IMPLEMENTING SOFTWARE PROCESS IMPROVEMENTS IN THE T&E COMMUNITY

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ABSTRACT

The Capability Maturity Model (CMM) developed by the Software Engineering Institute is widely promoted as a method to help decrease the volume of error riddled and late software projects. Because of the projected benefits, the 96th Communications Group/SC (SC) at Eglin Air Force Base began an intensive software process improvement effort in late 1997. This effort was rewarded in September 1999 when the group achieved a CMM Level 2 software rating on its first attempt. As of December 1999, 68% of assessed organizations remained at Level 1 on their first or second assessment. The SC success was not only obtained on its first attempt, but also 11 months ahead of the industry standard.

The Level 2 rating was accomplished in the volatile environment needed to support the test and evaluation mission. This environment includes frequent requirement changes, short notice modifications, and externally driven schedules. One reason this milestone was possible is close and direct involvement by management. This paper will present additional factors to implementing a successful software process improvement effort.

KEY WORDS

Capability Maturity Model (CMM), software process improvement, test and evaluation, data reduction, Software Engineering Process Group (SEPG)

INTRODUCTION

Quality software developed on schedule and within budget is critical to the nation's defense systems. In the mid 1980s, the Department of Defense (DOD) sought ways to eliminate what it perceived as the failure of software developers to consistently produce quality software on schedule and within budget. In December 1984, a contract was awarded to Carnegie Mellon University to establish a federally funded research and development center. The center—the Software Engineering Institute (SEI)—has as its stated mission "to provide leadership in advancing the state of the practice of software engineering to improve the quality of systems that depend on software" (SEI web page: http://www.sei.cmu.edu/).

The Capability Maturity Model for Software was developed by the SEI to help organizations and software engineers predict and control functional and non-functional properties of software systems. One of the objectives of the SEI model is to provide a tool for use in assessing an organization's software process maturity. The CMM defines an evolutionary path from an ad-hoc development process to a defined and optimized process. The model has five maturity levels as shown in Table 1. All levels except Level 1 have associated key process areas (KPAs) that identify issues that must be addressed to achieve that maturity level. Each KPA is assessed based on identified goals, commitments, and abilities.

1) Initial	The software 'process' is characterized as ad hoc and reactionary. Few processes are defined, and success depends on individual ability and heroics.
2) Repeatable	Basic software project management processes are established. Success can be achieved on similar projects though processes differ between projects. The process is characterized as disciplined and repeatable.
3) Defined	A standard software process for the entire organization is documented for both management and engineering activities. Individual projects tailor the standard process using approved methods to meet unique requirements. The process is characterized as defined and consistent organization-wide.
4) Managed	Detailed quality measures of the software process and products are collected. Both the software process and products are quantitatively evaluated, understood and controlled.
5) Optimizing	Continuous process improvement is the organization's focus. Improvement is possible through measurement feedback and innovative ideas and technologies.

Table 1. CMM Maturity Levels

A more detailed overview of the CMM v1.1 can be found in the article "Capability Maturity Model, Version 1.1" (Paulk, et al). CMM v1.1 is also available as a book: *The Capability Maturity Model: Guidelines for Improving the Software Process* (Carnegie Mellon University).

BACKGROUND

In an environment of a pending A76 (out-sourcing) study and increasing numbers of customers seeking to do for themselves what they had once asked of us, upper level management sought ways to improve the organization. One focus area was software development.

In August 1997, SC established a Software Process Improvement Team (later renamed the Software Engineering Process Group, or SEPG) with two primary objectives. The first objective was to focus on software process improvement; the second to prepare SC to participate in a CMM Assessment in 1999.

In September 1999, SC achieved a Level 2 CMM Software Rating on its first attempt. SC was assessed by the Software Technology Support Center (STSC), Hill AFB, Utah. Hill, a Level 5 organization, stated at the out-brief that SC's Level 2 rating was achieved 11 months ahead of the industry standard.

According to the SEI 1999 Process Maturity Profile Mid-Year Update, 68% of assessed organizations remained at Level 1 on their first assessment and 16% remained at Level 1 on their second or greater assessment. The Profile also states that the median time to move from Level 1 to Level 2 is 25½ months.

In one study (Hayes and Zubrow), the average time to move from Level 1 to Level 2 was approximately 30 months. These averages address the time between the organization's first assessment at Level 1 and the subsequent assessment at Level 2. These statistics highlight the significance of achieving a Level 2 rating on the first external assessment and of doing so in just 24 months after the effort was initiated. (Note: An external assessment provides an independent evaluation of an organization's software maturity level. The SC assessment was conducted using a method licensed by the SEI that also provides strengths and weaknesses of the organization by KPA.) SC conducted its first internal assessment in October 1998, so its time between being assessed at Level 1 and Level 2 was only 12 months! An internal assessment is conducted by personnel within the organization. Like an external assessment, it also determines strengths and weaknesses of the organization's CMM practices.

In another survey (Goldenson and Herbsleb), 86% of the process improvement champions surveyed agreed with the statement "process improvement is taking longer than we expected." Why was SC able to achieve its goal of Level 2 in record time? This paper reviews SC's journey to achieving Level 2 and enumerates what are believed to be significant contributing factors to its success.

ORGANIZATION OVERVIEW

The 96 Communications Group/SC supports the DOD and Eglin's core mission of munitions and C2 testing. SC provides support to external customers in three primary areas. 1) The Test and Analysis Division performs telemetry and test data reduction to support the test and evaluation of weapon systems. This Division provides frequency, mathematical, and software engineering services for both real-time and post-mission test data. The Central Control Facility managed by this Division provides a real-time mission control and analysis capability for all Eglin flight tests. 2) The Systems Technology Division provides computer and networking support to the research, development, test and evaluation communities. This Division provides software support in the areas of target control as well as in modeling and simulation. 3) The 96th Communications Squadron provides fixed base-level communications support and worldwide deployable initial communications support. A fourth Division, Plans and Programs, is responsible for the group's financial program. Figure 1 displays an organization chart.

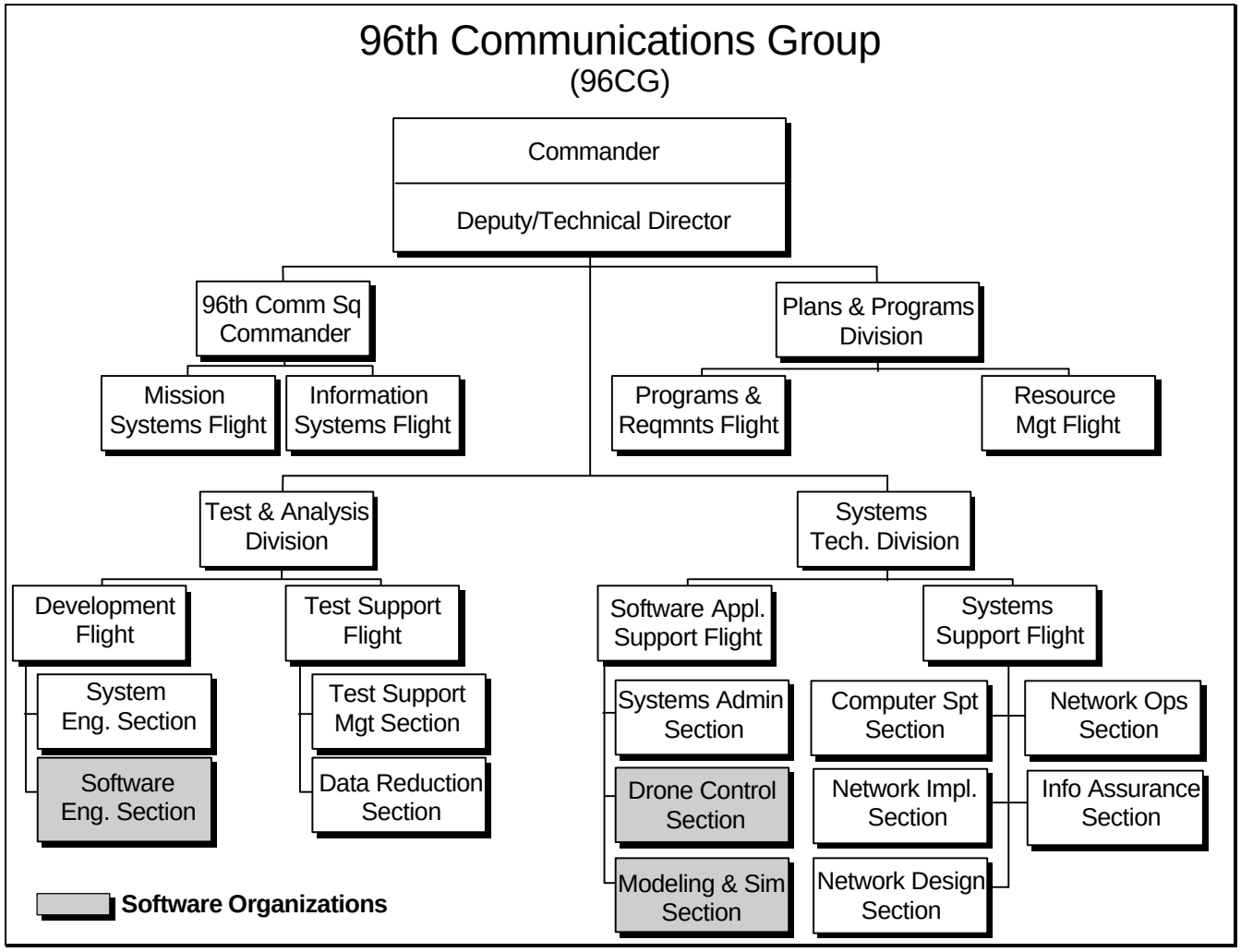

Figure 1. 96CG Organization Chart

SC has three sections whose focus is software development as represented by the shaded blocks in Figure 1. One of these sections is further divided into three focus areas yielding a total of five software areas—Gulf Range Drone Control System (GRDCS), Modeling and Simulation (M&S), and Software Engineering (Post Mission, Real Time, and Special Projects). All five areas were targeted for process improvement and participated in the assessment.

SOFTWARE ENGINEERING PROCESS GROUP

The SEPG reports to an Executive Steering Committee (ESC) whose original membership consisted of the SC Deputy and the Test and Analysis and Systems Technology Division Chiefs. The Development Flight and Software Application Support Flight Chiefs are now also members of the ESC. The SEPG met bi-weekly with the ESC to present progress, schedule, and recommendations. The original SEPG had membership from each of the five software areas, a member of senior management, and a software analyst. All SEPG members have technical degrees, with one having attended the 10-week CMM course

at the Air Force Institute of Technology, and another having a bachelor's degree in software engineering. All but one member of the original team had hands-on experience in software development.

A critical contribution to the success of the software process improvement initiative occurred in April 1998. At the recommendation of the SEPG and the approval of the ESC, a full-time Software Quality Assurance (SQA) manager was hired to support the SEPG. All other SEPG members were part-time (10-50%). The SC SQA manager had previously been a team leader with SC's support contractor during the contractor's advancement from Level 1 to Level 3.

Another contributing factor to the organization's success is the SEPG's philosophy in developing artifacts. (An artifact is any document, form, checklist, policy or other tool used in the software process improvement initiative.) The SEPG leverages existing resources while developing products specific to the needs of the organization. The SEPG reviewed existing processes and documents from the target software areas, the organization's support contractor, and other available resources.

One of the SEPG's first tasks was the development of an SC standard software process (SC SSP). Although a common process is not required for Level 2, the SEPG made the decision to start with a common process to minimize rework downstream, when we began pursuing Level 3. The diversity of the software groups posed significant challenges in developing and implementing a common process. The diversity included the following: differences in type of software being developed, externally versus internally imposed deadlines, one and only one area with defined and disciplined software development processes, 98% of projects in one area are maintenance efforts shorter than one month, and projects in three areas are developed primarily by single person 'teams'. See Table 2 for a six-month snapshot of the number and size of projects by target area. Small (S) projects are less than 3 months, medium (M) are 3-10 months, and large (L) projects are greater than 10 months as defined in the SC SSP.

Area Name	# Software Engineers	# Active Projects by Size S/M/L	# Completed
GRDCS	9	23/ 1/0	27
M&S*	7	1/ 0/ 0	1
Post Mission	7	11/ 1/ 0	41
Real Time	7	13/ 2/ 2	43
Special Projects	6	12/ 1/ 2	8

* M&S *analysis* efforts are not included

Table 2. Project Size and Number by Area

The formation of an SEPG is not required by the CMM until Level 3. The creation of an SEPG at the initiation of the software process improvement effort was another key to its success. The SEPG developed tools for use by software engineers, first level supervisors (FLSs) and senior management to aid in implementing the CMM. The SEPG developed the SC SSP and policy letters, defined required documentation, developed the SC SQA Plan, and developed and provided training to educate all involved parties. To aid in implementation, the SEPG developed Software Configuration Management (SCM), SQA, and other templates, forms, checklists and plans. To help keep the effort on track, an implementation schedule was established, regularly updated, and presented to the ESC and the software

engineers. Most members of the Test and Analysis and Systems Technology Divisions were required to take the overview CMM training, not just the members of the software sections.

FIRST INTERNAL ASSESSMENT AND RESULTING ACTIONS

SC conducted its first internal assessment in October 1998. The assessment goals were to:

- Obtain an independent assessment of each target group to provide insight into CMM process improvement initiatives
- Identify weak areas of the ESC, SEPG, first level supervisors (FLSs), senior management, and each target group to ensure proper focus is applied to attain Level 2 certification.

The assessment team identified strengths, weaknesses, and action items. The team used a strict pass (green) or fail (red) method to evaluate key process areas (KPAs). Using this method, the team rated no target area as currently performing at Level 2. M&S, GRDCS, and Special Projects had "good structure in place to achieve SEI Level 2 certification" by the projected external assessment date. Post Mission and Real Time did not reveal sufficient evidence that they were following the SC SSP or their SCM and SQA plans.

Assessment team action items were presented to the ESC, SEPG, Senior Management, and each target group. Of 790 key process area goals, commitments, and activities (158 per area), 367 were scored as red. Four hundred and ninety-five, 495, of the assessed items were under the direct control of the target groups. The other items related to the ESC, SEPG and Senior Management. First level supervisors (FLSs) were instructed to review their section's action items and provide a get-well approach with projected completion dates. It became clear from the assessment that increased attention needed to be placed on implementing CMM in the Software Engineering Section. Note that the two areas that scored the lowest were also the areas with the most volatile deadlines and greatest volume.

The first internal assessment team identified another success factor. In the summer of 1998, a member of M&S transferred to the GRDCS section and later became the supervisor of that section. In their report, the assessment team noted that the addition of that supervisor "and the importation of the M&S processes improved the group [GRDCS] significantly."

At the time of the first assessment, the SEPG membership included the first level supervisor of M&S and GRDCS and the team leaders of Post Mission, Real Time, and Special Projects. The senior manager for the Software Engineering Section, also a member of the SEPG, believed the Software Engineering FLS was not sufficiently aware of the CMM requirements. The senior manager made the decision to include the supervisor on the SEPG—replacing the three team leaders. The inclusion of the Software Engineering FLS on the SEPG also reinforced the importance of CMM. With the addition of this supervisor, all FLSs of the software areas were now members of the SEPG. Though other members were on the SEPG, including all software FLSs on the team strengthened the enforcement of the improvement effort.

The supervisor and team leaders from the Software Engineering Section began an intense series of activities to address the deficiencies identified in the assessment action plan. SEPG-developed processes were incorporated into the Software Engineering Section's practices. Detailed instructions were

developed to supplement the tools developed by the SEPG. These details, though potentially restrictive, provided the engineers with definite guidelines. An additional consideration in replacing the team leaders on the SEPG had been to free them to perform SQA duties. The assessment had clearly revealed that SQA was insufficient for the two sections that scored lowest. Team leaders believed they were best able to accomplish this function as they were the most familiar with the process, having served on the SEPG. With the supervisor on the SEPG, and the SQA managers ensuring the process was followed, real progress occurred!

SECOND INTERNAL ASSESSMENT AND RESULTING ACTIONS

The second internal assessment was conducted in April 1999. The results revealed considerable improvement (see Figures 2 and 3 and Table 3). The count of target area assessed items was now 58 red out of a total of 495 assessed key process area goals, commitments, and activities. This was down from the original count of 173 red out of 495 total. Table 3 includes SEPG, ESC and senior management related items. It should be observed that this assessment identified two target areas as completely green, or passed.

AREA	ASSESSMENT 1		ASSESSMENT 2	
	# Green	# Red	# Green	# Red
M&S	101	57	115	0
GRDCS	94	64	115	0
PM	62	96	80	35
RT	65	93	78	37
SP	101	57	82	33

Total items assessed per group: assessment 1=158, assessment 2=115

Table 3. Internal Assessment Results

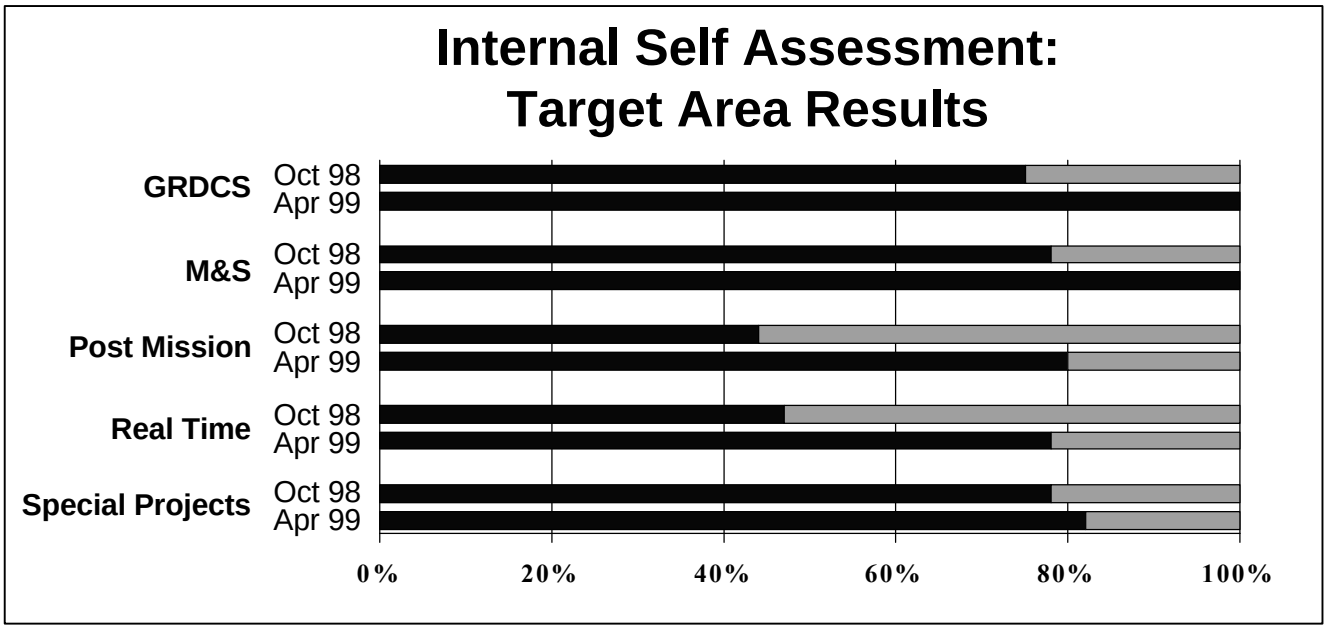

Figure 2. Assessment Results by Target Area

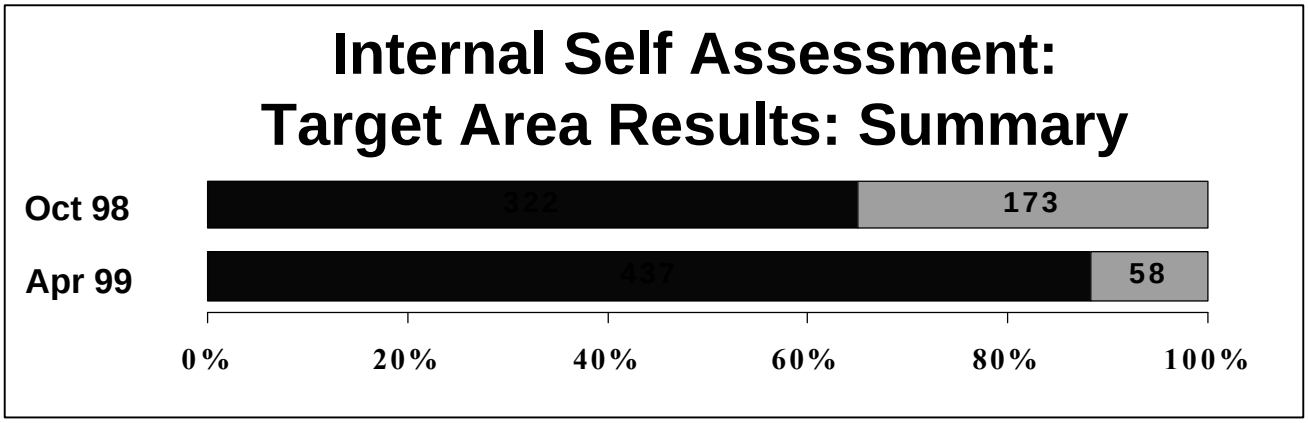

Figure 3. Summary Assessment Results

The apparent lack of significant progress in the Special Projects area was actually a result of merging the three Software Engineering processes into a single process. The primary area still outstanding was the implementation of management reviews. This activity had not yet been addressed by the FLS and team leaders and was a known deficiency. A deficiency that *did* surface during the assessment was the inability of the Post Mission and Real Time engineers to effectively and confidently communicate the process. This defect was attributed to the increased detail in the Software Engineering process. They knew the steps but not the process, similar to seeing the trees but not the forest.

The second internal assessment was modeled after an external assessment. This gave the engineers insight into what was to come and helped the SEPG identify additional items needed to ensure a successful external assessment. Each engineer participated in the equivalent of a project leader interview. It was during these interviews that the communication issue surfaced. In the first assessment, interviews were conducted in groups. In the second assessment, project leaders were interviewed individually.

To address the engineers' inability to relate their processes to the SC standard software process, the Software Engineering FLS and team leaders taught courses focused on each Level 2 KPA. To verify that information was being assimilated, the supervisor administered exams and required anyone scoring less than 80% to retake the exam. To partially address the communication issue, the exam questions were administered verbally. Written answers were scored and group results provided. Only two exams had to be retaken.

RESULTS

The STSC from Hill AFB conducted an intense two-week assessment in September 1999. Thirty-six software engineers, SEPG members, and managers were interviewed for compliance in ten key process areas. In addition to the Level 2 KPAs, five of seven Level 3 KPAs were assessed. All five software areas were evaluated. The assessment consisted of four project leader interviews, one each from M&S, GRDCS, Real Time, and Special Projects. The back-up project leader was from the Post Mission area. Of the software engineers interviewed, 12 were from M&S and GRDCS and the remaining 19 from the Software Engineering Section.

The results were extremely rewarding. All Level 2 KPAs and four of the five Level 3 KPAs were "satisfied." There were only two weaknesses noted in all of the Level 2 KPAs and only three in the four "satisfied" Level 3 KPAs. All SC software sections were assessed and engineers from every focus area were involved in the assessment. No areas were hidden from the assessors.

One unexpected aspect of the assessment is worth noting. Engineers were identified for the various functional area review (FAR) interviews based on their individual strengths. The SEPG believed the interview questions would be specific to a particular functional area while project leaders would be questioned from all aspects. This belief was based on input from the SC support contractor's commercial assessment. The STSC-led assessment team, however, asked questions from every KPA to every functional area review group. Thus interviewees were hit with questions they had not anticipated. Their success (as evidenced by the assessment results) indicates that the software process had indeed become institutionalized throughout all software areas.

CONCLUSION

Process improvement in any environment is a difficult task. The CMM was created for large projects, teams and organizations. The 96th Communications Group's success in adapting it to smaller projects and teams elevates the success of the software process improvement initiative.

This paper has briefly charted SC's journey to CMM Level 2. Several factors contributed to the organization successfully arriving at its destination. Most of the contributing factors could be duplicated by other organizations. The factors presented in this paper are enumerated below:

1. Management and SEPG commitment to the goal
2. SEPG formed at the beginning of the software process improvement initiative
3. Knowledgeable full-time member on the SEPG
4. Leveraging of existing resources
5. Regular attention by senior management and the ESC
6. Specific training provided when needed
7. Supervisors serving on the SEPG
8. Self evaluation through Internal Assessments
9. Existing software process in M&S
10. M&S processes transferred to GRDCS

Process improvement is an ongoing organizational effort. Practitioners must implement defined processes; management must back the effort. In the opinion of the author, SC's success enforces the need not only for management emphasis, but management involvement. I agree with Hayes and Zubrow's summary statement that "improving process maturity by an entire maturity level in less than 18 months is a fairly difficult task." It is, however, not impossible and we expect to reap the rewards of our continued process improvement for many years.

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