Level 3 in September 1997 (as per Philips assessment method) and ISO 9001/TickIT Certified in December 1997.

The journey towards Software CMM Level 5 began with a top management workshop. That was followed by a documentation gap analysis to enhance process definition, a Web-based abridged assessment, and two five-day mini assessments prior to the CBA IPI in June 2000.

4.17.1 ROI and Improvement Trend Data

The Business Plan for PSC is translated into long term Quality Improvement Plan (Macro plan for two years, updated every months) and SPI Plan derived from the QIP (Micro plan for six months, updated bi-monthly). PSC has a dedicated Corporate Quality Department that coordinates all organization-level improvement activities. The company's software process improvement journey was tracked for all expenses incurred including opportunity cost of time spent.

The target setting process in PSC's quality journey was evolutionary in nature. The earlier targets were process compliance targets and subsequently we have set three product-related targets. These targets are listed below.

1. Ensuring process maturity at Level 5. This included enhancing documented processes to meet Level 5 requirements (process definition target) and deploying documented processes to meet Software CMM Level 5 requirements (deployment target).
2. Putting in place a measurement program that gave us statistically derived limits for all key performance indicators (PIs) and tracking performance against these PIs. The performance indicators we used were – Time Slip, Effort Slip, Cost of Non Quality, Review Effectiveness and Pre-release and Post-release defect levels. Despite a huge influx of new staff and creation of several new Product Divisions, our performance during the year 2000 has improved for review effectiveness and CONQ.
3. Achieving a 10-fold reduction in post release defect levels at PSC, starting May-June 2000.

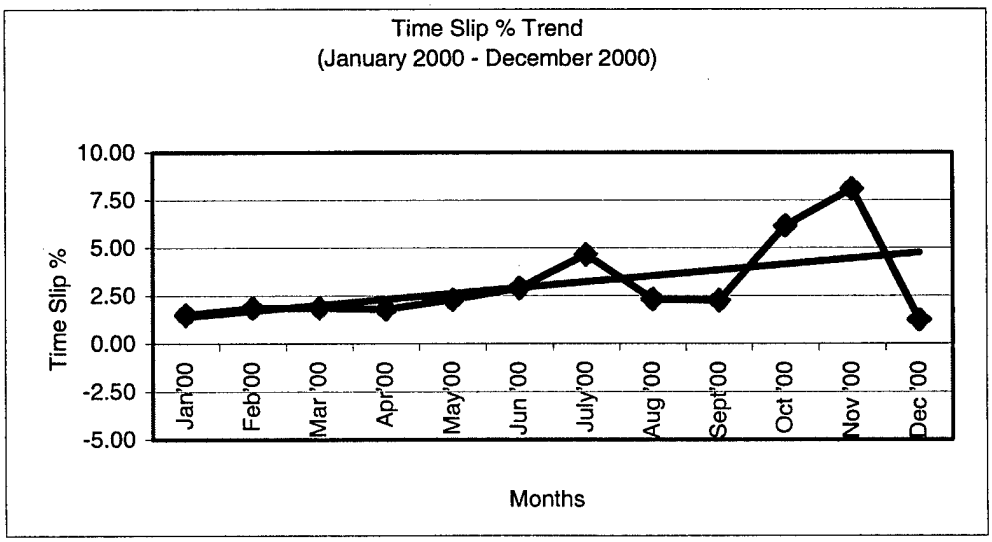

Figure 25: Philips Time Slip Trend

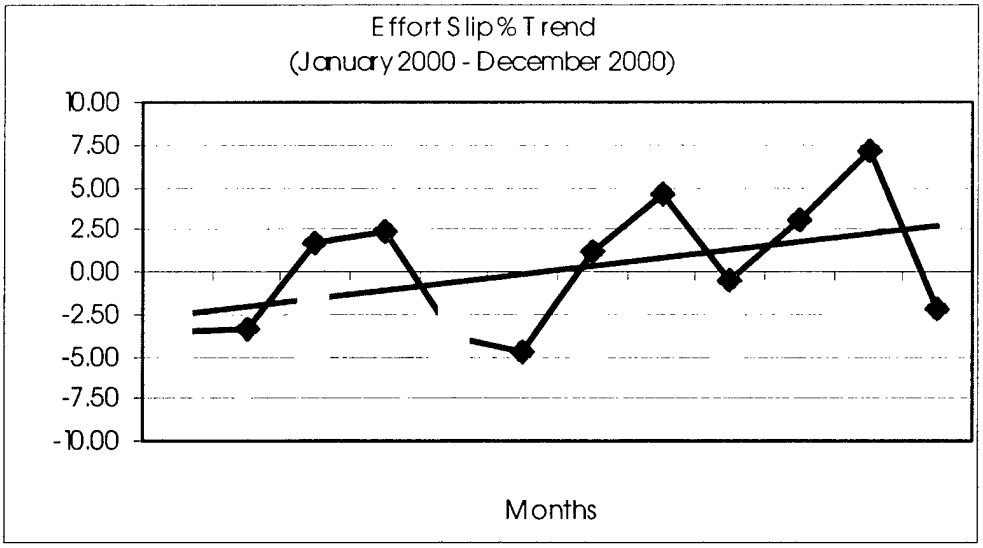

Figure 26: Philips Effort Slip Trend

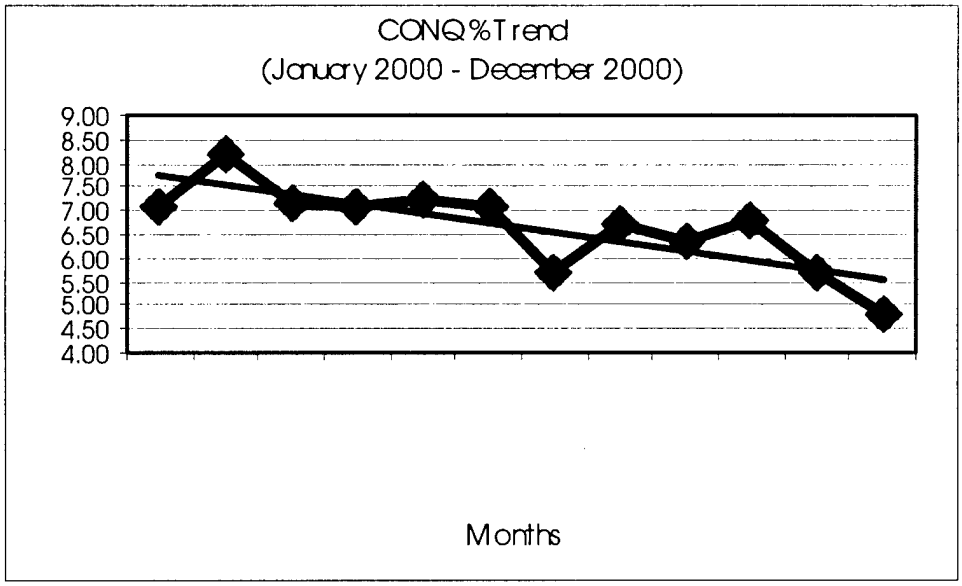

Figure 27: Philips CONQ Trend

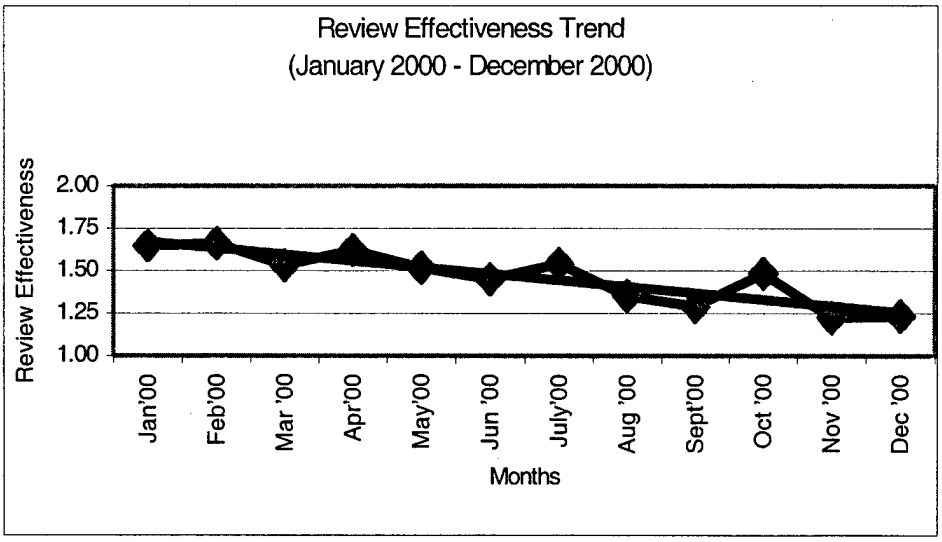

Figure 28: Philips Review Effectiveness Trend

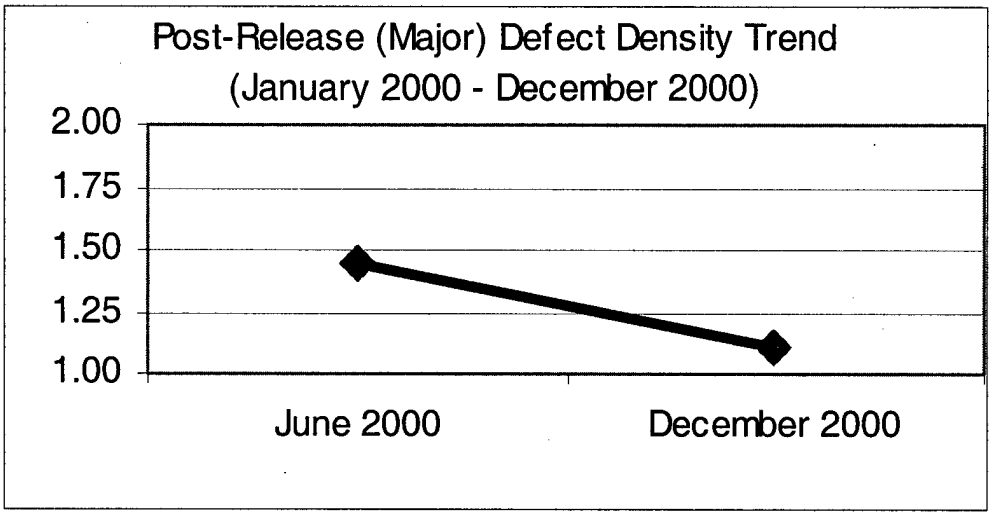

Figure 29: Philips Post-Release Defect Density Trend

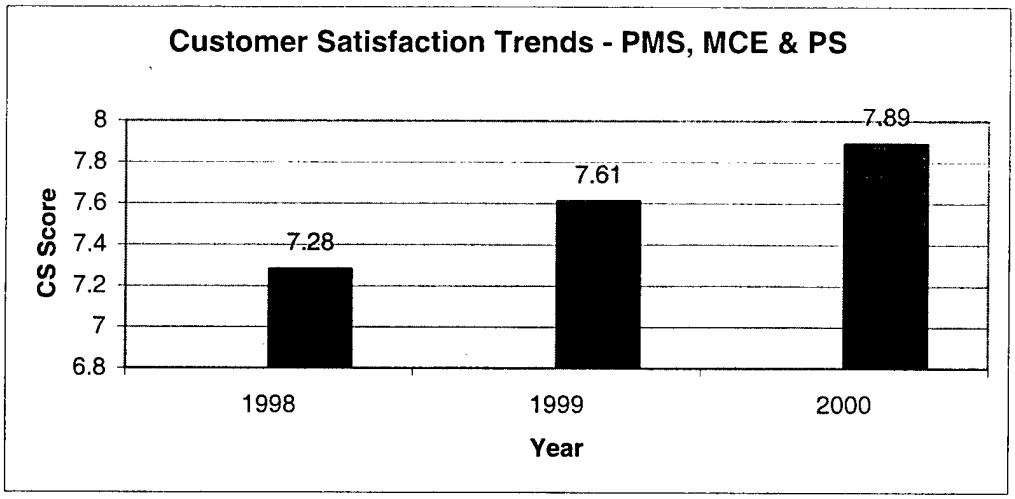

Figure 30: Philips Customer Satisfaction Trends

4.17.2 Barriers to Achieving High Maturity

The five barriers we encountered in moving up on the maturity rating were as follows:

1. We had a large percentage of new staff that were not trained to follow our processes. So we had issues at Levels 2 and 3 even while we were working on demonstrating capability at Levels 4 and 5. Inducting new staff takes time. To reduce the time required for new staff to follow our processes we organized:
   - process training for new entrants
   - refresher training for old staff on processes that underwent significant changes
   - more forums for sharing of best practices within the company
   - the annual calendar for core, process and technical training is published for staff to plan their training
2. A concern among senior project managers that a Software CMM Level 4 or 5 rating would raise customer expectations, and we may not be able to fulfill these expectations since performance may take some time to catch up. This was addressed by reviewing available data to see what the trends indicated in terms of performance. We also reviewed customer feedback scores and trends over the last few years. The reviews indicated that in most cases we had improved our performance and were being rated better by our customers too.
3. PSC, Bangalore is the first company in all of Philips to be assessed at Level 5. As of March 2001, out of 92 software groups in Philips, 3 are at Level 3, 24 at Level 2, and the rest at Level 1 (data taken from SPI Steering committee page). Since PSC, Bangalore services only Philips, this difference in process maturity led "customer" software organizations questioning many of our processes and process initiatives. This barrier was addressed by giving more flexibility to our project managers to define the PDSP through a software process handbook. To ensure that all KPAs were complied with, this process handbook needs to be signed off by the Corporate Quality department.
4. We also faced an issue of buy-in while treating all PSC as one entity while trying to establish statistical norms. As each Line-of-Business has separate customers who work

under different business circumstances, the time slip and effort slip norms vary across LOBs. Our initial approach of bringing all these together as the same process was followed did not bear fruit, and we could not convince project teams to follow these norms. We discontinued this approach and treated each LOB as a separate entity and the buy-in increased significantly.

5. Tight coupling of our LOBs / PDs with customer organization meant that the scope of a KPA like TCM was difficult to define since technology / tools are sometimes enforced by customer organization. We worked around this by defining our TCM process to address evaluation and deployment in cases where the customer did not mandate the tool.

4.17.3 Unique or Distinguishing Practices

The unique things we are doing today include the following:

- Collecting a lot more data than we did at Level 3. We're collecting data on "hard" measures like time and effort slip, cost of non-quality, etc., and "soft" issues like "competency ratio."
- Our norms today are based on statistically derived limits of XbarR Charts. Earlier the norms were set by top management and these norms were not statistically derived.
- We understand the key (root) causes of our defects and are taking systemic actions to reduce defect levels.
- We maintain a Tools Repository on available software tools and their benefits so new projects can use this information for planning. The software tools in this repository are categorized into the software engineering processes.
- We track employee participation in improvement activities.

4.17.4 People and Cultural Issues

Project Managers believing that being assessed at Level 5 could lead to greatly enhanced customer expectations that may not be met. A fear that this could cause customer dissatisfaction could lead to some opposition to a company's quest for Level 5.

For institutionalization, SPI should be owned by all staff. This is sometimes difficult because of project pressures or because there may not be enough improvement projects for all. Sometimes project teams view SPI as something different from their primary task of delivering the project.

4.17.5 Continuing Improvement

We have set the following targets:

- Continue operating at Level 5. To ensure this we have planned quarterly internal assessments based on the Philips Assessment Method. This method, we believe, gives the same results as CBA IPI.

- Achieve ten times reduction in post release defects over two years. This transforms itself into 1.8 times reduction every six months. We needed to be at 0.8 major defects / KLOC of code in December from 1.45 major defects / KLOC of code in June. We reached close to 1.0 major defects / KLOC of code so the improvement was close to 30 % but not sufficient. Our focus in the months to come will be on defect reduction. We intend achieving it through :
  - better deployment of Defect Prevention process
  - increased automation and usage of tools
  - increased levels of technical competency in PSC staff.

PSC, Bangalore is currently deploying a Business Balanced Score Card based Software Measurement Program at Project, LoB, and PSC Level, with clearly defined leading indicators to give better visibility and ensure timely corrective actions. This will ensure better performance on lagging indicators viz. customer satisfaction, post-release defects, etc.

We are targeting a Philips Business Excellence score of 600 by end of 2001. The Philips Business Excellence model is based on the EFQM model and looks at enablers as well as results in achieving excellence. The enablers include leadership, policy and strategy, people, partnerships, and resources, and processes. The results include customer results, people results, society results, and key performance results.

4.17.6 Summary

In PSC Bangalore, Levels 4 and 5 mean

- usage of statistical norms to control our performance on performance indicators (both process and product).

- having data to bring about improvements based on measured benefits. By this we mean that we have deployed the concept of measuring improvements in terms of monetary benefits.

- better controls on defect levels and a planned way to reduce defects. We use "Defect Prevention" at the project level as well as LOB Level and Organization Level and this gives indications of key actions required to reduce defect levels.

- bringing technology changes in a controlled manner based on data—we have used TCM primarily for increasing tool usage in our software creation process.

4.18 Satyam Computer Services Ltd., Hyderabad, India

Maturity Level	5
Date of Assessment	March 1999 for all Indian development centres
Lead Assessor(s)	Richard W Knudson
Point of Contact	Prabhuu Sinha, Prabhuu_Sinha@satyam.com
Web Page	www.satyam.com
Size of the Organization	7000
Typical Program Size	These numbers are extremely variable across Satyam's projects. This is because Satyam provides end-to-end software solutions and services to many different companies.
Primary Application Domain(s)	Systems software, used to control physical devices Commercial software, leased or marketed to external clients Information systems software, for business information Out-sourced software, developed under contract End user software, private software for personal use (shrinkwrap)

Satyam was established in 1987 and since then has been providing quality software services to large corporations all over the world. The company was one of the pioneers of the concept of remote software development using high-speed satellite communication circuits in India. Satyam was one of the first Indian companies to acquire a dedicated satellite circuit for data communication. Satyam today is amongst the top five offshore software development companies in the country.

Satyam achieved ISO 9001 certification under the TickIT scheme in March 1995 and was re-certified to the same in September 1998. In January 2001, Satyam achieved certification to the ISO 9001:2000 standard.

In March 1999, Satyam achieved Software CMM Level 5 accreditation for all its software development centers in India.

At the national level in India, Satyam has won several quality-related awards. It won the Golden Peacock National Training Award for its training program in July 1999 and the Golden Peacock Innovative Service Award for its teleconference facilities in January 2000. Satyam's Senior Vice President for Quality, Prabhuu Sinha, won the QIMPRO Silver Standard Award in October 2000 for his leadership of the quality movement in Satyam.

4.18.1 ROI and Improvement Trend Data

Satyam has observed the following improvement trends:

Table 2: Relative Improvements Observed at Satyam[4]

	Jan 1998–Dec 1998	Jan 1999–Dec 1999	Jan 2000–Dec 2000
Reduction in Effort Variance	40 %	No significant reduction[5]	41 %
Reduction in Schedule Variance	24 %	35 %	30 %
Increase in Productivity	Baseline not computed	No significant increase[1]	22 %
Reduction in Delivered Defect Density	8 %	42 %	No significant reduction[6]
Increase in Defect Removal Efficiency	Baseline not computed	12 %	6 %

4.18.2 Barriers to Achieving High Maturity

Some of the major barriers that Satyam had to overcome in achieving Level 5 are:

- Satyam has had a growth rate of 100% per year for the past five years. This required a massive training and SQA effort to institutionalize the processes.
- Standard industry tools for process automation were difficult to implement since they inherently impose a software process that does not match with Satyam's way of working. We have now developed our own tools for process automation.
- Due to the very high growth rate, it took quite a while for Satyam to find suitable and sufficient staff for the SQA and SEPG teams. This was because the large numbers required coupled with the low availability of such skills in the local market.
- While setting productivity and quality baselines at the organization level and goals for each project, it was difficult to quantify the impact of varying project attributes like environment, project size / complexity, team skills and customer's process maturity.
- During short duration projects (3-4 months), it was difficult to implement QPM due to high schedule pressures. The benefits of QPM in such small duration projects were also not tangible.
- It was difficult to set goals for new technology projects. While Software CMM recommends that this should be done by using a pilot project to set baselines, this is difficult because the pilots are very small size and may not give feasible data.

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4 These are not absolute figures.

5 Satyam was concentrating on T&M type of Year 2000 work at that time, and no improvements were observed after the significant improvement in Effort Variance in the previous year.

6 The mean of the Defect Removal Efficiency has not changed significantly, but the 3-Sigma band has narrowed in this year.

- Defect prevention learning in early life-cycle phases often cannot be used within the same project. It is used in other projects via sharing. Due to this, the project does not see the immediate benefit of causal analysis and DP meetings. This makes it difficult to motivate project teams on this.

4.18.3 Unique or Distinguishing Practices

The model "Leading the Initiatives for Excellence (LIFE)" is used by all units in Satyam for achieving strategic and operational excellence.

All business units and support units in Satyam operate as profit centers. Processes are defined for all business units and support units, and periodic customer satisfaction surveys are conducted for both internal and external customers to identify areas where performance can be improved.

Satyam's Quality Management System and Project Knowledge Base are available on-line to all company personnel via QUALIFY, an in-house tool. Another in-house tool, QUANTIFY, automates the processes for project planning / tracking / monitoring, defect tracking, metrics collection / analysis, defect prevention, and change management.

Satyam has a unique quality communications and rewards program run by an Intranet-based tool, the purpose of which is to sustain a vibrant quality culture in Satyam. This is achieved by recognizing organizational development activities in the area of quality. The objectives of the program are:

- ensuring organizational wide participation in Satyam's Quality Journey
- eliciting significant contribution from practitioners, to Satyam's Quality Journey
- creating a sense of ownership in Satyam's Quality Management System
- creating a sense of pride in using Satyam's Quality Management System

Satyam's Vision Compass tool is used for monitoring key targets and ongoing activities across Satyam. It helps Satyam in virtual operations, senior management reviews, and process monitoring.

4.18.4 People and Cultural Issues

The Satyam Learning Centre (SLC) facilitates dissemination of knowledge from diverse fields of management and technology for the benefit of employees and Satyam. SLC enables Satyam to learn continuously and thus be a learning organization. SLC enables employees to understand the businesses of the Satyam group, to understand the core purpose and core values of Satyam and to develop relationships with employees of various locations.

The objectives of SLC are to

- define competencies and learning requirements of various roles in the company
- provide learning inputs to employees to meet organizational needs and individual development needs
- establish academic linkages with reputed institutions to leverage on their competencies for organization's development
- work in cohesion with Satyam units to forecast future learning needs of the organization
- enable dissemination of information / knowledge through library, knowledge repository, and learning processes
- induct employee's family into Satyam's family
- provide counseling to an employee to overcome workplace / personal problems

4.18.5 Continuing Improvement

Satyam has several new initiatives in the area of quality. They are:

- **CMMI**—Satyam is studying this model. We plan to improve our processes based on this model and go for an assessment.
- **Six Sigma**—Satyam is working towards developing and institutionalizing its own Six Sigma model.
- **People CMM**—Satyam is improving its Human Resources and Training processes based on the People CMM and plans to go for an assessment.
- **Benchmarking**—Satyam is starting a benchmarking initiative for its critical processes.
- **Satyam Business Excellence award**—Satyam is developing a model for its own Business Excellence Award. All units of Satyam will compete for this award and win recognition for their business excellence.

Satyam is also improving several of its existing processes. They are:

- **Software CMM and ISO**—Currently, Satyam's delivery units in India have been assessed/certified on these models. Satyam is working towards extending the scope of these models to its units all over the world and conducting assessments/audits for them.
- **Process performance**—Satyam is working towards increasing its process performance, particularly in the areas of defect prevention, defect detection, and productivity.
- **Virtual services**—Globalization is one of Satyam's organizational goals. In keeping with this, Satyam is working towards virtual delivery of its internal services. In the quality area, this includes Web-enablement of the quality system, knowledge management framework, internal quality audits, and quality-related organizational development activities.

The barriers currently faced by Satyam are:

- **Growth Areas**—To keep in pace with the rapid changes in the IT industry, Satyam also introduces new competencies and areas of business at a rapid pace. This provides a challenge since new areas need new methodologies, processes, and skills.
- **Manpower**—Increasing the staff in the SEPG and SQA functions to keep pace with Satyam's rapid growth is still a problem due to lack of skilled manpower in the local market.

4.18.6 Summary

The quality movement in Satyam is now all-pervasive. It covers not only software development, but also areas like business and support processes. Continuous improvement is being achieved in process and product quality in all areas. There is now a "pull" culture for quality from all Satyam units, as opposed to a "push" culture that existed a few years ago.

Employees of Satyam feel a sense of pride in being part of a Software CMM Level 5 company. They are highly charged and committed to the quality system. The easy availability of data and other knowledge from projects has created a culture of sharing and learning.

Satyam has also achieved significant return on investment from its SPI movement. Besides improving the process performance and product quality, achieving Level 5 has also increased customer confidence in Satyam, resulting in increased business opportunity.

Our process maturity has reduced our learning curve, and thus increased our capability to deliver and continuously improve our processes even with a 100% growth rate every year.

After achieving Software CMM Level 5, we now have the confidence to go for other world class quality related models like Six Sigma, People CMM, etc.

4.19 Siemens Information Systems Limited, Bangalore, India

Maturity Level	4
Date of Assessment	August 2000
Lead Assessor(s)	Richard F. Storch
Point of Contact	Rakesh.singh@sisl.co.in, kathavarayan.t@sisl.co.in
Web Page	www.sislindia.com
Size of the Organization	250
Typical Program Size	20 staff
	40,000 to 1,40,000 LOC
Primary Application Domain(s)	Medical engineering, automotive engineering and, transportation

Siemens Information Systems Limited (SISL), is a joint venture between Siemens Limited (India) and Siemens Business Services of Siemens—Information and Communications, Germany. It is involved in software development, information technology consulting, and system integration services for the Indian and global markets through offices in Bangalore, Calcutta, Chennai, Delhi, Mumbai, and Pune in India. SISL has been an ISO-certified company since 1996 and again re-certified in the year 1999.

4.19.1 ROI and Improvement Trend Data

The following are the visible benefits SISL got as part of process improvement.

- estimate efficiency in SISL has improved
- defect removal efficiency has improved
- delivered defects density has come down

4.19.2 Barriers to Achieving High Maturity

Any process improvement initiative should be initially tried out within a limited organizational scope as any setback to improvement programs can cause long-lasting damage. When the organizational scope is not properly defined then exposing a large organization, consisting of several business units, to process changes can run into difficulties such as follows:

- There is large variation in process need, technology deployed, and domain-related priorities.
- They are at different phase in business life cycle such as initiation, stabilized, or phasing out.
- Managing logistics during process development and implementation is difficult.
- Cost of poor process or learning will have to be borne by all.
- Often needs and priority may be contradictory.
- Level of support and desire to improve will also vary.

It makes sense to consider a more manageable, at the same time significant, organizational scope for improvement. In addition, criteria such as readiness to innovate, resources at disposal, and timing of improvement programs should also be considered to select the right organizational unit. Lastly, the improvement program should fit their overall business schedule.

Some of the common difficulties encountered to the process improvement program are:

- poor priority for process development tasks
- difficulty in attracting and retaining the right talent
- top man's moral and resource support

- best people not available or interested in the definition phase of the project
- outside consulting costly and not always appropriate in content or timing
- data collection is not easy and most of the times not adequately representative to prove the point conclusively
- getting people for training is not easy due to priority to project work

4.19.3 Unique or Distinguishing Practices

Internal SEPG workshop being held bi-annually to share best ideas and practices.

Technology change for the organization's infrastructure is well managed (Unicenter, virus control, etc.).

4.19.4 People and Cultural Issues

The selection of authors and reviewer has to be done very carefully. Some of the key criteria to keep in mind are

- The authors and reviewers should be respected members of the organization, else external help should be sought.
- Selected members should have kept sufficient time allocated to their assigned tasks.
- Selected members should be stakeholders, i.e., they shall remain accountable during implementation stage.

4.19.5 Continuing Improvement

The experience of existing SEI Software CMM Level 5 organizations shows that Level 5 maturity does not provide the ultimate performance, but it is a critical milestone in their overall journey of continuous process improvement. Level 5 maturity does provide a very sound basis or foundation to launch performance driven programs such as Six Sigma programs. SISL has already drawn up its strategy to reach Level 5 maturity along with the next step to follow. This means that closure of Software CMM program overlaps with the launch of the next program.

At SISL, the Personal Software Process Program is planned to succeed the Software CMM Program. People CMM activities are also being executed in parallel. Organizations working at higher levels of maturity may find that processes are in place, but they are not as effective as they would like them to be. In other words the processes exist, but their performance is still not meeting the business challenge. This is largely due to the fact that the organizations performing at Managed and/or Optimizing Level may have put processes and mechanisms in place but have not created appropriate motivations to drive the performance of the organization. This may mean that the organization has become more bureaucratized and is unable to challenge the individuals adequately. At Level 5 maturity, the organization needs a systematic

flow of project information more or less in bureaucratic manner. But software individuals expect freedom to feel motivated. How can we solve this paradox?

4.19.6 Summary

Due to the improvement activities SISL is able to achieve the following.

- improved management of external and internal commitments
- effective project management with ability to "manage change"
- quicker post-delivery sign-off as requirements are better understood, leading to proper implementation
- reduced maintenance cost as result of better documentation

4.20 Tata Elxsi Ltd (TEL), Bangalore, India

Maturity Level	5
Date of Assessment	June 2000
Lead Assessor(s)	Pradeep Udhas
Point of Contact	M Thangarajan, mtr@teil.soft.net
Web Page	www.tataelxsi.com
Size of the Organization	400
Typical Program Size	5K to 150K source lines of code
Primary Application Domain(s)	Networking protocol development (TCP/IP, ATM, ISDN, SNMP, BGP, etc.) System development (embedded systems, ASIC design, VHDL and Verilog modeling, firmware including DSP) Visual computing (2D/3D graphics, animation, data visualization, etc.) Internet and intranet group (Web enabling of products)

The Design and Development Center of Tata Elxsi Limited, in Bangalore, was assessed at Software CMM Level 5 in June 2000. This achievement marked a significant milestone in the organization's quest for continued process maturity and improvement.

The Quality Management System of our organization was first designed to meet the ISO 9001, TickIT guidelines and we obtained the certification in February 1997. Subsequently our processes were greatly enhanced to meet the requirements of the Capability Maturity Model and the necessary implementations were carried out over the next three years. The organization was first assessed at Level 4 in August 1999 and subsequently the organization was assessed at Level 5 in June 2000, using the CBA IPI method. The assessment was conducted by KPMG (Lead Assessor: Pradeep Udhas).

4.20.1 ROI and Improvement Trend Data

A key factor in our success has been the ability to show that our efforts have added value to the overall organization. As a result of widespread use of data, our productivity has almost doubled, estimation accuracy has improved from 25% to 12%, our outgoing defect density has reduced from 3 defects / KLOC to 0.75 defects / KLOC, and there has been a 25% improvement in the effort overrun from what it was three years ago.

4.20.2 Barriers to Achieving High Maturity

We still have some way to go to achieve our ultimate goal of continuous process improvement as a way of life in the organization. Significant issues continue to place challenges in our path. These include:

- managing growth due to high infusion of new recruits
- new customers with unknown process maturity levels
- focus from projects to product development

We have made great progress over the last three years and we expect to continue.

4.20.3 Unique or Distinguishing Practices

The QMS is available to all employees through the intranet. Past data from projects, best practices, and customer input are shared across the organization through the "process database" and "knowledge management database" on the intranet. Organization baselines are established in line with the organization's quality policy. Each project sets tailored quality objectives based on the organization baselines, and stage-wise analysis is done to arrive at corrective actions if the objectives are not met. Statistical process control methods such as control charts, Rayleigh curves, and Gompertz curves are used widely across projects to measure the effectiveness of verification and validation activities. Defect prevention activities are carried out using defect prevention guidelines and orthogonal defect classification (ODC). The quality function plan is in line with the business plan of the organization. Key Result Area (KRA) sheets are available for SEPG, SQA and training functions, and the goals are aligned to the business goals of the organization. The SEPG and the SQA group are responsible for process improvement initiatives and ensure information is disseminated across the organization.

4.20.4 People and Cultural Issues

Extensive influx of new recruits, especially at the entry level, is a great challenge that we are currently facing. We have initiated a three-day, hands-on program for new recruits where the participants are exposed to all the life-cycle stages and the corresponding processes. This makes them familiar with the process flow of the organization prior to joining a live project. The last two programs were highly rated and the results have been significant.

4.20.5 Continuing Improvement

In order to meet the challenges of retaining employees and attracting fresh talent, our organization has decided to adopt the People CMM model. We believe that the co-existence of good software development practices using the Software CMM along with good strategies to manage people with the help of the People CMM could help meet this challenge.

4.21 Tata Consultancy Services, India

Twelve centers of TCS have been assessed at Level 4 or 5. These follow.

TCS Center	Level	Lead Assessor	Date
TCS, SEEPZ, Mumbai	4	Ron Radice	July 1998
TCS, US West, Chennai	5	Ron Radice	April 1999
TCS, HP Center, Chennai	5	Ron Radice	July 1999
TCS, SEEPZ, Mumbai	5	Ron Radice	August 1999
TCS, Shollingnallur, Chennai	5	Ron Radice	November 1999
TCS, Calcutta	5	Ron Radice	January 2000
TCS, Bangalore	5	Ron Radice	January 2000
TCS, Lucknow	5	Radhika Sokhi Jack Harding	January 2000
TCS, Ahmedabad	4	Ron Radice	March 2000
TCS, Hyderabad	5	Gargi Keeni Jack Harding	May 2000
TCS, Ambattur, Chennai	5	Ron Radice	July 2000
GEDC, Chennai	5	Jack Harding	July 2000
TCS, Ahmedabad	5	P. Suresh Ron Radice	November 2000
TCS, Gurgaon II, New Delhi	5	Ron Radice	February 2001

Point of Contact	Gargi Keeni, gkeeni@mumbai.tcs.co.in
Web Page	www.tcs.com
Size of the Organization	9,000 in 12 TCS centers. The staff strength of the individual centers range from 150 to 1600.
Typical Program Size	Number of people per typical project: 10-30 Number of lines of code per typical project: 10 KLOC–100 KLOC Number of function points per typical project: 400 FP–4000 FP
Primary Application Domain(s)	Examples of the various types of projects executed: - development - conversion - maintenance - package implementation - engineering services - product data management - architecture and technology consulting - language processing - strategic consulting - quality consulting

In 1992-93, TCS defined and documented its Quality Management System (QMS). All the TCS Centers were ISO certified in the period from 1993 to 1998. In 1996, TCS decided to enhance the QMS to align it with the Software CMM Version 1.1. At present 12 of the 17 development centers have been assessed to be at Level 5. Six Sigma is being implemented in two centers of TCS. Currently, TCS is in the process of benchmarking its people practices against People CMM Version 1.0.

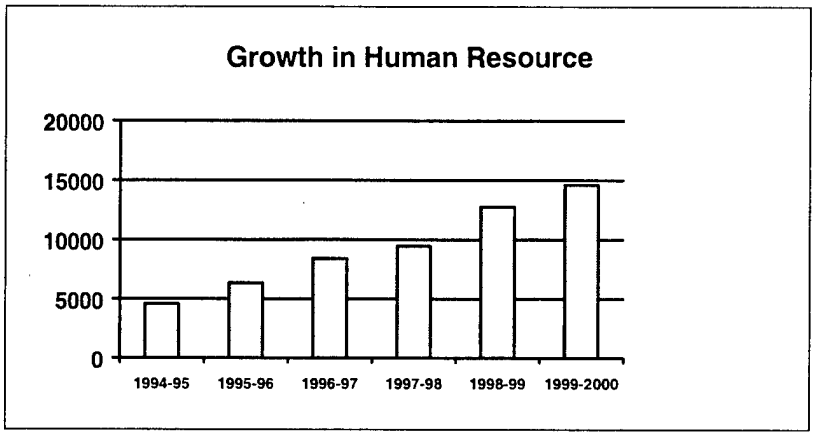

Figure 31: TCS Growth in Human Resources

4.21.1 ROI and Improvement Trend Data

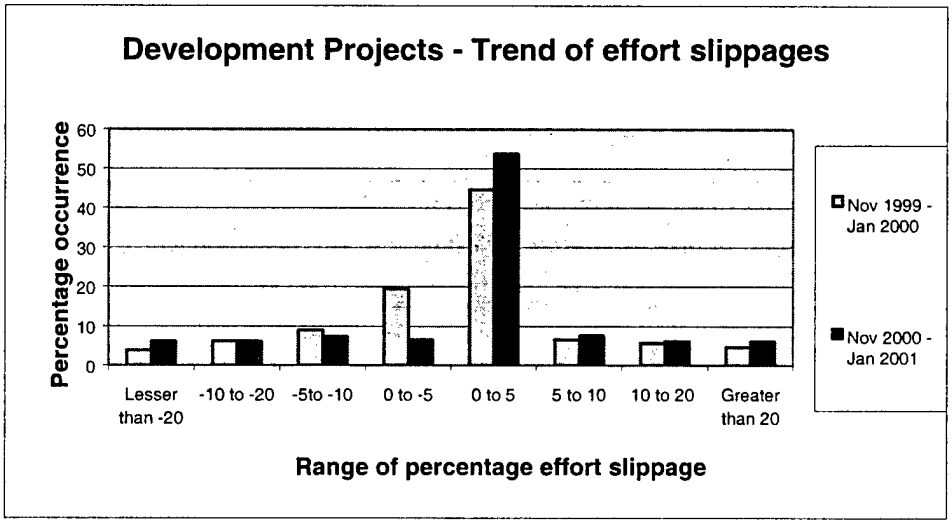

Figure 32: TCS Trend of Percentage Effort Slippage in Development

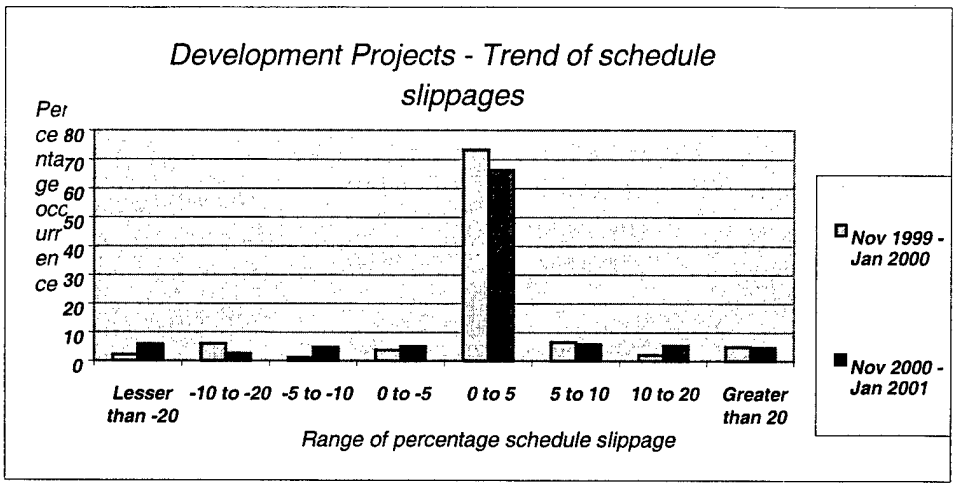

Figure 33: TCS Trend of Schedule Slippage in Development

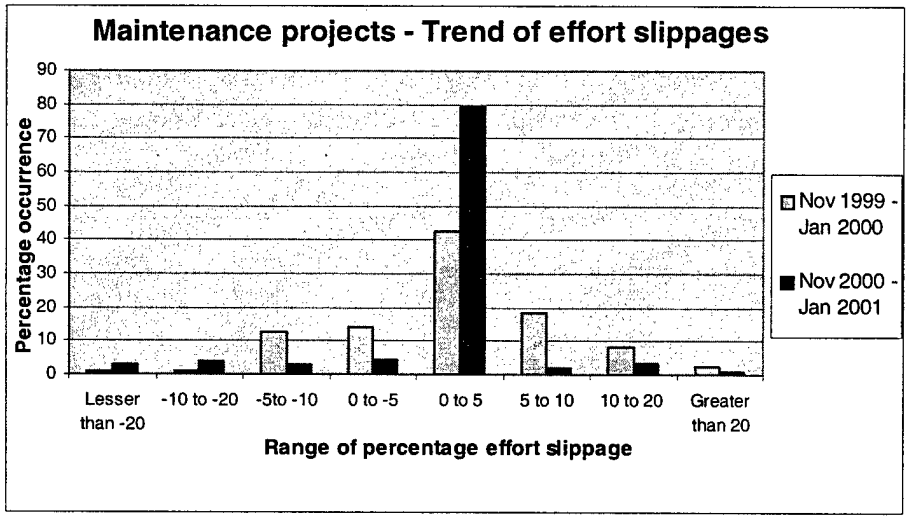

Figure 34: TCS Trend in Effort Slippage in Maintenance

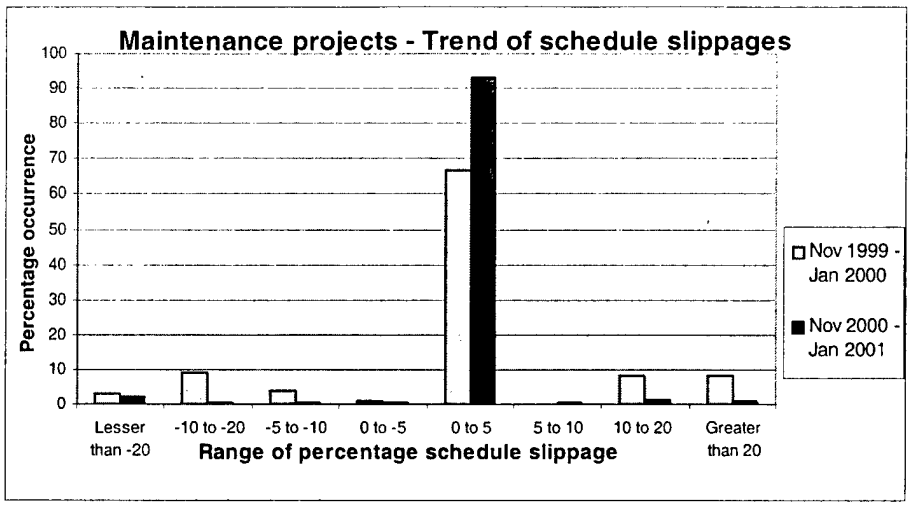

Figure 35: TCS Trend in Schedule Slippage in Maintenance

The figure below shows the trend in the capability for on-time delivery of one of the TCS centers implementing Six Sigma. The capability for on-time delivery has improved from 2.85σ to 4.63σ. These improvements have been possible through a number of defect prevention and productivity improvements implemented by the Six Sigma projects in the center.

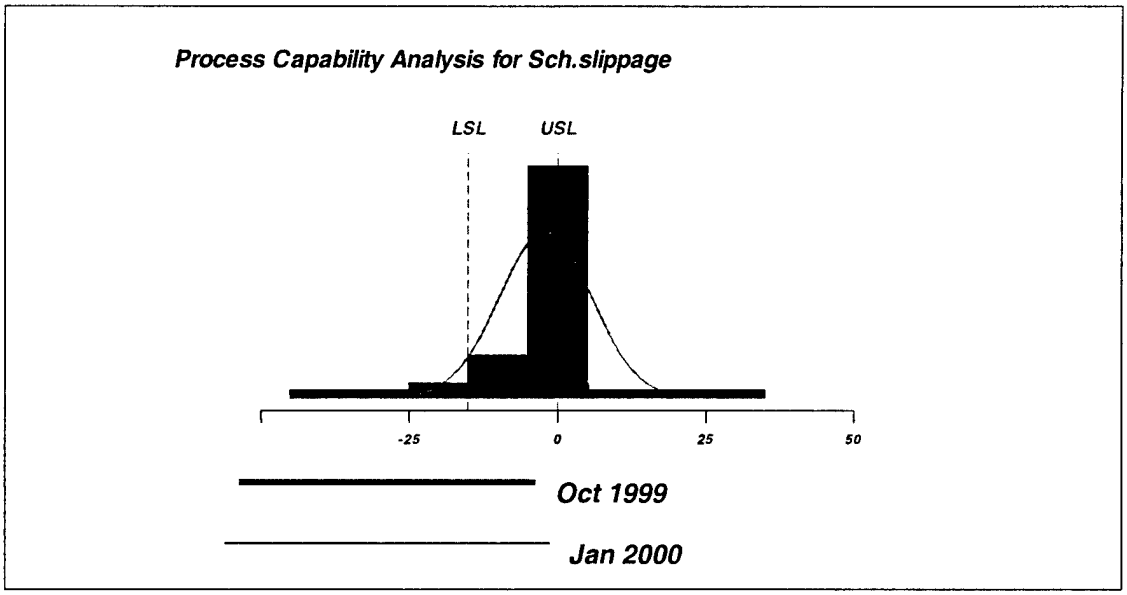

Figure 36: Process Capability Analysis for TCS Schedule Slippage

4.21.2 Barriers to Achieving High Maturity

There were a number of challenges in deploying the key practices of Level 4 and Level 5. Some of these have been listed below. In certain instances, the remedial method adopted is also mentioned.

- creating confidence in people that quality pays in the long run
- resistance towards process change in on-going projects
- prioritizing process change
- continuous training of people on new initiatives / processes, applying standard processes and institutionalization of these processes considering the size of the organization, and high mobility of personnel (persons going on-site, returning from overseas, new joiners, people turnover, etc.). This was further compounded due to the wide variety of projects executed across the centers.

Metrics-related challenges remain:

- understanding SPC and convincing project teams that it works for software
- application of statistical techniques to ensure Quantitative Process Management (QPM), Software Quality Management (SQM) and Defect Prevention (DP)
- logging of time sheets
- calculating ROI for benefits
- for online analysis of metrics, faster aggregation of data was required. In-house tools provided the support for aggregation of data and drawing SPC charts.
- motivating people to log defects
- attribution of appropriate causes for defect prevention Rigorous training/facilitation sessions required educating practitioners in how to assign appropriate causes and avoid ones like "Others."
- Submission of monthly status reports by all the project leaders to SEPG on time was not regular. Used Integrated Project Management System (IPMS) tool, developed by TCS, to assist the Project Leaders to log effort for different key process areas.
- initial participation of DP, PCM, and TCM project primes in the core group meeting was very thin. Participation of staff for raising process improvement proposals (PIPs) was initially thin too.
- implementing processes in short duration projects. Appropriate tailoring guidelines were prepared to tackle this issue.
- keeping Integrated Project Management System (IPMS) up-to-date with the changing processes
- manage projects that are being executed at customer locations. Standardized tools used which could be used at customer site and merged at periodic intervals into the centralized database.
- tracking PIPs manually was difficult leading to delay in feedback and implementation. Tool-based PIP management increased visibility into the system.

4.21.3 Unique or Distinguishing Practices

- Encouraging consultants to get CQA Certification. The target is to have at least 10% of the total strength as certified CQAs.

- Encouraging / sponsoring employees to become members of professional bodies (IEEE, ACM, etc.) in order to foster learning. (There are 2500 IEEE members currently.)
- Audit Pool, Reviewers' Pool and Assessors' Pool comprises of experts from the project teams.
- Quality Assurance Group (QAG) is entrusted with the responsibility of facilitating the projects in deploying the Quality Management System (QMS). The Audit group is an independent group, which is responsible for verification of process and product compliance.
- Usage of lessons learned and best practices shared within and across projects as well as centers of TCS through the use of the knowledge management tool
- Periodic QAG, Audit Group, and SEPG meetings are organized. These forums also provide knowledge sharing opportunities.
- Higher reliance on SPC to quantitatively manage the product and process quality.
- Usage of the project management tool IPMS across all projects, which serves as the single repository for process data.
- Project start-up meetings improve intergroup commitments and team building.
- Creation of roles such as process owners for DP, PCM and TCM at the organization level and distinct project primes for DP, PCM, and TCM at project level.
- Service level agreements (SLAs) defined for all support groups who measure their performance against the SLAs and constantly strive to refine them.
- Specialized training courses on soft skills like team building, Six Thinking Hats, Lateral Thinking, negotiations, and customer management.
- Using causal analysis for product defects, process defects, customer complaints, and customer satisfaction feedback and proposal won / lost analysis.
- Team members given the responsibility to present the project information and status during project management reviews
- Training of 20 days per year is mandated for every person in the center, which aims at orienting the individual towards continuous learning.
- Organized structure for Six Sigma culture at some TCS centers.
- Six Sigma projects for DP, QPM, SQM, and productivity improvement.

4.21.4 People and Cultural Issues

The SPI initiative has brought a strong cultural change among people of the organization. The mindset of the people has changed from reactive to proactive management.

Expectations of management and staff in terms of process effectiveness is high and pace of change for process improvement is expected to be high. A large number of people are willing to contribute and expectations need to be handled well.

Customer expectations too are high, and it is not always understood that high maturity of the subcontractor is not a silver bullet and still requires maturity of customer processes in order that mutual objectives be met. Some customers have mixed feelings and expect that high maturity processes are an overhead on cycle time.

Employee morale has improved due to a formal mentor-mentee program. This has been institutionalized for sometime. Each person who joins the organization is associated with a mentor, who helps the person with their personal problems, career, and technical growth in the organization.

Skills building has been the cornerstone for improvement activities. Skills of individuals are managed using the Skills Management System (SMS) tool developed in-house. A role profile is defined for each role in TCS. Skills of all staff are logged into this tool and based on his/her chosen career path, career development plans are prepared and training needs are identified. Individual skills are accordingly build.

There is an extensive 90-day Initial Training Program (ITP), which all fresh joinees undertake. This induction training covers most aspects of software engineering, process methodologies, and soft skills.

Specific training programs are given in the areas in which team members are required to work. Post-evaluation feedback helps to improve the training program.

Specialized training courses on soft skills such as Team Building, Six Thinking Hats, Lateral Thinking, Negotiations, Customer Management, Working in Teams Effectively, etc., help the project leaders to perform their tasks effectively. TCS has a variety of such courses and all persons eligible to become project leaders undergo these training programs.

With the organization operating at higher maturity levels, it becomes a continuous challenge to train the fresh joinees on SPI. In TCS, this is handled through the Initial Training Program (ITP). Apart from turnover, people in TCS keep going on overseas assignments for long duration. The Quality Groups face a continuous challenge of keeping these people up-to-date with the SPI activities that would have happened in their absence.

4.21.5 Continuing Improvement

The culture strongly supports quality and continuous improvement within the organization. To sustain the pace of continuous improvement, the quality structure is well maintained with more emphasis towards Defect Prevention, Technology, and Process Change. In each of these areas, apart from organization level process owners, there exist process primes at the project level. Regular evaluation of the improvement proposals is done and necessary improvement measures are adopted.

The improvement objectives are aligned to the business goals of the center. Centers are always on the look out for standards and methodologies that help in identifying new areas and sustaining continuous improvement. Some of these new initiatives are:

- Six Sigma: For example, one center has a target to complete 100 Six Sigma projects for 2001, which includes projects on design for Six Sigma focussing on commercial quality and product quality
- sustain the participation of all in suggestion schemes / PIPs
- causal analysis of customer complaints and customer dissatisfaction parameters
  - causal analysis of won / lost proposal
  - participating in various forums such as meetings, seminars, presenting and publishing papers, etc.
  - continuously trying to improve upon processes and metrics for short duration projects
  - improve tools for SPI
  - improving requirements capture in non-English speaking countries
  - the estimation procedures are being strengthened to cope with the rapid technology changes
  - strengthening our project management processes
- TCS plans to go in for reassessment for each of its centers that have achieved Level 5 every year using Software CMM v1.1 to re-affirm the organization's continuously improving policy.

TATA Business Excellence Model (TBEM) (on the lines of the Malcolm Baldrige National Quality Award – MBNQA) is the overall business excellence model adopted by TCS. In this context, apart from ISO 9001:1994 and Software CMM, TCS is working on:

- benchmarking with People CMM Version 1.0
- transitioning to CMMI

4.21.6 Summary

Level 5 has given a structured process framework, which has facilitated success of initiatives such as Six Sigma.

Level 5 has given market-place competitiveness.

Level 5 has streamlined the internal processes such as metrics, tools development and deployment, data-based decisions which help increase the empowerment at all levels.

Being at Level 5 means a lot of responsibility as the company sets trends in the industry by sharing its best practices. It continuously improves processes and therefore needs a strong mechanism to sustain the momentum. With changing business models and technology it is a tough challenge to keep the movement on.

4.22 U.S. Army Aviation and Missile Command (AMCOM) Software Engineering Directorate (SED), Redstone Arsenal, AL

Maturity Level	4
Date of Assessment	April 2000
Lead Assessor(s)	Dave Zubrow
Point of Contact	Jackie Langhout, Jackie.Langhout@sed.redstone.army.mil
Web Page	http://www.redstone.army.mil/amrdec/sed/
Size of the Organization	150 government employees and 600 contractors
Typical Program Size	5-10 people per typical project 10K SLOC for new development projects 340K SLOC maintained for sustainment projects
Primary Application Domain(s)	Military software Applications include: trainers, simulators, emulators, test devices / tools, and tactical systems

As the Army Aviation and Missile Command's (AMCOM's) Life Cycle Software Engineering Center, the SED's mission is to provide mission critical computer resource expertise to support AMCOM's weapon systems over their life cycle. This support includes providing software expertise to AMCOM weapon systems, providing affordable and effective post deployment software support, providing air defense interoperability engineering and testing and applying the latest in software technologies to these efforts.

Of the 750 personnel at the AMCOM SED, approximately 225 personnel are involved in the development / sustainment of software. The remaining technical personnel are involved in such tasks as supporting Army weapon system managers in the development of software acquisition plans and standards, performing evaluations of prime contractor's software development activity, and providing interoperability engineering support.

The AMCOM SED utilizes the skills of both government and contractor employees with a team approach to provide the highest quality services and products to its customers. It does not use subcontracting as a means for developing or maintaining software. The AMCOM SED staffs each project with a mix of government and contractor personnel who work together as an integrated team using the same set of project standards and procedures.

The AMCOM SED initiated its software process improvement efforts in 1991. The organization established the Software Engineering Institute's (SEI's) Software Capability Maturity Model (Software CMM) as the framework to be utilized in developing and maturing the organization's software process. The AMCOM SED conducted a self-assessment in September 1991 and was rated Level 1. A CBA IPI was performed in May 1994 and resulted in a Level 2 rating. The AMCOM SED conducted a third assessment using the CBA IPI method in November 1996. That assessment concluded that the SED was performing at the ~~Level 3 maturity. In April 2000, the AMCOM SED conducted another assessment using the~~

ity. In April 2000, the AMCOM SED conducted another assessment using the CBA IPI method and achieved a Level 4 rating.

4.22.1 ROI and Improvement Trend Data

As stated above, the AMCOM SED initiated its software process improvement efforts in 1991 and has maintained a consistent focus throughout the years. The estimation and planning activities have been greatly improved thus decreasing the opportunity for project failures. The organization's productivity (total SLOC developed / effort expended) has doubled since initiation of the improvement program. In addition to an increase in productivity, the software improvement program has had a positive impact on the growth in the amount of work received from customers. Since 1992 the workload has increased by a factor of four. The AMCOM SED's products continue to be of high quality, as the defect density in the delivered products average less than one per KSLOC. The cost benefit of peer reviews has been analyzed and it was determined that finding defects through peer reviews was nine times more cost effective than finding defects through testing.

4.22.2 Barriers to Achieving High Maturity

Understanding the Level 4 key practices was a barrier for the AMCOM SED. The terminology in Levels 4 and 5 of the Software CMM was difficult to grasp. Because there were so few organizations that had reached Level 4 when the AMCOM SED journey began, lessons learned were not readily available.

The AMCOM SED's metrics program had to be significantly revised to support the Level 4 activities. The metrics program was modified to measure process performance and quality throughout the project life cycle.

4.22.3 Unique or Distinguishing Practices

The AMCOM SED's analysis of metrics data has allowed for a better understanding of our process. The analysis of peer review data provides projects with timely insight into product quality issues. The use of automation and web-based tools has significantly enhanced the AMCOM SED's software process improvement program.

4.22.4 People and Cultural Issues

The employees at the AMCOM SED have great pride in their software development process. Employee turnover is not an issue. The organizational training program reinforces the process improvements that are initiated. The organization has experienced remarkable growth in the past 10 years and the software process improvement program has supported that growth. Each project has an assigned mentor from the Software Engineering Process Group, which supports the project's implementation of the defined software process and measurement program.

4.22.5 Continuing Improvement

The current and future activities for the AMCOM SED are (1) strengthen the software development process based upon the recommendations from the recent assessment; (2) migrate to the CMMI, thus expanding process improvement into other areas in our organization: (3) pilot PSP/TSP on 1-2 software projects.

4.22.6 Summary

The AMCOM SED has received much recognition because of the Level 4 rating. Organizations throughout the community frequently seek support from AMCOM SED when embarking upon a software process improvement initiative. Customers view the AMCOM SED as a center of excellence and have broadened the areas of support that AMCOM SED provides. The organization's defined software process is remarkably more entrenched into the AMCOM SED culture because of the efforts to continue up the maturity scale.

4.23 Software Engineering Division of the Ogden Air Logistics Center (OO-ALC/TIS), Ogden, UT

Maturity Level	Level 5
Date of Assessment	July 1998
Lead Assessor(s)	Brian Larman
Point of Contact	Jim Vanfleet, Jim.Vanfleet@Hill.af.mil
Web Page	http://www.tis.hill.af.mil
Size of the Organization	TIS employs approximately 560 engineers, technicians, configuration management specialists, and support personnel
Typical Program Size	Software project size can vary from a one engineer project to larger development projects of 75 or more engineers
Primary Application Domain(s)	Automatic Test Equipment (ATE) software, Operational Flight Programs (OFPs), and Mission Planning software for F-16, A-10, B-52, B-1, Minute Man, and Peacekeeper programs / systems

The Software Engineering Division at Hill AFB (TIS) initiated its software process improvement effort in 1991 and three years later was assessed as a Software CMM Level 2 organization. TIS was reassessed in 1995 at Software CMM Level 3. In July of 1998, TIS became the first government organization to be assessed as a Software CMM Level 5.

In addition to the Software CMM, TIS also utilizes the Personal Software Process (PSP) and the Team Software Project (TSP). TIS has three projects that utilize the Team Software Project (TSP), comprised of 30+ Personal Software Process (PSP) trained engineers. There are four PSP certified instructors and two TSP launch coaches in the division.

4.23.1 ROI and Improvement Trend Data

A discussion of the benefits that TIS has received would be incomplete without addressing some of the problems that have been encountered in trying to calculate ROI. At the beginning of the TIS SPI effort, the organizational capabilities were not known. As a result, the initial assumptions / estimates were difficult to make and are easy to challenge.

Because TIS is a non-profit organization, cost avoidance or savings was used rather than increased profit. The ROI formula that was used was: ROI = Savings / Investment. Investment is easy to capture, however, determining what constitutes savings is difficult.

The ROI calculations for TIS were based on a ten-year moving window. ROI ranged from 4:1 to 19:1, depending on the project. Level-of-effort projects yielded the highest ROI.

Some types of improvement are more tangible than others. Some of the cost reduction data is as follows: 34% reduction per source line of code (SLOC), 39% decrease in regression testing, and 65% to 75% reduction in cycle time for MIPs and OCPs. Schedule improvements, quality improvements, improved morale and customer satisfaction are impossible to quantify in terms of dollar savings, but these benefits have been observed and are attributed to TIS's SPI efforts.

4.23.2 Barriers to Achieving High Maturity

Some barriers that have been overcome in achieving Level 5 are: diverse projects/workloads, projects that had a significant amount of hardware development, and difficulty understanding the Level 4 and 5 issues.

TIS's size and diverse workloads caused some unique problems in achieving high maturity. TIS utilized the product line approach to overcome these barriers. Diverse projects (Automatic Test Equipment [ATE], Operational Flight Programs [OFP] / Mission Planning, and projects with a large percentage of hardware development) were organized into product lines. The product lines share similar processes. Extended SEPGs or ESEPGs were created to perform **product-line** SPI activities.

Another challenge TIS faced was understanding and implementing the Level 4 and 5 key process areas. In 1995, when TIS was assessed at Level 3, there were a limited number of high maturity organizations. Information and resources regarding the implementation of high maturity key process areas was nonexistent. TIS was forced to "break new ground" to achieve its Level 5 rating.

4.23.3 Unique or Distinguishing Practices

Two distinguishing characteristics of TIS are the quality assurance program and the extensive use of process tools within the division.

The Quality Engineering Support Team (QuEST) was developed to fill the quality assurance role within TIS. QuEST is unique because their activities focus on the processes used to produce the product rather than the product itself. QuEST regularly audits senior management, project management, practitioners, CM, and the SEPG to ensure that organizational policies and procedures are being followed. Findings are documented in reports and action plans are required to address the findings. QuEST is an invaluable resource in furthering the SPI efforts within TIS.

Tools have also become an important part of life in TIS. Due to the large amount data that our processes and projects collect and analyze, development of tools became necessary to manage, analyze, and present the data. Configuration management tools and process tools are also used extensively. Most of these tools have been developed in-house, but a few of them are commercial off-the-shelf products.

4.23.4 People and Cultural Issues

Although losing key project personnel can still be a problem, TIS has become less reliant on project "heroes." The time required for an employee to become knowledgeable and productive on a project process has decreased. Employees can be moved to new projects within the organization with greater ease and less risk. New employees are assigned mentors and receive training on the project's process and procedures. In addition, *all* employees are required to receive formal organization policy / process training and product-line process training.

TIS has become increasingly dependent on process "heroes". Project managers who are knowledgeable in the Software CMM and TIS policy are invaluable. One thing that has helped TIS to remedy this problem is to rotate perspective managers and leads through SEPG and QuEST. An understanding of the Software CMM and TIS policy is gained. Working in these groups allows the individual to be more competitive for leadership positions in the division.

4.23.5 Continuing Improvement

The Software Engineering Division is currently applying process improvement to our current Technology Change Management (TCM) process. Although benefit has been derived from our current TCM process, changes are needed. A new database and automated process are currently being developed to perform the TCM process.

TIS has the challenge of bringing in new and diverse workloads. Part of the challenge is dealing with customers who are Level 1 (e.g., don't want to document or establish requirements). Some of these workloads are very different from the work TIS has traditionally performed. Some projects have a large amount of hardware development with very little software development. TIS has struggled to develop new project processes tailored from the organization's Standard Engineering Process (SEP).

4.23.6 Summary

Because of TIS's SPI efforts, the division has realized improvements in cost, schedule, and quality. In addition, achieving a Level 5 rating has also had a positive effect on TIS's reputation and image in the DOD and SPI community. Improvements to efficiency, product quality, and image have improved relationships with TIS's customers and have helped to attract new workload.

4.24 TELOS•OK, Lawton, OK 73501

Maturity Level	4
Date of Assessment	November 1997
Lead Assessor(s)	Don Couch
Point of Contact	Phil Sperling, sperlips@fssec.army.mil
Web Page	www.telosok.com
Size of the Organization	270
Typical Program Size	18 people, 1.2 million LOC
Primary Application Domain(s)	Military systems, real-time, and embedded

4.24.1 ROI and Improvement Trend Data

The investment has been approximately 600K dollars per year, since 1990. The amount of code being developed / maintained has increased by 253%, without any increase in staffing. The defect rate during final / formal testing has decreased by 69%. The primary emphasis of the improvement program has been to decrease defects and increase efficiency of production and testing.

4.24.2 Barriers to Achieving High Maturity

In order to achieve Level 4, the primary barrier was education on the Software CMM methodology. Most of the concepts presented were familiar to the organization, however, we had to understand "CMM-ese." Of course, there were changes made in the declaration of outputs for process performance and product quality, however, these were relatively easy to convert.

4.24.3 Unique or Distinguishing Practices

We have a strong infrastructure that supports the monitoring of process compliance, which is coupled with a relatively easy mechanism to enhance / improve / change the process. This infrastructure is supported by quantitative control mechanisms and an excellent reporting scheme.

4.24.4 People and Cultural Issues

Not being located in a technological metropolis creates a challenge for hiring and retaining qualified personnel. Our current staff is excellent, however, the competition is steep. This really makes the institutionalization of a standard process critical.

4.24.5 Continuing Improvement

Our current direction is the institutionalization of a program that supports realistic and verifiable causal analysis. Most of our problems surround suppliers. We do a lot of integration work, which makes it critical to understand the design of received systems. These designs from suppliers are not always complete and accurate. We plan to re-appraise using the CMMI.

4.24.6 Summary

Being a Level 4 means that our organization has adequate visibility into and control of our processes and products. The organization (people) are excited and responsive to a formallized process improvement program because of the concrete returns they have seen over the last 10 years. Benefits are streamlined processes, ease of technology innovation, and less turmoil during testing.

4.25 U.S. Air Force, Tinker Air Force Base, OK

Maturity Level	4
Date of Assessment	November 1996
Lead Assessor(s)	Judah Mogilensky
Point of Contact	Kelley Butler, kelley.butler@tinker.af.mil
Size of the Organization	325
Typical Program Size	10-60 people per project Varies.
Primary Application Domain(s)	Department of Defense software, primarily Air Force Avionics (80%) and Jet Engine (9%) Test Program Set, Industrial Automation (5%), and Jet Engine Trending Software (5%)

Registered to ISO 9001/TickIT since November 1998. Maturity level history: SEI Level 1 – 1990, SEI Software CMM Level 2 – 1993; SEI Software CMM Level 4 – 1996.

In 1999, we were awarded the IEEE Award for Software Process Achievement. The SEI Technical Report, Software *Process Achievement at Tinker Air Force Base, Oklahoma*, CMU/SEI-2000-TR-014, September 2000, that was written in conjunction with winning the award may be found at

http://www.sei.cmu.edu/publications/documents/00.reports/00tr014.html

Much of the information requested for this paper is in that report and will not be repeated here.

4.25.1 ROI and Improvement Trend Data

See the SEI Technical Report [Butler 00].

4.25.2 Barriers to Achieving High Maturity

Below is a chart we prepared for the SEI technical report. We think it shows that organizations have to realize that not all improvements will be lasting and that they will have to make way for other improvements at higher levels. The biggest barrier that we see to getting to Level 4 or 5 is that improvement must move beyond checking boxes and into the culture. A Level 4 or 5 organization truly believes, at all levels of the organization, in what they are doing.

Table 3: Tinker SPI Time Line

Timeframe	# Improvements Implemented	# Still in Place in 1999	Percent
1990-1993, Level 2 in 1993	45	11	24%
1993-1996, Level 4 in 1996	31	24	77%
1996-Present	22	22	100%

4.25.3 Unique or Distinguishing Practices

We don't feel that this is unique to our organization, but it is unique to high maturity organizations, and that is emphasis on all aspects of the process as well as on suppliers and customers. High maturity organizations see the big picture and everything that is necessary to be successful, and they do whatever it takes to ensure success. They also realize that they can continually improve and push the boundaries, whether it be in quality, productivity, cost, or schedule.

4.25.4 People and Cultural Issues

Unfortunately in today's economy recruiting / retention is a difficult issue but we do find that people appreciate working at a higher maturity organization, so much so, that we have had several cases of personnel leaving and returning, or wanting to return, due to the work environment and focus on process.

4.25.5 Continuing Improvement

Our major focus at this time is SPC. Additionally we are moving our focus to the CMMI-SE/SW and ISO 9001:2000.

4.25.6 Summary

Being "Level 4" has helped out in innumerable areas. From how others perceive the organization, to organizational pride, to the bottom line, to making it a better place to work. It has made us a stronger, more aggressive organization.

4.26 Wipro GE Medical Systems Ltd, Bangalore,India

Maturity Level	5
Date of Assessment	January 1999
Lead Assessor(s)	C Rama Rao
	Richard Knudson
Point of Contact	K.Puhazhendi, k.puhazhendi@geind.ge.com
Web Page	www.wipro-ge.com
Size of the Organization	180
Typical Program Size	6 to 10
Primary Application Domain(s)	Medical – diagnostic imaging

4.26.1 ROI and Improvement Trend Data:

Table 4: Investment in Quality Tools

Defect tracking system		
	server	$35k
	software licenses, 25 no.	$61.8k
Web server		
	server	$30K
Software testing tools for quality (tools like Purify / bounds checker / Rational Rose / Doors)		
	systems	$20K
	software	$50k
Total		$196.8 k

4.26.2 Barriers to Achieving High Maturity

- High growth rate needs quick ramp-up of people towards expertise in new functional and technological domains.
- Pressure for continuous ROI for quality programs through COQ reduction.

4.26.3 Unique or Distinguishing Practices

- Six Sigma—methodology based on statistics to reduce defects in software and meeting the customer Critical to Quality needs with robust design
- Digitization—to webify all the manual processes within the organization
- Complete modality integration with parent organization

4.26.4 People and Cultural Issues

- Turnover is high at 25%
- There is an extensive induction training program for new hires
- Team building: year-end parties (within modality), open house conducted monthly
- Organization focus on competence development and hiring top talent
- Retention of talent—key focus area.
- Training on leadership development

4.26.5 Continuing Improvement

Focus areas for 2001:

- digitization
- software reliability
- integration of Six Sigma, quality system (ISO, FDA, CE), phase review discipline

4.26.6 Summary

- Maturity level 5 has given the organization a definite brand equity in the eyes of our customers and also been responsible for attracting top talent.
- All the KPAs well integrated with ISO 9001, FDA, EN46001 into a single software lifecycle process. It makes life easy for the development engineers to compliant with all the above requirements.
- Metrics collection is seen as a tedious issue; there is a need for better tools for automatic capturing of metrics. We need to re-look into the right metrics which have more business relevance and ensure customer satisfaction.
- Maturity level 5 drives a data-based culture and quantification of all activities. It is easy to measure the capabilities of various processes and the outcome.
- Maturity level 5 has given the organization a well-defined standard process to be followed across all the project groups to identify key improvement areas and deploy Six Sigma methodologies in achieving them. Level 5 helped the team to deliver high quality software in less time.

4.27 Zensar Technologies Ltd, Pune, India

Maturity Level	5
Date of Assessment	February 1999
Lead Assessor(s)	Richard Knudson
Web Page	www.zensar.com
Size of the Organization	1050 software professionals
Typical Program Size	10-12 people per project
	20-40 KLOC per project
Primary Application Domain(s)	Systems software
	Information systems software
	Outsourced software

The organization was certified to ISO 9001 / 9000-3 in the year 1994.

It was assessed at maturity level 3 in October 1996 and maturity level 5 in February 1999.

It has been using TQM Frameworks of EFQM since 1995 and IQRS since 2000.

4.27.1 ROI and Improvement Trend Data

We have improvement trends in product quality, where processes are stable. This significantly contributes to customer satisfaction and therefore customer retention.

We meet our delivery schedules as expected by the customer.

We meet our profit objectives, where we do projects in India.

4.27.2 Barriers to Achieving High Maturity

The first barrier was top management support / commitment. This support needs to reflect in the amount of time spent on these activities in reviewing the progress and setting process improvement goals that support business goals.

The second barrier was cultural, related to discipline at work. When a measurement program is implemented, the people realize that if they provide wrong or incomplete data, the data analysis shows numbers that do not reflect the reality and therefore it is useless. Timely collection of accurate data needs discipline.

4.27.3 Unique or Distinguishing Practices

Timely collection of reasonably accurate data from the process which is good enough for setting performance baselines.

Management support and commitment to support measurement program.

4.27.4 People and Cultural Issues

People do not believe in or like to support measurement programs. They believe that every project is too different from other projects for measurement data to be reused.

However, in reality, the business tries to get projects that are similar to past projects to reduce risk, and over a period it is possible to establish that measurements add value for project management and for better estimation.

4.27.5 Continuing Improvement

We have been using TQM models since 1995. Now the organization is more focused on overall business process improvement.

We are initiating People CMM based improvement to address people issues better.

We are also studying the CMMI and have plans to reassess within a year's time.

We are also working towards certification for ISO 9000 (revision 2000).

We are trying to become more customer focused.

4.27.6 Summary

We have the processes / tools to support measurement program. This supports building of a project database and library which is a real asset to the organization.

Customer expectations have gone high and they expect improvements in productivity and quality over a period of time. However, it is difficult to achieve this if the customer processes do not support this. This is especially true when the requirements keep changing and the delivery dates do not change.

We have developed in-house training programs to support software engineering training needs of the organization.

Some of our customers are engaging us for consulting assignments to improve their processes.

5 Working Groups

Four roles were recommended for each working group:

1. a facilitator, to make sure each session ran smoothly
2. a recorder, to take detailed notes during the session
3. a working group leader, a non-SEI participant to make the presentation at the general session and who had primary responsibility for the working group report
4. a scribe, to capture main concepts during the discussions on a flip chart or electronic projector

Eleven working groups were proposed, along with an initial set of questions and issues to spark discussion:

- Working Group 1.1: Measurement
- Working Group 1.2: Reliability of High Maturity Assessments
- Working Group 1.3: Six Sigma and Software CMM
- Working Group 1.4: Internet Speed and Process Improvement
- Working Group 1.5: CMMI
- Working Group 2.1: Statistical Techniques
- Working Group 2.2: Business Result of High Maturity Organizations
- Working Group 2.3: Change Management and People / Cultural Issues
- Working Group 2.4: Process Agility
- Working Group 2.5: e-Commerce
- Working Group 2.6: Product Lines

After the review of the proposed working groups by the workshop attendees, the working groups on business results, e-Commerce, and product lines were cancelled. The working group on CMMI was duplicated in both of the workshop sessions because of high interest. The working groups on Internet speed and process agility were combined.

5.1 Working Group 1.1 – Measurement

The participants in this working group included

- Phil Sperling (working group leader and presenter), Telos-OK
- Dennis Goldenson (facilitator), SEI
- Wendy Irion-Talbot (scribe and report lead), CSC
- Dave Zubrow (recorder), SEI
- Joan Romine, Boeing
- Jitendra Shreemali, Philips Software Centre Limited
- Mel Wahlberg, CSC
- Jim Vanfleet, USAF / Hill / TIS-3
- Somashekhar Ramadevanahalli, CG-Smith Software Ltd.
- Subrata Guha, Satyam Computer Services Ltd.

5.1.1 Questions, Observations and Hypotheses

The initial questions put forth by the workshop committee and group members included:

- Do measures change substantively as organizations move from Level 3 to Level 4? How does organizational size affect this, if at all?
- Are the changes in measurement a difference in granularity, e.g., collecting process data at the activity level as opposed to phase level, or a difference in kind, e.g., moving from defect density data to mean-time-to-failure data for measuring quality?
- Using measures as part of the causal analysis process can be challenging. To what level of granularity must causal analysis be carried? At what point does an organization cease causal analysis of an issue?
- What processes or subprocesses are typically being "quantitatively managed" at Levels 4 and 5 and what are the associated measures that are being tracked?
- What are the [measurement-based] decisions made by high maturity organizations? What needs to be considered? What analytical techniques are appropriate beyond SPC?
- Once you've reached Level 5, what are the next steps and challenges [in a measurement context]?
- How do you identify the right/appropriate data for "organizational metrics?"
- How have other organizations achieved Level 4?
- Is the Software CMM (version 1.1) addressing the right measurement issues?

During introductions, working group members shared the following observations and hypotheses as we got started.

- A disconnect often exists between measures required for management and those necessary to meet project needs on a variety of levels. For example:
  - Senior management cares about resource loading factors and planned vs. actual expenditures.
  - An SEPG cares about process quality measures, estimation, and effort and schedule variances.
  - A project leader cares about requirements stability, and effort.

  In addition, there are also concerns about the costs associated with the collection and reporting of measures (particularly redundant measures), especially up the management chain where the utility of some data is not clear and frequent changes in direction can be costly and frustrating. Aggregating data to some level of abstraction may be inappropriate. For example, rolling up to the enterprise level may not make sense for all measures, even when requested by senior management.

  How do you reconcile and balance these perspectives and issues? Consider that the project is the sole source of data for measures!

- A common set of metrics can be defined at the organizational level, perhaps by the SEPG, but also may be met with resistance and may not prove to be useful. Don't try to standardize measures across too large an organization. In heterogeneous organizations the common metrics approach across projects may not be at all successful. A better approach might be to identify common categories with specific common measures. Some organizations, perhaps with more homogeneous projects, had some success standardizing on measures that enabled resources to move between projects, increasing efficiency and saving dollars.

- Changing definitions of measures degrades the utility of historical databases, baselines, and parametric models, and makes automation of data collection difficult. The impact of changes in the definitions of measures can be sweeping. For example, changes to the definition of a line of code affect measures of total system size and all derived indicators using this measure, and make comparisons with historical data difficult or invalid. Within the DoD, new definitions have just been promulgated from the Navy (PEO-TSC). Some projects have data going back 30 years with many releases, high reuse, and historical defect densities. While the PEOs are trying to standardize across their programs, which is a useful approach at a high level, individual projects are now challenged to recalibrate to the new definitions, and lose some utility of historical data and models.

  Measurement definitions may influence how programmers choose to format their code, e.g., use of carriage returns, comments, indention. Changing definitions may or may not cause corresponding changes in code formats, and make calibration or factoring of historical data inconsistent. This calibration can further be impacted if measurement definition is accompanied by a corresponding tool change.

  These changes also impact comparison with others, tracking process improvement, and reporting to senior management. This can be especially troublesome when organizations come together to partner, as for a proposal, and measurement definitions are disparate and can't be easily normalized.

- Core data collected doesn't appear to change that much at maturity level 4 and 5. Rather, the derived metrics, sophistication of analysis, presentation and visualization, and relevance to decision making becomes more useful to the organization for control and improvement purposes. However, "who" had been doing the measurement (possibly devel-

oping additional derived measures) and analysis possibly shifted or expanded across roles as maturity advanced.

- Across the organizations represented in the working group there was a great deal of commonality in the data collected. Some groups had normalized on six core measures and others as many as 70 that reduced to a balanced score card for presentation, but most fell within common boundaries, e.g., cost, schedule, effort, size, changes, defects, etc.
- Managing the culture change as an organization seeks to move to Level 4 seemed to be a widespread issue. There are challenges in perception, especially where practitioners had just enough Software CMM literacy to "be dangerous" (e.g., "Measurement is only for high maturity organizations. I just want to be Level 3, so I don't have to...") and actually gives lower maturity projects a reason not to focus on measurement. There are challenges in understanding model requirements, for example probing may reveal the project is indeed making decisions based on defined thresholds, but did not understand the model's application in their context.
- A variety of experiences and "dos" and "don'ts" were surfaced that the group decided to discuss in more detail. These are captured below in the "Pitfalls and False Starts" section.

There were many questions and issues raised by the group, but the timebox allotted to each working group session did not allow exploration and resolution of all of them. Two issues that the working group decided to discuss in more detail were

1. Change management as applied to measurement
2. Pitfalls and false starts

5.1.2 Change Management as Applied to Measurement

Change management was considered to be a key issue in moving beyond Level 3. Most working group participants cited examples where the effort to promulgate the culture change needed to move from Level 3 to Level 4 was at least as challenging as the technical issues associated with quantitative management. The following key points were raised in association with this issue:

1. **Nurturing the workforce about higher maturity concepts is essential.** Working group participants pointed out that the core data collected at Levels 4 and 5 really did not change much. Rather, how it was applied and by whom and what additional measures were derived from the core set changed. This change requires that the practitioners understand the premise and intended application and impact of measures, especially from a quantitative management perspective. This nurturing can take many forms, and includes training, coaching and mentoring.
2. **Broadening the involvement of the organization, vertical and horizontal, with respect to measurement and analysis was also identified as essential.** High maturity organizations had very broad involvement of staff and management across their projects. One group characterized the change in senior management commitment as "enabling" budget and resources at Levels 2 and 3, whereas at Levels 4 and 5 it becomes "personal" leadership, knowledge, direct participation and is the basis for decision-making. This particular change was cited as key to their success in achieving Levels 4 and 5. Partici-

pation across the various functional groups in the organization was also prevalent. No longer was the SEPG trying to drive everything, but functional groups seemed to be more involved in measurement collection and analysis, and also use that as the basis for decision making.

3. **Organizations cannot stay at maturity level 3—they will either advance (use the data) or regress (quit measuring).** The working group's feeling was that Level 3 was inherently unstable. Advancing organizations apply the data or derive additional measures to control and improve processes across functional areas or project phases. Groups that don't take this next step tend to stop doing other than basic cost / schedule measuring and hence regress. **"Just enough" Software CMM literacy to be dangerous—measurement is not just for high maturity organizations (senior managers, project managers, customers).** This point really unites the change management issues fundamental to advancing the maturity of an organization. Practitioners need to understand that measurement is essential to knowing where you are with respect to your program and process goals, and this understanding begins with the first KPA at the lower maturity levels. They also need to understand advanced maturity concepts, approaches and benefits, and then they need to be involved. Comments indicating that measurement and analysis, which really begins with basic performance measures collected at Level 2, is only for "high maturity organizations" are a clear signal that education groundwork is needed.

5.1.3 Pitfalls and False Starts

Working group members were curious as to whether their false starts were common and how the other groups represented handled those challenges, and further felt that sharing their lessons learned could be beneficial to other organizations seeking to advance their maturity. The following four points were raised in association with this issue:

1. **Choosing the wrong measures is one of the biggest potential pitfalls.** Organizations need to understand the advanced maturity concepts and underlying measurement rationale first, then determine what measures are appropriate for them. Focus on the "why" do we want to collect them, then define "what" needs to be collected followed by "how" to perform the analysis and decision making. Be wary of silver bullets and packaged solutions—what worked for another organization may not be directly applicable to you in other than a general way.

2. **Disconnects between project goals and process improvement goals can cause perpetual confliction of priorities and prohibit understanding and progress.** Not involving the stakeholders (managers, customers, and workforce) in the design and purpose of the measures could be fatal to the success of your [quantitative] measurement program. Several examples were discussed in which the SEPG and other process resources were given goals like "get to Level 4" and managers were given goals like "contain cost and schedule." This separation of goals led to frustrating conflicts in resource use and task priorities. Success was not achieved until each of the goals was understood, the relationship between them was understood, and they each became goals for everyone. It's like a visit to the chiropractor, once the elements were in alignment, the organization as a whole was able to function more effectively and with less pain. **Beware the SEPG trying to do it all themselves and not getting involved in projects.** Not only is there the danger of the "Ivory Tower Syndrome," but very often the SEPG is spread very thin, and they are not necessarily directly responsible for project (product) work. In

Level 2 and 3 organizations you very often see the SEPG assigned as the clear focal point for all process improvement, particularly from the OPD / OPF perspectives. This expectation tends to remain as the organization looks to Levels 4 and 5. But, with advancing maturity, it is natural and appropriate to involve more and more resources across the projects and organization directly in process and quantitative management. The SEPG remains the focal point for some process-based activities, but, more and more, the advanced maturity institutionalizes ownership and participation throughout their organizational structure and the SEPG moves into a facilitator role. This is appropriate as analysis and decision making at all levels becomes based on the quantitative techniques. ***Bottom line: the organization moves to take ownership of the processes and process improvement initiatives as part of its activities,*** rather than as separate initiatives.

Some projects have successfully used "process consultants" as a way to deploy and involve process resources across the project(s), providing support and guidance, and enabling project resources to execute process initiatives.

4. **Citing irrelevant examples during deployment and implementation of QPM and SQM can throw more obstacles in your way.** The most effective analogies and examples are those that relate directly to the group with which you are working. Picking arbitrary examples may not enable understanding, and actually may further distance (or discourage) the target audience from the goal at hand.

5.1.4 Recommendations for Organizations Seeking High Maturity

As a result of the working group's discussions, the following recommendations for organizations seeking to achieve high maturity were identified as "critical factors for success":

- ***Involve*** those impacted by the measurement program is—do it ***with*** them, not ***to*** them. The importance of understanding and buy-in at all levels cannot be understated. Work with project resources to understand what they are already doing. Guide them through using these and additional primary or derived measures that can be used to more effectively address their problems, and eventually to predict and prevent problems. In addition, the approach to using the measurements should become ***proactive rather than reactive*** (predictive rather than correcting).
- ***Start with small, focused efforts*** to generate some early successes. Mandates, especially those generated external to the project, are rarely successful.
- ***Integrate*** project measures and business objectives. Failure to do so will probably prevent success. Use the Goal-Question-Measure method as a starting point, beginning at the highest level with your business goals. Ensure you show and reinforce your chosen approach and relevance to your project and organization. Comments such as "Thanks for the meeting, now I have to go do real work" are clear signals that the goals are not yet aligned and people still feel there is a gap between process and project priorities.
- ***Revisit the basics*** and review the purpose and need for each measure. This can and should be done early (even at Level 2 for those measures) and reinforced as the organization advances maturity. See the CMMI Measurement and Analysis PA.
- ***Automate*** collection and analysis as much as practicably possible. Invest in a statistical package if you can. This will not only streamline the measurement process and ensure

consistency of data and collection, but will enable people to focus on the analysis and decision processes rather than expend effort on the mundane collection tasks.

- ***Address change management*** as applied to measurement in the context of high maturity. As noted in the discussion above, change management and consideration of the cultural issues in moving beyond Level 3 are even more important than the high maturity organizations had realized at the outset. Determining the technical requirements for a quantitative process management system is a tremendous task, but if corresponding people issues are not handled, you run the risk of building an ineffective Level 4/5 infrastructure. In addition, as you tackle and achieve success in small pockets of the organization, communicate the successes and benefits of moving to Levels 4 and 5. Leverage the pockets of excellence and learn how to adjust and adapt these to other areas of the organization.

5.1.5 Recommendations for the SEI

As a result of the working group's discussions, the following recommendations were formulated. The SEI needs to:

- **Encourage organizations' understanding of measurement at lower maturity levels.** Influence the perception that measurement only applies to the higher maturity areas. Emphasize that it applies to everyone at some level. Organizations should establish the foundations of their measurement program early on to generate understanding and begin to build historical data sets. This will assist organizations in avoiding false and ineffective starts. Avoid false starts; start early, start small, and be real.
- **Address change management as applied to measurement in the context of high maturity.** Allow for the time and effort necessary to effect the culture changes that must accompany a move up from Level 3.
- **Provide guidelines and examples for quantitative analysis techniques and methods that are acceptable at Level 4 (other than SPC).** Group members agreed that not all processes could or should be quantitatively controlled using SPC—it just doesn't make sense. The community could benefit from additional guidance.

A useful mechanism to address these recommendations might be to augment training for high maturity organizations to provide additional focus and guidance in these areas.

5.2 Working Group1.2: Reliability of High Maturity Assessments

The participants in this working group included Roger Bate (SEI), Donna Dunaway (SEI), Will Hayes (SEI), Bill Hefley (Q-Labs), Gargi Keeni (Tata Consultancy Services), Linda Levine (SEI), Judah Mogilensky (Process Enhancement Partners), Joseph Morin (Integrated System Diagnostics), Muthuramalingam Rajamanickam (HCL Technologies), David White (SEI), and John Yu (Motorola-China).

The working group leader was Judah Mogilensky (Process Enhancement Partners). The facilitator was Will Hayes (SEI). The scribe was Bill Hefley (Q-Labs). The recorders were Donna Dunaway (SEI) and Joseph Morin (Integrated System Diagnostics).

5.2.1 Points of Departure

The working group had the benefit of the report from the working group on the same topic from the previous High Maturity Workshop, conducted in November 1999. (See [Paulk 00a].) Among the suggestions put forward in that report (page 46), and observations by the Working Group about what has happened since the last workshop, were the following:

- Re-establish the CMM Advisory Board. [Not done.]
- Establish mandatory supplemental training for any Lead Assessor to lead Level 4 or 5 assessments. [Not mandatory at present, but the SEI does now offer *High Maturity with Statistics* course and the *SPC for Software* course.]
- Gather data regarding the alleged problem of inconsistent or inappropriate Level 4 and 5 assessment results. [Assessment findings briefings and reports are collected, but there has been no program of quality analysis of the reported findings for Level 4 and 5 KPAs. It was noted that there is currently no such analysis of reported findings at lower levels, either.]
- Periodically conduct High Maturity Practices Workshops. [On the one hand, the second such workshop is now being held within two years. On the other hand, there is very low participation from Lead Assessors in this workshop.]
- Elicit papers on high maturity topics from the community at large. [It was noted that the last two SEPG conferences have had a significantly larger number of high maturity presentations than in earlier years, and, furthermore, these sessions have been quite well attended.]

The questions that inspired the creation of this working group included:

- Are a significant percentage, perhaps even a majority, of the organizations assessed at Levels 4 or 5 really just good Level 3 organizations?
- What are the typical misinterpretations that lead to inflated level ratings?
- What qualifications should Lead Assessors or Evaluators have to perform high maturity appraisals?
- How can we equitably evaluate Lead Assessors or Evaluators to demonstrate their ability to judge higher-level implementations? Curriculum of accepted training? An examination? Specialized certification through a body such as ASQ?
- What qualifications should an assessment team have to perform a high maturity assessment?
- Could the community support increased team training for higher maturity levels?
- What are the hard decisions as an assessor?
- What are the difficult things to get teams to understand?
- What are the most difficult findings to explain to an organization?
- What additional training, auditing, etc., should the SEI perform to retain the credibility of high maturity assessments?

- Do the CMMI models contain information that will help assure reliability, or might it lead to reduced reliability?
- Are there changes we can suggest to CMMI that will enhance reliability?

5.2.2 Topics Selected by the Working Group to Focus Discussion

After a discussion of the points of departure and the concerns of the participants, consensus emerged that the fundamental concern of the working group was the perception within the process improvement community (which may or may not be based on reality) that unacceptable variation exists in the determination of Level 4 and 5 appraisal ratings. This perception is not inherently restricted to any particular model or appraisal method.

This concern was based upon four key underlying issues, namely

1. The available descriptive models (to varying degrees) do not specify what is required to achieve Levels 4 and 5 in an exhaustive and unambiguous manner.
2. The community has no well-accepted and widely available consensus as to what is actually required for achievement of these ratings. Further, there is no recognized forum for achieving the desired consensus.
3. Currently, Lead Appraiser programs do not include specific qualification requirements for Levels 4 and 5, specific model and method training requirements for these levels, or corresponding training materials and implementation guides. Training materials and implementation guides are also lacking for those organizations attempting to achieve these levels.
4. There is no comprehensive mechanism functioning to validate the accuracy, quality, consistency, and reliability of Level 4 and 5 appraisal results. Similarly, there is no mechanism functioning to ensure that appraisal teams perform to any minimum standards.

The working group settled on the following main topics to discuss in more detail:

- **Qualification and Preparation of Lead Appraisers and Teams**
  - qualifications
  - training (both initial and sustaining)
- **Development and Dissemination of Public Guidance for Implementation and Interpretation of Level 4 and Level 5 KPAs**
  - assessment guidance
  - implementation guidance
  - interpretations or common misinterpretations
- **Achievement of Greater Reliability for High Maturity Appraisals**
  - analyzing assessment data
  - quality assurance

- reassessments (especially after achieving a Level 5 rating)
- approach; deployment; results

The working group recognized that, while these topics are to be discussed separately, they are very much tied together in terms of addressing the issues identified above. Thus, the reader will note significant overlap among the three main topics.

5.2.3 Qualification and Preparation of Lead Appraisers and Teams

The group addressed the first topic using a structured format: Why is this an issue? What is the current status? What are the implications and significance of the current status? What are some opportunities to improve (i.e., recommendations) that the group would like to make?

5.2.3.1 Why is This an Issue?

Reasons identified by the group for why preparation of leads and teams was an issue for high maturity appraisals included the following:

- The community has a need for consistency / reliability of assessment results.
- Appraisals are facing increased complexity; multiple models, multiple disciplines.
- There seems to be no broad community consensus on the specific requirements that an organization must satisfy to deserve a rating of maturity level 4.
- There currently exists a broad range of interpretation for the existing Software CMM v1.1 high maturity KPAs, encouraged somewhat by the vagueness of the text; currently required Software CMM training for both leads and teams is the SEI's *Introduction to the CMM* course, which is generally viewed as providing inadequate coverage of Levels 4 and 5.
- Organizations wishing to conduct serious benchmarking, especially for demonstrating continuous improvement, may find these efforts more difficult.
- There are Lead Assessors, Lead Evaluators, and Assessment Team Members who are inexperienced in maturity level 4 and 5 topics, and who may confront these topics without adequate preparation.
- The community desires assessment results to be more useful and less subject to dispute.
- Sharing experiences will improve the LA / LE community.
- Assessors are being questioned about how they conduct appraisals, and about the results of those appraisals, because appraisal method requirements and assessor qualifications are not well understood.
- Lead Assessors and Lead Evaluators may have to learn multiple disciplines to work with the CMMI models.

5.2.3.2 Current Status

Aspects of the current status highlighted by working group members included:

- Assessments are longer and more painful if supplementary on-the-spot Assessment Team Member training on Level 4 and 5 KPAs is required during the on-site period.
- Expectations are not well established for the qualifications of Lead Assessors and Lead Evaluators to address Level 4 and 5 KPAs.

5.2.3.3 Implications/Significance

Key implications and aspects of the significance of the current status in this area, as identified by the working group members, were as follows:

- Training is also needed for organization, not just for the Lead Assessors, Lead Evaluators, and team members; organizations lack understanding of how to implement maturity level 4 and 5 process areas.
- There is a need to beef up expectations (LA, ATMs) regarding what it means to be adequately trained and qualified to conduct high maturity appraisals.
- The current status results in potentially inconsistent assessments and promoting "claiming" levels, rather than focusing on real benefits. In other words, it enables "level-grabbing," with negative impacts on teams and on assessment conduct.
- The current status may cast doubt upon any maturity level 4 or 5 assessment, including the absolutely valid ones, resulting in poor perception of the model, assessments, etc.
- Organizations invest a lot in, and expect a lot of, assessments, so they should not have to be concerned about questions regarding the validity of the results.
- Results of assessments are at risk if the quality of the Lead Assessor or Lead Evaluator is not known to the organization being appraised, or to the users of appraisal results.

5.2.3.4 Opportunities to Improve

As already noted, the report from the November 1999 High Maturity Workshop listed several recommendations, most of which have not yet been implemented. In addition to these, the working group members noted the following suggestions:

- Encourage Lead Assessors / Lead Evaluators to take additional training in high maturity topics (e.g., current SEI courses in *SPC for Software* and in *High Maturity with Statistics*, as well as the *Intermediate Concepts of the CMMI* course, now required for CMMI Lead Assessors)
- Suggest appraisers use a standard experience / qualification matrix as a means for Lead Assessors and Evaluators to describe their level and scope of experience (maturity levels, disciplines, etc.) and for appraisal customers to better match LA / LE qualifications to the parameters of their appraisal. (The working group noted that all attempts in the past to establish different "classes" of Lead Assessors and Evaluators had failed, so we will not suggest that approach again.)

- Provide additional model and method implementation guidance for appraisers (which will also serve as useful input to organizations seeking appraisals) in such areas as:
  - What evidence is indicative of implementation and institutionalization of higher maturity practices?
  - How do organizations produce appropriate observations and findings with respect to high maturity practices and goals?
  - What circumstances trigger the need for a new baseline appraisal?

- Utilize newly available mechanisms for disseminating this guidance to the lead appraiser community (for example, the new SEI Lead Assessor Web site, the International Association of Professional Lead Assessors [IAPLA] Web site).

5.2.4 Development and Dissemination of Public Guidance

The working group chose not to have the same type of structured discussion for this second topic. Instead, the group chose to address the topic in a more free-form manner.

The primary issue underlying this second topic is that the process improvement community lacks a recognized and accepted mechanism for establishing consensus on model interpretation and implementation issues. (This issue is the basis for the suggestion in the November 1999 workshop report to re-establish the CMM Advisory Board. The CAB served as just such a mechanism for establishing interpretation consensus for the Software CMM v1.1.)

Nevertheless, it would be valuable for the community to have consensus guidance both for implementation and for appraisals in such areas as:

- What does quantitative management really mean (what aspects must be managed quantitatively, how to judge the suitability of the quantitative methods being used, etc.)?
- What constitutes effective defect prevention activities (how should defect classes be selected for root cause analysis, how often should root cause analysis be conducted, should defect prevention process changes be made just on a project or phase basis or must they be organization-wide, how much follow-up evaluation should be performed for defect prevention process changes, etc.)?
- What constitutes effective continuous improvement (how should pilot trials of new technology and new processes be conducted, how much data should be collected, how are data from pilot trials to be fed back into the OSSP, how much overall improvement and process change activity must be taking place, etc.)? [Please note that this topic is also addressed in the Working Group Report for WG 2.3, Change Management and People / Cultural Issues in High Maturity Organizations.]
- How do quantitative management and continuous improvement clearly and visibly connect to business goals and objectives?

The working group developed a general outline of the format that this guidance should take. The format would consist of four key sections:

1. A description of the topic, abstracted from multiple relevant models

2. Interpretive guidance for organizational implementation and for appraisals (e.g., rules of thumb, examples of successful implementations, non-attribution examples of specific judgments made by assessment teams, etc.)
3. Commonly encountered problems, misinterpretations, and misconceptions (including examples of misunderstandings from High Maturity Practices surveys and instances of apparent errors in assessment findings)
4. References for additional guidance, including mappings to specific model content and an annotated bibliography of supplemental resources (texts, tools, etc.)

Although the working group made no specific recommendation for a body to take responsibility to develop this interpretive guidance, conduct broad public reviews of it, and then make it generally available to the process improvement community, it was noted that a number of existing organizations could potentially contribute to these activities, including the SEI, IAPLA, ASQC Software section, IEEE Computer Society, ACM, NDIA, EIA, INCOSE, and ISO (with regard to 12207 and 15504). The goals for such guidance would be not only the publication of implementation guides and/or white papers, but also providing a forum for discussion of submitted questions. The objective is to move beyond the limitations of "descriptive" models into specific "prescriptive" suggestions, "how to" guidance, and detailed examples of typical implementations. A key critical success factor for any such guidance is that the organizations performing process improvement and seeking appraisals see the same guidance as the Lead Assessor and Lead Evaluator groups. The working group felt that providing this guidance would not only promote greater consistency and reliability in high maturity appraisals, but it would help move organizations away from the self-defeating perspective of "what is the least I can get away with and still pass."

5.2.5 Achievement of Greater Reliability for High Maturity Appraisals

The working group chose once again to address this last topic in a free-form manner.

The primary question underlying this third topic is: What steps can be taken to review and improve the reliability of high maturity appraisals? The working group further refined this broad question into four specific topic areas:

1. Increased focus on business results
2. Analysis of appraisal data received by the SEI
3. Quality assurance "audits" of appraisals and appraisers
4. Guidelines for reassessment of Level 5 rated organizations

Regarding the topic of increased focus on business results, the working group members made the following points:

- Now that appraisals are starting to use Confidence Reports, one possible component of a Confidence Report for high maturity ratings would be data on organizational performance that correlates with the expectation of high maturity. (This is similar to the idea of using behavioral maturity level indicators in Confidence Reports, suggested in the SEPG 2001 conference paper by Judah Mogilensky.)
- The working group wanted to emphasize that there was no suggestion here to change the formal maturity rating approach to include business results as a factor.
- It was also noted that business results could be captured in the Organizational Questionnaire submitted to the SEI, so that data on the correlation between high maturity levels and improved business performance could be analyzed.

Regarding the topic of analysis of appraisal data, the working group members made the following points:

- The existing findings in the Assessment Findings Briefings and Final Reports from high maturity assessments in the SEI database could be used to establish a baseline to support semantic and content analysis of such findings.
- This analysis of findings could be augmented in the future by having the appraisal team submit their observation databases to the SEI, and extending the semantic and content analysis to these observations. Having teams submit observations will require specifying data format standards and sanitization guidelines to a significantly greater degree than what is needed now for Findings Briefings and Final Reports.
- Once the baseline is established, the SEI could perform an ongoing review of appraisal results to identify trends and patterns in the content of findings and observations. These trends and patterns can, in turn, guide improvements to the appraisal program (in terms of method documentation and method training), as well as the future public guidance discussed in the previous section.

Regarding the topic of quality assurance audits of appraisals (and possibly appraisers), the working group members made the following points:

- It would be a helpful start for the SEI, perhaps in conjunction with the Lead Assessor / Lead Evaluator communities, to identify a common set of measures that indicate and characterize appraisal performance.
- These measures of appraisal performance could then be communicated to the appraiser communities, and to the organizations (high maturity and others) seeking appraisals.
- It would also be helpful for the SEI, in its role as steward of the models and the appraisal methods, to define and implement an appraisal quality assurance process (moving beyond the current candidate appraiser observation reports and PAIS submittals). This quality assurance process may well require separate components to address the separate topics of appropriate method implementation and lead appraiser performance on the one hand, and knowledge and interpretation of high maturity model practices on the other hand.

Finally, regarding the topic of guidelines for the reassessment of Level 5 organizations, the working group members made the following points:

- In the absence of the conventional motivation for conducting reassessments (namely, the desire to demonstrate achievement of the next higher maturity level), Level 5 organizations must decide for themselves when a reassessment is warranted, considering such factors as:
  - time elapsed since the last assessment
  - typical project life-cycle duration
  - documented improvement activities and results
  - changes in the organization's structure, leadership, ownership, areas of business focus, staff turnover, applicability of models, etc.

- The working group declined to suggest any fixed formula for "required" reassessments of Level 5 organizations, just as there are no fixed requirements at any other level for exactly when reassessments are to be conducted. (The conduct of periodic assessments is addressed in Organization Process Focus, but no specific reassessment interval is specified.)
- At the same time, it was pointed out that the buyers of the services of organizations rated at Level 5 (or, again, at any other level) still need to look at such factors as:
  - Model used, method used, scope, and leader(s) of prior appraisals
  - Measures of organizational process improvement since the last appraisal
  - Other differentiators of the organization relative to its competitors (that is, other differentiators besides maturity level rating at some point in time)

The members of the working group on High Maturity Appraisals enjoyed their task, and felt that they had been able to have useful discussions of the topics summarized in this report.

5.3 Working Group 1.3 – Six Sigma

The participants in this working group included Bill Curtis, Bob Hoekstra, Asha Goyal, Anthony D'Souza, Mary Lynn Penn, Joan Romaine, Kelley Butler, Jeannine Siviy, Christian Hertneck, Jim McHale, and Anita Carleton.

The working group leader was Kelley Butler. The presenter was Bill Curtis. The facilitator was Jeannine Sivy. The recorder was Christian Hertneck.

5.3.1 Hypotheses and Observations

The questions that inspired the creation of this working group included:

- What does Six Sigma really mean / imply?
- Compare / contrast Six Sigma and the Software CMM
- How to sell Six Sigma to a software organization and when / how to start Six Sigma

During initiation of the working group, the following questions or observations were posed by the working group members:

- Six Sigma as a toolbox, a collection of practices for continuous improvement

- Six Sigma as a method for driving the ownership of quality to the project groups/working level
- Six Sigma as a framework for improvement beyond Level 4 and Level 5, as a method to "re-energize" the improvement efforts

The issues that the working group decided to discuss in more detail were:

- How to start Six Sigma
- Software CMM, People CMM, and Six Sigma
- High Maturity Organizations and Six Sigma

5.3.2 How to Start Six Sigma

It is important to understand that Six Sigma does not require a maturity level and may be started at any time, but it must have management support. Training is key and it is best to start with one small project and with simple problems and data so that a business case can be made. The change agents "own" the Six Sigma process and Six Sigma involves the entire organization, not just software.

Being at a higher level of maturity aids in the implementation of Six Sigma due to the availability of data and the focus on continuous improvement and process changes. Additionally, Six Sigma focuses on the problems that are most important to an organization and its bottom line, e.g., shifting the discovery of defects to earlier in the process.

5.3.3 Software CMM, People CMM, and Six Sigma

While the Software CMM focuses on transformation of the organization and doesn't explicitly require better results, Six Sigma drives deeper into the process and requires measurable results. Six Sigma also enforces many of the principles of Personal Software Process (PSP) and Team Software Process (TSP) along with ISO 9001:2000.

Six Sigma clarifies the Level 4 and 5 goals and gives tools for analyzing the process according to business goals. Level 2 of the Software CMM is about local learning that fits well with using Six Sigma on individual projects, Software CMM Level 3 begins process mapping and actual data analysis begins at Level 4. The original basis for Software CMM Level 5 is the beginning of data-driven improvement, the foundation of Six Sigma.

Six Sigma starts within the organization with a strong foundation in training, focusing of development of the workforce and ownership of the process, much like the focus of the People CMM.

5.3.4 High Maturity Organizations and Six Sigma

Software CMM Level 5 implies that change is built into the process, Six Sigma focuses on the creation of the change engine – giving continuous and measurable improvement and helping to ensure that the organization is collecting the "right" data. Six Sigma allows a Software CMM Level 5 organization to move beyond the reference model and build an improvement foundation based upon the Six Sigma tools and techniques.

5.3.5 Experiences from Boeing and Lockheed Martin.

Mary Lynn Penn of Lockheed Martin and Joan Romine of Boeing shared their experiences with Six Sigma. For Boeing, it was originally applied to manufacturing and they are now bringing it to software with a focus on delivered product quality and reducing the cost of quality. One of their first efforts was to shift the discovery of defects to earlier in the process.

Lockheed Martin gained commitment from the top and trained the senior management so that they understood the process. Their president has set goals for the process owners with a current example being a goal of a 30% defect discovery shift. Ms. Penn discussed the involvement of the entire workforce and the fact that they are seeing a new culture emerge. She described their Process Board and that they zoom in on specific parts of the process. She also discussed the need for specific data.

5.3.6 Recommendations for High Maturity Organizations

As a result of the working group's discussions, the following recommendations for organization seeking to benefit from Six Sigma were formulated:

- Gain top-level management support. Show how Six Sigma can be used as tool and the "next step" after reaching Software CMM Level 5. Educate the entire organization on the different models, methods, and tools.
- Use Six Sigma to increase practitioner ownership, to give the practitioners a new tool, to generate new interest, to increase process agility.
- When implementing Six Sigma, place focus on training and piloting with one project and one problem.
- And, if currently using Six Sigma, publish experiences and results.

5.3.7 Recommendations for the SEI

As a result of the working group's discussions, the following recommendations for the SEI were formulated:

- Retain the Software CMM and the focus it brings to software.
- Explore including Six Sigma in future versions of the Software CMM as a tool to aid Level 4 and Level 5 organizations in continuous and measurable improvement. The very rich SPC tool kit provided by Six Sigma could make Software CMM Level 4 and Level 5

implementation more focused and less theoretical. Today Level 4 recommends process but is not supported by a toolkit.

- Recognize that Six Sigma is not standardized, that it has a wide spectrum of tools. Focus on referring the relevant tools from the Six Sigma assortment
- Publicly recognize Six Sigma as a useful tool for software organizations. Publish articles in publications such as *CrossTalk*.
- Show the relation between the different models and frameworks. Show the connections, mappings, and benefits. Describe the broad toolset necessary to develop a sound quality management system.
- Develop SEI courses on the application of Six Sigma to software organizations.

5.4 Working Group 1.5: CMMI

The participants in this working group included Julie Barnard (United Space Alliance), Bruce Boyd (The Boeing Company), Lynn Carter (SEI), Mary Beth Chrissis (SEI), Suzie Garcia (SEI), Diane Gibson (SEI), Vivek Govilkar (iFlex Solutions), Craig Hollenbach (Litton PRC), Mike Konrad (SEI), Gerry Ourada (Lockheed Martin), Lynn Penn (Lockheed Martin), Lita Schulte (The Boeing Company), Raj Shekher (Mastek), Ashok Sontakke (Zensar Technologies), and Albert Soule (SEI).

The facilitator was Mike Konrad. The scribe was Lynn Penn. The recorder was Diane Gibson. Julie Barnard and Bruce Boyd volunteered to be the report editors. Julie Barnard presented the working group's finding to the workshop.

Note that there were two separate working groups on the CMMI topic at the workshop, due to the level of interest in the topic expressed by the workshop attendees. This CMMI working group (1.5) was the first of the two working groups convened on the topic. Different participants were involved in each of the two CMMI working groups.

5.4.1 Hypotheses and Observations

This section discusses the observations, hypotheses, and propositions that initiated the discussion. Also included are the results of brainstorming activities that did not become a working group consensus.

The working group brainstormed the following set of initial questions to be discussed:

- How does an existing high maturity software organization integrate with a relatively immature systems engineering organization when transitioning from Software CMM to CMMI?
- What is the next step for CMMI development and release? How do we plan for CMMI over the next two years?

- How will CMMI help organizations that develop custom software? How will CMMI, which covers systems engineering, help those who don't see systems engineering as part of their business? How practical are CMMI assessments if they can take 2-3 weeks?
- Where can we find mapping from Software CMM to CMMI for higher maturity level organizations?
- What are the qualifications for SCAMPI assessors? How long do assessments take?
- How do you integrate a number of separate legacy organizations using CMMI following mergers? How difficult is it to cover a diverse organization with a common CMMI assessment?
- The CMMI product development team is interested in hearing the concerns of industry on the model. How do you apply CMMI to commercial products not currently covered by CMMI?
- When merging various companies into one, shouldn't we deal with the merger issues first, then CMMI? Software is just a part of what the company does—CMMI will cause companies to pull in more of the organization than just engineering into their improvement plans—for example, things in the factory, or in the quality side of the house. We're implementing Level 4 in software for commercial production because we know it is the only way to meet the contract. We would like to do similar improvement on the engineering side of the house.
- We are currently Level 5 with both Software CMM and Systems Engineering CMM. We are currently in the rollout and integration of CMMI. We were also member of the CMMI working group previously. We want to see how CMMI has evolved and get results from the pilot assessments. We'd also like to hear interpretations of the continuous vs. staged representations.
- SEI would like to understand what high maturity organizations think about the practices at Levels 4 and 5 in CMMI Version 1.01. How different are they from Version 1.1 of Software CMM? How much is enough to be assessed at Levels 4 and 5? How much of the product life cycle needs to be brought under statistical process control?
- We have a similar question regarding Technology Change Management – When high maturity organizations evaluate and decide to adopt new technology, is that activity supposed to be under Statistical Process Control (SPC)? Since technology is changing quickly and changes are happening so fast, should it be [under SPC]?
- What are the lessons learned that could be used by a novice organization applying CMMI vs. an organization experienced with Software CMM?
- Where is CMMI going in the future? Will it include the People CMM? Will it apply to an Information Technology organization? Will there be one assessment for the entire organization?
- What experiences have people had with CMMI lessons learned? What about extending the CMM to other areas?
- How do you perform SPC for areas other than software specific development?

Several working group members asked for background information on CMMI. Mike Konrad (SEI) provided a brief summary of relevant CMMI information to the group. Since this in-

formation is readily available from the SEI Web site and other sources, it is not reproduced in this report. Some of the members asked about mapping of various other models and standards to CMMI. It was noted that some useful mappings are available on the Software Technology Support Center (STSC) Web site: <http://www.stsc.hill.af.mil/>. Additionally, the SEI Web site includes pointers to the same mapping documents resident on the STSC Web site that compare the Software CMM to the CMMI and vice-versa.

During initiation of the working group, the working group members posed the following questions or observations:

Observation #1: Are software organizations using CMMI?

It was argued that software engineering and system engineering are not really separate disciplines – either or both have been characterized as encompassing the other. Engineering process areas talk about defining the processes that go with developing and using the product: manufacturing, customization, training, repair, etc. A broader view of life cycle is required—for example, maintainers of products who know all the effort required to make a product useful and keep it functional. CMMI gives more attention to these stages. Organizations that are only developing software still have integration issues about installation, help desk, tech support, etc. CMMI gives software organizations that develop applications a model to include other aspects of product development; e.g., relevant stakeholders. CMMI practices integrate more decision making and parts of product development. The value of Software CMM was to give focus to neglected areas such as support and project management. CMMI folds in lessons learned from Software CMM and from engineering (EIA 731). CMMI tried to capture these lessons learned. At Software CMM maturity levels 4 and 5 one of the lessons learned was that the Technology Change Management and Process Change Management Key Process Areas could be merged (from the workshop on TCM); also, product lines were included in Software CMM Version 2. There is still an opportunity to look upstream, downstream, and laterally for information about the products and services an organization provides.

The issue that the working group discussed in more detail was:

Marketing

- Commercial organizations have different issues from defense contractors; for example, marketing is so much more important. Does CMMI focus more on marketing, or might it?
- System engineering issues—customer requirements, product management, etc. – often focus on information needed by marketing. Someone is working on a Masters thesis on a CMM for marketing.
- Does the model sub-optimize the commercial, marketing approach?
- CMU is working with private, commercial companies—using the CMM as a focal point (e.g., Sun, Adobe, 3Com, Oracle).

- Look at the participants in the development of CMMI—most were defense contractors—but there were some commercial companies (Motorola, Ericsson); all were either defense or telecommunications companies. Software CMM began as a tool for defense contractors with the SEI shepherding the flock. The SEI wants input from commercial organizations, but Software CMM is something for software development—marketing folks are not very excited about it. It would be better if there were something that comes from marketing to get them involved. CMMI has stakeholder involvement; i.e., coordination with the stakeholders group; but it suffers from not having an explicit "marketing the product" process area. Maybe this will happen in the future?
- Business acquisition is a major focus of companies. Requirements are important, but also need the business acquisition process (business development, marketing) to focus on risks, etc. CMMs give a push to engineering but not to marketing.
- When we bring software or engineering improvement to the boardroom, CMM seems parochial. They are more interested in growing the business and making profits. We need to bring software improvement back into improving the business and addressing business issues.
- People are making the argument that CMMI has to be translated for specific business contexts. If CMMI constrains the ability to meet business goals, we would like to hear more examples or evidence of this.
- CMMI has weaknesses in the areas of marketing and business development. Whatever the SEI wants to address regarding marketing needs to be clearly addressed in training for instructors and for assessors. We don't expect this to really change in next three years.
- Is there a set of principles that can be used as guidelines in other parts of organization that are outside the CMMI? For example, are there architectural principles for adding new disciplines, or new generic practices? Is there a single model for product development processes / organizations and a path for adding other disciplines and application environments?
- We are looking to members of this group for people who are applying CMMI in the commercial world and in other areas for their insights.

Observation / Question #2: Standard CMMI Assessment Method for Process Improvement (SCAMPI) issues

- Initial concern—SCAMPI takes such a long time and is an intense effort. Today it takes about 100 hours (clock time) over nine days. The second time a Lead Assessor takes less time. It's getting more like CBA IPI, plus there are some innovations that could also be used in CBA IPI.
- Concern with CMMI—It is possible (likely?) that the requirement for Software CMM Level 3 will be changed to CMMI Level 3 or something equivalent. How assessments are done is critical here.

Observation / Question #3: CMMI changes

- CMMI Version 1.1 is expected to be released in December, 2001 and then be stabilized for four or more years. The desire is that v1.1 will be similar enough to v1.0 that folks

won't need to be retrained. No changes are expected in a number of process areas; goals and practices should be pretty much the same.

- The biggest changes will be in the evaluation techniques (SCAMPI). From OSD—there will be a "source capability evaluation" method. We do anticipate changes in the assessment method to save time and take advantage of lessons learned in pilot assessments.
- Regarding which new disciplines will be added to the model: there is no clear direction. We will add acquisition in some form; security is pushing also; enterprise modeling, program office, etc. are all being raised but no decision has been made. People CMM Version 2 is being crafted to be compatible with CMMI.

Observation / Question #4: Expansion to other areas

- One company tried to include other disciplines using the Software CMM—but when senior management heard about CMMI they stopped that initiative. They were moving improvement into product development processes, which is more than just integrated engineering processes.

Observation / Question #5: SPC

- CMMI promotes doing SPC where the business case suggests you need SPC. If TCM is very important to an organization, then they might want to use SPC for TCM. In other organizations, this may not be needed.
- How much SPC is enough? Are there any universal processes that should always be placed under SPC?

5.4.2 Novice vs. Mature Organizations

How will CMMI apply to a novice organization vs. one with a mature software organization? If you have several pockets of high maturity practices, how do you apply CMMI to additional areas? Examples of high maturity organization experiences:

- System engineers wanted to learn and adopt processes used by software folks when they participated in Integrated Product Teams (IPTs) with Level 5 software engineers.
- An executive commented that their company no longer received complaints about software, but they still got complaints about other engineering domains, so they tried to apply Software CMM principles to top level product development processes, including engineering, business, and end-to-end processes. They intend to apply CMMI at some point. This was an example of executive push. Having demonstrated the benefits of CMM in software, they wanted to apply it more broadly. It was somewhat awkward to apply CMM outside of software, but it was a valuable exercise. There was previously no concept of peer reviews of business plans, but the practice was introduced because it made sense – they were important documents.
- Experience getting ready for a CMMI pilot: It was recognized that Software CMM had added value and been beneficial to the software community, so engineering management

was ready to try it, even though they didn't know exactly what it was. They saw real benefits from the Level 3 aspects, rather than the high maturity aspects.

- Another organization doesn't have mature system engineering and has software engineering communities that are diverse. There are up-front components and back-end components that haven't paid enough attention to process improvement. When Systems Engineering CMM came out, they looked for areas to piggyback usage between software and system engineering—where they could use software processes in the system engineering world. System engineering processes became part of the improvement structure. Total Quality Management (TQM) also provided some foundational principles that extended across disciplines—TQM was highly leveragable. Quality techniques of the TQM approach were applied across the organization first, then they applied Software CMM.
- Another organization matured in both system engineering and Software CMM. They replaced SEPGs with an Engineering Process Group, with members from software, system engineering, quality, configuration management, business development, process improvement, etc. They needed this joint structure to achieve joint improvement. The resulting processes are credible because they have a representative from each area in the group. When they establish processes in software, they need involvement of estimators, managers, etc. It is beneficial to put all groups together in the process group so they define processes together, and allow for a more natural progression. This was the biggest benefit: to have everyone work together. As they pulled new organizations into the company (by merger), the process group was able to deal with the mapping and the processes in the new organization.

Question: If an organization is starting from scratch (no previous CMM experience), do you recommend first focusing on software and then including other engineering areas? Or should you go for them all concurrently?

- One organization embarked on an enterprise level improvement effort by first getting software to Level 3. They wished they had done it all together from the start. Software had a lot invested in their approach, and had to convince others that their way was good for all.

Conclusion: Depending upon the organizational circumstances there were examples described that support both positions – software can be an inspiration for other parts of the organization, or it can be best to introduce change across the entire engineering organization at one time.

Another organization implemented ISO 9001 first, then Software CMM, then TQM in 1995. They included Human Resources and other areas, including marketing, into their TQM implementation. They will limit the use of CMMI while still looking at the enterprise through TQM and benchmarking.

CMMI reinforces the shared model—defining high leverage process areas for all of the organization. It highlights commonality and areas for integration.

If an organization is looking at leveraging high maturity experience to areas with no maturity, the CMMI Generic Practices (GPs) are the basic behavioral principles that can be used in any discipline. They become a model to use in every discipline. The set of GPs is a candidate for high leverage processes for different areas. Generic practices can be used in many areas for process improvement.

5.4.3 Impact of Organizational Mergers

What is the effect of organizational mergers on high process maturity? Some examples follow of high maturity organization experiences with acquisitions, mergers, and reorganizations and its associated effect on blending processes and process maturity:

- One large company of approximately 8500 people integrated another organization of approximately 2000 people together through a merger. In discussions on the process standard to be used for the newly formed organization of 10,000 people, the company level process group began to talk about what level of process commonality should exist across the organization. The standard process existed prior to the merger; however, it was recognized that the existing process standard might not be immediately achievable by the new parts of the organization. Representatives from the new part of the organization participated in the company process group to review the process standard. The company process standard, which is the set of minimum standard processes to be used for all organization, covers 20 processes. Each process is represented in about 1 page of structured English text and is task oriented. As a result of the merger, the process standard was modified so that the level of detail was raised for the newly formed organization to something that everyone could live with, that their supporting procedures could support, and that everyone across the organization could use the process standard. As the revised higher-level standard was adopted and deployed by the newer group, then the company process group could revisit the level of detail in the standard. The process standard began to get more detailed as more parts of the organization used similar processes. At a later point in time when a second new group was incorporated into the company, the review of the processes began again to determine what lowest common denominator of standard process could be accepted across the board. The detailed process information was captured and retained during these revision periods so that the processes could be tailored subsequently and include the details as appropriate.
- Another organization of about 2200 software people tried a similar approach when affected by a merger. One of their big struggles was with the customer Defense Contract Management Agents, who report to different program offices. The program offices were resisting the standardization of processes, because they are site focused. They are comfortable with the way things are and don't want to see changes. In this case, if the customer was allowed to drive the standardization, then there could be backward, instead of forward progress.

In addition to the software process impacts associated with mergers, there was discussion of impacts to areas such as Human Resources, marketing, financial practices and the importance of these issues. In one company, there was focus on workforce issues (e.g., through the People CMM) once the high level process group was established and the technical processes had achieved a high level of maturity.

In one organization, the affected groups had to evaluate their compliance to the standard process through their implementation of it. This included use of tools and detailed procedures in implementation of the standard process. For example, the configuration management process standard contained a list of required tasks. Different parts of the organization used different configuration management tools; however, as long as the tools accomplished the required tasks and roles in the high level processes, then there was no need to change tools. If the tools in use did not accomplish the required configuration management tasks, then that part of the organization needed to show how it would accomplish all of the required tasks from the standard. In some cases this resulted in a change of tool use. New projects were expected to use centrally supported tools. A similar approach was used in evaluating the compliance of low-level procedures and their support of the high level process. If part of the organization used a procedure that accomplished all the required standard tasks, then it could be maintained. Commonality was sought where it made sense. For example, different kinds of peer reviews were being practiced in the organization. To try and standardize the inspection process, a formal kaizen event was conducted on inspections. This resulted in the same form of inspections being adopted throughout the organization.

In another organization, mapping and standards were in place across the new organization, but training and implementation were lagging behind a bit. In addition, there was some resistance to things such as quantitative management. So, that part of the organization does not achieve maturity level 4 in the targeted time period (e.g., 6 months.)

One organization divests itself of part of its group. The Level 4/5 group ended up trying to maintain their maturity level through "tribal knowledge." They winnowed down their documentation, but found that they did not have enough detail to adequately train new people. The organization's veterans knew the process, but many of them were retiring. This caused a need to re-document their processes. They struggled through a Level 3 assessment—and are climbing back up. The documentation was not adequate to sustain Level 4 when they lost so many people who had institutionalized processes and had created a stable organization. This organization recommended that documentation be evaluated using criteria of how easily someone can pick it up and learn to do the processes.

One organization represented in the working group was about to be involved in a merger and was seeking suggestions from experienced organizations for what it takes to maintain process maturity during take-over. Some ideas provided from "merger-experienced" organizations were provided:

- Be careful about how senior management describes, documents, and represents the take-over. In one case, the combining of organizations was declared to be a merger and not to be a take-over and that the best was to be combined from each of the merged organizations. However, the management of the combined organization was all from the organization that initiated the merger; which reflected the perception of take-over rather than merger. Teams need to be established as soon as possible and should begin talking before the "thou shall do..." is issued from the top management.

- In another organization, a lot of time was spent getting to know other process people in the organization to establish contacts and exchange process ideas. This resulted in not artificially forcing any combinations.
- In another instance, a Level 5 organization merged into a Level 3 organization. New people began to work with and help the Level 3 folks with their issues. They worked toward renaming processes – no one retained the old process names, but rather worked toward creating some new names that both organizations could live with and did not convey any ties to the past organizational structures.
- It was suggested to be cautious of the snob factor and not convey one organization as "better" than the other even when there are differing maturity levels. Ultimately, there should be common objectives and goals that unite the groups and the "more mature" groups should assist the "lesser mature" groups and do so in humility.
- In order to posture a high maturity company so that the impact of mergers is lessened, it was suggested that metrics be shared with new organization and new management as a part of the familiarization and transition.

5.4.4 Software CMM and CMMI—Key Differences?

One of the new process areas in CMMI is **Measurement and Analysis**. With the Software CMM, it was believed that there wasn't enough measurement represented at lower levels. Even though measures existed for each key process area, they were often considered not to be useful measures. For some organizations that were striving toward Level 4 maturity, they sometimes had to rethink a lot of measures that were put in place at lower level key process areas. Some organizations reported that they did not wait until maturity levels 3 or 4 to do process measurement and quantitative management, but rather that measurement was important to establish at lower levels. The existence of Measurement and Analysis is one of the things in CMMI that may help organizations get to higher maturity levels faster by providing the necessary foundation.

Some lower maturity level organizations may not see the need for metrics because they are so busy just trying to get the basics done. Projects may be producing measurable data, but until the Level 4 processes and improvement methods are established, they may not see any benefits.

One organization reported that they performed measurement for a long time. However, in 1989 they received a letter demanding improvement, because their costs were too high, schedules were unpredictable, and quality was poor. They performed an analysis of producing software from the perspective of cost and schedule—that was better than focusing on quality (alone). They established a solid earned value management process. What did they see in the Software CMM at that time? They were already doing measurement, so they focused on quality and configuration management because that was new. CMMI is saying that measurement is important at lower levels. Organization probably shouldn't try to focus on quality alone, but rather should focus on cost and schedule type issues as well.

Another area of key change in CMMI from Software CMM is the level of **detail** of the **engineering processes** for product development. The questions were raised:

- Is that detail helpful for process improvement or is it a hindrance?
- Is the lack of focus on software a problem or a benefit?

Engineering processes can be used to demonstrate what might be needed and where one might begin in implementing CMMI. The CMMI represents the basics of engineering processes. However, there may be problems encountered during implementation for Information Technology organizations, dot-coms, and/or shrink-wrap organizations, depending on previous experience, types of software development, the criticality of the software and experience with standards in the past. An example was offered of a backend Web company with no existing life cycle, no sense of process or project management or defect tracking yet CMMs could help the start-ups if used well.

The CMMI is not just a set of processes, but a model or a guide to improve processes. It appears some are using the CMMI as a model for their processes rather than as a model for measuring "maturity" of processes. Using CMMI as a model for measuring processes is a viewpoint from a mature organization. So, what can a mature organization do with CMMI? Do they have to rewrite processes? This is the wrong approach; it is not a set of processes. When a mature organization looks at a new model and tries to learn from it, somewhere they need to ask if what they have is adequate or is there something missing. There may be new insights or ideas coming from a new model—and once you know the new idea, you want to implement it and gain advantage from it. Improvement can come from within or can come from outside the organization.

Transition to CMMI means comparing processes against a new model. The CMMI embedded some of what was learned about maturity in organizations (e.g., PCM, TCM, and OID). Does CMMI capture the paths previously taken by higher maturity organizations better than the Software CMM?

5.4.5 Removing Stovepipes to Implement CMMI

How do organizations with Software CMM experience, but no CMM experience in systems engineering, remove stovepipes to implement CMMI? One Software CMM Level 4 organization engaged their systems engineering people. They pulled together their processes to be consistent with Level 3 software processes (on one particular program). Now, some system engineering groups exhibit L1 or L2 behavior, and now they have to deal with this. There are clearly defined interfaces, project-by-project, program-by-program. Software processes are institutionalized, but interfaces to systems engineering are chaotic.

Another organization has two levels of system engineering (aircraft level and detailed system level). Those areas that are associated with software have adopted some of the software practices. This hasn't been transferred to the aircraft-level system engineers. The software organi-

zation pulls process focused behavior—and the spread is slow and resisted. CMMI can bring such organizations to the awareness of process-focused needs—especially when customers say they are going to use CMMI to evaluate them.

When software and systems are tightly coupled, practices do diffuse—but other engineering areas may have no contact.

In one organization, the software process owner is running the software improvement program across the entire organization. The engineering process improvement effort is just beginning with self-assessments, documenting processes, and evaluating tools. The objective is to provide measures to the CEO as requested.

Another organization described a leap-frogging approach. Software engineering was way ahead but systems engineering was working with the software processes. When the company was bought out, it was noted that one of major problems was how different units work together. Systems engineering began an effort to document processes at the organization level to resolve this problem.

Hypothesis: A major difference between low and high maturity organizations is that high maturity organizations have the data to prove and demonstrate that their improvements are successful.

Since there is no mandate to use CMMI, one reason for system engineering choosing to go ahead with CMMI was having seen the success of software engineering using Software CMM.

In another case, a software person moved over to systems engineering because he knew the Software CMM and improvement methods and they wanted him to implement the systems engineering processes. In another, the software manager was made equal to the systems engineering manager, where previously software reported to systems.

Organizations choosing CMMI are making a strategic decision. The VP of Engineering was the sponsor in one case. CMMI should bring another organization closer to looking at business development and evaluation—so sponsorship may be at a higher level.

What made the light go on among senior executives and others? In one case, some people (engineers and leaders) recognized problems in their own area and saw what was happening with process improvements elsewhere in the organization—their initiative drove a bottom-up improvement effort. In another case, an enlightened customer made a huge difference by driving the organization to improvement (e.g., the customer said that they thought it would take a high maturity organization to win the contract). Engineers and program managers have to keep reminding senior executives of customer comments in order to maintain support.

There have been few CMMI assessments at this point. Many organizations are now looking at CMMI, making improvements, and evaluating internally against CMMI. Some organizations are planning for formal assessments in a year or two.

One organization is performing a Pilot Assessment. They formed a steering group at the beginning of the year to plan for the assessment. They have had Intro to CMMI taught on site to about 30 people, then conducted assessment team training. They allowed three weeks for the assessment, plus another week for the training. The goal was to evaluate the assessment method and not to focus on capability levels or outcomes. They are looking at 22 process areas (PAs). They are performing assessments with internal people and providing the data to the SEI. The SEI will take the data and do analysis for comparison with other pilots. A focus of the pilot is trying to reduce the time on site but maintain the rigor of the evaluation. Also, they will have SEI observers who will prepare reports during assessment. They will capture questions about the model as well as the assessment method (SCAMPI).

5.4.6 CMMI Representation – Staged or Continuous?

There was a brief discussion of some of the perceived differences between the staged representation and the continuous representation of the model.

In the staged representation

- the concepts can be communicated clearly with senior management
- there is an element of simplicity to the model structure
- all institutionalization understanding is contained to process areas
- if an organization is risk averse and does not have a process culture, the additional elaboration may help them
- the structure supports top-down process improvement

In the continuous representation

- material is parceled into arbitrary levels
- an organization can pick and choose an area and focus on the particulars of that area
- the 21 processes areas in Level 3 may be overwhelming to new organizations
- an organization can assess progress in specific process areas that are chosen for their business value
- an initial assessment may provide more granularity in results to help in decision-making afterward

There was a discussion of some of the organizational and environmental factors that may influence use of staged vs. continuous representation.

The staged representation works

- best in an organization with strong functional orientation
- in environments that typically do not use Integrated Product Teams, and/or software is not team-based
- in organizations where the management is far removed from engineering (i.e., a closed organization that requires push to management)
- for organizations that cannot use data well, since too much data is reported back from the continuous results
- for very large, differentiated organizations, since the staged results are more easily shared with senior management

The continuous representation works

- for organizations who may not have a real engineering process established/defined/ documented, since they can begin in designing a life cycle
- for organizations who have sophisticated engineering and products, since they may find the granularity and incremental change beneficial
- for organizations that are team-based, IPT-based, and/or management is very close to engineering
- for examination of a very focused area, with few levels of differences

Organizations who come to CMMI and have never done Software CMM will approach the model representation selection process differently. Some organizations may not see benefits of the staged representation, which software folks take for granted. Some organizations and customers need the constraints of the staged representation; while others find they cannot stand staged.

Organizations with experience using the Systems Engineering CMM and continuous assessments with a Software CMM experience-base react differently than organizations where software and systems were more separate and using different models.

When doing CMMI and communicating adoption principles to the higher executive level, this level of management may or may not have engineering background, model knowledge, etc. to fully appreciate the concepts of the model differences. Executives do not want to have to make decisions about subtlety. If an organization chooses to adopt CMMI, they have to figure out how to clearly communicate in concepts that can be understood by senior management (i.e., concepts that are based on business, not models.). In an organization where Software CMM has been used, senior management will still probably be conditioned to ask about maturity level ratings.

Even though there are multiple representations, it is not necessary that an organization stay with just one representation or methodology.

Both the continuous and staged representations of the model can help organizations get to maturity level 5; however, the model does not help organizations go beyond Level 5. The focus beyond Level 5 is uncharted territory for the model. This may require going back to TQM roots and looking at organization goals.

An organization may choose to focus on improvement of observable behaviors by applying the generic practices from CMMI. They can be used to communicate and work with improvement in organizations with a history of TQM. TQM was not based on clearly observable behavior; however, CMMs contain only observable behavior.

The CMMI model needs to be used and understood. Selection of the representation, or determining when to do what in terms of process improvement implementation, is coupled to both culture and perspectives of the organization and stakeholders. The model helps because an organization can make choices even within the model for improvement priorities.

5.4.7 Commercial or Other Software-Only Organizations

How will CMMI apply to commercial or other software-only organizations? What cautions and opportunities does CMMI provide the commercial software-only organizations? One organization has been doing improvements based on Software CMM principles across the entire company. They have been looking at CMMI generic practices and common process areas for the whole company and use the engineering Process Areas to improve where applicable. They develop software only, but they still have problems with product lines and problems with requirements. The differences between software-only companies and those working with large systems is one of scale rather than of engineering practices. They haven't seen problems with interpretation of practices—they have handled interpretations of terminology and scaling down practices to work in a small company. For example, they use a general Review Board for requirements control, configuration control board (CCB), and process reviews. They relied upon a former SEI staff member to help with interpretation during the first year of transition from Software CMM. After that, they did their own thing. CMMI makes explicit what they were doing already in using the Software CMM principles across the organization (i.e., the generic practices).

What part of CMMI might software-only organizations find irrelevant? Very few elements are believed to be irrelevant to most organizations, except for acquisition. All of the engineering practices may be applied to software only organizations. All organizations interpret models to satisfy business goals and objectives. Differences in interpretation come from differently sized organizations, or those with different outputs or products. What process areas are more important in a particular company? None of the practices are unimportant—some may be more important or implemented differently, depending on the context.

Concern: The maturity levels have gotten very large (large number of process areas). Is it possible to extract the process essentials at different levels?

Organizations have to tailor the model to their specific context. Determine what you want to accept and what you don't need. This is the key to making the CMMI work in different organizations. Is it easy to tailor this model? If you don't want to use part of the model, you should document your reasons so you can explain this to an evaluator or assessor. With a large project and teams, you can take slavish obedience to CMMI. Smaller organizations may need expert knowledge in tailoring the model. CMMI is larger than Software CMM, but it may have lost some of the essentials. There is a dichotomy between being lean and providing information that helps users and assessors. Everything in CMMI is right in line with what are called "lean practices," but it is 700+ pages.

In 1997, high maturity organizations were concerned they were losing senior management sponsorship because they had made it to Level 5. Still true?

These days, senior management sees Six Sigma, Lean, and CMM as different initiatives, although they are all basically the same. Six Sigma became an initiative in TQM and was recognized to be of value beyond software and system engineering. It became the focus of all workforce practices. By defining defects in other processes, e.g., marketing, Six Sigma became the umbrella, and for software and system engineering, another tool for SPC. At one organization, all senior management are green belts in Six Sigma. They set quantitative goals for their areas. Executives that came from different backgrounds and from different companies are now all working together under this umbrella.

If we are saying that the basic Software CMM improvement process can be tailored for any environment, why is the CMMI model different? Why is it bigger? Case-specific tailoring sometimes leaves out specific practices. The assessment time is longer. It isn't clear that a given organization needs to adopt all of the practices in CMMI and whether that would improve the bottom line.

What practices in the CMMI are not applicable? The consensus is that software organizations will apply all of the practices in CMMI. How is it too heavy? Implementation of CMMI should be focused on continuous improvement not on assessments. CMMI is a process model not just a set of best practices to evaluate the maturity of an organization.

Do the engineering PAs add value to software-only organizations?

The Risk Management PA will strengthen weak areas that haven't been able to communicate to senior management. The continuous model with its focus on continuous improvement is opening up areas for process improvement. At least one organization is using the CMMI as a checklist for finding improvement opportunities in their current engineering processes.

Another organization adopted the Software CMM and Systems Engineering CMM with one single process group. They had been continually comparing the two CMMs, wanting to emphasize the similarities, and CMMI helps with this. Now everyone is working toward one model.

CMMI seems to be providing a logical extension to what many organizations already had for software. In many ways, it can be considered a kind of a super-set of the Software CMM. If so, why are they separate programs (Software CMM and CMMI), without a clear progression from one to the other? Why does Software CMM have to be "sunsetted?" Why isn't there a logical progression from software CMM to CMMI—training, assessment, everything? We need to ask the SEI this question.

5.4.8 Alternative Practices

Do Level 5 organizations develop very different alternative practices? Are there differences based on organizational structures (e.g., hierarchical vs. flatter)? This issue was raised in the working group; however, was not discussed during the working group session.

5.4.9 Recommendations for High Maturity Organizations

The group discussion expanded to cover wider maturity with respect to CMMI adoption rather than just higher maturity. Much of the discussion centered on strategic issues and business decisions of model selection. It was noted that CMMI offers the wider maturity option and a broader opportunity for integration of disciplines.

As a result of the working group's discussions, the following recommendations for organizations seeking to achieve high maturity were formulated:

Recommendation HM-1—High maturity software organizations have some valuable lessons learned that other organizations can use in advancing through the maturity levels and as other organizations mature through CMMI. Implement measurements early, set up an engineering process group, peer reviews and other forms of verification, process improvement adoption lessons learned.

Recommendation HM-2—There are not huge differences between CMMI and Software CMM, so that is comforting. Follow TQM principles during strategic planning; identify marketing areas and operational direction. If you have an initiative that crosses the organization (i.e., establishes an "umbrella"), it becomes easier to deploy CMMI due to a common framework.

Recommendation HM-3—Industry has to examine territory beyond maturity level.

5.4.9.1 Observations

In addition to the observations above, the working group identified a number of other observations relevant to high maturity organizations. These were:

- Level of impact and effort in a high maturity organization should be minimal due to natural extension from Software CMM to CMMI.
- Selection of the Staged versus Continuous implementation may depend on some cultural, environmental, and management factors.
- CMMI can be especially beneficial to organizations with less mature Systems Engineering groups.
- CMMI provides commonality in process improvement across Software and Systems engineering disciplines.
- CMMI assessments, formal and/or less formal, can be used to assess the feasibility of application of the CMMI practices and assessment method for an organization.
- CMMI generic practices can be successfully applied to non-engineering business areas to support process improvement.
- Basically CMMI has broadened the base. Implementation has more to do with size of the organization than with disciplines in the organization.

It was also noted that the cost for process assessments is very high, and that the SEI needs to provide a less expensive and less time-consuming assessment method for CMMI. The three classes of planned CMMI assessments were briefly discussed. Class A assessments reflect the rigorous process used in order to achieve ratings and proclaim results to the world. The Class B and C assessments are designed to be more lightweight methods that cost less but are a quick check of where an organization stands against the model.

5.4.10 Recommendations for the SEI

As a result of the working group's discussions, the following recommendations for the SEI were formulated:

Recommendation SEI-1—Why is CMMI not considered Software CMM Version 3.0? Why is there not a logical progression from Software CMM to CMMI (in models, training, and assessment methods)? In lieu of such a progression, organizations will have a more complex transition.

Recommendation SEI-2—Develop a CMMI time-bound release plan for industry involving all aspects of the organizations (e.g., marketing, Human Resources, etc.). Take an enterprise-wide assessment approach, e.g., Malcolm Baldrige.

Recommendation SEI-3—High maturity organizations have learned how to quickly and intelligently implement continuous process improvement. Capture those lessons learned for

the sake of others and provide industry a road map to get through the model. That information could be used to fine-tune the model (e.g., case studies).

Recommendation SEI-4—Software CMM has established itself as an international de facto standard. It is not desirable to risk that investment by a badly managed transition to CMMI, such that the user community loses faith in CMMs. The defense/aerospace industry community alone cannot keep CMMI alive and surviving; it has to be accepted around the world. Establish industry-wide support and buy-in, including involvement from the commercial sector. CMMI has been focused on too narrow of a world (initially). Ensure that software-only organizations can see that the model works for them too and that there are clear guidelines of the model for application to software-only organizations.

5.5 Working Group 2.1: Statistical Techniques

The participants in this working group included Joan Romine, Gerry Ourada, Jim Vanfleet, Bill Curtis, Phil Sperling, Ashok Sontakke, Bruce Boyd, Anita Carleton, Dennis Goldenson, and Mark Paulk.

The working group leader was Bill Curtis. The facilitator/scribe was Dave Zubrow. The recorder was Will Hayes.

5.5.1 Hypotheses and Observations

The questions that inspired the creation of this working group included:

- Do high maturity organizations use control charts? XmR charts? U-Charts? Other charts? On what data? On what processes?
- Do high maturity organizations use regression analysis? On what data? For what purpose?
- Do high maturity organizations use tests of hypotheses? On what data? For what purpose?
- Do high maturity organizations use multivariate analysis? On what data? For what purpose?
- What other statistical techniques do high maturity organizations use? On what data? For what purpose?
- What statistical techniques (if any) must an organization use to be validly considered high maturity?
- What is the business value of statistical techniques that has been observed? Is it worthwhile?

During initiation of the working group, the following questions or observations were posed by the working group members:

- Managers generally do not have an understanding of statistical methods. Training in basic statistical concepts and methods is needed before introducing Level 4 practices.
- Levels 4 and 5 and Six Sigma need to be integrated. Six Sigma is a set of analysis tools used to facilitate process improvement. The similarities between Levels 4 and 5 and Six Sigma are too great to treat Six Sigma as a "new approach." The software community needs to better understand Six Sigma to learn how it can best be used to direct process improvement.
- The working group was in complete agreement that metrics and process improvement activities must be tied to business results. The Goal-Question-Metric (GQM) approach to defining metrics ensures this link. Practitioners need to keep in mind that the success of a measurement program is determined by the successful achievement of business goals.
- Most examples demonstrating the use of statistical techniques involve inspection or defect data. Statistical process control has primarily been focused on analysis of peer review data (the members of the working group reported use of u-charts or z-charts to analyze this data). The software community needs to explore how other types of data (e.g., cost, schedule, reliability) can be analyzed to improve processes.

The issues that the working group decided to discuss in more detail were

- Level 3 measures often not adequate to support Level 4
- What is required for Level 4?
- Relevant statistics
- Use of organizational capability baselines

5.5.2 Level 3 Measures Often Not Adequate to Support Level 4

The measures used by Level 3 companies generally stay at the project phase level and do not provide the granularity needed at Level 4. The Software CMM needs to provide better guidance on the measures to have in place at Level 3 in preparation for Level 4. The focus for these measures needs to go beyond just cost and schedule; it is also important to measure quality at Levels 2/3. Measures that provide valuable insight and control should be used by all organizations, regardless of maturity.

5.5.3 What Is Required for Level 4?

Some courses and consultants have stated that

- Level 4 requires control charts
- every process must be under statistical control

The software community needs to understand that there are many statistics relevant to process improvement. Statistical process control is one statistical technique that has its purpose, but it should be treated as one tool in a "process improvement toolkit." Control charts done badly (e.g., when sources of variation are large and vary widely across process events) is

worse than not doing SPC at all, since it can give a false impression of process stability (large variation with little predictive value). In general, classic SPC should be used in situations where sources of variance are better controlled. It should be used because it is the correct analysis technique, not just to achieve Level 4.

5.5.4 Relevant Statistics

Statistics should be matched to the purpose for the analysis—prediction, control, or understanding and improvement. High maturity organizations have a limited view of the relevant statistics to achieve these purposes. The working group discussed a number of statistical techniques that have proven to be useful outside of software development, but are rarely used by Level 4 or 5 companies:

- Multivariate methods for exploring and understanding sources of variance
- Non-parametric statistics for unusual distributions
- Reliability and statistically based testing for determining operational performance profiles
- Bayesian methods

These and other more advanced statistical methods should be explored further to understand their benefit to software development.

5.5.5 Use of Organizational Capability Baselines

The usefulness of organizational capability baselines is dependent on aggregating data at the appropriate level, and selecting the right attributes to determine which projects are "similar." However, often organization-wide baselines are not meaningful to projects. Once data from many projects has been combined, the value to an individual project (e.g., for prediction and control) is limited. Therefore process performance baselines also need to be maintained at a lower level of detail.

The members of the working group reported maintaining process capability baselines for the following:

- productivity
- delivered defects
- in-process defects (defect profiles by phase)
- defects per LOC, defects per hour for each type of peer review

5.5.6 Recommendations for High Maturity Organizations

As a result of the working group's discussions, the following recommendations for organizations seeking to achieve high maturity were formulated:

- Get competent statistical guidance with experience beyond manufacturing.
- Let the data and objectives determine the statistical methods used.
- Set quantitative objectives tied to business goals.
- Simplify the presentation of statistical results.
- Use data to gain understanding and control (Level 4) and guide improvement (Level 5).
- Learn about Six Sigma and the tools it offers for Level 4 and 5 activities.

5.5.7 Recommendations for the SEI

As a result of the working group's discussions, the following recommendations for the SEI were formulated:

- Improve CMM/CMMI to focus on implementing quantitative management rather than focusing too narrowly on a specific method of implementation (i.e., SPC).
- Perform research and offer training on quantitative methods in addition to SPC.
- Continue to capture and disseminate community experience.
- Encourage Level 4 and 5 organizations to publish their results and insights.
- Provide better guidance and training for Lead Assessors.

5.6 Working Group 2.3 – Change Management and People/Cultural Issues in High Maturity Organizations

The participants in this working group included Julie Barnard (United Space Alliance), Lynn Carter (SEI), Eileen Forrester (SEI), Bill Hefley (Q-Labs), Christian Hertneck (Siemens), Bob Hoekstra (Philips Software Centre), Judah Mogilensky (Process Enhancement Partners), Lynn Penn (Lockheed Martin), Lita Schulte (Boeing), Somashekhar R.H (CG Smith Software Ltd.), and Gian Wemyss (SEI).

The working group leader was Bill Hefley (Q-Labs). The facilitator was Eileen Forrester (SEI). The scribes were Diane Gibson (Carnegie Mellon University) and Lynn Carter (SEI). The recorders were Gian Wemyss (SEI) and Christian Hertneck (Siemens).

5.6.1 Hypotheses and Observations

The questions that inspired the creation of this working group included:

- Does your high maturity organization do periodic surveys of employee satisfaction?
- Is turnover less in high maturity organizations? Do some people leave the organization as a result of disliking the process discipline? What impact has that had on organizational capability?

- What percentage of workers participate in improvement?
- How many process improvement proposals per engineer per year are being processed? Would a target of 10 / eng / year be reasonable?
- What percentage of improvement proposals should be accepted? Would 70-80% be reasonable?
- What latency should improvement proposals have before closure? Would five working days be reasonable?

Other questions that were raised by the facilitator from the SEI's Accelerating Software Technology Adoption (ASTA) initiative included:

- In your organization, is the motivation for adopting technology most often driven by external demand (customer needs) or internal needs? Both?
- What are the characteristics of an effective "program" of technology change management (TCM)? Are good TCM programs all similar or do they vary? Can we make any judgments about what works best in different settings?
- Are you using any models (besides the material in CMMs) to guide your implementation of TCM? What has proved most useful?
- Do you notice any differences between change management for process innovations and for all other types of technology? What metrics do you find most useful to collect on TCM?
- How do you monitor new technologies?
- Do your TCM practices seem to work well for both disruptive technologies and for incremental improvements?

During initiation of the working group, the working group members posed the following questions or observations relating to change management:

- Cycle time for process improvement activities
- Evidence of enterprise wide technology / process change management approach
- Quantitative evidence of process improvement proposal participation in organization
- Constructs of automated tool for managing process improvement proposals
- Benchmark data on processing time / scope / size of process improvement proposals from high maturity organizations
- Report of experiences on innovative approaches to encourage broader participation in submitting process improvement proposals
- Understanding of how TCM (a Software CMM maturity level 5 key process area) is operationalized in an organization
- Capture examples of TCM practices
- Identify candidates for TCM studies

During initiation of the working group, the working group members posed the following questions or observations relating to people and cultural issues:

- Changing in the face of change (mergers / acquisition / reorganizations)
- Learn what barriers to change (people / cultural barriers to process improvement) have been faced by organizations
- How to maintain momentum when growing big
- How to get *EVERYONE* involved in improvement
- Learn ways in which organizations have overcome the people / cultural barriers that they have faced
- Methods used to increase employee satisfaction with process improvement
- Retention activities
- Employee attrition as connected to high maturity
- Are yearly surveys enough?
- How to measure management maturity and their impact on organization maturity
- How do you continually measure employee satisfaction
- Methods / measures used for employee satisfaction
- Information on formal adoption of employee satisfaction surveys
- Hear pitfalls / issues re: people and change in high maturity organizations

The issues that the working group decided to discuss in more detail addressed both change management and people / cultural issues. The four issues in these two categories discussed in more detail were:

- **Change Management**
  - Identification, evaluation and monitoring of potential changes
  - What is an effective change management process? (i.e., how do high maturity organizations make change happen?)

- **People and Cultural Issues**
  - People / cultural / value issues and barriers
  - Employee attrition / retention / satisfaction

5.6.2 Identification, Evaluation and Monitoring of Potential Changes

The group's discussion of identifying, evaluating, and monitoring potential changes flowed into a broader discussion of effective change management processes, of which identifying, evaluating, and monitoring potential changes are the early stages of a robust, effective change

management process. The topics discussed here confirm earlier observations regarding high maturity organizations [Paulk 00], which include the following:

- Focus of improvement activities is both strategic and tactical, while clearly understanding that continual improvement depends on universal participation.
- Apply PDCA cycles and Deming's "System of Profound Knowledge."
- Identify and select new technologies and process innovations based on organization's process improvement goals, business case, and objective criteria.
- Use analytic techniques to understand the impact of proposed changes.
- Plan and manage deployment of the whole change.
- Establish measurably better and better processes (and products).

5.6.3 Effective Change Management Processes

Organizations represented have in place effective change management processes; each tailored to their unique environments. However, in discussing the question "What are effective processes (or best practices)?", it was evident that similar process architectures for the change management process were typically implemented in these organizations. This paragraph provides a summary of this change management process, which is shown in Figure 37.

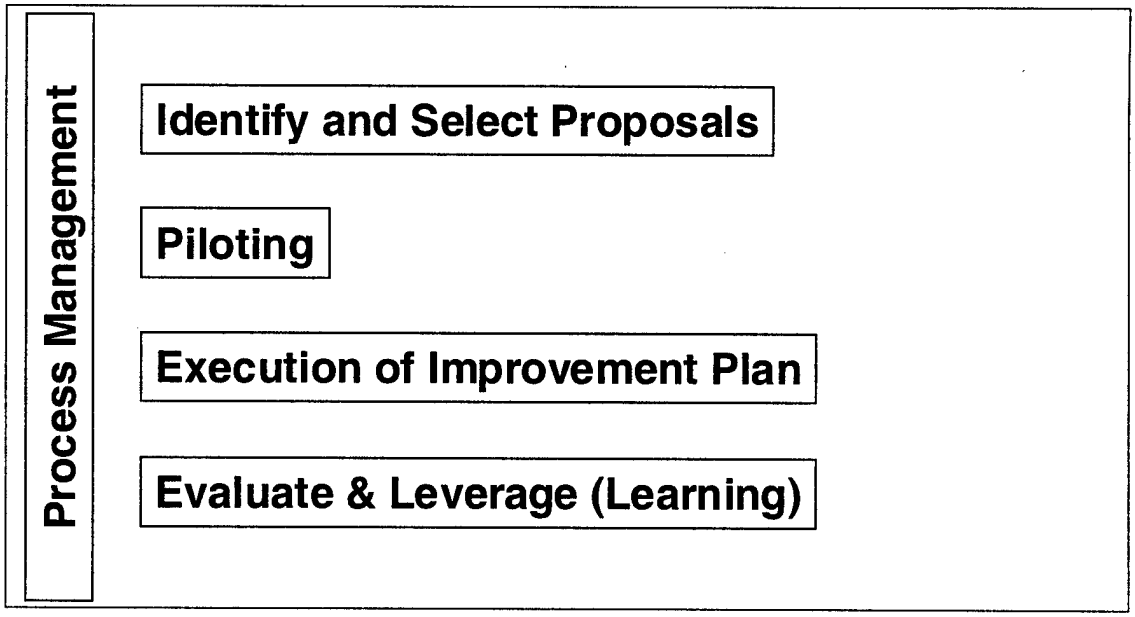

Figure 37: Change Management Process

The first component of the change management process was to identify and select improvement proposals. The process improvement proposal process is widely communicated across the organization. Without communicating this, and ensuring that individuals know that there

are ways to suggest improvements, organizations do not always ensure that they will overcome a key barrier to effective change management—people do not always understand that change applies to them. Some organizations reinforce this communication and solicitation for improvement proposals by employing various reward mechanisms. These include individuals receiving a lottery entry for some prize as a result of submitting suggestions for process improvement or other similar recognition and reward mechanisms.

Once the process improvement proposal process is communicated, it must utilize appropriate sources of improvement proposals to collect improvement proposals from across the organization. Numerous sources and mechanisms were reported to be in use by high maturity organizations, as shown in Table 5. Once the improvement proposals are received, each is classified and evaluated. Where appropriate, pilot activities are instituted to select what level to institutionalize.

Process management activities deal with evaluating the proposed changes and selecting those to implement. Some organizations apply process modeling and simulation to model the current process. Data on current process performance is also evaluated. The evaluation examines performance before and after implementation of the proposed process improvement. Six Sigma techniques are used to determine what part of the process to "attack." Planning for implementing the approved improvement proposals is begun, and plans are tracked until the process owner (or relevant individual) closes the internal improvement plan. Verification of the process change is made after the change is institutionalized by analyzing the before and after states for expected values.

The second component of the change management process addressed piloting or trial use of the proposed improvements. Improvement proposals are classified, and, in some organizations, this includes a determination if a change is a minor or a major change, as major changes are piloted. Pilot activities are planned, when appropriate. For identified pilots, budgets and schedules are prepared and evaluation activities are planned. Appropriate measures to support the evaluation of the proposed improvement are developed. Pilot activities are carried out to determine the effectiveness of the proposed change, how best to implement the proposed change, and at what level the proposed change should be implemented.

Table 5: Sources of Improvement Proposals

Primary Source of Improvement Proposals	**Mechanisms Used to Collect Improvement Proposals**
Internal staff	Quality system change requests (bottom-up) Improvement proposals Interest nets (like news groups supporting discussion and measuring interest) Expert net (mentors or coaches) Support center (SEPG) Request for tools

Primary Source of Improvement Proposals	Mechanisms Used to Collect Improvement Proposals
Management	Policy deployment from high level goals (top-down)
Internal and external benchmark organizations	Best practices quality improvement team, performing internal and external scans
SEPG	Process audit and process compliance activities as a source for best practices
Technology group	Annual technology plan – technology planning as an integral part of business planning and forecasting, answering the questions, "What are our customers expecting us to offer and support?" and "What technology is needed to support new processes?" The technology plan is often the tactical implementation of the strategic plan.

The third component of the change management process is to implement the proposed change according to the approved execution or implementation plans. Three activities were identified as essential in implementing changes. The first activity is training. Training issues included not only considerations for providing training to support specific changes implemented, but also considerations for supporting ongoing process training needs. Examples of these other ongoing training mechanisms used included:

- building a discipline of reviewing each process before invoking the process, ensuring that only the most recent instances were invoked
- ensuring that each individual completed an annual process training module, which is a mandatory process training event

The second activity is executing a disciplined process for managing the implementation, including release management considerations for controlling releases of new processes or tools into the workplace.

The third activity is communicating about the planned change. Communication about changes being implemented was identified as being quite important. Communication topics covered business objectives being satisfied or supported by the change, notification about the changes themselves, and information about training to support the change. Specific mechanisms used to support communication about processes and process changes include using common process repositories, distributing automated notification of process changes, and sending weekly change email for changes to the process asset library (PAL).

It was identified that communications regarding changes is quite important, as it can be a key mechanism for overcoming barriers to successful implementation of changes. Identified barriers that communications can help to overcome include people not always learning of changes and people not always understanding that the change applies to them.

The fourth component of the change management process is the crucial steps dealing with evaluating and leveraging from the change, or learning from the improvement. This is ad-

dressed in high maturity organizations both at the level of evaluating the impact of individual improvements, but also in the aggregate to evaluate the overall process trends. Examples of measures used in these evaluations include ROI and customer satisfaction. Other measures are addressed below.

In parallel with all the other change management activities, the organizations maintain an ongoing set of process management activities. These activities are consistent with a range of process management endeavors and typically involve participants from the organization, the SEPG, and its management steering committee. Process Management activities reported include:

- process performance analysis, including data analysis by the SEPG of data from individual projects
- process coordination, including those activities associated with
  - the process owners and updating and refining processes
  - configuration control activities, such as a CCB and managing the periodic releases of updates to the organization's set of standard processes
  - a process board (e.g., a management steering committee or enterprise executive steering committee)
- ongoing communication about change management activities, including communication about changes, holding process improvement forums for all departments (which meet twice a month), and communicating the status of change management activities

5.6.3.1 Essential Change Management Functional Roles

A number of roles were identified as being essential to the change management process. These are functional roles, each having a specific function that may be implemented in a variety of different ways, depending on the specific organization. These roles and their typical functions are as follows:

- senior manager/sponsor: providing leadership, commitment, and support for process definition, maintenance, and improvement
- strategic planning: setting direction for the organization and the processes it must deploy
- process management: manages a set of standard processes; responsible for process performance analysis, process coordination, and relevant configuration control activities, including CCB
- scanning: performs benchmarks and monitors external sources to identify best practices or potential innovations that may be useful to the organization
- process owner: defines and maintains a process. At the organizational level, the process owner is the person (or team) responsible for the description of a standard process; at the project level, the defined process.
- process consultant: provides subject matter expertise and consulting on specific processes or tools
- individual initiator: generates or initiates improvement proposals

Examples of these roles in place in high maturity organizations included the following:

- senior manager/sponsor
  - upper management leadership and support
  - process board (enterprise executive steering committee)

- strategic planning
  - technology group to screen technology requests
  - university partners forecast technology changes and needs
  - corporate research

- process management
  - SEPG as process owner
  - SEPG analyzing data from individual projects
  - change control board (corporate quality)
  - process control board (procedural activities, regionally based)
  - SEPG as CCB

- scanning
  - TCM committee as part of the SEPG
  - TCM role in quality management systems

- process owner
  - SEPG as process owner
  - individual people as process owners (autonomous)

- process consultant
  - subject matter experts
  - SEPG as process consultants

- individual initiator
  - process improvement forum, all departments (meet twice a month)
  - task force as improvement owner
  - inputted/initiator of process improvement proposals

5.6.3.2 Change Management Measures

Organizations reported using a wide variety of change management measures. These measures addressed outcomes of the change management process, the status of the change management efforts, evaluation of change management actions, and the utilization of innovations or improvements.

Outcomes measures addressed both employees and customers, as well as the impact of changes as financial measures (e.g., ROI) and other tangible impacts. Employee satisfaction data was often collected at multiple levels, including a corporate level; a process level en-

compassing those who use a process, a site or location, and a specific project. Collected metrics provided insight into general employee satisfaction as well as satisfaction with the process. Asking employees for this latter metric was sometimes seen as a demotivator, however. Some organizations report using surveys based on the People Capability Maturity Model with both manager and non-manager populations as a means of determining outcomes of improvement. Financial measures were addressed in the represented organizations both as ROI of proposed changes and as ROI of the implemented changes. Other tangible impacts of changes were determined by examining the impact of the change in measures of productivity, defects and quality. Customers also provided outcomes data through customer satisfaction or customer intimacy surveys, as well as interviews. This customer data, as well as other tangible data, could be examined using trend analysis for determining the impacts of the changes implemented.

Status measures were used by high maturity organizations to track the volume of improvement proposals or requests for assistance, as well as the status of each. In one organization that used a formal mentoring structure to identify improvement needs, one measure of volume was the demand for experts (i.e., mentors) and the support center. Other organizations track the number of process improvement proposals, classified and reported by process and their severity (i.e., major or minor). Some organizations report assigning improvement proposals as priority, and also use this as an additional category in tracking improvement proposals. In addition, the progress of improvement proposals is tracked, so the organizations know the status of each, how many are completed, the planned and actual schedules for each, and the aging (or latency) of each proposal in the change management process. A drawback to using raw measures of quantity is that such measures are not always normalized per person in the organization, and may not provide a meaningful insight into the true volume or rate of adoption of change management (i.e., continual improvement) practices as an integral part of individual's work. However, those organizations using PSP/TSP have specific measures of the number of improvement proposals generated by each trained engineer.

A number of measures were used to support evaluation of process improvements. These included standard tool evaluation measures, such as ROI, the usability of the tool, satisfaction of current tool users, and data indicating the volume of use. Volume of use could address adoption rates organizationally (i.e., number of projects adopting the innovation) as well as adoption rates within each project. Other measures used to evaluate potential or implemented improvements included simulations of processes. Six Sigma techniques were also used to evaluate and narrow down options to the most effective improvements. Other evaluation measures were based on pre- and post- implementation questionnaire data. In one organization, these questionnaires were based on a standard set of questions from a repository of relevant questions

Utilization measures provide another means to gain insight into the processes and tools used in the organization. When viewing the change management process as yet another process in the organization's set of standard processes, such utilization measures also provide a way to

gather data about the change management process. Utilization measures reported in use addressed both tool utilization, as well as process utilization. A variety of process utilization measures were reported in use: number of hits on a Web page for each specific process, data available from process non-compliance reports, and data available from a process compliance matrix. This last approach provided insight into how each project was developing its project's defined process based on the organization's set of standard processes. Each project reported their compliance and tailoring of the organization's set of standard processes into their project's defined process via a compliance matrix. Centrally, this data is kept in a relational database so that it can be analyzed quarterly to provide insight into process adherence and to identify possible improvements to the organization's processes.

5.6.3.3 Tool Support for Change Management

A number of tools were identified across high maturity organizations as being in place to support their change management activities. In addition to metrics databases used to support the measurements above, other commonly used tools included integrated repositories of processes, directories of subject-matter experts and process owners, process modeling and simulation tools (e.g., BPWIN), and desktop tools used to submit improvement proposals. These desktop tools took a number of forms, depending on the technology in use in the organization. Various forms described by high maturity organizations included an "Improve me" button on a screen which sent an e-mail form to the process owner, individual process improvement notes or proposals captured in a Lotus Notes repository, or an enterprise-wide recommendations template.

5.6.4 People/Cultural/Value Issues and Barriers

This section captures the working group's discussions that covered a wide range of people/cultural/value issues and barriers. Consistent with earlier findings [Hefley 99], this group identified that the two most critical people issues facing their organizations were retention and turnover and enabling their staffs to deal with continual change.

5.6.4.1 Retention

Retention was a common concern to high maturity organizations. Retention is addressed further as a separate issue (see "Employee attrition/retention/satisfaction" below).

5.6.4.2 Change Management Barriers

A number of barriers to change management were identified. Many of these are the standard concerns one thinks of when addressing change in human organizations; others are somewhat unique to high maturity organizations. Standard concerns include resistance to change and individuals' hesitation to change. It was noted that it is important to explain why a change is being made and the context of the proposed change to overcome this inherent resistance to change.

Other common issues noted include the perception of process as overhead or that there has developed a perception of bureaucracy involved in managing change. Some organizations report concerns that the organization is undertaking multiple improvement initiatives. In some cases multiple initiatives are seen as resulting in rapid-fire, "flavor of the month" or "change du jour" improvement efforts with one replacing the next, while, in other cases, giving individuals the perception of a high volume of change or too much change happening in the organization. This points to a need to communicate about the change efforts, as the group discussed the need for improvement in a number of areas (see our first recommendation).

Communication is clearly important is overcoming some barriers. People need to understand that they have the time to change while doing their work. People do not always learn of changes, and they do not always understand that changes apply to them.

In high maturity organizations, there is a risk of developing a certain process arrogance or perception that "we are a high maturity organization and we have our act together, so why do we need to do more process improvement?", rather than developing a culture of continual improvement.

5.6.4.3 Process Motivation

Organizations considering moving to higher maturity levels need to be clear about their motivation for continual process improvement. Some organizations strive to achieve or allegedly achieve a maturity level for the wrong reasons, such as having an organizational badge of honor. In such organizations, it is hard to sustain continued improvement, as people aren't bought in to the changes. Some organizations pursue higher levels of organizational maturity because of explicit or implicit requirements of their regional culture or their competitive situation.

In some cases, there is resistance to continued improvement beyond maturity level 3. This is often manifested as resistance because attaining higher levels of maturity is "too difficult" or "doesn't apply to our environment." Some organizations are afraid of higher customer expectations resulting from their attaining higher maturity levels. This is somewhat related to the understanding of "outsiders," such as customers, about what to expect from a high maturity organization. Some organizations report an expectation from customers that high maturity organizations will never produce a defect or that there is an expectation that high maturity means they must be perfect, while high maturity organizations understand that even high maturity processes are executed by humans, and are capable of being fallible and continually improved.

Several issues were addressed as both motivators and demotivators for developing and sustaining a process focus in a high maturity organization. First, as a motivator, there is a need for higher process maturity. In some cases, this is driven by business realities, in others; it is necessary to deal with turnover (i.e., employee departure) rates ranging from ten to fifty percent per year. When experiencing these high rates of turnover, it is essential to have defined

processes in place, as the processes are what will carry the organization forward. In many organizations, the people themselves want high maturity, as they see the benefits that accrue as a result of attaining higher levels of maturity.

As demotivators, some organizations report that they continue to experience resistance to implementing higher levels of maturity from the middle of their ranks. Mid-level personnel are sometimes perceived as caught with a double burden as the organization matures, not only having the burden of managing their projects and producing and using data to quantitatively manage their projects, but also the burden of producing data that is important to the organization to establish organizational capability baselines and establish process performance baselines. In these instances, it has been found helpful to make use of a process consultant as a facilitator to support learning and implementation of higher-maturity quantitative management practices in middle management. In other organizations, it has been found less successful to move this function to a quality assurance function, giving it the role of both enforcing process adherence and trying to cajole reluctant managers into using the processes.

In some organizations, there was reportedly more comfort with TCM issues than with PCM issues. This is somewhat natural, given that software engineering has traditionally had a technology-driven nature, and organizations may feel more adept at coping with technology changes than with process changes. Organizations implementing effective change management processes report that they address both technology and process changes in their change management processes.

The local regional culture can have significant impact on the process motivation of organizations. Areas, such as Bangalore with multiple high maturity organizations, reinforce attainment of higher-maturity, while the culture in other areas, such as Silicon Valley, can tend to be a barrier to process improvement.

5.6.4.4 Culture

Culture issues were also raised involving both developing a culture of continual change and dealing with aspects of culture as a component of a merger, acquisition, or reorganization. Three issues were identified as important in developing and deploying a culture of continual change:

1. changing in the face of change, or dealing with continual need for change and multiple, continuing change efforts
2. acknowledging change and those who do it, providing communication, recognition, and reward for those involved in all aspects of change management
3. intergroup coordination, which is addressed in the next paragraph

Mergers, acquisitions, or reorganizations present difficulties (or challenges) for high maturity organizations. They present issues dealing with process management, such as how much of the processes should be retained in common across the entire new organization, what should

be the standard processes for the new organizations, and how detailed should be the common processes in the organization's set of standard processes.

Other issues in mergers, acquisitions, or reorganizations arise as a high maturity organization acquires a lower maturity organization and develops a long-term process management roadmap. It is important to understand the consequences of the merger, acquisition, or reorganization for process maturity, as well as any potential infrastructure loss.

There are also issues of merging these different cultures and reconciling multiple cultures. Some organizations have expressed the need for a tool to support forms of "cultural due diligence" to understand the culture within the acquired organization. High maturity organizations also report that there is some fear of losing their high maturity achievements as their culture changes through the merger, and the need to establish a new stable level of capability from the newly merged processes.

5.6.4.5 Boundary Management

Boundary management is an important aspect of intergroup coordination. In high maturity organizations, process issues affect, and sometimes exacerbate, boundary management issues. Like cultural mismatches, some of these boundary management issues stem from differences in process maturity. For example, issues may arise on integrated product teams (IPTs) for team members from organizations having differing levels of maturity. High maturity team members don't want to be on IPTs with low maturity team members for fear of damage to their rating. These process maturity mismatches also occur at other boundaries, such as those that the organization shares with its customers, suppliers, and teammates. Some of these mismatches are truly mismatches between levels of capability, caused by differing maturity levels, while others are process mismatches, caused by ineffective or non-existing interfaces between processes. It is especially important when these issues arise that a shared agreement on roles be developed and put into place.

5.6.4.6 Individual Skills for Management, Technical and Process Management

Skill issues cut across all aspects of developing and sustaining a high maturity culture. The most critical aspects of these issues deal with developing individuals to perform effectively in a high maturity organization. The culture (and processes) of the high maturity organization must be transferred to new staff. This infusion of high maturity culture to new staff often requires that new staff go through a transition to shed low maturity ways of doing business, and adopt new, higher maturity practices and skills. There can be a lack of skills or a gap between people and roles as individuals or the organization adapt to a higher-maturity norm. These issues point to a clear need to:

- understand and develop the competencies needed in the organization as it moves to and sustains higher levels of maturity

- gain shared agreements about roles and their interactions, as well as knowledge of each other's roles in teams in high maturity organizations

Bringing new employees into a high maturity organization presents issues in addition to the skills-building issue. Some new employees may be intimidated by the high maturity nature of their new organization, and fail to take part in the change management process. These individuals may have feelings of insecurity, asking themselves, "Who am I to make suggestions for improvement?" In some cases, high maturity organizations have abandoned hiring outside management staff as the challenge of bringing them up to higher maturity performance outweighs the perceived benefits. This shift to exclusively hiring managers from within is because the cost and impact of bringing in outside management people is so disruptive.

5.6.4.7 Interpersonal Skills

Interpersonal issues that can arise deal with maintaining individuals' perceptions of the balance of power, and gaps between people and roles. Making improvements changes relationships between people; change upsets the balances of power / influence. Several concerns affect people's perceptions of power. These include a reluctance by some to give up their power over people and move to management by fact, concerns by individuals about losing their expert power as processes become institutionalized, concerns about resisting the use of data to manage and of being monitored. Attaining higher levels of maturity requires developing new skills for dealing with empowerment for both individuals in the organization and for management. High maturity organizations need to develop ways of helping people who've been addicted to being in power positions to accept a less "powerful" position due to the empowerment of a process orientation and quantitative management by facts.

Gaps between people and roles can also be seen by the resulting symptoms, which appear as interpersonal issues as individuals adapt to change, new roles, new processes, and new ways of high maturity management. Appropriate forms of training, mentoring, and process consultation can address these symptoms.

5.6.5 Employee Attrition / Retention / Satisfaction

5.6.5.1 Retention and Attrition Issues

Retention is a very common issue in many software organizations. This is also true of high maturity organizations. Retention must be managed. One organization reported that management sets retention goals overall and for regions. Management is held accountable for achieving these goals and their performance in doing this is a part of their measurable management objectives.

Coupled with retention is the opposing side of the coin: attrition. Attrition will always be there, so organizations must have ways to deal with it and overcome it. One way is through attaining higher levels of process maturity.

Some attrition in high maturity organizations is perceived to be useful. In these cases, those individuals who excel at being "cowboys" or "heroes" of low-maturity settings or who are "in love" with the romance of Level 1 chaos may choose to leave. These individuals do not feel comfortable in higher maturity settings, and their leaving creates a win-win situation when these firefighters leave a high maturity organization.

In other cases, people who leave high maturity organizations become "boomerangs." Through their initial attrition, they create long-term retention for the organization as they return to their high maturity organizations searching for the high maturity environment that they had left. This is one example of how organizations report that higher maturity helps retain both people and knowledge.

Software professionals have been shown to have amongst the highest growth needs among professions. In high maturity organizations, "career tigers" shouldn't be able to misuse the system as much, only the really able career tigers should be able to succeed (measurably by their projects' successes). To some extent, organizations always need the power hungry (or at least those willing to deal with increased responsibility). This should be supported by clear career paths for these career tigers, but, at the same time, offering possibilities in growth for the technically oriented people who may not want to pursue a management career path.

Salary was discussed as a related issue. It was commonly perceived, as prior studies have shown, that salary gets an employee in the door as a new hire, but salary alone doesn't keep them in the organization. More important are long-term opportunities for employee growth. Some organizations report a mismatch of expectations of college recruits for growth with reality.

Some organizations reported setting regional salaries, based in part on regional or industry studies. Others report salary compression issues, salary mismatches across comparable positions after mergers, and the use of a separate critical (or "hot") skills fund in addition to flexible merit planning for salaries.

5.6.5.2 Best Practices to Support Retention

A number of best practices were identified to support organization retention of personnel. These are summarized in Table 6.

Table 6: Best Retention Practices of High Maturity Organizations

Topic	Best Practice
Communication	Status is communicated simultaneously to all levels, regardless of the management chain
	Management by walking around (MBWA) at all levels of the organization
	Management accessible by hosting lunches, conducting round tables, being available for "skip level" interviews

Topic	Best Practice
	Performance feedback comes to individuals through 360° evaluations
Career Development	Dual career ladders available, providing support for growth through management and technical ladders Formal mentoring programs Job rotation
Teams	Good team relations, cohesion and loyalty Use of teaming Keeping / retaining teams Team formation based on behavioral characteristics (e.g., Myers-Briggs Type Indicator)
Culture	Sense of ownership Meeting-free day (i.e., a business day—not Sunday or Saturday—that is set aside as a meeting-free day)

5.6.5.3 Satisfaction/Retention/Attrition Measures

High maturity organizations routinely gather and use measures of employee satisfaction. This is implemented in a number of different ways and at differing periods. Surveys are typically made not only at the corporate level, but also at lower levels in the organization. These lower levels can include both the site or location and the project level. These local surveys allow a focus on relevant issues that may not affect the entire organization. Surveys are often conducted once or twice annually, while some organizations use a monthly or quarterly survey. Issues addressed in these surveys include employee satisfaction, satisfaction within group, technical and environmental indicators, satisfaction with management, and factors relating to stressors.

Some organizations report using an organizational survey based on the People CMM. The People CMM gives a framework for assessing organizational workforce practices. In some organizations, questionnaires based on the People CMM are perceived as resulting in more actionable items than from their corporate survey. These questionnaires typically provide coverage of most of the People CMM, with full coverage of Level 2, most all of Level 3, and major components of Levels 4 and 5.

Other forms of evaluation include external evaluations by customers, and a "Dilbert quotient," which is a measure of the number of Dilbert cartoons posted in the organization.

In conducting organizational surveys, high maturity organizations understand the need to act on what you find, and not to conduct the surveys, if the organization is not willing to act on results. These surveys provide an additional means of identifying improvement needs or of identifying potential problems. As an example of such results, Figure 38 shows the results of an internal team survey as a "Happy Team Index." Data were collected in a monthly survey in the project, collected into a simple MS-Excel application. Evaluation of the data was done by the project's quality assurance staff.

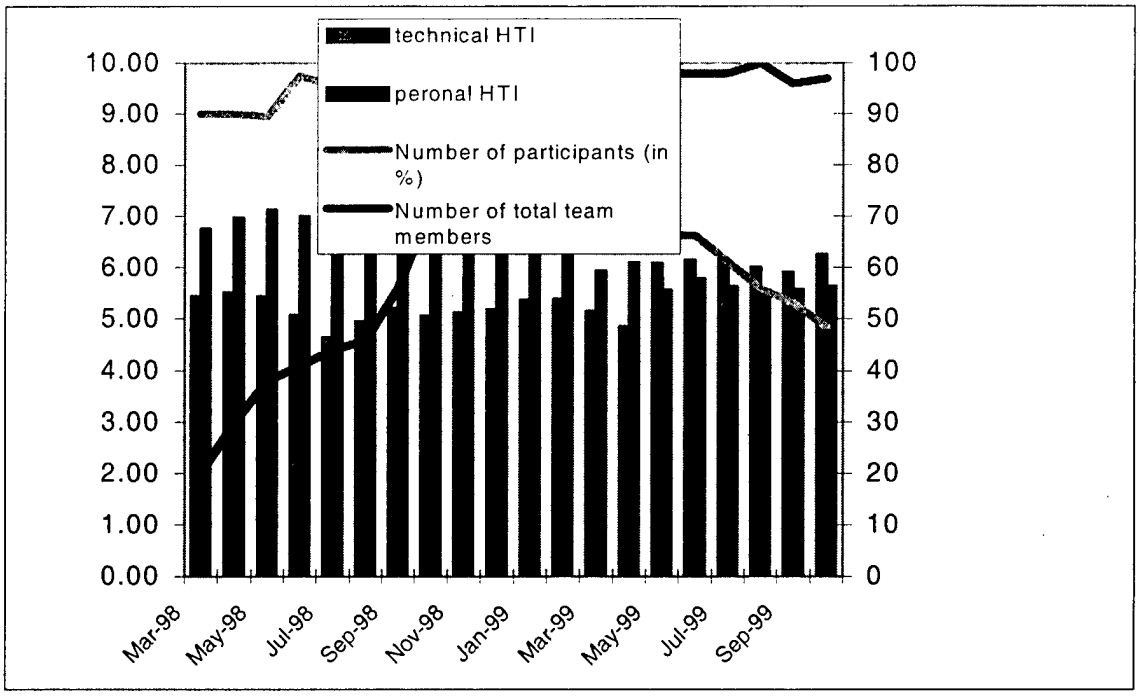

Figure 38: Results of Internal Team Survey

In this example, the survey is based on questions relating to a technical HTI, addressing issues such as technical communication, environment, and the organization; and a personal HTI, addressing the individual's personal influence of project (communication, relation to colleages and customers) and feelings. Each of the questions in these categories is rated from 1-10 (with 10 being the best).

The above diagram shows an example of a troubled project in a lower maturity organization. It depicts a situation you don't want to see in your project: Increasing team size coupled with decreasing participation in the monthly surveys, while the perceived project situation was being reported by respondents as actually becoming worse each month (as rated by personal HTI). Even though the technical environment (technical HTI) seemed to be getting better within the project, the real problem was the internal communication to management and the customer. This project ended in a disaster (with millions lost and a lawsuit pending).

High maturity organizations also report measuring management effectiveness. In these settings, this feedback is part of manager's measurable business objectives. Several techniques are used for collecting this feedback. These include focused surveys, feedback on management from team members (every 6 months), surveys based on the People CMM, and 360° evaluations.

Another example of a template used to collect feedback on management from team members is shown in Figure 39.

This is part of the evaluation at High Maturity Organization (HMO) to make sure that are we meeting the expectation of the internal customer (i.e., you). Feel free to voice your opinions so that we can improve and provide better support, which goes a long way in making **HMO** a **Mecca for software engineers**. We request your comments for the ratings to enable us to further work on all aspects of Total Internal Customer Satisfaction.

The rating scale for the group ranges from 1 to 5:

1–Unacceptable **2**–Needs Improvement **3**–Average **4**–Good **5**–Excellent

Process and Technology Group (SEPG) (Process support, tools, etc.)
1 2 3 4 5
O O O O O
Comments:

Human Resources Dept. (Recruitment, training, grievances, transport, etc.)
1 2 3 4 5
O O O O O
Comments:

Finance Dept. (Salary, travel, reimbursement, etc.)
1 2 3 4 5
O O O O O
Comments:

Administration Dept. (Facilities, parking, coffee/tea, cafeteria, etc.)
1 2 3 4 5
O O O O O
Comments:

System Administration Dept. (PCs, printers, software, services, telephones, etc.)
1 2 3 4 5
O O O O O
Comments:

Feedback regarding Project Members
1 2 3 4 5
O O O O O
Comments:

Feedback regarding Supervisors (Project Coordinators, Project Leaders, Project Managers, Vice-President etc.,)
1 2 3 4 5
O O O O O
Comments:

Figure 39: Management Feedback Template

Employee satisfaction and process maturity are inextricably linked. In high maturity organizations, it is important to have personalized attention, as individuals are contributing members of high-performing teams, and not just robots in a software factory. However, there may be resistance to asking these questions in some settings, as asking about employee satisfaction with processes can get a very negative reaction in a process-disciplined, well-established, high maturity organization that has numerous functioning mechanisms to surface and correct process problems.

5.6.6 Recommendations for High Maturity Organizations

5.6.6.1 Recommendations

As a result of the working group's discussions, the following recommendations for organization seeking to achieve high maturity were formulated:

Recommendation HM-1—Work force management processes must mature commensurate with other disciplines; the workforce expects high maturity in all areas.

Numerous organizations are using the People CMM as a guide in maturing their workforce practices.

Recommendation HM-2—Use broad range of sources for improvement ideas.

Examples of the sources used by organizations are found in Table 5.

Recommendation HM-3—Explore how to do "cultural due diligence" to handle the pressure and risk of acquisitions and mergers.

Some organizations report use of the People CMM to support this need for cultural due diligence. Although a People CMM-based assessment method exists [Hefley 98], a lightweight, Class B or C appraisal technique that provides a common organizational measure could support this need to provide a characterization of the workforce capability of organizations.

Recommendation HM-4—Establish resources and energy for process improvement.

An organization's process improvement activities should actively solicit improvement proposals, encourage participation in proposing and implementing change, and reward participation in effective change management activities.

Recommendation HM-5—If an organization asks its people to participate in change activities, it should make it easy by providing appropriate support (tool support, etc.) and make sure it provides a benefit to the people.

5.6.6.2 Observations

In addition to the recommendations above, the working group identified a number of other observations relevant to high maturity organizations. These were:

- Organizations striving to become high maturity organizations need to develop a culture of continuous improvement throughout the whole organization.
- Participation in improvement is essential across the entire organization.
- The functional roles identified by this working group need to be assigned and in place for effective change management. While this report has provided multiple examples of how to assign these roles to manage change effectively, the actual roles and responsibilities in the organization should be clearly assigned and communicated.
- Effective evaluation of improvements requires understanding of the organization's capability baselines as well as the impact of changes.
- High maturity organizations need to be prepared to manage transition when working with lower maturity organizations and members.
- Organizations should not address change with out addressing the people issues. These issues should be addressed in planning, implementation, and evaluation of changes. In evaluating the impact of changes on people, consider a wide variety of things to measure, such as employee satisfaction, technical satisfaction, stress factors, and management effectiveness.
- If an organization has high attrition, it needs high maturity practices to survive.

5.6.7 Recommendations for the SEI

As a result of the working group's discussions, the following prioritized recommendations for the SEI were formulated:

Recommendation SEI-1—Consider hosting an explicit, ongoing, invitation-only forum targeted to senior management, for example, "a sponsor workshop" to cover roles and skills for sponsors.

Recommendation SEI-2—There should be a "What Does Management Look Like in High Maturity Organizations?" course.

Recommendation SEI-3—A group from this workshop should work with the SEI to capture best practices in change management because we heard considerable consistency in what works, and this common, best practice could be captured and disseminated throughout the community.

Several participants from this workshop have volunteered to participate in preparing a best practices guide for change management. The SEI should consider publishing this guide.

Recommendation SEI-4—Define and support reasonable expectations of Level 4 and 5 organizations—better educate customers on concepts of process capability vs. process performance.

Recommendation SEI-5—The SEI should more consistently consider global issues. For example, consider holding the next high maturity workshop in Bangalore, India.

Recommendation SEI-6—The SEI might try to become a high maturity organization or provide more working examples of high maturity organizations.

5.6.8 Conclusion

Effective change management processes that consider people, process, and technology can reinforce an organization's evolving and optimizing culture of continual improvement. Even these change-management processes are components of the organization's set of standard processes and can (and should) be continually improved. Paying attention to the people issues, as well as the process and tools issues, is essential, as even Level 5 processes are executed by humans!

5.7 Working Group 2.4: Process Agility, Internet Speed, and Process Improvement

The participants in this working group included Vivek Govilkar, Subrata Guha, Raj Shekhar, Anthony D'Souza, Albert Soule, Jitendra Shreemali, Muthuramalingam Rajamanickam, Jim McHale, Suzie Garcia, Linda Levine, and Gangi Keeni.

The working group leader was Gangi Keeni. The facilitator / scribe was Suzie Garcia. The recorder was Linda Levine.

5.7.1 Hypotheses and Observations

The original questions that inspired the creation of this working group included questions on:

- Internet speed and process improvement:
  - Do "lightweight" or "Internet-speed" processes such as XP and Scrum substantively address Software CMM practices?
  - Can an organization be Level 2+ if it has a high percentage of projects following lightweight processes?
  - Are there specific practices in "lightweight" processes that would be considered unacceptable in a mature software process?
- Process agility
  - Is a high maturity organization, by virtue of its process discipline, more conservative with respect to process change?

- Can a high maturity organization, with all its infrastructure, change as rapidly as the business environment may demand?
- Should high maturity organizations focus on "lightweight" processes?

First, the group covered introductions and also described the level of experience each had with process agility and Internet speed issues: typical project and project size.

5.7.1.1 Early discussion

During initiation of the working group, the following questions or observations were posed by the working group members.

The group did not have much experience in lightweight methodologies such as XP. There were discussions about what is a lightweight process; does lightweight imply specific lack of practices. Process Change Management implies continuous improvement, which may result in lightweight processes to suit the business requirement.

The group had lots of experience with tailoring standard processes for short-duration projects (1-3 months) and/or creating standard processes for short duration projects. The definition of "light" was expanded to include these homegrown processes as well. The group used "agile" in place of "light" for most of the discussions.

The group decided to concentrate on the following questions:

1. How can Software CMM be relevant for organizations doing only short-duration projects? Or those who are using only light processes such as XP?
2. How/do high maturity practices help/hinder organizations in performing short duration projects?
3. How do you leverage experience in high maturity into Internet speed projects?
4. Do "lightweight" or "Internet-speed" processes such as XP and Scrum substantively address Software CMM practices?
5. Are there specific practices in "lightweight" processes that would be considered unacceptable in a mature software process?
6. Should high maturity organizations focus on "lightweight" processes?
7. Is a high maturity organization, by virtue of its process discipline, more conservative with respect to process change?
8. Can a high maturity organization, with all its infrastructure, change as rapidly as the business environment may demand?
9. Which Software CMM practices help/hinder you with short duration projects?
10. What are the major differences in your "light" and "normal" processes?
11. What problems have you found with regard to Software CMM adherence or business results when trying/using your "light processes?

12. How is your ability to respond to rapidly changing business demands helped/hindered by your high maturity practices?

The issues that the working group decided to discuss in more detail were:

- Which Software CMM practices help you with short-duration projects?
- What are the major differences in your "light" and "normal" processes?
- What problems have you found with regard to Software CMM adherence or business results when trying/using your "light processes?"
- How is your ability to respond to rapidly changing business demands helped/hindered by your high maturity practices?

5.7.2 Software CMM Support for Short-Duration Projects

The following KPAs have a key role in successful execution of short-duration projects.

- ISM (Integrated Software Management) – Tailoring is the key for short-duration projects
- SPE (Software Product Engineering) – Tailoring of SPE practices based on data to analyze risk
- PCM (Process Change management) / TCM (Technology Change Management) – Piloting practices to reduce the risk and get better insight

Though these KPAs have an explicit impact, it was felt that the experience of all Software CMM practices help in effective tailoring and understanding of the risks involved. As the maturity increases, the granularity in measurements generally shift to enable better insight in the processes. The Software CMM focus on measurement encourages one to look at the right granularity for short-duration projects.

Having a family of standard processes, instead having a single standard process was considered to be an advantage in this context (e.g., there could be one for short-duration projects).

5.7.3 Agile Processes for Short-Duration Projects

The participants were of the view that these processes could be a methodology or just selected processes adjusted. However it would be defined well enough to be trained/performed by new people. Light is not just leaving things out or skipping something; sometimes the activity may be diluted, which starts out as tailoring. It is a different process, but it may be about degree of formality. Eventually, an agile tailored process may become "standard."

Organizations may trade off their current optimal set of processes for a lighter process that is less rigorous than today's best processes in order to reap other benefits, such as time to market.

Today's "light" process (less than optimal) may become tomorrow's optimal process, because of the learning. Here, the risks are accepted because of the ability to quickly respond to problems.

It was highlighted that in context of PSP/TSP, one of the things that Watts Humphrey always emphasizes is that the fastest way of doing something is almost always the right way of doing something. And not everything worth doing is worth doing well.

Some of the helpful practices, for short-duration projects, discussed were:

- Project startup, where all the performers/stakeholders and support groups such as SEPG, meet and decide on the approach to be taken. The risks are discussed and the parties come to a common agreement. The SEPG would be involved in tracking new processes or any deviation from the organization's standard software processes and would initiate corrective actions as required.
- online review: whereby the turnaround of review processes is reduced to real time
- automation for many system processes (especially measurement) makes it transparent
- defect prevention is never tailored out

5.7.4 Problems in Software CMM Adherence in Short-Duration Projects

The discussions here mainly concerned fully meeting the Level 4 KPA requirements (e.g., is the process measurement driving the process change?).

- What tailoring is: cutting things out, finding shortcuts, and shrinking things down.
- What's a lightweight process?
- Maintenance may be short duration but it is quite different from the Internet projects.

The above recurring issues led the group to reiterate, how short is short? When is a project too short to be a project? And the group agreed on the following:

- Each and every emergency bug fix is not a project by itself.
- Maintenance project enhancements bundled into a time box can be treated as a project.
- A four-day Web site development with six people can be treated as a project by itself.
- To be a short-duration project, the project should have goals and delivery criteria similar to larger projects that can be planned and measured.
- There may be different granularity of measurements but it is still required to be able to identify control points.

5.7.5 Ability to Respond to Rapidly Changing Business Demands

While discussing the business pressure for speed it was discussed that

- in some environments, lower quality might be tolerated with innovative products for first to market
- in many environments, tolerance for low quality is not there

These are different categories altogether and need to be addressed accordingly. However, all agreed that data is the key in making decisions in this regard.

- Data allows one to see trends from the outside.
- Data helps create realistic expectations.
- Data allows more experimentation and fast feedback.

5.7.6 Recommendations for High Maturity Organizations

As a result of the working group's discussions, the following recommendations for organizations seeking to achieve high maturity were formulated:

- Participate in SEI research in this area.
- Publish and share learnings on agile high maturity organizations.
  - business drivers
  - measures
  - best practices
  - case studies, experience reports
- Contribute to a common database (industry wide). Include
  - information on techniques
  - experiences
  - experiments
  - benchmarking data
- Encourage the community to make data available to the Software Engineering Information Repository (SEIR).
- Keep an open mind, evaluate new trends. Propose changes as relevant to the SEI.
- Balance rigor with agility when defining project processes.
- Gather and use data to understand risks and consequences associated with agile processes.

5.7.7 Recommendations for the SEI

As a result of the working group's discussions, the following recommendations for the SEI were formulated:

- Provide a better definition of "light" if this topic is intended to be studied.
- Sponsor a study of high maturity organizations that are doing Internet development projects.
- Sponsor follow-on work to existing exploratory study on Internet speed.
- Sponsor a user group (high maturity organizations) to consider Internet speed and other topics.

5.8 Working Group 2.7 – CMMI

Because of the interest in CMMI, Working Group 1.5 on CMMI was duplicated in the second set of working group sessions. The participants were Donna Dunaway (Facilitator), David White (Scribe), Joseph Morin, Mel Wahlberg, Wendy Irion Talbot (Scribe-flip charts), Mary Beth Chrissis, Roger Bate, John Yu, and Asha Goyal (Leader). Visitor: Mark Paulk.

5.8.1 The Model

There is a large community using the Software CMM model and a transition has to be built in to any new model or new version of the model from the point of view of cost, return, and perceptions.

5.8.1.1 Software Aspects

QPM (Quantitative Project Management) and OPP (Organization Process Performance) need interpretation and mapping vis-a-vis SQM and QPM (as in Software CMM). One issue at the base is how can we find common/special causes? The root cause can be at the project or organization level. While distinguishing between common and special causes, it all comes down to causal analysis. Special causes are addressed via corrective action and common by process reengineering.

A lack of requirement at Level 3 in CMMI for measuring specific process elements has been observed and may require a change request (CR). With the change, with respect to SQM and QPM, this will need to be looked at carefully.

QPM AC5 may need a correction in the text. (This AC is written as a goal.)

How is CMMI addressing soft points of Software CMM?

5.8.1.2 Systems Engineering Aspects

One will have to clearly understand system engineering work products, their appropriate estimation models and measures.

What are appropriate measures for system engineering? (Do they measure artifacts as UI / interfaces, systems, subsystems and work with units such as pages for requirements or requirement expansion rate)?

The "software only" organizations may not understand some of the aspects and hence an integrated approach may remain missing. For other organizations, there may be a need to know how to convert the concepts to actual process requirements.

5.8.2 The Transition

5.8.2.1 Model

There is a need to build translation matrix/mechanism from Software CMM to CMMI in terms of how KPAs, practices, and subpractices map on to new ones. There is also a need to know what/why practices have been dropped, added, or changed and if there is any terminology difference. If this reflects improvements to engineering discipline or a consolidation of learnings from Software CMM, it needs to be available in some documents so that one understands the basis for change.

Use of the term "tailoring" needs to be well described. It was possible to indicate a KPA such as SSM as "not applicable" if an organization was not performing it. But if SE subpractices are intermixed, then SW-only organizations may need to be able to tailor more extensively than in the Software CMM. These need to be analyzed, perhaps, based on pilot experience.

If there is any information on business benefits of CMMI or difference in ROI from Software CMM, it needs to be shared so that transition to CMMI can be justified.

5.8.2.2 Information

Some documentation on why from Software CMM to CMMI is needed for SW-only organizations that are working fine with Software CMM, since their investment in Software CMM training / understanding is at risk.

There needs to be documents explaining what exceptions or extra processes a SW-only organization will need due to SE-related model elements, and how it will use tailoring or exceptions. The same will have to be well explained in Lead Assessors training.

People understand the model as in Software CMM. In that context the mapping documents to CMMI need to be available.

It has been mentioned that some information regarding considerations mentioned at the SEPG conference 2001 need to be checked out.

5.8.3 Recommendations for High Maturity Organizations

In high maturity psyche it is natural to apply Level 4 or 5 processes to both project and organization levels. They keep feeding each other in a cycle (e.g., QPM, DP, and PCM). One continuously looks at new ways to improve. So one can utilize the positive environment.

One has to see how to protect the investment in Software CMM, not to lose the momentum of continuous improvement and how to retain the confidence of professionals in the ongoing activity. This has a relation with reassessment time frame to be looked at by the organization and if CMMI can be looked at as a new version of the Software CMM etc, with only incremental change.

One has to see the value of bringing in the new CMMI model from management point of view, any extra investment, risks and evaluation with other competing or collaborating models (ISO 9001:2000 or Six Sigma, European Quality Model) and the role these can play.

The decision to move to CMMI will involve tailoring and a number of interpretations that have no precedence. Clarifications may be sought directly from the SEI (and, perhaps, not from the individual Lead Assessor) long before one really embarks on the move to CMMI.

The issue is how can we find common/special causes? Root cause can be at the project or organization level? Why distinguish between common or special causes? All comes down to causal analysis. Special causes address via corrective action and common by process reengineering.

The causal analysis is all integrated, but you have to determine what type of analysis to perform and what to do with the results.

5.8.4 Recommendations for the SEI

The current reference point for organizations is Software CMM and CMMI. They should not be expected to work backward from CMMI. The onus of explaining the change is on CMMI, because there is a need to know what/why practices have been dropped, added, or changed and the best practice concept or data behind it, not just the analytical approach.

There is concern regarding how much measurement is necessary. What's enough? Is it for those critical few that impact business? Can that measurement be used for decision making? How far does one have to go with SPC or Quantitative? Has real life experience been used to create the model? If yes, does it correlate the measurements to other project success measures and accurate predictors of success?

For a "SW-only" scenario, there may not be much published about tailoring, and the CMMI assessment may ask, Did you evaluate process change quantitatively? Have you measured the benefit of CMMI vis-à-vis existing Software CMM? Have you piloted the new process? If not, this may raise questions on the reliability of the assessment for SW-only organizations.

Sunset has been planned to withdraw support after 12/2003 by not making changes, not giving courses, no further Lead Assessor training, and no analyses on data received. How Software CMM can be supported and taken further for SW-only organizations should be addressed.

Software CMM Level 3 organizations that are likely to move to higher levels will wonder what to do. Maybe, up to Level 3, the options of commonality in two models for assessment should be looked at.

High maturity organizations will have to explain to customers why to sustain Software CMM if the SEI does not support it any more. The date of sunset needs to consider ways to give choices and not an impression of cutoff.

5.8.5 Summary

Process model approach is measurement-decision-result-belief as well as process-belief-decision-result-measure. What is involved in transitioning to CMMI are people, culture, and new approaches with little data. High maturity organizations work with all simultaneously. A "popular model" that is widely used is a suitable vehicle to take this forward. Software CMM is one of the most successful SW benchmarks and change needs to avoid disconnect.

6 Recommendations for High Maturity Organizations

6.1 Recommendations for High Maturity Organizations from the 1998 Workshop

The following 37 recommendations for high maturity organizations were made by the working groups in the November 1998 workshop. They are summarized below, but no status is reported since they were for the community to act on.

From the statistics working group:

1. Level 4 organizations should provide the project teams with sufficient training, tools, and mentoring in statistical and/or modeling methods to apply appropriate quantitative management techniques effectively.
2. Data collection should be frequent enough to provide real-time control of the process.
3. Understanding variation is required at Level 4, but not the use of control charts. A high maturity organization should choose the appropriate statistical or modeling technique to answer the specific questions that it has.
4. A Level 4 organization is not required to have capable processes, but it must understand the capability of its processes.
5. Continue disaggregating process control data until the chart is usable.
6. The use of SPC in earlier phases of the life cycle, such as requirements analysis, should be institutionalized.

From the measurement working group:

7. For data cost and quality, enforce the idea that staff who generate data should get to use it.
8. For data cost and quality, model the behavior to have projects use data by having measurement group work with projects.
9. For data cost and quality, keep the linkage to use and goals.
10. For data cost and quality, keep clear whether measures are for the enterprise or for the process only.
11. For data cost and quality, have statisticians and practitioners collaborate on defect and effort analysis.
12. For data cost and quality, define analysis at same time as defining measures.

13. For data cost and quality, have clear process definitions and define measures as part of defining processes.
14. For data cost and quality, have management pull for need for data.
15. For data cost and quality, have common measurement criteria.
16. For data cost and quality, do not fragment collection and use completely.
17. For data cost and quality, do not enter the same data multiple times.
18. For data cost and quality, do not bite off more than you can chew.
19. For creation and use of capability baselines, explore data to understand points associated with special causes of variation.
20. For creation and use of capability baselines, let downstream processes (e.g., testing) set specifications for upstream processes (e.g., defect detection activities such as inspections).
21. For tying software quality to business objectives, define process requirements like you would a product requirement.
22. For tying software quality to business objectives, look at processes that are involved and audience to identify measures.
23. For tying software quality to business objectives, look at products that are result of process to identify entities to measure.
24. For tying software quality to business objectives, identify critical dimension of requirement (cost, schedule, quality) as attributes for measurement.

From the technology transition working group:

25. Select pilot teams based on technology adoption curve (early adopters preferred).
26. Consider "line of sight" coupling of technology objectives to organization and individual objectives, and budgeting and statusing.
27. Establish a separate group looking externally for "good matches" – NOT on project!
28. Establish widespread publication/briefing of tactical and strategic business and technology plans.
29. Make the proposer the owner for implementation.
30. Establish technology architecture for SPI support early; deploy supporting technologies "just in time" with process deployment.
31. Do "stop the world" training for pilot teams and explicit coaching/mentoring.
32. Note that mentor does NOT equal owner of the adoption (these are, however, complementary).
33. For increased sharing of technology deployment process with stakeholders throughout the TCM process... communicate... communicate.
34. Add mentors/coaches from process group and budget as "extra" staff to help pilots be successful.
35. Do establishing/employing feedback/refinement of whole product.

36. Recognize that first iteration does NOT equal the last iteration.
37. Identify the owner of the "sustaining" part of technology explicitly.

6.2 Summary of 2001 Recommendations for High Maturity Organizations

The following 34 recommendations for high maturity organizations were made by the working groups in the March 2001 workshop. They are only summarized below (some re-writing was necessary to summarize the recommendations); more detailed discussions may be found in the above section on working group reports.

1. From the measurement working group: Involve those impacted by the measurement program is – do it with them, not to them.
2. Start with small, focused efforts to generate some early successes.
3. Integrate project measures and business objectives.
4. Revisit the basics and review the purpose and need for each measure.
5. Automate collection and analysis as much as practicably possible.
6. Address change management as applied to measurement in the context of high maturity.

From the Six Sigma working group:

7. Gain top-level management support. Show how Six Sigma can be used as tool and the "next step" after reaching Software CMM Level 5.
8. Use Six Sigma to increase practitioner ownership, to give the practitioners a new tool, to generate new interest, to increase process agility.
9. When implementing Six Sigma, place focus on training and piloting with one project and one problem.
10. If currently using Six Sigma, publish experiences and results.

From the CMMI working groups:

11. Use valuable lessons learned from high maturity organizations. Implement measurements early, set up an engineering process group, peer reviews and other forms of verification, process improvement adoption lessons learned.
12. Follow TQM principles during strategic planning; identify marketing areas and operational direction. If you have an initiative that crosses the organization (i.e., establishes an "umbrella"), it becomes easier to deploy CMMI due to a common framework.
13. Industry has to examine territory beyond Level 5. Protect the investment in Software CMM, not to lose the momentum of continuous improvement and how to retain the confidence of professionals in the ongoing activity.
15. See the value of bringing in the new CMMI model from management point of view.
16. Seek clarifications directly from the SEI before embarking on the move to CMMI.

From the statistics working group:

17. Get competent statistical guidance with experience beyond manufacturing.
18. Let the data and objectives determine the statistical methods used.
19. Set quantitative objectives tied to business goals.
20. Simplify the presentation of statistical results.
21. Use data to gain understanding and control (Level 4) and guide improvement (Level 5).
22. Learn about Six Sigma and the tools it offers for Level 4 and 5 activities.

From the change management working group:

23. Work force management processes must mature commensurate with other disciplines.
24. Use broad range of sources for improvement ideas.
25. Explore how to do "cultural due diligence" to handle the pressure and risk of acquisitions and mergers.
26. Establish resources and energy for process improvement.
27. If an organization asks its people to participate in change activities, it should make it easy by providing appropriate support (tool support, etc.) and make sure it provides a benefit to the people.

From the Internet speed working group:

28. Participate in SEI research in process agility and Internet speed.
29. Publish and share learnings on agile high maturity organizations.
30. Contribute to a common database (industry wide).
31. Encourage the community to make data available to the SEIR.
32. Keep an open mind, evaluate new trends, and propose changes as relevant to the SEI.
33. Balance rigor with agility when defining project processes.
34. Gather and use data to understand the risks and consequences that are associated with agile processes.

7 Summary of Recommendations for the SEI

7.1 Recommendations for the SEI and Status – November 1998 Workshop

The following 25 recommendations for the SEI were made by the working groups in the 1998 workshop. Status with respect to SEI actions that have been taken on these recommendations is included.

From the statistics working group:

1. The SEI should clarify to the SPI community whether the current operating model is Software CMM Version 1.1 as written; Version 1.1 as reinterpreted, clarified, and elaborated in Software CMM Version 2 Draft C; or what we wish we had said when we wrote Version 1.1, which is not exactly what we said.

   Status: Accepted. Version 1.1 as written is the current operating model of the Software CMM.

2. The SEI should clarify confusing high maturity issues in the CMMI model for Level 4 at the goal and practice level.

   Status: Accepted. Interpretation issues for Software CMM v1.1 are addressed in the High Maturity with Statistics course. The emphasis is on the terminology used in v1.1 and what it means.

3. The SEI should maintain flexibility in the range of quantitative methods that are legitimate (or required) at Level 4. Many different quantitative methods can be used to support quantitative management.

   Status: Accepted. The High Maturity with Statistics course suggests that a number of statistical and quantitative techniques can be effective. Some recommendations, e.g.,, XmR charts, are made for those who wish a starting point to consider.

4. The SEI should get input from more organizations in building consensus on high maturity practices and disseminate this information for review and guidance to organizations that need its guidance.

   Status: Accepted. The High Maturity Workshop is becoming a regular event, scheduled on roughly an 18-month time frame. Panels on SPC, what it means to be Level 4, what it means to be Level 5, etc., that involve SEI staff, Lead Assessors, and representatives from high maturity organizations have been held at the various SEPG conferences around the world.

5. The SEI should publish a compendium of quantitative management practices (including examples other than SPC) currently in use and their benefits.

Status: Accepted. The High Maturity with Statistics course contains the beginning of such a compendium.

6. The SEI should request Lead Assessors to supply case studies on Level 4 and 5 organizations.

   Status: Accepted. Position papers from Lead Assessors and Evaluators were solicited for this report, with limited success. Lead Assessors have been encouraged to present case studies at various conferences and journals.

7. The SEI should create guidelines for applying quantitative management techniques based on industry lessons learned.

   Status: Accepted. This will probably be a technical report.

8. The SEI should not be the final authority on statistics.

   Status: Accepted. The SEI is, however, the authority on interpreting the Software CMM, which is really the intent of this point. The real problem is that the guidance on interpreting the model has been inadequate, although steps are being taken, such as developing the High Maturity with Statistics course, to address this problem.

   As was discussed in the report on the 1999 workshop, this point was inspired by a discussion of 2-sigma versus 3-sigma control limits. Some high maturity organizations are using 2-sigma limits to trigger action, and it was observed that several SEI statistics experts have commented that these are not valid control limits. Paulk stated that, in his judgment, "action limits" based on 2-sigma were legitimately based on an understanding of variation and thus could be considered a valid quantitative management technique at Level 4. Some statisticians consider these to be valid control limits; other statisticians note that this is an explicit violation of Shewhart's rationale for choosing 3-sigma limits and state that 2-sigma limits are incorrect. Given the rift in the statistical community on this issue, anyone using 2-sigma limits should be educated that this is not generally accepted practice, and the use of the term "2-sigma control limits," unless made in ignorance, is likely to be considered as taking a position in a heated debate that makes the proponent fair game. It is fair to say that most SEI staff knowledgeable in SPC are aligned with Don Wheeler's philosophies, so characterizing 2-sigma limits as control limits is likely to lead to a correction in terminology.

   In general, the SEI acknowledges that there are many sources of statistical expertise, and not all of those sources are in perfect accord. While the SEI will continue to act as an arbiter of unreasonable interpretations, it is accepted that some quantitative and statistical questions remain inherently controversial, and a wide latitude of implementations will advance the understanding of our community of what techniques are effective over time.

From the assessment working group:

9. Re-establish the CMM Advisory Board.

   Status: Rejected. The CMMI Steering Group fulfills this function for CMMI, which will replace the Software CMM in 2003.

10. Establish mandatory supplemental training of any Lead Assessor (to lead Level 4 and 5 assessments).

    Status: Under consideration. Implementation will probably be in the context of CMMI.

11. Gather data regarding the "problem of inconsistent results at Level 4 and 5."

    Status: Accepted.

12. Strengthen QA provisions for Lead Assessors.

    Status: Accepted. Will Hayes is the contact person for further information in this area.

13. Periodically conduct High Maturity Workshops.

    Status: Accepted. The High Maturity Workshop is planned to be held on roughly an 18-month cycle.

14. Elicit papers from the community at large.

    Status: Accepted.

15. Identify criteria for qualified referees.

    Status: Accepted. For the SEPG Conferences, a relatively small pool of qualified referees has evolved. For further information, contact Mark Paulk at the SEI.

16. Add Report of the Workshop Proceedings and mandate to grow further.

    Status: Overcome by events. Specific to a draft document reviewed at the workshop, "SEI Strategy for Ensuring Valid Implementation and Appraisal of Level 4 and Level 5 Process Areas–October 28, 1999," which has not been released.

17. Drop the word "informal" from title of paragraph 8. Re-title "Communications between the SEI and the CMM User Community."

    Status: Overcome by events. Specific to a draft document reviewed at the workshop, "SEI Strategy for Ensuring Valid Implementation and Appraisal of Level 4 and Level 5 Process Areas–October 28, 1999," which has not been released.

18. Make high maturity materials available through the Transition Partners.

    Status: Accepted. It is intended that a CD with a high maturity tutorial will be provided to attendees of the High Maturity with Statistics course, but this CD has not yet been built.

19. Provide high maturity training in other geographic areas (e.g., Middle East, India, Australia, etc.).

    Status: Accepted. This has been done to a limited degree, primarily with the European Software Process Improvement Foundation in the U.K. A few other offerings are planned in Europe in the near future. No plans currently exist for high maturity training outside of the U.S. and Europe, but opportunities will be considered as they arise.

From the CMMI working group:

20. Pick a single representation, continuous or staged, for the CMMI model.

    Status: Rejected.

From the technology transition working group:

21. OPF should address integrating process architecture and technology support architecture.

Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

22. Include more "feasibility" focus for technology—encouraging organizations to master analyzing the feasibility of different technology alternatives earlier.

    Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

23. Add subpractices / examples on appropriate technology support in relevant KPAs (e.g., problem report tracking, defect tracking).

    Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

24. Add more front matter on technology implementation vs. TCM mastery.

    Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

25. Emphasize appropriate "data collection" technology support at Level 2/3 and above as a way to reduce barriers to process deployment.

    Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

7.2 Recommendations for the SEI and Status – March 2001 Workshop

The following 38 recommendations for the SEI were made by the working groups in the March 2001 workshop. They are only summarized below (some re-writing was necessary to summarize the recommendations); more detailed discussions may be found in the above section on working group reports.

From the measurement working group:

1. Encourage organizations' understanding of measurement at lower maturity levels.

   Status: Accepted. This is addressed by the Measurement and Analysis process area at Level 2 in the CMMI model (staged representation).

2. Address change management as applied to measurement in the context of high maturity.

   Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

3. Provide guidelines and examples for quantitative analysis techniques and methods that are acceptable at Level 4 (other than SPC).

   Status: Accepted. Under consideration for papers and revisions to the High Maturity with Statistics course.

From the assessment working group:

4. Encourage Lead Assessors and Lead Evaluators to take additional training in high maturity topics.

   Status: Accepted. The High Maturity with Statistics and SPC for Software courses are the recommended training at this time.

5. Suggest appraisers use a standard experience / qualification matrix as a means for Lead Assessors and Evaluators to describe their level and scope of experience (maturity levels, disciplines, etc.) and for appraisal customers to better match LA / LE qualifications to the parameters of their appraisal.

   Status: Passed along to the CMMI team for consideration in a future version of the SCAMPI method.

6. Provide additional model and method implementation guidance for appraisers.

   Status: Accepted. The High Maturity with Statistics course embodies this guidance. Papers will be published as they are completed.

7. Utilize newly available mechanisms for disseminating this guidance to the Lead Appraiser community (for example, the new SEI Lead Assessor web site, the International Association of Professional Lead Assessors [IAPLA] Web site).

   Status: Accepted.

From the Six Sigma working group:

8. Retain the Software CMM and the focus it brings to software.

   Status: Rejected. CMMI contains the software model that will replace the Software CMM in 2003.

9. Explore including Six Sigma in future versions of the Software CMM as a tool to aid Level 4 and Level 5 organizations in continuous and measurable improvement.

   Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

10. Recognize that Six Sigma is not standardized, that it has a wide spectrum of tools. Focus on referring the relevant tools from the Six Sigma assortment.

    Status: Accepted.

11. Publicly recognize Six Sigma as a useful tool for software organizations. Publish articles in publications such as *CrossTalk*.

    Status: Accepted.

12. Show the relation between the different models and frameworks. Show the connections, the mappings, the benefits. Describe the broad toolset necessary to develop a sound quality management system.

    Status: Passed along to the CMMI team for consideration in a future version of the CMMI model.

13. Develop SEI courses on the application of Six Sigma to software organizations.

Status: Accepted. This will probably be done within the context of the High Maturity with Statistics course as it continues to be refined.

From the CMMI working groups:

14. Why is CMMI not considered Software CMM Version 3.0? Why is there not a logical progression from Software CMM to CMMI (in models, training, and assessment methods)?

    Status: Passed along to the CMMI team for consideration.

15. Develop a CMMI time-bound release plan for industry involving all aspects of the organizations (e.g., marketing, human resources, etc.).

    Status: Passed along to the CMMI team for consideration.

16. Capture the lessons learned from high maturity organizations in how to quickly and intelligently implement continuous process improvement and provide industry a road map to get through the model.

    Status: Passed along to the CMMI team for consideration. The High Maturity with Statistics course is largely model independent and may address this concern. PSP and TSP are also likely to be helpful.

17. Establish industry-wide support and buy-in for transition to CMMI, including involvement from the commercial sector. Ensure that software-only organizations can see that the model works for them too and that there are clear guidelines of the model for application to software-only organizations.

    Status: Passed along to the CMMI team for consideration.

18. Explain the changes in CMMI because there is a need to know what / why practices have been dropped, added, changed and the best practice concept or data behind it, not just analytical approach.

    Status: Passed along to the CMMI team for consideration.

19. Clarify how much measurement is enough for CMMI. How far does one have to go with SPC or quantitative?

    Status: Passed along to the CMMI team for consideration.

20. Provide quantitative information on the benefit of CMMI vis-à-vis existing Software CMM.

    Status: Passed along to the CMMI team for consideration.

21. Clarify how the Software CMM can be supported after the 2003 sunset of Software CMM v1.1 and taken further for software-only organizations.

    Status: Passed along to the CMMI team for consideration. A position paper has been drafted and is currently under review.

22. Consider options of commonality in the two models for assessment, especially at Levels 3 and higher.

    Status: Passed along to the CMMI team for consideration.

23. Explain the date of sunset in ways to give choices and not an impression of cut off.

Status: Passed along to the CMMI team for consideration. A position paper has been drafted and is currently under review.

From the statistical techniques working group:

24. Improve Software CMM / CMMI to focus on implementing quantitative management rather than focusing too narrowly on a specific method of implementation (i.e., SPC).

    Status: Passed along to the CMMI team for consideration. The High Maturity with Statistics course attempts to balance these issues.

25. Perform research and offer training on quantitative methods in addition to SPC.

    Status: Accepted. A number of measurement courses and quantitative research are being performed relative to process improvement at the SEI, primarily by the Software Engineering Measurement and Analysis project.

26. Continue to capture and disseminate community experience.

    Status: Accepted.

27. Encourage Level 4 and 5 organizations to publish their results and insights.

    Status: Accepted.

28. Provide better guidance and training for Lead Assessors.

    Status: Accepted. The High Maturity with Statistics and SPC for Software courses attempt to address this concern.

From the change management and people/cultural issues working group:

29. Consider hosting an explicit, ongoing, invitation-only forum targeted to senior management, for example, "a sponsor workshop" to cover roles and skills for sponsors.

    Status: Passed along to SEI management for further consideration.

30. There should be a "What does management look like in high maturity organizations?" course.

    Status: Rejected. We will consider adding material on this topic to the High Maturity with Statistics course and/or incorporating it into other SEI courses.

31. A group from this workshop should work with the SEI to capture best practices in change management because we heard considerable consistency in what works, and this common, best practice could be captured and disseminated throughout the community. Several participants from this workshop have volunteered to participate in preparing a best practices guide for change management. The SEI should consider publishing this guide.

    Status: Accepted. The primary means we have been using are the high maturity workshop and survey reports, plus papers and panels at various conferences (primarily the various SEPG Conferences). We will try to be more proactive in addressing change management in collaboration with our industry colleagues.

32. Define and support reasonable expectations of Level 4 and 5 organizations—better educate customers on concepts of process capability vs. process performance.

Status: Accepted. We have been building a consensus on what the expectations should be via panels and presentations at various conferences, as well as the workshops and surveys. The mechanism is likely to be in the form of published papers.

33. The SEI should more consistently consider global issues. For example, consider holding the next high maturity workshop in Bangalore.

    Status: Accepted. Sally Cunningham has been appointed as the SEI's Director of International Relations. She will be apprised of these and related concerns as we become aware of them and work with our sponsor and the community to address them.

34. The SEI might try to become a high maturity organization or provide more working examples of high maturity organizations.

    Status: Accepted. We have been, and will continue to be, strong advocates of case studies of process improvement and high maturity practices. We will continue to encourage this kind of information exchange.

From the Internet speed working group:

35. Provide a better definition of "light" if this topic is intended to be studied.

    Status: Accepted. We are moving to the "agile methodologies" terminology recently espoused by the Agile Alliance. See http://www.agilealliance.org/ for further information.

36. Sponsor a study of high maturity organizations that are doing Internet development projects.

    Status: Under consideration. This could be folded into the next high maturity survey, which will probably be in 2003.

37. Sponsor follow-on work to existing exploratory study on Internet speed.

    Status: Under consideration. Contact Linda Levine for further information.

38. Sponsor a user group (high maturity organizations) to consider Internet speed and other topics.

    Status: Under consideration. Contact Linda Levine for further information.

8 Conclusions

The March 2001 High Maturity Workshop discussed a number of important issues to the software community and the SEI. Although there was less participation than anticipated, this was at least partially due to insufficient advance notice that the workshop would be held. Tentative plans are to hold another High Maturity Workshop in the second week of November in 2002.

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Paulk 00d Paulk, Mark C. "Understanding High Maturity Practices – a Software CMM Tutorial." *The European Software Engineering Process Group Conference*. CD-ROM. Amsterdam, Netherlands, June 5-8, 2000. Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 2000. <http://www.sei.cmu.edu/activities/cmm/slides/UnderstandHM.pdf>.

Appendix A: List of Workshop Participants

Julie Barnard	United Space Alliance, Houston, TX
Roger Bate	Software Engineering Institute, Pittsburgh, PA
Bruce Boyd	The Boeing Company, St. Louis, MO
Kelley Butler	US Air Force, Tinker AFB, OK
Anita Carleton	Software Engineering Institute, Pittsburgh, PA
Lynn Carter	Software Engineering Institute, Pittsburgh, PA
Mary Beth Chrissis	Software Engineering Institute, Pittsburgh, PA
Bill Curtis	TeraQuest Metrics, Austin, TX
Anthony D'Souza	Satyam Computer Services Limited, India
Donna Dunaway	Software Engineering Institute, Pittsburgh, PA
Eileen Forrester	Software Engineering Institute, Pittsburgh, PA
Suzanne Garcia	Software Engineering Institute, Pittsburgh, PA
Diane Gibson	Carnegie Mellon University, Pittsburgh, PA
Dennis Goldenson	Software Engineering Institute, Pittsburgh, PA
Vivek Govilkar	i-flex solutions Ltd., Mumbai, India
Asha Goyal	IBM Global Services, New Delhi, India
Subrata Guha	Satyam Computer Services Limited, Charlottesville, VA
William Hayes	Software Engineering Institute, Pittsburgh, PA

William Hefley	Q-Labs, Pittsburgh, PA
Christian Hertneck	Software Engineering Institute, Pittsburgh, PA
Bob Hoekstra	Philips Software Centre Limited, Bangalore, India
Craig Hollenbach	Litton / PRC, McLean, VA
John, Jun An Yu	Motorola (China), Beijing, China
Gargi Keeni	Tata Consultancy Services, Calcutta, India
Mike Konrad	Software Engineering Institute, Pittsburgh, PA
Linda Levine	Software Engineering Institute, Pittsburgh, PA
James McHale	Software Engineering Institute, Pittsburgh, PA
Judah Mogilensky	Process Enhancement Partners, Inc., Silver Spring, MD
Joseph Morin	Integrated System Diagnostics, Inc., Pocasset, MA
Muthuramalingam Rajamanickam	HCL Technologies, Chennai, India
Gerald Ourada	Lockheed Martin Aeronautics Co., Fort Worth, TX
Mark Paulk	Software Engineering Institute, Pittsburgh, PA
Mary Lynn Penn	Lockheed Martin, Philadelphia, PA
Padmanabhan Rajasekharan	Mastek Ltd., Andheri, India
Somashekhar Ramadevanahalli	CG-Smith Software Ltd., Bangalore, India
Joan Romine	The Boeing Company, St. Louis, MO
Elizabeth Schulte	The Boeing Company, Huntington Beach, CA
Jitendra Shreemali	Philips Software Centre Limited, Bangalore, India

Jeannine Siviy	Software Engineering Institute, Pittsburgh, PA
Ashok Sontakke	Zensar Technologies LTD, Pune, India
Albert Soule	Software Engineering Institute, Pittsburgh, PA
Phillip Sperling	Telos-OK, Lawton, OK
Wendy Irion Talbot	Computer Sciences Corporation, Moorestown, NJ
Jim Vanfleet	US Air Force, Hill AFB, UT
Mel Wahlberg	Computer Sciences Corporation, Laurel, MD
Gian Wemyss	Software Engineering Institute, Pittsburgh, PA
David White	Software Engineering Institute, Pittsburgh, PA
David Zubrow	Software Engineering Institute, Pittsburgh, PA

Appendix B: List of High Maturity Organizations Participating

The following list of high maturity organizations lists most of the known Level 4 and 5 organizations. The organizations that participated in the workshop are noted with a √ in column 1 of the table.

As of May 2001, the full list, of which the published list is a subset, includes 132 high maturity organizations, a subset of which is listed below: There are

- 71 Level 4 organizations
- 61 Level 5 organizations

It is interesting to note that 74 of the high maturity organizations assessed are outside the United States.

- Australia: 1 Level 4 organization
- China: 2 Level 5 organizations
- France: 1 Level 4 organization
- India: 30 Level 4 organizations
- India: 39 Level 5 organizations
- Israel: 1 Level 4 organization

Of the 132 known high maturity organizations, 35 participated in the workshop. In some instances, the same person represented multiple organizations, e.g., Gargi Keeni. Of the 35, there were representatives from 23 organizations in India and one organization in China.

Please be aware of the following issues regarding this list.

- The SEI does not certify companies at maturity levels.
- The SEI does not confirm the accuracy of the maturity levels reported by the Lead Assessors or organizations.
- This list of Level 4 and 5 organizations is by no means exhaustive; we know of other high maturity organizations that have chosen not to be listed.
- The SEI did not use information stored within its Process Appraisal Information System to produce this document.

- The organizations listed gave explicit permission to publish this information.
- No information obtained in confidence was used to produce this list.

The following information is contained in this table, as reported by the organization:

- **Full, correct name of the organization** (with acronyms defined), including city and state (or country)
- **Point of contact**: name and email address
- **Maturity level assessed**
- **Month and year of assessment** *(Including the form of assessment if different from CBA IPI with Lead Assessor.)*
- **Lead Assessor(s)** *(Lead Evaluators are annotated with LE; some appraisers are both LAs and LEs Some Lead Assessors are now inactive (I) and no longer listed on the LA and LE lists.)*

High Maturity Organization	
	Alitec Laval, France Point of Contact: Jerome Barbier, jeb@alitec.net; Jean Noel Martin, jnm@alitec.net Maturity Level: 4 Date of Appraisal: July 2000 Lead Assessor(s): Jean-Yves Le Goic
	Atos Origin India (formerly Origin Information Technology India Limited) Mumbai, India Point of Contact: Darayus Desai, darayus.desai@atosorigin.com Maturity Level: 5 Date of Appraisal: Nov 2000 (CAF-compliant Process Professional Assessment Method) Lead Assessor(s): (Cyril Dyer - Compita Assessor)
	BFL Software Limited Bangalore, India Point of Contact: Madhukumar P.S., Madhukumar.PS@bflsoftware.com Maturity Level: 4 Date of Appraisal: June 1999 Lead Assessor(s): Carolyn Swanson
	Boeing Company, Aircraft & Missiles & Phantom Works Southern California, Long Beach, CA Point of Contact: George H. Kasai, george.h.kasai@boeing.com Maturity Level: 5 Date of Appraisal: Dec 1997 Lead Assessor(s): Andy Felschow, Jeff Facemire
√	Boeing Company, Military Aircraft & Missile Systems F/A-18 Mission Computer St. Louis, MO Point of Contact: Bruce A. Boyd, bruce.a.boyd@boeing.com; Robert L. Allen, robert.l.allen3@boeing.com Maturity Level: 4 Date of Appraisal: Nov 1999 (SCE) Lead Assessor(s): Roy Queen (LE), Jeff Perdue

High Maturity Organization	
√	Boeing Company, Reusable Space Systems and Satellite Programs Downey & Seal Beach, CA Point of Contact: Don Dillehunt, donald.d.dillehunt@boeing.com Maturity Level: 5 Date of Appraisal: Oct 1999 Lead Assessor(s): Andy Felschow, Jeff Facemire
	Boeing Company, Space Transportation Systems Kent, WA Point of Contact: Gary Wigle, gary.b.wigle@boeing.com Maturity Level: 5 Date of Appraisal: July 1996 Lead Assessor(s): Steve Masters, Mark Paulk
√	CG-Smith Software Bangalore, India Point of Contact: G.N. Raghavendra Swamy, raghav@cgs.cgsmith.soft.net Maturity Level: 5 Date of Appraisal: Sept 1999 Lead Assessor(s): Richard Storch
	Citicorp Overseas Software Limited (COSL) Mumbai, India Point of Contact: Makarand Khandekar, makarand.khandekar@citicorp.com Maturity Level: 5 Date of Appraisal: Oct 1999 Lead Assessor(s): John Sheckler
	Cognizant Technology Solutions Chennai, India Point of Contact: Emani BSP Sarathy, esarathy@chn.cts-corp.com Maturity Level: 5 Date of Appraisal: Sept 2000 Lead Assessor(s): V. Kannan
√	Computer Sciences Corporation (CSC), Aegis Program Moorestown, NJ Point of Contact: Wendy Irion Talbot, wirionta@csc.com Maturity Level: 5 Date of Appraisal: March 2001 Lead Assessor(s): Kathryn Gallucci (LE)
√	Computer Sciences Corporation (CSC), Civil Group Greenbelt, MD Point of Contact: Mel Wahlberg, mwahlber@csc.com Maturity Level: 4 Date of Appraisal: Jan 2001 Lead Assessor(s): Paul Byrnes (LA & LE)
	Computer Sciences Corporation (CSC), Civil Group, Systems, Engineering, and Analysis Support (SEAS) Center Greenbelt, MD Point of Contact: Frank McGarry, fmcgarry@csc.com; Mel Wahlberg, mwahlber@csc.com Maturity Level: 5 Date of Appraisal: Nov 1998 (SCE) Lead Assessor(s): Paul Byrnes (LA & LE)

High Maturity Organization	
	Computer Sciences Corporation (CSC), Defense Group Aerospace Information Technologies Dayton, OH Point of Contact: Cheryl Plak, cplak@csc.com Maturity Level: 5 Date of Appraisal: Feb 1999 (SCE) Lead Assessor(s): Kathryn Gallucci (LE)
	Computer Sciences Corporation (CSC), Integrated Systems Division (ISD) Moorestown, NJ Point of Contact: Bryan Cooper, bcooper1@csc.com Maturity Level: 4 Date of Appraisal: May 1998 (SCE) Lead Assessor(s): Paul Byrnes (LA & LE)
	Computer Sciences Corporation (CSC), Tactical Systems Center (TSC) Moorestown, NJ Point of Contact: Wendy Irion Talbot, wirionta@csc.com; Jeff McGarry, jmcgarr1@csc.com Maturity Level: 4 Date of Appraisal: May 1998 (SCE) Lead Assessor(s): Paul Byrnes (LA & LE)
	Covansys San Francisco, CA Point of Contact: Prasanth Kedarisetty, KPrasanth@Covansys.com Maturity Level: 4 Date of Appraisal: Jan 2001 Lead Assessor(s): Richard Knudson
	DCM Technologies, DCM ASIC Technology Limited New Delhi, India Point of Contact: Naresh C. Maheshwari, ncm@dcmds.co.in Maturity Level: 5 Date of Appraisal: April 2000 Lead Assessor(s): Richard Storch
	DSQ Software Chennai, India Point of Contact: K.N. Ananth, kna@md.in.dsqsoft.com Maturity Level: 4 Date of Appraisal: June 1998 Lead Assessor(s): Judy Bamberger
	Future Software Private Limited Chennai, India Point of Contact: M.G. Thomas, thomasmg@future.futsoft.com Maturity Level: 4 Date of Appraisal: June 1999 Lead Assessor(s): Pradeep Udhas
	HCL Perot Systems Noida and Bangalore, India Point of Contact: Rakesh Soni, rakesh.soni@hpsglobal.com Maturity Level: 5 Date of Appraisal: Feb 2000 Lead Assessor(s): Pradeep Udhas

High Maturity Organization	
√	HCL Technologies Limited, Applications Solutions Development Centre Chennai, India Point of Contact: N. N. Jha, nnjha@msdc.hcltech.com Maturity Level: 4 Date of Appraisal: May 2000 Lead Assessor(s): V. Kannan
√	HCL Technologies Limited, Core Technologies Division Chennai, India Point of Contact: K. R. Gopinath, krg@hclt.com Maturity Level: 4 Date of Appraisal: Dec 2000 Lead Assessor(s): Krishnamurthy Kothandaraman Raman
	HCL Technologies Limited, Gurgaon Software Development Center Gurgaon, India Point of Contact: Sanjeev Gupta, gsanjeev@ggn.hcltech.com Maturity Level: 4 Date of Appraisal: July 2000 Lead Assessor(s): V. Kannan
	Hexaware Technologies Limited, Mumbai and Chennai Operations Chennai, India Point of Contact: Sulochana Ganesan, sulochana@hexaware.co.in Maturity Level: 5 Date of Appraisal: Dec 2000 Lead Assessor(s): V. Kannan
	Honeywell International, Avionics Integrated Systems (formerly AlliedSignal, Guidance & Control Systems) Teterboro, NJ Point of Contact: Steve Janiszewski, stephen.janiszewski@honeywell.com Maturity Level: 4 Date of Appraisal: Nov 1996 Lead Assessor(s): Larry Bramble (I)
	Hughes Software Systems Bangalore and Gurgaon, India Point of Contact: Gautam Brahma, gbrahma@hss.hns.com Maturity Level: 4 Date of Appraisal: Jan 2000 Lead Assessor(s): V. Kannan
√	IBM Global Services India Bangalore, India Point of Contact: Asha Goyal, gasha@in.ibm.com; Maya Srihari, smaya@in.ibm.com Maturity Level: 5 Date of Appraisal: Nov 1999 Lead Assessor(s): Richard Storch
√	i-flex solutions limited (formerly Citicorp Information Technology Industries Limited aka CITIL) Bangalore, India Point of Contact: Vivek V. Govilkar, vivek.govilkar@iflexsolutions.com Maturity Level: 4 Date of Appraisal: Dec 1995 Lead Assessor(s): Ken Dymond

High Maturity Organization	
√	i-flex solutions limited (formerly Citicorp Information Technology Industries Limited aka CITIL) Mumbai, India Point of Contact: Vivek Govilkar, vivek.govilkar@citicorp.com Maturity Level: 4 Date of Appraisal: Dec 1995 Lead Assessor(s): Cindi Wise, Ken Dymond
√	i-flex solutions limited Data Warehouse Center of Excellence Bangalore, India Point of Contact: Vivek V. Govilkar, vivek.govilkar@iflexsolutions.com Maturity Level: 5 Date of Appraisal: Nov 1999 Lead Assessor(s): Ken Dymond, Santhanakrishnan Srinivasan, Anand Kumar
	i-flex solutions limited IT Services Division Bangalore, India Point of Contact: Anand Kumar, anand.kumar@iflexsolutions.com Maturity Level: 5 Date of Appraisal: Dec 2000 Lead Assessor(s): Santhanakrishnan Srinivasan, Anand Kumar
	i-flex solutions limited IT Services Division, Mumbai, India Point of Contact: Anand Kumar, anand.kumar@iflexsolutions.com Maturity Level: 5 Date of Appraisal: Dec 2000 Lead Assessor(s): Santhanakrishnan Srinivasan, Anand Kumar, Atul Gupta
	Information Technology (India) Ltd. Delhi, India Point of Contact: Madhumita Poddar Sen, madhumitap@itil.com Maturity Level: 4 Date of Appraisal: April 2000 Lead Assessor(s): Pradeep Udhas
	Intelligroup Asia Private Limited, Advanced Development Center Hyderabad, India Point of Contact: G.V.S. Sharma, gvs.sharma@intelligroup.co.in Maturity Level: 5 Date of Appraisal: Oct 2000 Lead Assessor(s): Raghav S. Nandyal, John Harding
	ITC Infotech India Limited Bangalore, India Point of Contact: Paresh Master, pareshmaster@vsnl.com Maturity Level: 5 Date of Appraisal: Aug 2000 Lead Assessor(s): Richard Storch
	Kshema Technologies Limited Bangalore, India Point of Contact: V. Bhaskar, vbhaskar@kshema.com Maturity Level: 4 Date of Appraisal: March 2001 Lead Assessor(s): Krishnamurthy Kothanda Raman
	L & T Information Technology Limited Chennai, India Point of Contact: Anil S. Pandit, anil.pandit@vashimail.ltitl.com Maturity Level: 4 Date of Appraisal: Feb 2000 Lead Assessor(s): V. Kannan

High Maturity Organization	
	Litton Guidance and Control Systems Woodland Hills, CA Point of Contact: Roy Nakahara, nakaharr@littongcs.com Maturity Level: 4 Date of Appraisal: Dec 1998 Lead Assessor(s): Mark Amaya
√	Litton/PRC Inc. McLean, VA and Colorado Springs, CO Point of Contact: Al Pflugrad, pflugrad_al@prc.com Maturity Level: 5 Date of Appraisal: March 2000 (SCE) Lead Assessor(s): Joseph Morin (LE)
√	Lockheed Martin Aeronautics Company (formerly Lockheed Martin Tactical Aircraft Systems - LMTAS) Fort Worth, TX Point of Contact: Phil Gould, philip.c.gould@lmco.com Maturity Level: 4 Date of Appraisal: Dec 1999 Lead Assessor(s): Leia Bowers White
	Lockheed Martin Air Traffic Management Rockville, MD Point of Contact: Jim Sandford, jim.sandford@lmco.com Maturity Level: 4 Date of Appraisal: Dec 1999 Lead Assessor(s): Carol Granger-Parker, Jeff Facemire
	Lockheed Martin Federal Systems Owego, NY Point of Contact: Ed Fontenot, ed.fontenot@lmco.com; Warren A. Schwomeyer, warren.schwomeyer@lmco.com Maturity Level: 5 Date of Appraisal: Dec 1997 Lead Assessor(s): John Travalent, Mary Busby
	Lockheed Martin Information Systems Orlando, FL Point of Contact: Michael Ziomek, michael.ziomek@lmco.com Maturity Level: 4 Date of Appraisal: June 2000 Lead Assessor(s): Gene Jorgensen
√	Lockheed Martin Management & Data Systems King of Prussia, PA Point of Contact: M. Lynn Penn, mary.lynn.penn@lmco.com Maturity Level: 5 Date of Appraisal: Dec 2000 Lead Assessor(s): Andy Felschow, Carol Granger-Parker, Dennis Ring
	Lockheed Martin Mission Systems Gaithersburg, MD Point of Contact: Paul Weiler, paul.weiler@lmco.com; Al Aldrich, al.aldrich@lmco.com Maturity Level: 5 Date of Appraisal: Oct 1999 (SCE) Lead Assessor(s): Paul Byrnes (LA & LE)

High Maturity Organization	
	Lockheed Martin Naval Electronics & Surveillance Systems - Syracuse Syracuse, NY Point of Contact: Peter Barletto, pete.barletto@lmco.com Maturity Level: 5 Date of Appraisal: Nov 1999 Lead Assessor(s): Carol Granger-Parker, Andy Felschow
	Lockheed Martin Naval Electronics & Surveillance Systems–Eagan Eagan, MN Point of Contact: John Travalent, john.travalent@lmco.com Maturity Level: 4 Date of Appraisal: Oct 1999 Lead Assessor(s): Mary Busby
	Lockheed Martin Naval Electronics & Surveillance Systems–Manassas (formerly Undersea Systems) Manassas, VA Point of Contact: Dana Roper, dana.roper@lmco.com Maturity Level: 5 Date of Appraisal: Feb 1999 Lead Assessor(s): Judah Mogilensky, John Travalent, Donald White
	Lockheed Martin Naval Electronics & Surveillance Systems–Moorestown Moorestown, NJ Point of Contact: Nghia N. Nguyen, nghia.n.nguyen@lmco.com; Jeff Tait, jeffery.a.tait@lmco.com Maturity Level: 4 Date of Appraisal: Dec 1999 Lead Assessor(s): Kevin Schaan, Kent Johnson, Dennis Ring
	Lockheed Martin Space Electronics and Communications Systems–Manassas (formerly Loral Federal Systems) Manassas, VA Point of Contact: Dana Roper, dana.roper@lmco.com Maturity Level: 4 Date of Appraisal: June 1995 Lead Assessor(s): Judah Mogilensky, John Travalent, Chris Manak (I)
√	Mastek Limited Mumbai, India Point of Contact: P. Rajshekharan, rajshekhar@mastek.com Maturity Level: 5 Date of Appraisal: Sept 2000 Lead Assessor(s): Ron Radice
	Motorola Australia Software Centre Adelaide, Australia Point of Contact: Peter Dew, pdew@asc.corp.mot.com Maturity Level: 4 Date of Appraisal: Aug 1997 Lead Assessor(s): John Pellegrin (I)
√	Motorola China Software Center Beijing & Nanjing, China Point of Contact: John Jun'an Yu, johny@sc.mcel.mot.com Maturity Level: 5 Date of Appraisal: Sept 2000 Lead Assessor(s): Dan Weinberger, Patricia McNair

High Maturity Organization	
	Motorola India Electronics Ltd. (MIEL) Bangalore, India Point of Contact: Sarala Ravishankar, sarala@miel.mot.comMaturity Level: 5 Date of Appraisal: Nov 1993 Lead Assessor(s): John Pellegrin (I)
	Motorola, Asia Pacific Telecom Carrier Solutions Group (TCSG) Applied R&D Center Beijing, China Point of Contact: Graham Hu, qch1422@email.mot.com Maturity Level: 5 Date of Appraisal: Dec 2000 (CAF-compliant Motorola QSR Subsystem 10 Software Assessment) Lead Assessor(s): (Fathi Hakam -- Motorola Assessor)
	Motorola, GSM (Global System for Mobile Communications) Systems Division, Network Systems Group Arlington Heights, IL Point of Contact: Barbara Hirsh, hirsh@cig.mot.com Maturity Level: 5 Date of Appraisal: Oct 1997 (CAF-compliant Motorola QSR Subsystem 10 Software Assessment) Lead Assessor(s): (Ellen Pickthall -- Motorola Assessor)
	NCR Corporation, Teradata Development Division, Massively Parallel Systems San Diego, CA Point of Contact: Ron Weidemann, ron.weidemann@sandiegoca.ncr.com Maturity Level: 4 Date of Appraisal: Oct 1999 Lead Assessor(s): Ron Weidemann
	Network Systems and Technologies (P) Ltd Trivandrum, India Point of Contact: S K Pillai, skp@nestec.net Maturity Level: 5 Date of Appraisal: May 2000 Lead Assessor(s): Ron Radice
	NIIT Limited New Delhi, India Point of Contact: Bhaskar Chavali, BhaskarC@niit.com Maturity Level: 5 Date of Appraisal: Sept 1999 Lead Assessor(s): Richard Storch
	Northrop Grumman Electronic Sensors and Systems Sector (ESSS) Baltimore, MD Point of Contact: Eva M. Brandt, eva_m_brandt@md.northgrum.com Maturity Level: 4 Date of Appraisal: Oct 1999 Lead Assessor(s): John Blyskal
	Northrop Grumman, Air Combat Systems, Integrated Systems and Aeronautics Sector El Segundo, CA Point of Contact: Leitha Purcell, purcele@mail.northgrum.com Maturity Level: 4 Date of Appraisal: Oct 1998 Lead Assessor(s): Don Dortenzo

High Maturity Organization	
	Northrop Grumman, Integrated Systems & Aerostructures, AEW & EW Systems (formerly Surveillance & Battle Management) Bethpage, NY Point of Contact: Dennis Carter, cartede@mail.northgrum.com Maturity Level: 4 Date of Appraisal: Oct 1998 Lead Assessor(s): Andy Felschow
	Oracle Software India Limited, India Development Center Bangalore, India Point of Contact: Ashish Saigal, asaigal@in.oracle.com Maturity Level: 4 Date of Appraisal: May 1999 Lead Assessor(s): Pradeep Udhas
	Patni Computer Systems Ltd. (PCS), Mumbai, Navi Mumbai, Pune and Gandhinagar Facilities Mumbai, India Point of Contact: Sunil Kuwalekar, sunil.kuwalekar@patni.com; N A Nagwekar, nilendra.nagwekar@patni.com Maturity Level: 5 Date of Appraisal: Aug 2000 Lead Assessor(s): Pradeep Udhas
√	Philips Consumer Electronics, Philips Software Centre Bangalore, India Point of Contact: Bob Hoekstra, bob.hoekstra@philips.com Maturity Level: 5 Date of Appraisal: July 2000 Lead Assessor(s): Richard Knudson
	Raytheon (formerly Raytheon E-Systems) Garland, TX Point of Contact: Mary E. Howard, mary_e_howard@raytheon.com Maturity Level: 4 Date of Appraisal: Dec 1998 Lead Assessor(s): Neil Potter
	Raytheon C3I Fullerton Integrated Systems, Command and Control Systems/Middle East Operations Fullerton, CA Point of Contact: Jane A. Moon, jmoon@west.raytheon.com; Janet Bratton, jabratton@west.raytheon.com Maturity Level: 5 Date of Appraisal: Oct 1998 Lead Assessor(s): Paul Byrnes (LA & LE), Jane Moon, Ronald Ulrich, Ivan Flinn, Bruce Duncil (LA & LE), Janet Bratton
	Raytheon Missile Systems, Software Engineering Center Tucson, AZ Point of Contact: Michael D. Scott, mscott1@west.raytheon.com Maturity Level: 4 Date of Appraisal: Oct 1998 Lead Assessor(s): John Ryskowski, Michael Scott
	Raytheon, Electronic Systems, Sensors Engineering El Segundo, CA Point of Contact: Paul Curry, pcurry@west.raytheon.com Maturity Level: 4 Date of Appraisal: Oct 2000 Lead Assessor(s): Janet Bratton, Michael Scott, Ivan Flinn

High Maturity Organization	
√	Satyam Computer Services Ltd India Point of Contact: Prabhuu Sinha, prabhuu@satyam.com Maturity Level: 5 Date of Appraisal: March 1999 Lead Assessor(s): Richard Knudson
	Siemens Information Systems Limited (SISL), Software Development Group Bangalore, India Point of Contact: T. Kathavarayan, kathavarayan.t@sisl.co.in Maturity Level: 4 Date of Appraisal: Aug 2000 Lead Assessor(s): Richard Storch
	Silverline Technologies Limited Mumbai, India Point of Contact: S. Purushotham, sp@silverline.com Maturity Level: 4 Date of Appraisal: Dec 1999 Lead Assessor(s): V. Kannan
√	Tata Consultancy Services Ahmedabad, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; Rosemary Hedge, rhedge@ahd.tcs.co.in Maturity Level: 5 Date of Appraisal: Nov 2000 Lead Assessor(s): Ron Radice, P. Suresh
√	Tata Consultancy Services, Ambattur, Chennai, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in Maturity Level: 5 Date of Appraisal: July 2000 Lead Assessor(s): Ron Radice
√	Tata Consultancy Services Bangalore, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; Uma Rijhwani, umarijhwani@blore.tcs.co.in Maturity Level: 5 Date of Appraisal: Jan 2000 Lead Assessor(s): Ron Radice
√	Tata Consultancy Services Calcutta, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; Arunava Chandra, achandra@tcscal.co.in Maturity Level: 5 Date of Appraisal: Jan 2000 Lead Assessor(s): Ron Radice
√	Tata Consultancy Services, Global Engineering Development Center Chennai, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; M. Mala, mala@wst03.tata.ge.com Maturity Level: 5 Date of Appraisal: July 2000 Lead Assessor(s): John Harding

High Maturity Organization	
√	Tata Consultancy Services, Gurgaon II New Delhi, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in Maturity Level: 5 Date of Appraisal: Feb 2001 Lead Assessor(s): Ron Radice
√	Tata Consultancy Services, HP Centre Chennai, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; P. Vasu, pvasu@hp.india.com Maturity Level: 5 Date of Appraisal: July 1999 Lead Assessor(s): Ron Radice
√	Tata Consultancy Services Hyderabad, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; N V Jayaramakrishna, jayaram@hydbad.tcs.co.in Maturity Level: 5 Date of Appraisal: May 2000 Lead Assessor(s): John Harding, Gargi Keeni
√	Tata Consultancy Services Lucknow, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; Nirmal Kumar, nirmal_kumar@lko.tcs.co.in Maturity Level: 5 Date of Appraisal: Jan 2000 Lead Assessor(s): John Harding, Radhika Sokhi
√	Tata Consultancy Services, SEEPZ Mumbai, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; P. Suresh, p.suresh@seepz.tcs.co.in Maturity Level: 5 Date of Appraisal: Aug 1999 Lead Assessor(s): Ron Radice
√	Tata Consultancy Services Shollinganallur, Chennai, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; R. Ravishankar, rravisha@chennai.tcs.co.in Maturity Level: 5 Date of Appraisal: Nov 1999 Lead Assessor(s): Ron Radice
√	Tata Consultancy Services, US West Chennai, India Point of Contact: Gargi Keeni, gkeeni@mumbai.tcs.co.in; R. Umasankar, rumasan@uswest.com Maturity Level: 5 Date of Appraisal: April 1999 Lead Assessor(s): Ron Radice, V. Muralidharan, John Harding
	Tata Elxsi Limited Bangalore, India Point of Contact: M. Thangarajan, mtr@teil.soft.net Maturity Level: 4 Date of Appraisal: Aug 1999 Lead Assessor(s): Pradeep Udhas

High Maturity Organization	
	Telcordia Technologies, Inc. Morristown, NJ Point of Contact: Bill Pitterman, wpitterm@telcordia.com Maturity Level: 5 Date of Appraisal: May 1999 Lead Assessor(s): Pat O'Toole, Bill Curtis, Norm Hammock
√	U.S. Air Force, Ogden Air Logistics Center, Technology & Industrial Support Directorate, Software Engineering Division Hill AFB, UT Point of Contact: Jim Vanfleet, Jim.Vanfleet@Hill.af.mil Maturity Level: 5 Date of Appraisal: July 1998 Lead Assessor(s): Mark Paulk, Brian Larman, Donna Dunaway, Bonnie Bollinger, Millie Sapp, Mike Ballard
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Acronyms

ANSI	American National Standards Institute
ASQ	American Society for Quality (formerly ASQC)
ASQC	American Society for Quality Control
CAF	CMM Appraisal Framework
CBA IPI	CMM-based appraisal for internal process improvement
CCB	configuration control board
CM	[Software] Configuration Management (Software CMM Level 2 KPA)
CM	configuration management
CMM	capability maturity model
CMMI	CMM Integration
CMU	Carnegie Mellon University
COQ	cost of quality
DoD	Department of Defense
DP	Defect Prevention (Software CMM Level 5 KPA)
EIA	Electronics Industries Association
EITVOX	entry criteria, inputs, task, verification, outputs, and exit criteria
ETVX	entry criteria, task, verification, and exit criteria
FFRDC	federally funded research and development center

FTE	full-time equivalent
HMO	high maturity organization
HTI	happy team index
IC	Intergroup Coordination (Software CMM Level 3 KPA)
IDEF0	function modeling method
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers, Inc.
IM	Integrated [Software] Management (Software CMM Level 3 KPA)
ISM	Integrated Software Management (Software CMM Level 3 KPA)
ISO	International Organization for Standardization
IT	information technology
KPA	key process area
KSLOC	1000 source lines of code
LA	Lead Assessor
LE	Lead Evaluator
LOC	lines of code
MoD	Ministry of Defence (United Kingdom)
NSIA	National Security Industrial Association
OPD	Organization Process Definition (Software CMM Level 3 KPA)
OPF	Organization Process Focus (Software CMM Level 3 KPA)
OSD	Office of the Secretary of Defense

PAL	process asset library
PCM	Process Change Management (Software CMM Level 5 KPA)
PD	[Organization] Process Definition (Software CMM Level 3 KPA)
PE	[Software] Product Engineering (Software CMM Level 3 KPA)
PF	[Organization] Process Focus (Software CMM Level 3 KPA)
PM	Process [Change] Management (Software CMM Level 5 KPA)
PP	[Software] Project Planning (Software CMM Level 2 KPA)
PR	Peer Reviews (Software CMM Level 3 KPA)
PSP	Personal Software Process
PT	[Software] Project Tracking [and Oversight] (Software CMM Level 2 KPA)
PTO	[Software] Project Tracking and Oversight (Software CMM Level 2 KPA)
QA	[Software] Quality Assurance (Software CMM Level 2 KPA)
QA	quality assurance
QFD	quality function deployment
QM	[Software] Quality Management (Software CMM Level 4 KPA)
QMS	quality management system
QP	Quantitative Process [Management] (Software CMM Level 4 KPA)
QPM	Quantitative Process Management (Software CMM Level 4 KPA)
RM	Requirements Management (Software CMM Level 2 KPA)
ROI	return on investment

SADT	structured analysis and design technique
SCAMPI	standard CMMI assessment method for process improvement
SCE	software capability evaluation (method)
SCM	software configuration management
SCM	Software Configuration Management (Software CMM Level 2 KPA)
SEI	Software Engineering Institute
SEPG	Software Engineering Process Group
SLOC	source lines of code
SM	[Software] Subcontract Management (Software CMM Level 2 KPA)
SME	subject matter expert
SOW	statement of work
SPA	software process assessment (method)
SPE	Software Product Engineering (Software CMM Level 3 KPA)
SPIN	Software Process Improvement Network
SPP	Software Project Planning (Software CMM Level 2 KPA)
SQA	Software Quality Assurance (Software CMM Level 2 KPA)
SQA	software quality assurance
SQM	Software Quality Management (Software CMM Level 4 KPA)
SSM	Software Subcontract Management (Software CMM Level 2 KPA)
TCM	Technology Change Management (Software CMM Level 5 KPA)

TM	Technology [Change] Management (Software CMM Level 5 KPA)
TP	Training Program (Software CMM Level 3 KPA)
TQM	Total Quality Management
TSP	Team Software Process
USAF	United States Air Force
WBS	work breakdown structure
WG	working group

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In March of 2001, the Software Engineering Institute (SEI) in Pittsburgh, PA, hosted a workshop for high maturity organizations to better understand practices that characterize Capability Maturity Model® for Software (Software CMM®) Level 4 and 5 organizations. Topics of discussion included practices described in the Software CMM as well as other practices that have a significant impact in mature organizations. Important themes included statistical process control for software, the reliability of Level 4 and 5 assessments, and the impact of the CMM Integration℠ effort. Additional topics solicited from the participants included measurement, Six Sigma, Internet speed and process agility, and people and cultural issues. This report contains overviews of more than 30 high maturity organizations and the various working group reports from the workshop.

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