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The Level 4 Software Process from the Assessor's Viewpoint

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ABSTRACT
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From the time the Capability Maturity Model (CMM) was developed (late '80s, early '90s), it was a matter of speculation whether software organizations existed or would be assessed at the higher maturity levels, levels 4 and 5. In the last two years, a few organizations with processes at these high levels have been reported. But most assessors (including compilers of the CMM) have never seen a Level 4 or Level 5 company. This paper describes a Level 4 company (one therefore in the top 2% of all organizations ever assessed) from the viewpoint of an outside assessor. Features that make this particular Level 4 process a paradigm case of implementing the CMM are described as well as innovations that go beyond the CMM and contribute to noteworthy robustness of implementation (institutionalization). The description serves as a brief case study of Level 4 practices and as an example for other organizations following the CMM road map. One hopes that with time a whole series of case studies will appear as organizations climb the maturity scale to Levels 4 and 5 and choose to make known how they implemented the CMM in their business environments.

Section 1. Introduction

The SEI's Capability Maturity Model for Software has 5 maturity levels.[1] Since the early days of the CMM's development and its use for assessing software processes, it was a hypothesis that organizations would be found at each level.[2] In 1989, SEI's first published data on the maturity profile of assessed organizations showed few above Level 2 and none at Levels 4 or 5.[3] Assessment results accumulated through 1991 still showed

[1] Mark C. Paulk et al. *Capability Maturity Model for Software, Version 1.1* (CMU/SEI-93-TR-24). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, February, 1993.
[2] Watts Humphrey, personal communication.
[3] Watts Humphrey, David Kitson and Tim Kasse. *The State of Software Engineering Practice: A Preliminary Report* (CMU/SEI-89-TR-1). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, February, 1989.

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no organizations above Level 3.[1] Recent SEI data show a few companies at Levels 4 and 5, about 2% of all assessments reported.[2]

Evidently these high maturity organizations are a rare species. Few assessors and professionals in software processes have ever seen a Level 4 or 5 organization. (If you happen to be an assessor, your experience is likely to be mostly with Level 1 processes.) Since there were no Level 4 organizations assessed at the time the CMM was written, its compilers had to envision what such an organization would be like. It is instructive to compare a living example with the imagined construction.

The Level 4 software process should exhibit routine and effective use of all the key process areas of Levels 2 and 3 plus a pervasive understanding and control of processes and products by means of quantitative data. Thus, well-regulated processes under control of metrics should be the picture obtained by an assessment team in a Level 4 software-producing company.

The paper is organized as follows. Section 2 sketches the business environment of the Level 4 organization called X Company and describes how the company has implemented certain Key Process Areas (KPAs).[3] To stay within the compass of a short paper, I have highlighted only certain KPAs, those which displayed innovative features that seemed to go beyond the general recommendations in the CMM practices. Aside from the space constraints of a short paper, the requirements of non-disclosure of proprietary information limit more detailed descriptions of processes and tools. Section 3 summarizes observations on the rare life form of a Level 4 company.

The assessment method used to appraise the software process at the two sites involved was the CMM-Based Appraisal for Internal Process Improvement (CBA-IPI)[4] as defined by the Software Engineering Institute, Pittsburgh, Pennsylvania, USA. CMM version 1.1 was the process benchmark.

Section 2. Processes in a Level 4 Company

In this section a short sketch is given of the business environment and process improvement history of the case study organization, called in this paper, X Company. This is followed by descriptions of process areas implemented in a particularly striking way, especially processes interlinked for mutual support and synergy.

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[1] David H. Kitson and Steve Masters. *An Analysis of SEI Software Process Assessment Results: 1987-1991* (CMU/SEI-92-TR-24). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, July, 1992.

[2] Software Engineering Measurement and Analysis Team. *Process Maturity Profile of the Software Community 1995 Update*. Copy of presentation transparencies. Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, November, 1995.

[3] KPAs and other elements of the CMM are described in Mark C. Paulk et al. *Key Practices of the Capability Maturity Model, Version 1.1* (CMU/SEI-93-TR-25). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, February, 1993.

[4] CMM-Based Appraisal Project. *CBA-IPI Lead Assessor's Guide* v1.0. Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, May, 1995.

Section 2.1. Business Environment and Evolution of Process Improvement at X Company

X Company is located at two sites in India 1000 km. apart with a total professional staff of about 280. The company produces commercial software products for a worldwide financial market of banks and insurance companies. These commercial products operate on a variety of platforms. The company began as a spin-off in the early 90s of an Indian software company that is an internal division of a large international bank with headquarters in America. The founders wanted to sell products to customers in any financial market, not just to internal customers of the international bank. To do so, they had to incorporate separately from the international bank. X Company is majority-owned by Indians, though it retains the logo of the American headquarters company which is part owner.

Process improvement has been a part of X Company's business strategy since its founding. For example, the spin-off company adopted the standards and procedures manual of the parent company. Also, the founders of X Company, all software-knowledgeable, ensured that as the company grew, new hires would understand and follow the standards and procedures manual. The company's Chief Executive Officer (CEO) and founders determined that continuous quality improvement would characterize X Company's growth. By 1994, after examining ISO 9000 and the CMM as possible improvement scenarios, the company decided to follow the CMM as a road map for long-range process improvement. A Software Engineering Process Group (SEPG) function[1] existed from the early days. The motivation for an assessment was to have an independent check on what management and employees felt was a beneficial program. In other words, the improvement program was normal business practice, producing a return on investment (ROI) of more than 2 to 1; the assessment was not imposed by external customers but was to be an internal verification of process maturity level.

Section 2.2. Processes in a Level 4 Company as Seen by the Assessment Method.

This section gives a snapshot of certain key process areas and use of metrics as seen in this case study organization.

Key Process Area: Training

At the beginning of each year, X Company's upper management and the Training Coordinator estimate the organization-wide training needs and outline a training calendar of in-house and external courses to satisfy them. Special skills needed for upcoming projects, the annual business plan, and individual training needs are inputs to constructing the calendar. Individual training needs come from each employee's Individual Learning Plan or ILP. The ILP is a career-spanning document accumulating over time and filled out by both the employee and the employee's supervisor at the time. It lists the person's

[1] The SEPG function in a software organization coordinates process improvement. See below under "Key Process Areas: Software Quality Assurance (SQA) and Organization Process Focus (SEPG)."

training needs as his or her career unfolds and records that the training was actually received when needed. The ILPs, as one source of input to the Training Calendar, are audited by SQA to ensure training delivery. The Training Calendar is then used to plan a training budget.

Most training courses are developed and given in-house. People who become proficient in a function like project management give training on that topic and develop or enhance the training course. Users or adapters of new processes or technology become trainers in that area. Everyone at some time thus has experience as trainer and as trainee. New hires receive mandatory induction training specialized differently for young people taking their first job fresh from school or for experienced people hired from another company. This induction training, which may include banking and financial applications if these are unfamiliar to the new hire, takes 6 to 8 weeks.

Planning and delivery of training for both sites is accomplished with a full time training staff of just one person, the Training Coordinator. There is no specialized cadre with full-time training responsibilities. Of special interest to an outsider, the training process was organized as a self-sustaining system for spreading expertise and lessons learned within the company. The question of outsourcing such a training function does not even arise in a case where the function is spread over all employees in the company and serves as a tool for reusing knowledge and for technology transfer.

People accept their roles as trainer or trainee as a normal job task, and the uniform coordination of all employee training is a major contributor to the sharing of processes and culture between the two sites. The resulting similarity in software and management practices between sites was easily noted in the assessment.

Key Process Area: Organization Process Definition (OPD)

The OPD key process area is abstract and one of the hardest to visualize among the 18 process areas of the CMM. A company fulfilling this KPA uses a standard set of processes so that each software project will organize itself in a repeatable fashion to reuse best practices the company considers vital. At the same time each project should be allowed to customize within agreed limits how it carries out the standard company approach for its own requirements of customer, platform, schedule, etc. The idea is to have both a standard way of operating for all projects, as a stable basis for improvement of the whole organization, and to have a systematic way of customizing the standard for project peculiarities.

X Company's solution to having a general standard and also a standard way of deviating from it is to define a set of core processes that all projects share and to define a number of different project life cycles in use. As part of a project initiation process (see below under Project Planning), the appropriate life cycle is chosen. Core processes include planning, construction (development or maintenance), configuration management, etc. Pre-defined project life cycles include rapid application development, client-server, etc.

Employees use the company's standard processes in the form of templates, process descriptions, procedures, and "how-to" guides in an on-line environment. The standard process is available through the same interface on everyone's desk top, so that processes are largely automated. Automation makes it easier to follow the standard way of doing things by starting from a fill-in-the-blanks template with on-line help and from examples of documents from previous projects. The automated interface to the process is also the employee's interface of record to the rest of the organization, that is, to one's colleagues and managers. The on-line process library, called QuBase for Quality Base, is also a source of training with tutorials and filled-out examples.

Though QuBase provides a standard way of discussing, deciding and recording work issues, paper documents do not disappear. The automated process interface did not prevent people from communicating face-to-face or by telephone or in writing. The templates and final versions of implementation documents were on-line; the in-process documents were on paper and recorded the details of a project's life cycle -- audit comments, signature approvals, test results, meeting minutes, etc.

Key Process Areas: Project Planning, Intergroup Coordination, and Integrated Software Management

These three CMM KPAs are closely related in a Level 3 or higher organization and so are discussed together. X Company has a Project Office, staffed by a senior manager who is also the quality director, but the function itself is carried out by a number of managers. The Project Office is a focal point that oversees projects from start to finish.

A project begins by going through an initiation process. The initiation templates in QuBase require estimating and recording information on the technical aspects of a potential project (e.g., software size in function points and task complexity, functional requirements or methods of requirements elicitation) as well as on non-technical aspects (e.g., needs for: training, hardware and software platforms, office space, special equipment, travel, types of skills and number of workers, etc.). QuBase converts these non-technical requirements of the potential project to e-mail messages which are sent to the appropriate managers (directors of Finance, Facilities Management, Administration, Training Coordinator, Process and Quality Management -- Software Engineering Process Group or SEPG and Software Quality Assurance or SQA). The customer requirements and acceptance criteria for the project's deliverables are also recorded. For a new standard product (as opposed to a custom software product for a specific client), the International Marketing group acts as the customer and defines the acceptance criteria. Only after project risks have been assessed and all the managers agree to their commitments is the project authorized to consume resources, signaled by the assignment of a project identifier.

X Company has built a smoothly operating commitment process[1] for coordination among groups who support many projects with office space, computers, skills, travel, and technical functions like reviews and testing. Tracking of fulfillment of project commitments and the status of project risks as well as progress on overall business goals is done in company Quarterly Reviews of annual goals, monthly Senior Management Reviews across projects, and scheduled project status reviews. One of the topics in all these reviews is progress on the quantitative quality goals of the organization. (Goals for 1995 included reduction in defects by 50% and increase in productivity by 16% in all projects and functions.) Project performance is managed and measured against quantitative parameters (threshold or control limits on software size, effort, and schedule slippage). Risk management work sheets describing risks identified at project initiation as well as subsequent reviews and mitigation plans to offset risks are monitored. SQA plays a part in all reviews, raising issues that must be escalated for upper management attention. The results of review meetings, including issues raised and their disposition, are posted in QuBase and available to everyone in the company.

At a project's end, project closure templates describing lessons learned on the project and recommendations for improvements to company standard practice are filled out by the project leader and recorded in QuBase and thus made available to company staff. Process innovations, technical and management lessons learned and project quantitative data are thus accumulated in what the CMM would call a process library and process database.

The result of practicing such a smooth and automated commitment process is that project problems are foreseen early and there are few crises. Though the messages generated automatically to company groups at project initiation time were process elements noteworthy to outsiders on the assessment team, X Company people pointed to the training in team building and group dynamics required of everyone as a major factor in their culture of cooperation.

Key Process Areas: Software Quality Assurance (SQA) and Organization Process Focus (SEPG)

Quality assurance, the job of SQA, and serving as the focal point for company processes, the job of the SEPG, are separate functions in the CMM, but the relation between them is often problematic in implementation. X Company structured the roles of these two groups to be mutually supporting. The SQA group reports independently of projects to the Process and Quality Manager. The SEPG is similarly independent of projects and reports to the same manager, who also heads the Project Office.

SQA conducts process audits at project milestones and reports results to the Project Leader and at the monthly Senior Management Review meeting. SQA audits all project artifacts, starting at the project initiation phase when the project plan is being

[1] For a description of the commitment process see: Watts Humphrey. *Managing the Software Process*. Reading, Mass.: Addison-Wesley, 1989, pp. 69-82; and Kenneth Dymond. *A Guide to the CMM*. Annapolis, Md.: Process Inc US, 1995, pp. 2-31 through 2-36.

formed. SQA also audits product testing and must certify a product as ready in order for it to be released. The release certificate depends on a numerical rating computed as a function of measures of test coverage, errors discovered, errors fixed, and requirements satisfied. SQA also certifies entry and exit criteria for the project to proceed to construction (development) and to test phases based on data specified in the quality plan section of the project plan. SQA is a member of the Change Control Board which, among other configuration management functions, determines the level of regression testing required for product modifications.

SQA also audits the SEPG's activities. The unanswered question of the CMM "Who shall audit SQA?" (like the ancient Roman question, "Who shall guard the guards of the state?") receives the answer in X Company: the SEPG. SQA audits every other function (including the Financial Dept. and International Marketing) and the SEPG audits SQA. X Company people refer to their "culture of compliance," natural to the banking environment, as one factor in their comfort at being audited. Another factor, noteworthy to outsiders, is the staffing of SQA by rotation from projects and other functions. There are no career positions in SQA. People serve for a time as auditors of their colleagues and then in rotation assume project or functional roles that are audited routinely by their peers.

The SEPG has a complement of 5 full-time people assigned out of approximately 280 total over 2 sites. Its roles include process awareness (induction training on X Company's processes), internal assessments, following and enhancing its own internal SEPG process (audited by SQA), and assisting projects to use pilot processes and technology. Like SQA roles, SEPG positions are not permanent but rotate among employees.

According to the CMM, process improvement should include participation by everyone, not just by the people assigned full time to the SEPG. Aside from participating in pilot process changes in a project or function, people become part of the process improvement effort by contributing technical lessons learned called "ECNs" (for Environment Capability Notes) to the on-line QuBase. The typical ECN is written by someone who has discovered the solution to a problem encountered in a commercial software tool (editor, compiler, etc.) used by the company. This was an example of reuse and of lessons learned.

Metrics

Though not a separate KPA, metrics are a theme in all KPAs (through the "Measuring and Analysis" practice in every KPA), and use of metrics data is expected to be mature (routine, effective, and efficient) in a Level 4 organization. X Company exemplified this maturity by collecting a handful of standard metrics on all projects, and then making the results known for projects and the company as a whole. Product defect density (from peer reviews and tests), effort data (collected via an internally developed tool, "PROMOTR", described below), software size (in terms of function points, lines of code, and module complexity), and schedule elapsed time and slippage are measured and

recorded routinely. The data is summarized and analyzed in standard reports that everyone uses. Therefore the whole company had the same up-to-date knowledge of trends in defect density, defect origin by project phase, or productivity. Everyone viewed processes and spoke about them in terms of the same metrics, from the CEO to the most recent new hire.

One of the SEPG's crucial responsibilities is maintaining the company processes in QuBase and making process data available. The latter task involves collecting metrics data on projects and activities, which means making it easy for people who generate data to record it. Automation enables collection of effort data (time spent on a task) through the "PROMOTR" tool which interfaces to a widely used commercial project planning tool. The project leader develops and maintains in the planning tool the tasks, responsibilities, and schedule for an entire project. PROMOTR is networked to the desk top computer of everyone working on the project. A worker enters the number of hours spent on a task into PROMOTR, which uses the project identifier to insert the data into the relevant portion of the on-line project plan. As tasks are completed (for example by passing a planned review audited by SQA), PROMOTR causes the updating of the project plan for milestones achieved.

Project leaders complete a monthly Metrics Action Plan (MAP) report to track quality objectives (both project-specific and organization-wide) on their project -- for example, data on actual and projected defect and productivity rates. The SEPG compiles MAP reports for the whole company (both sites) and publishes a monthly QPCA (Quantitative Process Control Analysis) report within the company. This report tracks progress on X Company's quantitative goals for process improvement and product quality. Far from fearing the use of metrics data, everyone the team interviewed at the two sites said how much they depended on the MAP and QPCA reports to see how well the company's processes and their particular activity or project were faring. If a project's results to date fall outside control limits in the QPCA report, the project will identify the cause and describe actions it will take to correct the situation.

Finally, the release of a product was not determined by reaching a schedule date or passing the test phase or achieving sign off by department heads. Product release was the achieving of a product rating as certified by SQA encompassing all those things, but primarily the quantitative thresholds for defect density, process quality (all review issues resolved), requirements coverage, documentation, etc.

Section 3. Summary and Conclusion

The CMM, though quite detailed for a process standard, describes recommended practices in general terms. The CMM gives little information on Level 4 (2 KPAs out of a total of 18 for all Levels). It is hard to visualize the look and feel of "Level 4ness", historically rare, so that few people, including the authors of the CMM, have seen it.

It is noteworthy that a Level 4 company when seen through the formal instrument of the SEI assessment fulfills what the CMM predicts: Level 2 and 3 KPAs solidly in

place and a marked understanding of software processes in quantitative terms. More striking is that the Level 4 company implements those KPAs in unexpected ways that go beyond the CMM. A few of the innovations beyond the CMM have been highlighted above:

1) The training function for more than 200 people delivered with a full-time staff of one and little outsourcing because most training courses are internal, with the instructor roles distributed over the entire staff.

2) The rotation of people from projects through the SQA and SEPG so that these latter roles are not proprietary but filled by peers.

3) The smooth functioning of a commitment process coordinated by a project office and supported by an automated process environment (QuBase).

4) The uniform use of the standard process even across sites a thousand kilometers apart. This is due in part to having the process environment on line at one's desk top (easier to follow the standard process than to invent one's own) and networked to the rest of the organization. It is also due to the evident care to have the two sites feel equal (senior managers and staff functions like SQA, SEPG, training, senior management are distributed over both sites). A further cause of uniformity is that the standard process was not imposed but has been evolved by X Company people themselves over time.

Underlying the achievement of these notable features of the Level 4 company was something less tangible: the commitment of senior management to quality by means of continually improving processes. Process improvement is seen as a method for managing profits and ensuring jobs and therefore as an element, and a critical one, of business strategy. The Level 4 processes, no matter how impressive to an outsider, are not just fulfilling the CMM but make a difference in the business. The CEO expressed it this way: "We invest the equivalent of 13 people in process improvement for a year and we get back the productivity of 26."

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