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AN EVALUATION OF THE SOFTWARE ENGINEERING
INSTITUTE'S CAPABILITY MATURITY MODEL AS A
FRAMEWORK FOR SOFTWARE PROCESS
IMPROVEMENT AT THREE AIR LOGISTICS CENTERS

THESIS

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SOFTWARE ENGINEERING INSTITUTE'S
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THESIS

Presented To The Faculty Of The School Of Logistics And

Acquisition Management Of The Air Force Institute Of Technology

Air University

In Partial Fulfillment Of The Requirements For The Degree Of

Master Of Science In Software Systems Management

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Preface

We chose to study software process improvement and the Software Engineering Institute's Capability Maturity Model as a result of discussions of previous, related AFIT research by Captain Sommers and Captain Dickerhoff (6) and material discussed in several of our Software Systems Management courses. This research is a valuable step toward understanding and improving the software processes within the Air Force.

We would like to thank both our advisors for their teamwork and insight. Dr. Freda Stohrer provided input on technical writing, research methodology, and a common sense view of the software world. Capt John Robinson helped with technical software details of selecting organizations, review of the questionnaire, and general encouragement and direction. Each team member played a crucial role in this research effort. We would also like to thank our advisors for their humor and encouragement that made the process more enjoyable

Finally, we thank our wives for their unfailing support and for putting up with too many telephone calls, too many late nights, and too much time away from our families during our research.

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Captain Brian G. Hermann

Captain Raymond J. Lewis, Jr.

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Abstract

This research sought to determine whether a relationship exists between the maturity level of the software process, as determined by the Software Engineering Institute's Capability Maturity Model (SEI CMM), and the actual success of particular software projects at three US Air Force Air Logistics Centers. Project success is defined in terms of cost, schedule, and quality criteria. In addition, each organization's acceptance of the SEI assessment as well as its effectiveness in setting up follow-on process improvement programs were evaluated. Finally, the process improvement programs were reviewed individually inasmuch as these programs are the mechanisms for achieving improved quality, lower cost, and on-time software projects. The research was accomplished through a combination of information gathering techniques and data analysis. A literature review, both within and external to the Department of Defense, summarized current software process research, discussed the CMM in detail, presented case studies using the SEI CMM, and introduces software project success criteria. Using information gathered from three Air Force software organizations, we addressed each research objective.

AN EVALUATION OF THE SOFTWARE ENGINEERING INSTITUTE'S CAPABILITY MATURITY MODEL AS A FRAMEWORK FOR SOFTWARE PROCESS IMPROVEMENT AT THREE AIR LOGISTICS CENTERS

I. Introduction

1.1 General Issue

The budget for the Department of Defense (DoD) is getting smaller while the price of weapon systems is getting larger. In this environment, the DoD's reliance upon software intensive systems has been increasing at an astounding rate. At the same time, one of the major problems plaguing the software industry is late, over-budget software. This combination of increased software reliance, late software delivery, and high software price-tags creates a critical problem for DoD acquisition and support of software dependent weapons systems.

In 1986, the DoD founded the Software Engineering Institute (SEI) to develop a methodology for characterizing the process used by software organizations to develop software products. The SEI methodology consists of a self-assessment to be used internally by organizations and a Software Capability Evaluation (SCE) conducted by trained evaluators to establish the current capability of an organization to generate software and to identify weaknesses in existing processes. The evaluation assesses the

maturity of the functions in an organization that contribute to the development of software. Some of these functions include project management, configuration management, training, software quality assurance, and automation. At the conclusion of the Software Capability Evaluation, a level of process maturity (I{lowest} through V{highest}), reflecting the overall maturity of the organization as a software producer, is assigned to the organization .

Whether software is developed internally by Air Force organizations or produced by contractors, the software development process must be controlled and managed properly to gain improvements necessary to maximize future Air Force investments. By studying Air Force software development organizations that have used the SEI methodology, we may be able to determine if a relationship exists between successful software development and support projects and SEI assessment levels. If the SEI rating proves to be a sound predictor of project success, it may be a valuable aid in reducing persistent problems with late, over-budget software within the Department of Defense and private industry. This relationship should indicate whether the SEI rating is an accurate predictor of software project success.

1.2 Specific Problem

A number of Air Force software organizations have undergone the SEI self-assessment during the past few years. However, no information is available on the relationship between the resultant maturity level and the ability of an organization to produce quality, maintainable software. Studies of a few defense-related software contractors seem to suggest that a higher maturity level is related to increased efficiency and software generation capability (7, 8, 14, 16). An accurate evaluation of the relationship between the Capability Maturity Model (CMM) levels and the success

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organizations have in producing quality, on-time, within-budget software is needed, however, to establish the CMM's value to the Air Force..

1.3 Research Objectives

By studying organizations that have used the SEI's Capability Maturity Model to assess their software processes, we determined if a relationship existed between maturity level and project success. In addition, we evaluated the impact of the assessments and follow-on process improvement programs on the assessed organizations to determine the overall effect on the organization.

1.4 Scope/Limitations

We chose a case study methodology to limit the scope of this research to a manageable effort within our time constraints. Selection of three similar cases enabled us to study each case in depth and provided results that can be further generalized. Further discussion of the case study methodology is contained in chapter three.

Candidate case study organizations were limited to Air Force organizations that have been evaluated at least once by the SEI CMM. Results from these cases can be used not only by the case study organizations, but can also serve as background information or a guide for other Air Force software organizations.

Although there are many different definitions of project success, we chose to define project success by the combination of cost, schedule, and quality (customer satisfaction). Justification for this definition is discussed in section 2.3.

1.5 Overview

This chapter has outlined the problem and importance of the research to be undertaken. In addition, we have limited the scope of the thesis to studying, via case

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study, organizations that have been assessed using the SEI CMM. The research objectives have also been briefly stated as: 1) Determine whether a relationship between maturity level and project success exists. 2) Examine the managerial and worker level reaction and perception, within assessed organizations, to the SEI CMM process assessment and follow-on process improvement efforts for the purpose of establishing whether the environment was conducive to an effective process improvement program. 3) Review organizational process improvements following the assessment(s) because a process improvement program is the mechanism for achieving improved quality, lower cost, and on-time software projects.

II. Literature Review

2.1 Introduction

The importance of software quality to the Department of Defense cannot be understated. This literature review discusses t : current state of software development, acquisition, modification, and maintenance. Following this introduction, the second section briefly explains the processes used to build and support software. The quality of a software product is also discussed here as an element of the process used to build and maintain it. Project success in the software industry is discussed in the third section of this chapter. Sections four and five, respectively, introduce the Software Engineering Institute and its Capability Maturity Model. After these explanations, some cases demonstrating the value of the Software Engineering Institute's approach are summarized in section six. Section seven outlines present DoD use of the SEI methodology and presents some expectations concerning future use of the SEI methodology within the DoD and civilian software markets.

2.2 Software Process

A software process is simply a method used to develop, modify, or maintain software. One example is the waterfall model (Figure 1), which begins with determining the requirements, proceeds to analysis and design of the system, and continues with coding the system, testing the system, and finally implementing the software. With the simple waterfall model, the events are entirely sequential. More complex models have been developed in order to perform tasks that can be done at the same time. In some cases, for example, coding and test development can occur simultaneously.
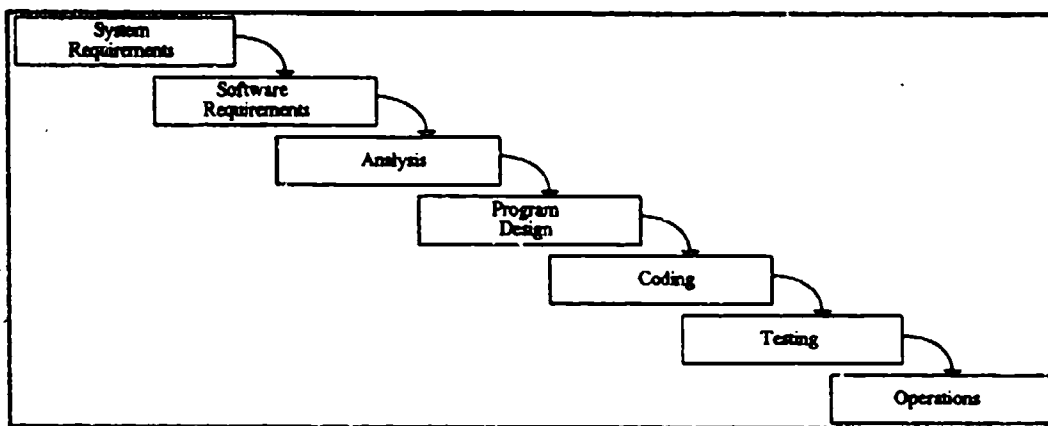
Figure 1. Waterfall Model of Systems Development (21:83)

2.3 Project Success and Quality

In order to determine whether the SEI's Capability Maturity Model (CMM) is a useful tool, we must understand what constitutes project success in the software realm. In general, "successful projects are judged to be those doing better than average on the criteria of cost, schedules, and the satisfaction of key project participants (client, project manager, project team, and syste: .. .evelopment organizations). Other criteria include follow-up work, end-user satisfaction, end-item quality, and meeting specifications" (17:472). In short, project success is defined as meeting a pre-defined schedule within cost while simultaneously achieving the technical requirements of the project.

The premise of software process improvement is that product quality or project success is directly related to the quality or maturity of the software process. "All failures are system failures in the sense that they are actually the output of a particular system. That is to say that there are features or defects in the system which produced or allowed that failure" (17:463). This implication that the process is responsible for the failure of a project is especially true of complicated software development efforts where a large amount of the effort is expended in configuration management, design, and the

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implementation of a supportable system that conforms to rigid programming and documentation standards.

"The software process is the set of tools, methods, and practices we use to produce a software product. The objectives of software process management are to produce products according to plan while simultaneously improving the organization's capability to produce better products" (12:3). The basis for the SEI's CMM is to assess the software process, recommend changes, and guide improvement efforts resulting in more successful projects. Each level in the CMM has specific requirements that should result in a better software process, and consequently more successful projects.

Process improvement in the civilian software arena is undertaken at great expense with the express goal of producing higher quality software in a more efficient manner. Other benefits include developmental cost savings and long-term support cost reduction due to increased initial product quality. According to Hersh, product quality should be the focus of all process improvement efforts (9:12). In addition, Hersh points out that many professionals confuse the distinction between process change and improvement (9:12). Finally, he advises organizations embarking upon process improvement to:

   (1) select a model for defining the process and relevant data,
   (2) collect relevant data in a uniform and consistent manner, and
   (3) evaluate and refine based upon detailed analysis of this data. (9:12)

Curtis suggests two separate measures of maturity that differentiate between product quality and process quality. First, internal maturity, the type of measure used by the Software Engineering Institute, identifies an "organization's engineering and management practices" (5:89). The second measure, external maturity, is the user's view of the maturity of the product and the organization based on experience with the product (5:89). Regardless of the process used to develop the software, the quality of the product determines the user's view of the organization. This is certainly true for the customer who

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buys off-the-shelf software for home computers. It is also true for the purchase of large defense related software projects, although costs and schedule play a larger part in the latter's consideration because the customer, the DoD in this case, is more directly aware of the production or support effort.

2.4 Software Engineering Institute

The Department of Defense sounded a note of urgency for improvement of the software development process when it founded the Software Engineering Institute (SEI) in 1986 (10:30). The SEI is located at Carnegie-Mellon University in Pittsburgh, Pennsylvania. One of the goals of the SEI is to "develop and refine a process framework and assessment methodology for characterizing the processes used by software organizations to develop or evolve software products" (11:277). The framework produced, called the Software Process Maturity Model, is based on the premise that "the quality of a software product is largely governed by the quality of the process used to create and maintain it" (11:278). In addition, the paradigm assumes that "the process of producing and evolving software can be defined, managed, measured, and progressively improved" (11:278).

The SEI assessment methodology consists of a self-assessment for internal use and a "Software Capability Evaluation (SCE) used by government agencies to judge how capable companies are at developing software" (3:25). Because of its close relation to the SCE, the internal software process assessment has become valuable beyond its intended ability to help manage the quality of a software development process. Companies frequently use this voluntary self-assessment as a preparatory test prior to a government required SCE. Many Department of Defense agencies currently require capability evaluations prior to major software contract awards in order to weed out low-scoring organizations from the bidding process for government contracts.

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2.5 SEI Capability Maturity Model

According to the director of the SEI software process program, "the SEI maturity model is based on quality principles that have been widely proven in both engineering and manufacturing and are now being demonstrated as equally effective for software" (13:45). These quality principles predicate that the stages of the software development process must be clearly identified. Treating software development like an assembly line or factory, the SEI process model assumes that once the process is defined, it can be replicated and will respond to the same quality control management and improvement ideas that apply to producing sheets of copper in an industrial factory (3:35).

To put this theory into practice, the software process maturity model identifies five levels of process maturity (table 1). Each level is based on the capabilities of lower levels and

- represents an historical phase of evolution for a software organization,
- represents a reasonable measure of improvement to achieve from the prior level,
- suggests interim improvements goals, and progress measures, and
- makes obvious a set of immediate improvement priorities once an organization's status in the framework is known. (14:14)

At Level I of the model, the organizational process operates without formal procedures (11:279). The simplest example of this is a small "mom and pop" operation that consists of talented programmers designing software as they write it. This ad hoc or chaotic process can also exist in larger organizations with defined procedures but without management controls to enforce those procedures. The most of software producing organizations operate at this initial level, although a few advanced organizations have scored much higher. The model does not contend that success is not possible in this type of organization, it just claims that success is less likely and more dependent on key personnel.

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Table 1

SEI Software Process Maturity Model   (11:279, 14:14)

Level	Characteristics	Key Challenges	Resulting Risk	Productivity And Quality
5. Optimizing	Improvement fed back into process	√ Automation	Extremely Low	Very High
4. Managed	(Quantitative) Measured Process	√ Changing technology √ Problem analysis √ Problem prevention	Low	High
3. Defined	(Qualitative) Process defined and institutionalized	√ Process measurement √ Process analysis √ Quantitative quality plans	Moderate	Moderate
2. Repeatable	(Intuitive) Process dependent on individuals	√ Training √ Technical practices - reviews and testing √ Process focus - standards, process groups	High	Low
1. Initial	(ad hoc/chaotic)	√ Project management √ Project planning √ Configuration management √ Software quality assurance	Extremely High	Very Low

Level II organizations have established basic project controls and are capable of repeating prior successes with similar projects. New challenges represent great risks to these organizations because they have continual quality problems and lack a systematic framework for improvement (11:279).

In order to move from Level II to Level III, an organization must define its standard software process architecture. In addition, a software engineering process group must exist to lead process improvement. Despite having a defined process, key challenges, including process measurement and analysis, remain.

Progression to Level IV depends on an organization's ability to examine and improve its development process. Unlike the examination and process improvement possible at the defined level, the managed level implies the ability to measure the effectiveness of improvements to the process.

Automated data gathering (as opposed to manual data gathering which is subject to bias) on process improvements is one of two key differences that distinguish the optimizing level from the managed level. The second distinction between the two highest levels is that at the optimizing level, "management redirects its focus from the [software] product to [the software development] process analysis and improvement" (11:279).

In order to receive any value from this framework, a company must know its position in the structure. The self-assessment and capability evaluation determine status within the framework through questionnaires, interviews, and documentation reviews. The questionnaires are divided into key process areas that represent the important requirements of each level of the model. Each level in the CMM is assessed by a questionnaire consisting of four to 33 questions and covering each of the relevant key process areas in each level.

Because there is no minimum requirement to be declared a Level I organization, this plateau contains a wide range of organizational abilities. Critics point to the fact that although an organization exhibits some of the characteristics of a Level IV process, its failure meet the requirements of Levels II and III results in a Level I rating (3:31). The SEI justifies this rating process by arguing that some of the higher-level benefits are meaningless within an immature process with no proper foundation to build upon (13:46). An analogy to this lack of foundation is having a super computer on your desk without the knowledge to use it for anything but word processing.

In February 1993 the SEI released version 1.1 of the CMM. Although no significant changes to the basic structure of the CMM had been made, there were several

enhancements and wording changes. "Most of the changes we made to CMM version 1.0 were done to improve the consistency of the key-practices structure, clarify concepts, and provide consistent wording" (18:19).

The most significant change is the goal oriented approach used to satisfy each key process area. "We rewrote all the goals, to emphasize the process end states rather than results, and to remove subjective words like 'effective.' Each key practice maps to one or more goals, and each goal and its associated practices can be considered a subprocess area. Satisfying all the goals satisfies the key process area" (18:19). This change serves to guide an organization clearly through process improvement by providing specific goals that, when met, satisfy key process areas which in turn lead to a higher maturity level.

2.6 Assessment and Evaluation Case Studies

Several cases have been reviewed here to illustrate how the SEI CMM has been used by organizations to evaluate their software development processes. The purpose of the discussion is to show that the CMM is a useful assessment and process improvement guide. In addition, since each of these organizations is civilian (although defense-related), differences between their process assessment/improvement experiences and those of Air Force organizations may become evident. Our literature search revealed only examples of successful implementations of the SEI's CMM. That is not to say that the SEI's CMM always results in success, only that no published examples to the contrary were found.

2.6.1 Hughes Aircraft. The Software Engineering Division (SED) of Hughes Aircraft in Fullerton, California underwent SEI process assessments in 1987 and 1990 and provides an excellent example of a successful application of the SEI software process model. Hughes SED requested and paid $45,000 for the initial assessment by the SEI. During each assessment, the team reviewed questionnaires, interviewed key players, and

verified documentation for approximately six projects. The 1987 assessment graded Hughes a Level II organization (14:11). The assessment team recommended

- establishing a centralized database on cost estimates, cost experience, and schedule performance,
- establishing uniform data definitions across projects, and
- providing the resources needed and the responsibility assignments required for gathering, validating, entering, accessing, and supporting the projects in analyzing this data. (14:13)

These recommendations are consistent with the shortcomings of most Level II organizations. Hughes agreed with these recommendations and implemented an action plan to correct their deficiencies. This action plan cost approximately $400,000 and 78 man-months of labor over the next two years (14). As a result of this effort, the 1990 assessment found Hughes SED to be a strong Level III organization. Once again the recommendations were consistent with the key challenges of the defined level.

Hughes SED earned the benefits of improved working conditions, employee morale, and performance in terms of project schedules and costs. In fact, "Hughes estimates the resulting annual savings to be about $2 million" (14:11). Obviously, from Hughes SED's point of view, the assessments and their associated costs are well worth it.

2.6.2 Westinghouse Electronic Systems. Westinghouse Electronic Systems Group (ESG) also participated in an SEI assessment. Because the results of an assessment are confidential, Westinghouse ESG chose not to publicize their numerical rating, but did publish the "primary recommendation from the assessment," which was to "review ESG's existing software engineering process group activities against the SEI's charter and functions and make appropriate recommendations for improvement" (16:1582).

We can assume Westinghouse was rated Level II because the improvement recommendations represent the key challenges for that level. In this case, Westinghouse

already had a software engineering process group, but it had failed to completely perform the functions normally associated with an SEPG. Reasons for their failure include organizational constraints and a lack of understanding of the SEPG's function. The Westinghouse report points out that virtually all SEPG functions were being performed somewhere in the electronic systems group, but many were not specifically assigned to the SEPG. To alleviate this problem, Westinghouse created charters for each component of their SEPG. In addition, Westinghouse ESG satisfied all SEPG requirements by creating new technology groups for education, requirements, and metrics (16:1584).

Overall the SEI model was implemented successfully. While still in the process of implementing their action plan, Westinghouse demonstrated that its ability to work in new project areas such as Ada and CASE (Computer Aided Software Engineering) tool visibly improved (16:1584)

2.6.3 Raytheon Equipment Division. Raytheon is another defense related corporation that implemented an SEI process improvement program. In 1988, Raytheon began a software engineering initiative through an SEI-style process assessment. The in-house reviewers rated the corporation at the initial (ad hoc) level and identified four key areas for process improvement. Many software professionals were involved in the process improvement program on a part-time basis. This strategy helped to increase ownership of changes, reduced the need to re-solve problems already corrected by parts of the organization, and smoothed the implementation of changes within on-going projects (7:83).

Raytheon is proud to say the improvements are already paying off. Using Phil Crosby's Cost of Quality idea, Raytheon identified four costs categories for software:

- Performance costs are those associated with doing it right the first time.
- Non-conformance costs are rework costs.
- Appraisal costs are associated with testing the product.
- Prevention costs are incurred in attempts to prevent faults. (7:84)

The sum of the final three cost categories is called the "cost of quality" (7:84). Raytheon's initiative increased prevention costs, had virtually no effect on appraisal costs, and dramatically reduced non-conformance costs. By 1992, Dion estimated $9.2 million in savings as a direct result of the initiative (7:84). In 1993, the savings were even more impressive. Additional projects added to the original study increased the estimated savings to $15.8 million (8:28).

In addition to cost savings, the initiative has an impressive list of accomplishments:

- a $7.70 return on every dollar invested (8:28).
- a two-fold increase in productivity (8:28).
- an evolution from Level I on the SEI maturity scale (through Level II) to the defined level (Level III) (8:28).
- Increased business justifying a 25 percent personnel increase (8:35).

During the five-year initiative, nearly $1 million has been invested in process improvement. Where late, over-budget software was the norm in 1988, Raytheon increasingly achieves early and under-budget software efforts (8:35). In fact, early delivery bonuses are not even counted in the costs savings for the process improvement initiative.

Obviously, Raytheon is pleased and proud of their success. Top management has been convinced that the process improvement climb up the SEI maturity ladder more than pays for itself. Dion credits much of the success to management commitment to and employee ownership of the software engineering initiative.

2.6.4 NASA. NASA is also exploring the benefits the software process maturity model has for their mission-critical software. NASA had two teams trained by the SEI to perform assessments. Once trained, they decided to "perform an SEI contractor capability

evaluation on the Space Shuttle flight software program" (8:299). Surprisingly, the contractor was rated at the optimizing level (Level V). Of course, this did not mean there was no room for improvement. In fact, the team identified entry-level training, consolidation of formal inspection data, and quality assurance procedures and testing as areas for potential improvement (4:299).

To get the complete picture of contractor performance, NASA also wanted the ability to test contract management and software quality assurance organizations. As a result of these requirements, they decided to adapt the SEI contractor capability evaluation "for evaluating contractors developing NASA software and for NASA-developed software" (4:300). At this time the software quality assurance has been developed, tested, and fielded. Four major problems were found in each NASA center:

- No center-wide software assurance policies or standards
- Very little or no software quality assurance training
- No procedures to ensure that specific software assurance requirements were specified on internally developed software or on contracts
- No recourse for independent software assurance personnel to document and resolve problems early in development. (4:302)

NASA still plans to develop a model for evaluating contract or acquisition management capabilities. Early success with the software assurance model suggests the SEI model can be adapted for contract management also. In fact, recently-completed research by Captain Summers and Captain Dickerhoff of the Air Force Institute of Technology outlines a prototype model that evaluates the ability of an Air Force organization to acquire software systems through the contracting process (6).

2.7 Viability of the SEI Model

2.7.1 Private Sector. While the SEI program was developed primarily for software developers associated with the Defense Department, no constraints limit the

model to this group. In fact, this chapter has already discussed other government agencies such as NASA (4) using the SEI system. According to Bollinger and McGowan, even private industry is likely to use the SCE ratings "based on the assumption that a rating system that is good enough for the US government should be good enough for them too" (3:26).

Earlier research by David Jobber and others showed that 75 percent of software consumers said they would choose software with a quality certificate in preference to software without certification (15:24). Carrying this into the present, we can be fairly certain that the same would hold true for choosing software with or without a SEI process capability evaluation.

Another reason to believe the SEI model will spread is that current figures show that 85 percent of all organizations that have undergone SEI capability evaluations have been rated Level I. Only 13 percent were rated Level II and a smaller 0.9 percent were rated Level III (11:282). This low average maturity agrees with Humphrey's assertion that "not enough attention is paid to the overall software development process itself" (10:28). He also states that the ad hoc approach currently in use by most software development companies " will not be sufficient to tackle the task of developing complex software systems for today and tomorrow" (10:28).

The relative immaturity of the software engineering field is also fuel for the argument that use of the SEI model will spread. Until now, all organizations were competitive because nearly all organizations were operating at the initial level. Soon, however, dedicated companies using the SEI approach will begin to show the dramatic improvement demonstrated by Hughes and Raytheon (14, 7, 8). No longer able to compete, inefficient Level I companies will either go out of business or begin to use the newly established software engineering tools including the SEI software process model.

2.7.2 Department of Defense. Although the private sector use of the SEI capability maturity model appears to be on the upswing, the Department of Defense and its associated contractors are currently and will probably continue to be the largest group to utilize the Capability Maturity Model (CMM). Within the Air Force and the Navy, ratings are already being used as part of contract source selections (2, 19:36).

The Navy estimates that the SEI's software capability evaluations have been used in "more than 20 acquisitions since late 1987, some of them involving contracts worth more than $100 million" (19:36). Much like the waterfall model, defense acquisitions follow a time-phased process. The process used for selecting the contractor for the three-year, $95 million software avionics contract is presented in figure 2.

The key to making these steps work with the DoD acquisition process is to involve the evaluation team early--in the planning stages. The Naval avionics acquisition program regularly uses the SCE on contracts that include major software efforts (19). While the Air Force acquisition process is similar to the Navy's, the Air Force has yet to incorporate the SCE on a regular basis. A similar methodology within the Air Force is Aeronautical Systems Center's (ASC) Software Development Capability/Capacity Review (SDCCR) (1). This review is used by ASC for major software acquisition efforts and parallels the Software Capability Evaluation (SCE) used in the Naval acquisition case.

The evaluation team members must also be trained in the evaluation process. Once the proposals have been received, the team must assist in the evaluation of proposals and selection of bidders worthy of on-site evaluations. The on-site review requires careful planning in selection of projects to be reviewed, team-member roles, and reviewing proposal information for further questions. In the Naval avionics acquisition case, one of the lessons learned was the need for more preparation time prior to the on-site evaluation.

Since the Navy project was software intensive, the evaluation was weighted heavily in the source selection. In fact, the evaluation, which counted for one-third of the overall

score for each bidder, was by far the largest factor and significantly penalized those bidders who failed to complete the request for proposal questionnaires (19). According to the evaluation team leader, Rugg, the evaluation process was beneficial to the Navy in the selection process and also each contractor involved. Managers at both winning and losing contractors commented on the evaluations' value (19:45).
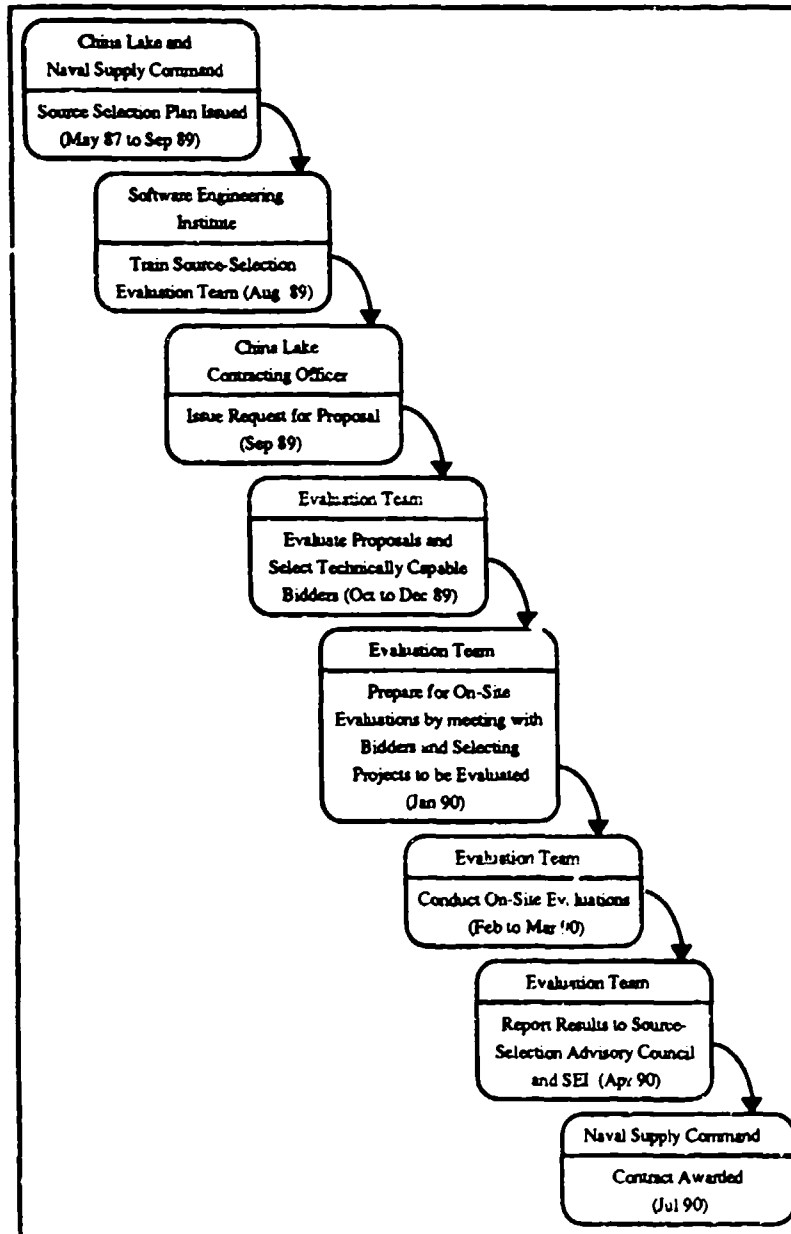
Figure 2. SCE Process and Time Line for Avionics Contract Award (19:37)

2.8 Summary

The Software Engineering Institute's software process maturity model is based on the notion that the software product can only be as good as the process used to develop it. The SEI model uses accepted quality improvement principles applied to software problems. For practical purposes, the five tiered rating system enables managers to determine where they stand within the framework. The ratings can be determined through in-house assessments and through capability evaluations. Capability Evaluations are currently used by many government agencies to aid in the contracting process.

Early assessments and evaluations have demonstrated utility when used in combination with diligent action plans based on identified problem areas. Despite the effort and expense required to undertake these assessments and associated improvements, Hughes Aircraft and Raytheon Equipment Division have shown the process to be financially beneficial (14, 7, 8). Besides evaluating software development capability, this framework can be adapted successfully for use in software assurance and software contract management capability.

The potential impact of this model extends far beyond the bounds of the Department of Defense. This far-reaching potential emphasizes the need for further research into the model's success in specific software efforts. Low world-wide software capability levels demonstrate the need for process improvement strategies. In addition, the sales value of this type of certification is proven in the public marketplace and is evolving with the Department of Defense. Companies that intend to be technically sound a successful in the late 1990s will undoubtedly require good SEI capability ratings.

III. Methodology

3.1 Overview

Using questionnaires and telephone conversations, we searched for a relationship between SEI maturity ratings and successful software development projects. In addition, we evaluated organizational acceptance and the impact of SEI assessments and reviewed organizational process improvement responses following assessments. Our research consisted of three phases which will be discussed in the following sections.

3.2 Exploratory Phase

A literature review of the SEI maturity model framework and rating system as well as case-study methodologies was performed. In addition to this review, candidate software organizations that have been evaluated using the SEI CMM were identified for case study.

3.3 Research Design Phase

A case-study research design was developed to accomplish the research goals within accepted practices identified during the prior literature review. In addition, projects for case-study were selected from those identified in the Exploratory Phase. Candidate organizations met the following criteria:

1. At least one prior SEI assessment

2. Significant in-house software development or support

3. Willingness to participate in thesis research

We used a multiple-case study design for several reasons:

1. Our research goals focus on contemporary events

2. Researchers have no control over the respondent behavi..

3. Our research questions are of the *how* and *why* form rather than *how much* or *how many*.

4. The availability of quantitative data concerning correlation between SEI ratings and project success is virtually non-existent.

5. Case-study research can provide a good pilot example for future statistically-based efforts.

According to Yin (20:17),

"research methodology should be chosen based on three conditions:
(a) type of research question posed, (b) the extent of control an
investigator has over actual behavioral events, and (c) the degree of focus
on contemporary as opposed to historical events."

According to Yin's matrix (20:17), a case study strategy is the most-appropriate strategy for research possessing the first three characteristics shown above as our reasons for selecting the case-study approach.

In order to identify correlation, a multiple-case study approach is required. "Replication, not sampling logic" (20:48) is the basis for multiple-case studies. Projects (cases) selected to participate will be expected to have either (a) similar results or (b) contrary results but for predictable reasons (20:49). While each case will be a free-standing study, the most meaningful analysis will be the cross-case comparisons for correlation.

3.3.1 Data Gathering. Study data were gathered primarily by questionnaire (Appendix A). Clarifications and further information were also gathered through telephone interviews.

The questionnaire consisted of Software Engineering Process Group (SEPG) and project level questions. Under top-level management's direction, SEPG personnel define, document, and introduce improvements to an organization's software process. Using the SEPG guidance, project level personnel develop and support software. The questionnaire was designed to collect data at each of these important levels of software organizations. The instrument consisted of questions that collectively address each of our thesis objectives. Once drafted, it was reviewed by advisors and software professionals from organizations not selected to participate in the case-study. The final questionnaire (Appendix A) was sent to individuals from selected organizations and projects.

3.3.2 Data Analysis. For each organization under study, results are presented as they relate to the thesis objectives. Once the individual cases were presented, the cross-case analysis isolated common threads existing among the cases. Our primary concern was to determine if a relationship existed between SEI Capability Maturity Model ratings and project success. Reasons for organizational acceptance, impact, and responses to SEI assessments were also compared to address the organizational and personnel environment responsible for the success or failure of the assessments.

3.4 Research Execution Phase

During this phase we followed the research plan set forth in the previous section. The process started with case selection for the multiple-case study. Next, individual projects within each case organization were identified. Data gathering included assessment reports, questionnaires, and telephone conversations. Finally the data was analyzed with respect to the research objectives. The following sections detail the specific research efforts for each of these stages.

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3.4.1 Case Selection. The primary objective in the case selection was to include DoD organizations that produced software in-house. In addition, the organization must have been evaluated using the SEI's Capability Maturity Model at least once. The second requirements reduced the available pool of organizations considerably because relatively few organizations have undergone assessments to date. Finally, we also wanted to compare similar types of organizations would ensure valid comparisons among the individual cases studied. The Air Force Air Logistics Centers, having recently been assessed using the SEI's Capability Maturity Model, provided a collection of organizations meeting all of the requirements for case selection.

Initially, five of the Air Logistics Centers (ALCs) were contacted. The Software Engineering Process Group (SEPG) in each was contacted via telephone and interviewed. During the interviews, each SEPG representative was asked about the assessment at their respective ALC. The SEPG representative provided insight into several key areas of interest with respect to the assessment process, follow-up actions, overall project performance, and willingness to participate in the study.

The interviews revealed that the ALCs were at different stages in their process improvement programs. All had been assessed at least once, with one having been assessed twice. Based on these preliminary interviews, a down-selection to three ALCs for case study was made. The entire thesis team agreed that three individual cases provided an adequate cross-section, while at the same time limiting the study to a manageable level of effort.

3.4.2 Data Gathering.

3.4.2.1 Questionnaire. In addition to SEI assessment reports from each participating ALC, the primary data was collected through the specially developed questionnaire. The questionnaire mirrored the research goals of this project.

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Prior to distribution, the questionnaire was sent to several experienced software professionals, some from non-participating ALCs, for comments and validation. These comments and suggestions, together with those of the thesis team advisors, were incorporated into the final data collection instrument. The questionnaire was subsequently distributed to the ALCs for completion by both SEPG and software project personnel. Once again, each selected ALC was to be considered as a case which consisted of a number of individual projects.

The following three sections describe each question, possible answers, and the relationships of the question to the research objectives. The discussion examines the questionnaire by research objective. To achieve our first objective, section three of the questionnaire seeks to determine if a relationship exists between project success and SEI ratings. To fulfill our second objective, sections one and four of the questionnaire deal with ALC acceptance and impact of the SEI assessment. Finally, to accomplish our third objective, section two of the questionnaire seeks to determine the effect on process improvement resulting from the SEI assessment and/or ongoing process improvement issues.

3.4.2.2 SEI Maturity and Project Success. The first objective of this research is to determine if a relationship exists between project success and SEI capability maturity model levels. The third section of the questionnaire concentrates on collecting data regarding this research question.

Question "3a" asks the respondent to identify the level at which the organization was rated by the capability maturity model. Possible answers for this question are:

- Level I, II, III, IV, or V, or
- Initial, Repeatable, Defined, Managed, or Optimizing.

These answers provide the first half of the necessary information to establish the existence or non-existence of a relationship.

Question "3b" asks what actions, taken as a result of the assessment, have been part of the project. Answers to this question suggest how the process improvement program has affected the project.

Question "3c" asks the respondent how successful the subject project was or is. Answers to this question complete the direct information required to demonstrate the existence or non-existence of a relationship between CMM levels and project success. As previously discussed, project success is defined using the triad of customer satisfaction, costs, and schedule considerations.

While questions "3a," "3b," and "3c" request data directly necessary to demonstrate the relationship, question "3d" searches for other possible reasons for improvement. The goal of this question is to determine if project success can be attributed to post-assessment process improvements or previously existing conditions or capabilities. The question asks how the post-assessment actions have affected the success of the project. Once again, the same criteria for project success are used. The purpose is to determine to what extent the assessment and resulting process improvement program have affected the success of a specific project.

Finally, question "3e" asks the respondent for an opinion on whether the process improvements will or have directly benefited the project. In addition to helping to identify whether the process improvement program has commitment at different levels, this question clarifies whether the project success is due to assessment related improvements or business-as-usual.

3.4.2.3 *Acceptance and Impact of SEI Assessment.* A second objective of this research is to study the acceptance of the assessment process by

management and workers and the impact of SEI assessments on the organizations . The primary reason for this portion of the study is to identify circumstantial information concerning the assessment and process improvements. As previously stated in the literature review, several authors have suggested that organizational commitment and personnel "buy-in" are key reasons for the success of their process improvement program (14, 16, 7, 8). For these reasons, the first and fourth sections of the questionnaire delve into the ALC environment prior to, during, and following the assessment.

Question "1a" asks what factors led to the initiation of a process improvement program. Expected short answers will describe the motivation for improving the software process. Previous studies have followed similar patterns of grass-roots interest in process improvement to management commitment and action (14, 16, 7, 8). While the same may be true in the Air Force, in some cases, organization factors have also led to the imposition of a process improvement program. Question "1b" continues with the motivation theme by asking what factors led to using the SEI (CMM) methodology for process improvement. Toward the same goal, question "1e" asks for which reasons striving for higher-level ratings is valuable.

Questions "1c" and "1d" identify the respondent's general opinion of SEI, CMM, and assessment methodologies. Question "1c" asks for an overall opinion of the SEI assessment process/methodology. Short responses will identify top-level advantages and disadvantages of the SEI methodology. Finally, question "1d" asks respondents whether the maturity level is a legitimate representation of an organizations ability. The purpose of this question is to address a prior critique of the SEI, that the maturity level number was too simple to characterize the complex software process (3).

Where section one concerned motivation and management level motivation for the process improvement program, section four concerns the personnel and management

reaction to the program. Question "4a" asks for the worker level feeling concerning the SEI assessment. Parallel to management commitment, this personnel "buy-in" has been identified as a key reason for process improvement success (14, 16, 7, 8). Question "4b" asks for management's reaction to the assessment. This question's purpose is to see if motivation for process improvement corresponds to reaction. One possible example could be that process improvement was directed by higher authorities and ALC management actively pursues the resulting process improvement initiatives. Question "4c" concerns management's pursuit of the assessment recommendations.

Question "4d" asks for any negative effects that resulted from the SEI assessment. Similarly Question "4e" examines whether the desired non-attributive environment has been maintained or if administrative discipline has accompanied the process. Both questions concern how completely the workers and management have embraced the SEI methodology. Finally question "4f" asks whether the environment has changed since the assessment.

3.4.2.4 Process Improvement Responses.
The final research objective is to study organizational process improvement responses following assessments. Section two in the questionnaire explores this area. In order to determine to what extent the assessment recommendations came from within the organization, question "2a" asks whether the assessment included SEI personnel only, local personnel only, or a combination of the two.

Questions "2b", "2c", and "2d" directly investigate what actions have been taken as a result of the assessment, what other unrelated process actions have taken place, and what the benefits have been realized through the SEI assessment process. The final question "2e" asks what process improvements have been identified. Expected answers

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should include only top-level issues such as training and configuration management. These answers help put the corrective actions in context.

3.4.3 Data Analysis

For each case (ALC) considered, a history was developed detailing the assessment(s), organizational acceptance of the assessment(s), implementation of process improvements resulting from the assessment, and the effect on projects considered within each ALC. The primary source of information was the questionnaire responses; however, follow-up interviews were used to provide additional information where necessary. Once the individual cases had been analyzed, a cross-case analysis was performed.

The cross-case analysis consisted of analyzing the three individual cases as a whole, rather than separately. Of primary interest was to identify common factors contributing to project success or any of the other factors in the individual case analysis. Based on the cross case analysis, inferences were made as to certain conditions or activities that had contributed to the overall success or failure of individual projects and the assessments nselves.

3.5 Summary

The objectives of this thesis were three-fold: (1) determine if a relationship exists between SEI Capability Maturity Model ratings and project success; (2) evaluate organizational acceptance and impact of SEI assessments for the purpose of establishing whether the environment was conducive to an effective process improvement program; (3) review organizational process improvement responses following assessments because a process improvement program is the mechanism for achieving improved quality, lower cost, and on-time software projects. These objectives were met in a three-phased manner. The exploratory phase consisted of literature review and project selection. The data

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gathering phase consisted of telephone conversations and questionnaires. Finally, the
analysis phase included single-case study summaries and cross-case comparisons.

IV. Individual Case Analysis

4.1 Background Behind the Air Logistics Center Assessments

Because the ALCs and other DoD maintenance organizations must compete for a share of DoD resources, Air Force Materiel Command (AFMC) required that the Air Logistics Centers' (ALCs) software production/maintenance process be assessed via the SEI CMM. The goal of the assessment program is continuous process/quality improvement, resulting in more effective maintenance organizations better able to compete in the DoD market. The assessment program is managed by the Embedded Computer Resources Office at Air Force Material Command (HQ AFMC/ENSR). All five ALCs have been assessed with four achieving a Level I maturity rating.

AFMC plans to have each ALC assessed every two to three years with the second round of SEI assessments to be completed by the end of 1994. The goal of AFMC is for each ALC to achieve a Level III rating by 1998. This goal is consistent with the Air Force guidance that all Air Force software producing/maintaining organizations to achieve a maturity rating of Level III by 1998.

4.2 Case Study Ground Rules

Because the ALCs have requested confidentiality, references to specific documents and ALCs will not be made. It should be understood that a significant portion of the information contained in the case analyses was obtained from internal planning documents, assessment findings reports, and questionnaires that are not releasable. References to the ALCs and individual projects have been eliminated to maintain confidentiality and conceal the identities of the organizations and individuals participating in the case studies. Responses to the questionnaires, without reference to individuals or organizations, have been tabulated in appendices B through D.

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4.3 ALC Number 1

In the late 1980s, ALC Number 1 desired to implement a software process improvement program. Management was introduced to the SEI CMM in 1989 and believed that it could be used to assist them in assessing their process and implementing a process improvement program. This interest in the SEI CMM resulted in the beginning of serious software process improvement efforts at ALC Number 1.

ALC Number 1 was first assessed in March 1990 by a team consisting of SEI and ALC personnel who had completed the SEI assessment training program. The assessment was viewed rather skeptically by a large number of ALC software personnel but was supported strongly by management. At this time, the ALC was found to be at CMM Level I, the initial level. The 1990 self-assessment provided insight into the software process at ALC Number 1, and the results were used to formulate an initial Action Plan which was the beginning of the structured software process improvement program.

Specifically as a result of this first assessment, two permanent teams were established to guide process improvement efforts. The first was a steering committee that has been meeting monthly to discuss and quantify process improvement forts. The other was a software engineering process group (SEPG) that was formed to in and implement a process improvement program. Most of the effort since the first assessment has been spent putting together the process improvement infrastructure.

ALC Number 1 was again assessed in March 1993 by a team of ALC and SEI personnel. This assessment was the first performed using the SEI CMM Version 1.1, the February 1993 version. The format for this assessment was similar to the first assessment, involving a similar number of projects and personnel. According to interviews with an SEPG representative, the second assessment was supported much more strongly than the first, largely due to the continuous focus on process improvements during the previous

three years. Efforts since the first assessment, having been focused on developing the process improvement infrastructure, showed that process improvement coulc be accomplished in a structured, common-sense manner. Employee acceptance o. ihe ongoing process improvement concept was enhanced as a result of these efforts. ALC Number 1 was found to be at Level II as a result of this assessment.

There were forty-four specific improvements implemented between the March 1990 and March 1993 assessments. Process improvement efforts have largely been goal oriented, focusing on employee morale, customer satisfaction, and product quality. Continuous, non-intrusive, measurement of these three aspects are made through monthly meetings with supervisors and the SEPG. The goal is not to constantly monitor the low-level effects of process improvement efforts, but to observe the effects on the three aspects referred to above. Throughout the process improvement effort, begun in 1990, management has been extremely supportive. ALC Number 1 has a goal of achieving a Level III assessment rating by 1995, well in advance of AFMC's goal of Level III by 1998.

The following two sections address the assessment findings and the process improvement program at ALC Number 1. These two sections are the product of our data collection efforts which include questionnaires, interviews, and the findings and follow-up action reports from ALC Number 1. The third section analyzes the data with respect to our three objectives.

4.3.1 Summary of Assessment Findings. The findings of the March 1993 assessment showed that there are six key areas which need to be addressed in the continuing process improvement effort. Each area is defined by first explaining the key area and citing the specific problem(s) associated with it.

1. **Organized Process Definition** (Organizational process definition involves developing and maintaining the organization's standard software process along with related process assets.)

Specific Problem: There is no single software process architecture. Little guidance is provided on how software process guides are to be tailored to create individual project processes or how the tailoring is to be documented and approved.

2. **Training Program** (The training program involves first identifying the training needed by the organization projects, and individuals, then developing or procuring training to address the identified needs.)

   Specific Problem: Training needs are not systematically identified and used to plan future training. For some roles such as project leader, training is not required by the organization or routinely provided.

3. **Integrated Software Management** (Integrated software management involves developing the project's defined software process and managing the software project using this defined software process.)

   Specific Problem: Lessons learned from project process execution are not routinely collected and made available to all personnel.

4. **Software Product Engineering** (Software product engineering involves performing the engineering tasks to build and maintain the software using the defined software process and appropriate methods and tools.)

   Specific Problem: No specific problem areas noted, but this area was identified as an area of concern to be monitored as process improvement continues. This area is closely related to other key process areas.

5. **Peer Reviews** (Peer reviews involve a methodical examination of software word products by the producers' peers to identify defects and areas where changes are needed.)

   Specific Problem: Peer reviews are not planned and conducted in a consistent manner across the organization. There are no documented procedures for conducting peer reviews. Peer review leaders are not formally trained and measurements on peer reviews are not collected and analyzed.

6. **Coordination with the Software Control Center** (Does not directly relate to the CMM but is recognized as an issue that must be considered because the Software Control Center is believed to be a very reliable source of strong configuration management support.)

Specific Problem: Contractors do not always follow the proper Computer Program Identification Number (CPIN) request procedures. Turn-around time through the Software Control Center is highly variable.

4.3.2 Process Improvement Program. ALC Number 1 has updated their Action Plan to include the findings of the March 1993 assessment. This updated Action Plan is the mechanism by which process improvement efforts needed to resolve the specific problems identified in the March 1993 assessment can be addressed. The Action Plan also includes other improvements not directly related to assessment findings.

In order to facilitate process improvement, ALC Number 1 employs two permanent groups to manage the implementation of the process improvement program. These groups were formed as a result of the March 1990 assessment. The first is a management steering team that provides management support for the process improvement program and is composed of division and branch level management. The second is the SEPG. The SEPG provides the technical implementation details of how best to implement specific improvements.

In addition to the two permanent groups, ad hoc technical working groups (TWGs) are formed as needed in response to specific problems in specific areas. The SEPG coordinates the activities of the management steering group and the TWGs and maintains the overall process improvement plan.

Once a specific improvement is approved by the management steering team, a TWG is usually established to work the initiative. The TWG drafts a Tactical Plan that includes a statement of why the organization is adopting a new technology or procedure. In addition, the Tactical Plan notes the goals of the new initiative and an estimate of the return on investment for the project. Next, the problem and possible solutions are researched, a solution is proposed, and an implementation plan for the solution is developed.

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A prototype group is now chosen to test the new procedure or technology, and measures and indicators are decided upon to monitor the impact of the change. Measures are taken prior to the implementation to establish a baseline against which to compare measures taken afterward. The implementation is monitored for some time (prototype period varies with specific improvement) to determine if it is successful.

If a process improvement has succeeded in the prototype phase, it is implemented throughout the organization. The improvement is subject to the same measures and indicators after broad implementation to monitor its status. The improvement is monitored closely until it has been determined to be successful at which time the improvement initiative is closed, and it is accepted as a part of the software process.

The success of improvement efforts is measured in two ways. The first is an employee satisfaction survey that solicits suggestions and feedback on the process improvement program. The second is the SEI CMM. The next assessment is planned for late 1995.

Because ALC Number 1 was assessed most recently in March 1993, there are no specific examples of improvements that have been implemented directly as a result of these findings. However, this mechanism was used to advance ALC Number 1 from a Level I organization (March 1990) to a Level II organization (March 1993), and according to interviews with the SEPG leader, it has been very effective and is well accepted by ALC personnel.

Finally, interviews with the SEPG revealed that improvements are not implemented directly in response to SEI assessment findings, but are implemented to fix perceived problems that may only indirectly effect the maturity level. This method of identifying and correcting problems, rather than responding to a template for improvement has allowed ALC Number 1 to take ownership for the improvement program resulting in well respected and accepted program.

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4.3.3 Analysis for a Relationship between Project Success and SEI
CMM Ratings. Our first objective was to determine if a relationship existed between SEI Capability Maturity Model ratings and project success. Unfortunately, because the most recent assessment was in March 1993, information from the questionnaires and interviews provided little data on it's impact on project success, although one of the projects commented that it anticipated positive effects on project success due to the continuing process improvement efforts.

4.3.4 Analysis of Organizational Acceptance and Impact. The second objective was to evaluate the organizational acceptance and impact of the SEI assessment process. One of the SEPG respondents stated that some first-level supervisors were "somewhat resistant" to the assessments because the improvements were perceived as taking too much time for the potential benefit. However, this opinion was not typical of all supervisors. In addition, all three SEPG respondents indicated that management has definitely maintained the non-attributive environment within the ALC. The preservation of a non-attributive environment enhances the effectiveness of the assessment by encouraging more candid responses, resulting in more accurate assessment findings. Two of the three SEPG responses stated that there were no negative effects as a result of the assessment. The remaining respondent did not indicate that there were any negative effects.

The SEPG responses to the first section of the questionnaire indicated that the results of the assessment were valid and represented the actual state of the software process at ALC Number 1. Two of the three respondents from the SEPG stated that it was good to have an outside organization assess their process and identify areas of weakness. The assessment results were the basis for the Action Plan which identifies

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specific improvements to be implemented to meet the address specific problems in key process areas.

Responses from both of the projects noted that the worker level reaction was positive. Both projects also indicated that they benefited by being made aware of their strengths and weaknesses. Both projects stated that they believed that management was pleased with the results of the assessment. Both projects indicated that there were no negative reactions due to the assessments and that the non-attributive environment was maintained.

4.3.5 Analysis of Organizational Process Improvement Responses. The third research objective was to review organizational process improvement following the assessments because the process improvement program is the mechanism for achieving improved quality, lower cost, and on-time software projects. The focus at ALC Number 1 has *not* been to respond to assessment results and implement improvements specifically to fix problems. ALC Number 1 has spent considerable effort developing the process improvement infrastructure detailed in the section on the process improvement program. Interviews with the SEPG Leader confirmed that this infrastructure is used as described to implement and measure process improvements. Also, as previously stated, forty-four specific improvements had been implemented between the 1990 and 1993 assessments.

The questionnaire responses stated that several process improvement initiatives were begun at ALC Number 1 as a result of the most recent (March 1993) assessment. One of the projects stated that peer reviews were begun. In addition, the other project is "in the process of developing better and documentable metrics for our projects." One of the projects also stated that the identification of training needs as well as monthly meetings to address a standardization of the software process were begun as a result of the

assessment. These improvement efforts directly address the findings of the most recent assessment.

Following the March 1993 assessment, the Action Plan was completed by mid-July 1993 using the assessment recommendations. This rapid turnaround suggests that ALC Number 1 respects the findings and is very much concerned with continuing process improvement.

Section two of the questionnaire deals with the process improvement issue relating the assessments. One SEPG respondent noted that on-going process improvements were re-focused as a result of the recent assessment, again illustrating the attention paid to the assessments and process improvement in general. The overall status of the process improvement program at ALC Number 1 is such that continuing improvement is the norm rather than the exception. The structure that has been established seems to be effective at implementing, managing, and measuring process improvement efforts.

As a result of interviews with the SEPG leader, it is clear that throughout the process improvement effort, begun in 1990, management has been extremely supportive. The assessments have been the means by which ALC Number 1 assesses the overall maturity status of their software process. Their focus on process improvement, specifically their commitment to a well defined process improvement plan, has resulted in an effective continuing process improvement environment.

The successes of ALC Number 1 are not due to a blind acceptance of the CMM, but to implementation of those improvements that further those goals which advance the effectiveness of the software process. By following their action plan, which was formulated with the assessment findings in mind, ALC Number 1 will address each key process area that was identified as being deficient. ALC Number 1 has a goal of achieving a Level III assessment rating by 1995, well in advance of AFMC's goal of Level III by 1998.

4.4 ALC Number 2

ALC Number 2 was assessed in March 1992 by a team of personnel from the SEI, SEPG, and from other ALCs. The rationale for the SEI process assessment and subsequent improvement program is two-fold. First, Air Force directives mandate in-house software developers achieve a Level III rating by 1998. Second, ALC management sought to improve their software capability in order to be more competitive for future software development and support work. One of the process related problems identified before the assessment was a lack of management visibility into the software process. The result of this problem was that management did not become aware of problems until the problems had become catastrophic.

During the assessment, leaders of five projects completed the SEI questionnaire and were interviewed by the assessment team to clarify their answers and address specific concerns. The assessment concluded with a briefing to the ALC Commander, his staff, and most of the software development personnel.

A thorough report on the assessment findings and recommendations was created and distributed shortly after the assessment detailing the results and process improvements necessary to meet identified areas of concern. This report was used as the basis for developing a specific action plan which will help guide the ALC to their goal -- a Level III rating by March of 1994.

Sources for information for this case study include questionnaires, the assessment report, and telephone conversations with ALC personnel. Questionnaires were sent to software engineering process group (SEPG) personnel as well as key software personnel from several representative projects within the software engineering division of ALC Number 3. A summary of the questionnaire responses for ALC Number 3 is included as Appendix D. The next section, summary of assessment findings, reviews the process assessment report. After the assessment report discussion, the process improvement

program section outlines the ALC's subsequent process improvement efforts. Telephone conversations with SEPG leaders and members were the sources for process improvement information.

4.4.1 Summary of Assessment Findings. The assessment resulted in ALC Number 2 receiving a Level I maturity rating. Seven areas of concern were noted. Improvements in the first five are needed to advance to a Level II maturity rating, while the last two areas require improvement to develop an infrastructure in which process improvements can be implemented and sustained.

1. **Requirements Management** (Involves establishing and maintaining an understanding with the customer on the requirements for the software throughout the life cycle.)

    Specific Problem: Project requirements are not always clearly stated.

2. **Project Planning** (Involves project planning at the developing organization and uses the previously developed requirements specification to estimate required resources and guides the process of meeting customer requirements)

    Specific Problem: Project planning and resource estimating are not always effective. Ineffective process for documenting project plans and estimates.

3. **Project Management and Oversight** (Involves tracking and reviewing the software accomplishments and results against documented estimates, commitments, and plans.)

    Specific Problem: Perception exists that management is not involved, does not understand, and is not concerned about software issues. Project status not adequately tracked. Perception exists that people are working on unrelated activities.

4. **Configuration Management** (Involves identifying configuration of a system at discrete points in time and maintaining the integrity of a the system as it is modified.)

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Specific Problem: There is a lack of a basic understanding of the configuration management function. Lack of a documented configuration management process.

5. **Software Quality Assurance** (Involves reviewing and auditing software products and activities to ensure that they comply with applicable product and process standards.)

    Specific Problem: Lack of standards guidelines or procedures for the software life cycle. Software quality functions under total quality management (TQM) concept are not clearly defined or understood.

6. **Acquisition** (Involves both the supportability by the ALC of a system following SPO acquisition, and the procurement of tools and materiel needed for internal work.)

    Specific Problem: Support issues not adequately addressed. Local procurement of parts and tools inefficient resulting in schedule slippage.

7. **Human Resources** (Involves the training of personnel within the ALC.)

    Specific Problem: Inadequate software training in project and software management as well as other related areas. Inadequate emphasis on personnel issues such as career progression.

The summary of assessment findings will be the basis for discussion in the next section where individual questionnaire responses will be addressed.

4.4.2 Process Improvement Program. As stated earlier, the final assessment report was published in December 1992. Since that time, the SEPG has been involved drafting the action plan and addressing the first three unsatisfied Level II Key Process Areas (KPAs) identified in the assessment report. According to the SEPG chief, project planning and project management and oversight were two of these high priority KPAs that directly relate to realistic project expectations and increasing management visibility into the software process. The third KPA of immediate concern was requirements definition. Improvement in defining requirements is expected both to increase customer satisfaction and reduce long-term costs.

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The SEPG chief stated that with these three efforts underway, teams are being formed to address software quality assurance and software configuration management. These two areas represent the last KPAs required for ALC Number 2 to achieve a Level II rating.

Although not CMM KPAs, two other efforts are planned once the five KPA teams are formed and working. These efforts are intended to improve the acquisition and human resources areas of the ALC. The effort in acquisition must concentrate on establishing a timely and flexible means to acquire tools needed to compete for and accomplish software efforts. The second category for improvement was human resources, where lack of technical and managerial training, lack of a technical career path, ineffective rewards for performers, and failure to challenge non-performing team members are major deficiencies.

A great deal of time is required to begin efforts in these seven process categories and even more time will be required to demonstrate improvements. For these reasons, the SEPG estimates that the organization will now achieve their Level II goal in September of 1994 rather than March of 1994.

4.4.3 Analysis for a Relationship between Project Success and SEI CMM Ratings. Our first objective was to determine if a relationship exists between SEI Capability Maturity Model ratings and project success. Section three of the questionnaire and subsequent follow-up telephone conversations were the sources of information for this objective.

Prior to the assessment, management did not have visibility into the software process. Because management was not involved in the process, they were unable to see problems growing and were unable to estimate costs and schedules. Among the assessment findings were shortfalls in project planning, project management and oversight,

and requirements definition. In response, teams were set up to implement improvements in these areas.

Both project respondents from ALC Number 2 indicated that their projects were already more successful than before the assessment, in terms of quality and customer satisfaction. Much of the credit for this success has been attributed to the early process improvements of increased customer interaction, cost and schedule tracking, and some process standardization. Each respondent indicated that the ability to accurately predict costs and schedules has impressed customers. In this case, improvement within the Level I rating has already led to increased project success, specifically regarding the quality and customer satisfaction aspects of project success. This relationship will also be studied across all three ALCs in the Cross-Case Analysis (Chapter V).

4.4.4 Analysis of Organizational Acceptance and Impact. The second objective was to evaluate the organizational acceptance and impact of the SEI assessment process. Sections one and four of the questionnaire and the assessment report are the primary sources for information related to this objective.

ALC Number 2's primary motivation for the SEI process assessment/improvement program was the Air Force mandate to achieve Level III by 1998. SEPG members understand the CMM and its associated advantages and disadvantages. ALC Number 2 adapted their process improvement effort to include human resources issues, which are not specifically addressed by the CMM. One SEPG member stated that customers are concerned only about cost, schedule, and quality -- not SEI levels. Other respondents, however, agreed that the maturity level is a valid measurement of their software generation and support capability.

The worker level response ranged from "wait and see" to active support. The two SEPG respondents listed the relatively slow rate of change and a lack of quick and visible

results as reasons for apprehension among workers. One project respondent noted that the worker level acceptance appeared to slowly improve with time. The second project respondent stated that workers felt that the assessment and improvement program were "just another formality."

Opinions of management's response, again, ranged from solid acceptance to mere compliance with the Air Force mandate. SEPG members stated that management was initially just "filling the square," but had recently begun to back the program. At the project level, one respondent stated that management had to be forced to participate; the othr management's interest had slacked off from its initial backing. These differ pinions could be attributed to workers' different points of reference with respect to management. Workers deal with project leaders, branch chiefs, and section chiefs. SEPG members work with all levels of management within the ALC. In all cases, respondents stated that management had maintained the non-attributive environment.

According to all respondents, the software professionals of ALC Number 2 have cautiously accepted the SEI assessment and improvement efforts. Since the process assessment, support has grown. Management's reaction to the SEI program, according to respondents, spanned the range from forced acceptance to active interest. SEPG members felt slightly more positive about management's reaction than did project personnel. In addition, SEPG members indicated that management support for the process improvement effort was growing, while project respondents stated that managerial efforts had slacked off. Despite these disagreements, project level workers indicated direct process improvements that involve managers of their projects.

Both project respondents agree that the improvement programs have already affected their projects through increased quality and customer satisfaction and more accurate cost and schedule estimation. While improvements are not currently quantifiable, the cost and schedule tracking information will enable future return on investment (ROI)

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calculations. The ALC will use the ROI to gauge the value of the improvement program. All respondents expect further cost and schedule improvements.

4.4.5 Analysis of Organizational Process Improvement Responses. The third research objective is to review organizational process improvement responses following assessments. Section two of the questionnaire and the telephone conversations with SEPG members are the sources of information for this discussion.

ALC Number 2 initially responded to the assessment with a very thorough findings and recommendations report. Process groups were created to address requirements definition, project planning, and project management and oversight. As previously stated, project personnel have already realized quality and customer satisfaction improvements that have directly resulted from the efforts of the these process groups. In addition, management and executive level committees were established to guide software engineering process improvement. These groups have increased management awareness and involvement in the improvement effort.

The SEPG is currently drafting specific strategic and tactical action plans to help the software engineering division achieve its goal of Level II by March of 1994. Due to the slower than expected pace of change, SEPG members now expect to achieve Level II by September of 1994. Process groups have recently been established to address the software configuration management and software quality assurance. Achievement of the goals of these two key process areas, plus the three underway, are the only remaining KPAs required for a Level II rating. Once these efforts are on track, the SEPG plans to create implementation teams focused on acquisition and human resources issues.

4.5 ALC Number 3

In May of 1992, ALC Number 3 initiated their first software process assessment in compliance with the Embedded Computer Software Program Management Plan (ECS PMP). This assessment is the most recent stage in their ongoing program to improve their software development process.

The assessment report listed the assessment's objectives as identifying key areas for process improvement and proposing a framework for subsequent improvement actions. In addition, the report emphasized concern that the findings were not intended to be critical of personnel or projects. Finally, although the results of the assessment were considered private, the ALC commander agreed to release both the maturity level and findings.

The assessment team consisted of local ALC SEPG personnel, representatives from other ALCs, and an observer and coach from the SEI. The team reviewed five software projects during the assessment. In addition to in-depth study of projects, the team met with 45 functional area representative from all areas of the software engineering division.

Sources for information for this case study include questionnaires, the assessment report, and telephone conversations with ALC personnel. Questionnaires were sent to software engineering process group (SEPG) personnel as well as key software personnel from several representative projects within the software engineering division of ALC Number 3. A summary of the questionnaire responses for ALC Number 3 is included as Appendix D. The next section, summary of assessment findings, reviews the process assessment report. After the assessment report discussion, the process improvement program section outlines the ALC's subsequent process improvement efforts. Telephone conversations with SEPG leaders and members were the sources for process improvement information.

4.5.1 Summary of Assessment Findings. At the conclusion of the assessment, the team graded the software engineering division of this ALC as "emerging into Maturity Level II, the Repeatable Level." This terminology was used to differentiate between organizations at different stages within the first maturity level. Essentially, the assessment team found relatively few unsatisfied key process areas for Level II. In fact, some evidence of strong Level II processes and even Level III activities were discovered. Nine areas of concern were noted. The first three finding areas were the only unsatisfied Key Process Areas for a Level II rating. Within these shortfalls, software quality assurance was regarded as the biggest hurdle between ALC Number 3 and a Level II rating. Training, peer reviews, and organizational process definition represent challenges for the third or Defined level. Finally, human resources, test equipment, and project resources were specific areas of need identified by the assessment team rather than CMM key process areas. The following list includes all finding areas for ALC Number 3's software processes, a brief description of each domain, and ALC Number 3's related problem(s).

1. **Software Quality Assurance** (Software quality assurance involves reviewing and verifying the software products and activities to ensure that they comply with the applicable processes, standards and procedures)

   Specific Problem: The software quality assurance functions are not well-defined.

2. **Software Project Planning** (Software project planning involves developing estimates for the work to be performed, establishing the necessary commitments, and defining the plan to perform the work)

   Specific Problem: No effective mechanism exists to ensure that software size, cost, and schedule estimates are consistent, accurate, and used.

3. **Software Management** (Software management involves tracking and reviewing the software accomplishments and results against documented

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estimates, commitments, and plans, and adjusting these based on the actual accomplishments and results)

Specific Problems: Critical software metrics are not adequately defined, recorded, and tracked. There is a lack of a mechanism to ensure periodic management review of each project.

4. **Training** (Training involves identifying the training needs of the organization, the projects, and the individuals, and developing and procuring courses to address these requirements)

Specific Problems: There is a lack of an adequate formal training program for software managers and practitioners. The formal training that is available is often not coordinated with project needs or schedules. Some mandated courses are inappropriate (not relevant to the software division).

5. **Human Resources** (The talented people that make up an organization are its greatest resource. The way it rewards, manages, and fosters the growth of its employees is crucial to its lasting success)

Specific Problems: There is a lack of a technical career path in the software division for engineers and technicians. The opportunities to broaden one's career path by moving from one technical position to another are limited. High performance is not adequately rewarded. Low performance is not effectively managed.

6. **Test Equipment** (Test equipment includes both automatic test equipment, used to test electronic circuits, and the wide variety of computers and equipment used to test the operational flight programs)

Specific Problem: Test equipment is often a bottleneck, and is sometimes inappropriate for testing needs.

7. **Project Resources** (The resources required to successfully complete a software project need to be acquired in a timely fashion. For most software projects, these resources include manpower, equipment, and tools. Some projects also require the design or modification of hardware, and any required parts must be received before the software may be integrated)

Specific Problems: The process for acquiring "dime-store" parts is cumbersome and inefficient. The acquisition of software engineering tools is often impeded

8. **Peer Reviews** (Peer reviews involves a methodical examination of work products by the products by the producer's peers to identify defects and areas where changes and improvements are needed)

   Specific Problem: Peer reviews are not consist   conducted and the documentation for the peer review process is lack .g

9. **Organizational Process Definition** (Organizational process definition involves establishing and maintaining a standard software process for the organization, for use by the projects in establishing their software process.)

   Specific Problems: The is little standardization of processes. There is no standard method for documenting and maintaining processes. A central repository for software processes has not been organized.

4.5.2 Process Improvement Program. ALC Number 3's process improvement efforts reflect the complexity of software processes and the difficulty in starting a full-scale organizational effort. After the May 1992 assessment, SEPG and assessment team members spent ten months in carefully publishing their report and drafting an action plan. Since the assessment report's publication in March of 1993, SEPG leaders have described the process group as "a flurry of activity." Working under the guidance of the draft action report, 15 Implementation Teams were setup. Each team is responsible for either a specific Level II or III CMM Key Process Area (KPA) or a non-CMM finding area. Rather than concentrating only on specific finding areas, this aggressive approach ensures that all Level II and III KPAs are addressed.

All teams function with the same basic guidance. Initially, each team is expected to baseline current practices and organize process evaluation techniques. Once underway, the teams implement process improvements and use the evaluation techniques for feedback. If changes are beneficial, they will be baselined and the process will be repeated.

Each implementation team meets at least weekly. One major issue surfacing in most team meetings is conformance. Because of differing requirements in the many types of

software projects underway in ALC Number 3, teams are having difficulty reducing the number of different software processes and tools to a manageable number. One example of this problem is the different software development tools required for Automatic Test Equipment (ATE) projects and Operational Flight Program (OFP) projects. Each type of work has evolved to its current processes and tools as a result of past necessity, and while none are necessarily incorrect, the number of different methods and tools must be reduced for consistency.

4.5.3 Analysis for a Relationship between Project Success and SEI CMM Ratings.

Our first objective was to determine if a relationship exists between SEI Capability Maturity Model ratings and project success. Section three of the questionnaire and subsequent follow-up telephone conversations was the primary source of information regarding this objective.

All five respondents, representing the four projects studied, indicated good customer satisfaction. Two respondents, representing project A, stated that costs were within or below budget estimates. Two other respondents, from projects C and D, indicated that costs were either on-target or average. Finally, the respondent for project B stated that costs had not changed as a result of process improvements. The respondent believed the project's relatively late stage of development to be the reason for the lack of change.

In terms of schedule, respondents from project A indicated the effort was within schedule. Project B's response, once again, indicated that the project was too far along to be affected by recent process improvements. Project C's respondent indicated that the project was behind schedule due to subcontractor difficulties. Finally, project D's respondent did not indicate anything concerning project schedule.

Only the respondents from projects B and D stated that the process improvements had already increased project success. Both respondents indicated that more customer

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interaction had increased customer satisfaction. Other respondents stated that improvements had yet to affect their projects.

As far as their expectations, representatives from project A indicated that the process improvements would not likely affect their project. As reasons for not expecting benefits from the process improvement program, project A's respondents indicated that they had already addressed some of the improvements and the program was nearing completion. The respondents from the remaining projects each felt the improvements will affect project success in the future. Reasons for projecting future improvements included improved ability to handle the unexpected, better tools, tracking, and teamwork.

While the outlook is optimistic, the results from ALC Number 3's projects did not indicate a conclusive relationship between SEI ratings and project success. In addition to determining the effect of process improvements on project success, Chapter Five compares project success across cases in search of more evidence of a relationship.

4.5.4 Analysis of Organizational Acceptance and Impact. The second objective is to evaluate the organizational acceptance and impact of the SEI assessment process. Sections one and three of the questionnaire and the assessment report are the primary sources of information for this objective.

Reasons for initiation of the SEI assessment/improvement program differed among the SEPG respondents. One respondent indicated the directorate had made a commitment to quality improvement. Two stated that the Air Force mandate was the only reason for the assessment. Clearly the concept of process improvement was not originated locally within this ALC.

SEPG members were obviously supporters of the SEI CMM methodology. Two respondents identified process consistency as the main benefits of the SEI's methodology. Another response stated that the quality improvement concept provided a voice for

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workers in the process. Finally, the one respondent indicated the SEI assessment methodology had the advantage of thorough assessments and provided a sound process for managing software projects.

Each respondent also recognized several disadvantages of the CMM. Among those disadvantages were the CMM's failure to consider hardware (system) issues, sometimes vague criteria, and difficulty understanding the CMM. Despite these disadvantages, all SEPG members agree that the maturity level was a valid representation of their organization's ability to produce software.

Three of the five SEPG respondents indicated that worker level response to the SEI process assessment/improvement program was positive. Two reasons were given for the positive response. First, according to SEPG responses, workers now feel that management is more likely to listen to their problems and ideas. Second, respondents stated that because the implementation teams mostly came from worker level personnel, there will be better acceptance of their changes. The two disagreeing SEPG respondents felt that some workers have taken a "wait and see" or "it will go away" position.

Project responses to the issue of worker level reaction were very different. Four of the five responses indicated a lack of worker level acceptance of the process assessment/improvement program. These four respondents stated that workers were not well informed, not sure of what would happen after the assessment, not involved, or taking a "wait and see" approach. Only one project level respondent indicated that most workers felt like part of the team. None of the respondents indicated that all of the workers were negative, but clearly there are groups of practitioners that were not behind the initiative.

Management's response to the assessment and improvement program also drew mixed opinions. Three of five SEPG members agreed that management was actively participating in the program. One respondent felt that some branch or section level

managers seemed to think their portions of the organization were doing things well and didn't pay much attention to the efforts. The final SEPG respondent indicated that management simply continued "business as usual." The project respondents also had mixed responses. Two of five project respondents stated that management had, although slowly, accepted the assessment results and actively pursued process improvement. Two remaining project respondents indicated that management was simply complying with the mandated program and one felt that management's commitment had dwindled since the assessment.

To summarize the second objective, SEPG and project level respondents are solidly behind the SEI assessment/improvement methodology. SEPG respondents indicated a much more positive worker level response and acceptance of the assessment and improvements than indicated by project level respondents. Roughly half of both sets of respondents indicated that management was solidly behind the improvement process. The differences between perceptions are probably a result of respondents' experience working in different portions of the organization with different management personnel and workers. In addition, the perceived lack of worker level support, identified by project level respondents, indicates a lack of communication throughout the organization concerning the improvement effort.

4.5.5 Analysis of Organizational Process Improvement Responses. The third research objective was to review organizational process improvement responses following assessments. Section two of the questionnaire and the telephone conversations with SEPG members are the sources of information for this discussion.

The creation of eighteen Key Process Area (KPA) implementation teams is the biggest action taken as a result of ALC Number 3's assessment. These teams are not, however, designed to simply answer the assessment. Instead, a team has been created for

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each KPA associated with Levels II and III of the CMM. The charter of each team is to baseline their specific portions of the software process, develop a means to evaluate their process, and implement and test improvements to the process in order to meet the related goals of the CMM. One of the challenges faced by these teams was the issue of conformance. The widely different types of projects within the ALC have made it difficult to reduce the number of different processes and tools in use.

At the project level, four of five respondents specifically indicated that a newly formalized peer review program has been put in place. One of these four also indicated that weekly status meeting had improved project tracking. These two improvements are directed toward improving the software management and peer review findings areas. SEPG personnel identified the creation of the process area teams, but this action has not yet affected most project level personnel.

The goal of ALC Number 3 is to achieve CMM Level III by their next assessment in September of 1994. Several improvements have already been put in place on the way to that goal. Most importantly, the SEPG and implementation teams have used the CMM to develop a framework for process understanding and improvement. Project level improvements also include formal peer reviews, regular status meetings, identification and documentation of processes, and the identification of bottlenecks in processes. ALC Number 3 will likely achieve their goal through the customized improvement program established by the SEPG. More important, a cadre of supporters has developed to improve the way ALC Number 3 develops and supports software. Finally, ALC Number 3 still faces the challenge of gaining and holding management commitment and worker-level buy-in of the process improvement program.

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V. Cross-Case Analysis

5.1 Relationship Between SEI Ratings and Project Success

The first objective of our research was to determine if SEI ratings are related to project success. In the case of ALC Number 1, the recency of their latest assessment (March 1993) made it difficult to conclude that a relationship existed between their SEI maturity rating and project success. In addition, the resulting improvement efforts have not been implemented yet. However, several on-going efforts, somewhat re-focused as a result of the most recent assessment, were identified by some of the questionnaire respondents as having the potential to affect the success of the projects we looked at.

The analysis of ALC Number 2 indicated that a relationship did exist between project success and the improvements implemented as a result of an assessment. Process improvements regarding requirements definition, project planning, and project management have increased customer interaction, improved cost and schedule estimates, and helped to solve problems while they were still minor. Although it we will not learn if the organization has increased to a higher maturity level until the next assessment, the improvemen's are surely a step toward achieving their current goal -- CMM Level II. These recent improvements have already led to increased customer satisfaction, product quality, and thus project success.

ALC Number 3's results do not conclusively indicate a relationship between project success and maturity level. The differences in the responses from the four projects suggest that effects of the assessment recommendations can vary within a single organization, making it difficult to conclude that a relationship exists between project success and maturity level. Two of four projects studied felt that the process improvements had led to increased customer satisfaction, but the remaining projects indicated no effect. Respondents were, however, optimistic that improvements were likely

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to increase the future success of these projects. The only exception to this optimism was the in the case of one respondent whose project is expected to end prior to implementation of many of the process improvements.

The analyses of ALC Number 1 and ALC Number 3 were showed no conclusive relationship between project success and maturity levels. The reason for lack of conclusive evidence in ALC Number 1 was largely due to short time between the assessment (March 1993) and this research effort. Although some ALC Number 3 projects suggested that process improvements had led to increased customer satisfaction, others indicated no relationship. Differences between the responses can not be attributed to process improvement efforts, worker level response, or management acceptance of the improvement program. Therefore, a relationship between project success and maturity level or process improvements cannot be determined.

5.2 Organizational Acceptance and Impact of the SEI Assessment Process

Overall, ALC Number 1 reacted favorably to being assessed, including the findings in the on-going process improvement program, and generally maintained an enthusiastic attitude toward the SEI assessment process. Management has consistently supported assessment efforts and remains committed to the CMM and its guiding influence on the overall organizational process improvement plan.

The reaction of ALC Number 2 to the assessment and improvement process has varied considerably through the organization. All respondents indicated that resultant maturity level is a valid representation of their organization's ability to produce and support software. Some, however, stated that the main issue is not process improvement, but product quality and customer satisfaction. In the view of these respondents, process improvement is valuable only to the extent that it improves product quality and customer satisfaction. Worker level response varied from cautious to active support. Management

support was similarly categorized. None of the respondents indicated that a majority of personnel (worker level or management) were not supportive, merely some of the personnel. Respondents also suggested that worker support had increased with time. All respondents were optimistic about the benefits of the program, and project level respondents indicated quality and customer satisfaction benefits.

ALC Number 3's reaction to the assessment and improvement process has also varied considerably through the organization. All respondents were clearly supporters of the SEI methodology and indicated that maturity is a valid representation of their organization's ability to produce and support software. SEPG respondents viewed management and worker level reaction to the assessment as very positive. Project respondents indicated, however, that some members of both the management and the worker levels were skeptical about the initiative.

Respondents from all three ALCs stated that the maturity rating was considered a valid indication of their organization's ability to produce and support software. While minor skepticism concerning the value of the assessment process was noted at ALC Number 1, the other two ALCs identified significant doubt among some personnel. At both ALC Number 1 and ALC Number 2, worker level support for the program was perceived as less solid than management support. Reasons for this lack of support range from caution on the workers part to belief that the process improvements are "just the latest fad." All three ALCs met the spirit of the SEI methodology by maintaining the non-attributive atmosphere throughout the assessment process.

ALC Number 1 accepted the assessment the most favorably of the three ALCs. This is probably due to several factors. First, ALC Number 1 had been assessed once before and was familiar with the assessment process. Second, ALC Number 1 has been interested in software process improvement for several years and had already defined an action plan and set up the mechanism for implementing and measuring process

improvements. Third, the initial assessment was performed at the request of ALC Number 1 and was not the result of a Command mandate. The only assessments performed at ALCs 2 and 3 were the direct result of AFMC's mandate that all ALC be assessed.

5.3 Organizational Process Improvement

As mentioned above, ALC Number 1 has been working toward an on-going process improvement program since 1989. Most of the improvements, both recent and planned, are the result of efforts not related to the most recent (March 1993) assessment. However, several process improvements have been undertaken as a direct result of the March 1993 assessment. A process improvement plan is maintained by the SEPG that was formulated using the results of the 1989 assessment and internal recommendations for improvements. The rapid inclusion of the March 1993 assessment findings in the July 1993 version of the process improvement action plan illustrates the commitment to improvement efforts and specifically, high regard for the SEI CMM. As stated already, the focus is on continuous process improvement, not response to specific findings. The SEI CMM is merely used to measure the overall cumulative success of ALC Number 1's improvement efforts.

The process improvement efforts at ALC Number 2 were centered around the findings from their 1992 SEI-assisted process assessment. The first three finding areas: requirements definition, project planning, and project planning and oversight were the first to receive attention. Process action teams were assembled to address each Key Process Area (KPA). Increased customer interaction regarding software requirements and more thorough tracking of cost and schedule information directly resulted from these teams. These initial improvements have already increased customer satisfaction and thus project success.

Although these accomplishments are impressive, they were just the first step in ALC Number 2's process improvement program. Teams were recently teams organized to address the two remaining Level II KPAs. In addition to these CMM-related improvements, the SEPG plans to establish working groups for human resources and acquisition issues.

While the pace of improvement was not as rapid as some personnel hoped for, the early success appeared to have helped build organizational support. The process improvement framework in place at ALC Number 2 will likely lead to attainment of their modified goal -- Level II maturity by September 1994.

ALC Number 3 approached software process improvement much as ALC Number 1 did. Rather than using the assessment results as their only guide, they established teams to address each KPA for Levels II and III of the CMM as well as other findings areas not specifically part of the CMM. This broad effort indicates a major commitment by both management and personnel to continue process improvement. While opinions about tangible results are mixed, most agree that increased customer interaction and peer reviews are positive steps. Although ALC Number 3's effort was the last to begin, they have clearly embraced the SEI assessment/improvement program and will likely achieve their goal of Level III by September of 1994.

Each organization implemented its process improvements in a slightly different manner. All three organizations, however, agreed that the assessment results and the CMM should not be used as the only basis for process improvement. Top management of each ALC have given complete support to each effort. While some indication of skepticism or lack of support was found among management and workers at each ALC, stronger support from each group was evident at ALC Number 1. Their support may be the result of the length of time ALC Number 1's program has been underway. Process improvement efforts at both ALC Number 2 and ALC Number 3 have strong support, but

also more skeptics, especially among workers. Most respondents at each location felt that support continued to grow with the program.

Each ALC organized their personnel into implementation teams for each CMM key process area and/or other areas designated for improvement. Use of project level personnel on these teams was noted to benefit worker level "buy-in" or acceptance of the process improvement effort.

While each effort is different, each ALC has customized their process improvement efforts to their organizational needs. None of the ALCs is following the CMM like a cookbook. Each SEPG has studied the CMM as part of a comprehensive software process improvement effort. ALC Number 1 is surely further along in the process than the other two, but based on improvements already underway and planned, each will likely achieve their immediate process maturity goals.

VI. Conclusions

6.1 Summary

The primary objective of this study was to determine if a relationship existed between maturity level and project success. Project success was defined as the combination of quality, cost, and schedule. In addition, we examined the impact on the assessed organizations of the SEI CMM assessment and follow-on process improvement. Finally, we reviewed organizational process improvements following the assessment(s). The research was accomplished through a combination of information gathering techniques and data analysis. A literature review, both within and external to the Department of Defense, summarized current software process research, discussed the CMM in detail, presented case studies using the SEI CMM, and introduced software project success criteria. Using information gathered from three Air Force software organizations, we addressed each research objective.

6.2 Results

For the most part, it cannot be concluded that SEI maturity level is an indication of project success for the organizations studied. This does not mean that, in general, maturity level is not a good indicator of project success, but rather for the organizations studied, it could not be conclusively determined that CMM ratings were an indicator of project success.

The participating projects, within the organizations studied, could not determine whether their success was the result of improvements implemented as a result of their assessments, or the result of other factors such as personnel capability or previous domain experience. For some of the respondents from the individual projects, the process improvements resulting from the most recent assessment should, when implemented,

influence their projects' success. For others, the projects were either recently begun, nearly complete, or the process improvements were not yet fully implemented.

All of the organizations indicated that their organizations accepted and supported the assessment process and findings. They believed that the assessments accurately measured their organizations' software process maturity level. Also, having an outside group of software experts, from the SEI, assess the organization was thought to add credibility to the assessment results. In addition, having in-house personnel participate in the assessment increased the organizational acceptance of the findings and recommendations.

Organizations that have focused on continuing process improvement, seemed to be more open to the assessment process, recommendations, and follow-up action plan. Those organizations that were relatively new to the software process improvement, were less enthusiastic. Respondents indicated that management and worker level support was stronger in organizations that have been actively involved in an ongoing process improvement program. Finally, all of the organizations indicated that there were individuals who were skeptical of the assessment process initially but that this skepticism eventually faded.

Finally, our third objective was to review the organizational process improvement efforts following the assessments. Each organization has a process improvement plan in place, but there were differences among them. ALC Number 1's process improvement plan does not directly focus on the SEI assessment findings, but instead seeks to implement improvements based on their internal requirements. ALC Number 2's plan is built upon the SEI assessment findings report which contains recommendations outside the realm of the CMM. ALC Number 3 also bases its process improvement plan on the SEI CMM and has established a working group for each Level II and III key process area (KPA).

6.3 Remarks

Although this study could not conclusively establish a relationship between project success and SEI maturity levels, we have shown that an organization that has invested effort in developing a process improvement infrastructure can use the CMM as a guide to develop an on-going process improvement program. The basic tenet of process improvement is that the product can only be as good as the process, and in each case, respondents from each case studied were confident that process improvements will concurrently lead to higher maturity levels and increased project success.

During the research design portion of our effort, we hoped to find quantitative information demonstrating or disproving the relationship between project success and SEI CMM ratings. Because this information was not yet available, we chose to evaluate the relationship in a more qualitative manner using a few Air Force organizations that have been assessed. This study was an important first step in evaluating the value of the SEI's CMM to the Air Force. As process improvement programs and related software projects mature, more conclusive information regarding this relationship will become available.

6.4 Recommendations for Further Research

Data concerning our primary thesis objective, to determine the relationship, if any, between SEI CMM ratings and project success. was inconclusive primarily because of the relative immaturity of the process improvement efforts at some ALCs. As a result of the newness of the efforts, many of the projects that participated in the study had either not yet been affected by process improvements, or they were too far along to be affected by changes. Further research needs to develop more comprehensive data on project success and process improvement efforts, preferably from organizations that have been through several iterations with the CMM. In addition, we recommend that the organizations used in this research be studied because the effort required to collect the preliminary assessment

and process improvement data is too time consuming to allow for a signi cant research effort beyond what was accomplished in the thesis.

6.4.1 Study Replication. Using the same methodology, replicate the research with the same organizations using the same projects. This strategy will incorporate the added maturity of the process improvement programs and its effect on projects. Using the same projects and organizations will be the basis for interesting comparison related to all three research objectives. Using the same organizations will demonstrate the evolution of incorporation and acceptance of the total quality management within the organizations.

6.4.2 Study Replication with Different Projects. Using the same methodology, replicate the research with the same organizations using the several different individual projects. This strategy will also allow for added maturity of the process improvement programs and its effect on projects. Selecting projects that are more likely to be affected by the process assessment/improvement will provide better information concerning the suggested relationship between project success and SEI CMM ratings. Once again, using the same organizations will demonstrate the evolution of incorporation and acceptance of the total quality management within the organizations.

6.4.3 In-Depth Single Case Study. An in-depth case study of any of the organizations included in this study would yield valuable insight into the internal software process improvement plan development. An in-depth study of ALC Number 1 would be especially interesting because their process improvement program is the most defined. They have had much success in implementing improvements and have advanced to a Level II as a result. A study of this scope would enable the researchers to interview project and SEPG personnel extensively, thereby gathering more detailed data on project success, process improvement progress, and organizational acceptance of the assessment. As an

initial effort in this area, the scope of the current study was limited to a higher level survey of the three organizations that touched on issues, and not specific findings.

Appendix A: Research Questionnaire

General Information:

Date: _____

Interviewee Name: _____

Interviewee Organization/Position: _____

_____

Interviewee Phone Number: _____

Project Information

Project Name: _____

Brief Statement of Project Purpose:

_____

_____

_____

Cost: _____

Number of Personnel Involved: _____

Scheduled Length of Project: _____

Section 1. Motivation for Process Evaluation/Improvement (ALC Level)

a. What factors led to the initiation of a process improvement program?

_____

_____

_____

b. What factors led specifically to SEI involvement?

_____

_____

_____

c. What is your overall opinion of the SEI assessment process/methodology?

(1) Advantages:

_____

_____

(2) Disadvantages

_____

_____

d. Is maturity level viewed as a legitimate representation of your organization's ability to produce/support software? _____

_____

_____

e. For which reasons is it valuable to strive for higher-level ratings? (Circle all that apply)

(1) Perception (of improvement)
(2) Improved Product (Quality, Cost, etc.)
(3) Headquarters Mandate (Required to stay in business)
(4) None/Other _____

Explain your answer: _____

Section 2. General Process Improvement/Assessment Issues (ALC and Project Level)

a. Was the evaluation accomplished entirely by the SEI, through an SEI-assisted team, or a self-assessment?

_____

_____

_____

b. What process improvements/actions have been taken solely as a result of the assessment process?

_____

_____

_____

c. What other process improvements/changes have been undertaken within the same time frame?

_____

_____

_____

d. What benefits have been realized through the SEI Assessment Process?

_____

_____

_____

e. What process problems have been identified?

_____

_____

_____

Section 3. Impact on Project Success (ALC and Project Level)

a. At what level was the organization rated?

_____

_____

b. What actions taken as a result of the SEi assessment(s) have been part of this project?

_____

_____

_____

c. How successful was (is) this project? (Please address the following areas)

    (1) Customer satisfaction
    (2) Cost
    (3) Schedule
    (4) Other areas?

_____

_____

_____

d. How have the post-SEI assessment actions affected the success of this project in the following areas? (Please address the following areas)

    (1) Customer satisfaction
    (2) Cost
    (3) Schedule
    (4) Other areas?

_____

_____

_____

e. Do you feel the proposed improvements will directly result in benefits to this project? Why?

_____

_____

_____

Section 4. Human Factors (ALC and Project Level)

a. What was the worker level feeling concerning the SEI assessment?

_____

_____

_____

b. How did management react to the SEI assessment?

_____

_____

_____

c. How thoroughly has management embraced the SEI assessment results/suggestions (active or just filling a square)?

_____

_____

_____

d. What, if any, negative effects have been realized as a result of the SEI assessment?

_____

_____

_____

e. Has the non-attributive environment been maintained? (or has head-hunting taken place)

_____

_____

_____

f. Has the status of these factors changed since your process improvement efforts were initiated?

_____

_____

_____

Appendix B: ALC Number 1

This appendix contains a complete listing of the questionnaire responses for ALC Number 1.

Section 1. Motivation for Process Evaluation/Improvement (ALC Level)

a. What factors led to the initiation of a process improvement program?

RESPONDENT	RESPONSE
SEPG 1	Division chief attended the 1989 SEI Affiliates Symposium. We had been working since 1987 and assessments looked like they would provide focus.
SEPG 2	Management directed as a result of a quality symposium several years ago
Project 1	N/A
Project 2	N/A
Project 3	N/A

b. What factors led specifically to SEI involvement?

RESPONDENT	RESPONSE
SEPG 1	Same as above.
SEPG 2	Management.
Project 1	N/A
Project 2	N/A
Project 3	N/A

c. What is your overall opinion of the SEI assessment process/methodology?
   (1) Advantages

RESPONDENT	RESPONSE
SEPG 1	The new method is a major improvement. We were the Alpha 1 site for the new process. The findings are now CMM based. Also, it involved over 40% of the organization so the findings are seen as having validity.
SEPG 2	Outside perspective. Knowledge of S/W engineering processes procedures, and concepts.
Project 1	N/A
Project 2	N/A
Project 3	N/A

(2) Disadvantages

RESPONDENT	RESPONSE
SEPG 1	The assessment itself is almost two weeks long and very intense. At times it almost felt like an audit.
SEPG 2	Terminology. Lack of detailed understanding of our specific software type etc.
Project 1	N/A
Project 2	N/A
Project 3	N/A

d. Is maturity level viewed as a legitimate representation of your organization's ability to produce/support software?

RESPONDENT	RESPONSE
SEPG 1	I think it is. We're getting more organized and people know their part. As we grow in maturity we will reduce our need for heroes.
SEPG 2	For the most part-yes.
Project 1	N/A
Project 2	N/A
Project 3	N/A

e. For which reasons is it valuable to strive for higher-level ratings? (Circle all that apply)

(1) Perception (of improvement)
(2) Improved Product (Quality, Cost, etc.)
(3) Headquarters Mandate (Required to stay in business)
(4) None/Other

Explain your answer:

RESPONDENT	RESPONSE
SEPG 1	Improved product, Headquarters mandate: We started this before any mandates but the mandates have helped provide attention and focus or process improvement.
SEPG 2	Improved product. The SEI "higher level" inherently reflects common-sense aspects of process improvement in a structured framework(CMM).
Project 1	N/A
Project 2	N/A
Project 3	N/A

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Section 2. General Process Improvement/Assessment Issues (ALC and Project Level)

a. Was the evaluation accomplished entirely by the SEI, through an SEI-assisted team, or a self-assessment?

RESPONDENT	RESPONSE
SEPG 1	Our first assessment (Mar 90) was a self assessment with one SEI member. Our second assessment (March 93) was the Alpha 1 for the SEI's new process. 7 SEI members, 2 SEI observers, 2 ALC members.
SEPG 2	Entirely by SEI personnel.
Project 1	SEI--Two of us were on the team.
Project 2	Entirely by the SEI.
Project 3	SEI only.

b. What process improvements/actions have been taken solely as a result of the assessment process?

RESPONDENT	RESPONSE
SEPG 1	We continually monitor our fir('ings and what we're doing to correct them. Basically everything relates to the assessment
SEPG 2	After the initial self assessment the division management steering team was organized and has since become a key aspect of our efforts.
Project 1	We have had several lunches to discuss improvement issues. We have re-focused some on-going issues to be organization-wide.
Project 2	Speaking for my section only, we have begun having peer reviews and are in the process of developing better & documentable metrics for our projects.
Project 3	Identify training needs for all personnel. Monthly meetings to define the organization's standard software process.

c. What other process improvements/changes have been undertaken within the same time frame?

RESPONDENT	RESPONSE
SEPG 1	All improvements go through our steering team.
SEPG 2	Many. The organization has grown tremendously over the past 5 years. Inherent in this growth was the necessity to define our processes and improve the way in which we function.
Project 1	All improvement issues are related.
Project 2	Just prior(about 4-6 months) to the assessment we started using 'Earned Value Reports & Charts' to track our projects. This should help to establish a lot of necessary data & history.
Project 3	Development of database to track software media and documentation.

d. What benefits have been realized through the SEI Assessment Process?

RESPONDENT	RESPONSE
SEPG 1	Return on Investment of 5.9 to 1. Helped morale.
SEPG 2	Outside perspective of process problems or deficiencies. The findings (good & bad) can be related directly to a structured framework. i.e. the CMM.
Project 1	We have identified areas of improvement and more aware of our current process.
Project 2	Mostly, the areas where we were weak have been identified an other areas where we were lacking process were brought out. It was also encouraging to see what we were doing well.
Project 3	Everyone realizes where our weaknesses are and strives to improve in those areas.

e. What process problems have been identified?

RESPONDENT	RESPONSE
SEPG 1	Lack of tailoring guidelines or documentation. Undefined ad-hoc processes.
SEPG 2	Problems have been identified and documented in the findings report.
Project 1	Very difficult to collect data for metrics.
Project 2	Lack of peer reviews, not enough clearly defined and rigidly documented process plans.
Project 3	No standard organization process defined. Training needs. Peer reviews not accomplished.

Section 3. Impact on Project Success (ALC and Project Level)

a. At what level was the organization rated?

RESPONDENT	RESPONSE
SEPG 1	March 90--Level 1. March 93--Level 2.
SEPG 2	Level 2.
Project 1	Level 2.
Project 2	Level 2 with attributes of level 3.
Project 3	Level 2.

b. What actions taken as a result of the SEI assessment(s) have been part of this project?

RESPONDENT	RESPONSE
SEPG 1	N/A
SEPG 2	N/A
Project 1	We have re-focused to be organizational.
Project 2	Nothing specifically because our projects are such short term. However, the overall scope of our projects is being refined.
Project 3	None yet.

c. How successful was (is) this project? (Please address the following areas)

    (1) Customer satisfaction
    (2) Cost
    (3) Schedule
    (4) Other areas?

RESPONDENT	RESPONSE
SEPG 1	
SEPG 2	
Project 1	
Project 2	Again, our projects are such small scale that it is too early to measure any substantive effect.
Project 3	Customers are quite satisfied with software maintenance activity. Cost is a non-issue. Software maintenance generally accomplished ahead of schedule.

d. How have the post-SEI assessment actions affected the success of this project in the following areas? (Please address the following areas)

    (1) Customer satisfaction
    (2) Cost
    (3) Schedule
    (4) Other areas?

RESPONDENT	RESPONSE
SEPG 1	
S.PG 2	
Project 1	
Project 2	None have been drastically affected yet, but as we continue to develop new processes & refine old ones everything should continue to improve.
Project 3	No impact at this time.

e. Dn you feel the proposed improvements will directly result in benefits to this project? Why?

RESPONDENT	RESPONSE
SEPG 1	N/A
SEPG 2	N/A
Project 1	N/A
Project 2	Yes, because as we continue to improve our successors it is likely that the customer will get more for the money.
Project 3	Yes, because personnel will be better trained. Software development will result in more maintainable code.

Section 4. Human Factors (ALC and Project Level)

a. What was the worker level feeling concerning the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	From my viewpoint, having been through the last assessment, our people are proud of what they've done and they've embraced process improvement.
SEPG 2	As far as I know, the workers have agreed with and accepted the assessment findings/results--(good and bad).
Project 1	We realized the necessity of it. Exited about the competition. Anticipation what will come out of it.
Project 2	Pretty good for the most, some felt it was a waste of time.
Project 3	Most felt that they would benefit and their jobs would be easier to perform.

b. How did management react to the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	Top-level management has always been supportive. We've had some first-level resistance.
SEPG 2	Management continues to be supportive of SEI-related process improvement efforts.
Project 1	Well.
Project 2	Very good, they were pleased with the resulted.
Project 3	Quite favorable. They are 100% in favor of improving our posture in maintaining software.

c. How thoroughly has management embraced the SEI assessment results/suggestions (active or just filling a square)?

RESPONDENT	RESPONSE
SEPG 1	Our monthly management steering teams usually last over 3 hours.
SEPG 2	Management has been actively involved with "pre and post" assessment activities.
Project 1	Well.
Project 2	About as well as could be expected. Change is not something that happens very fast. Management is fully behind SEI though.
Project 3	They are actively participating in the process that need improvement.

d. What, if any, negative effects have been realized as a result of the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	none.
SEPG 2	none.
Project 1	A little bit of feeling that SEI doesn't help us very much.
Project 2	None that I can see yet.
Project 3	None that I am aware of.

e. Has the non-attributive environment been maintained? (or has head-hunting taken place)

RESPONDENT	RESPONSE
SEPG 1	We don't target people but we do target specific projects. I don't think people have a problem with that if their problems get solved.
SEPG 2	Management key project people and workers have not pointed the finger at other personnel associated with some of the assessment findings.
Project 1	No head-hunting has taken place.
Project 2	Has been maintained.
Project 3	The non-attributive environment has been maintained.

f. Has the status of these factors changed since your process improvement efforts were initiated?

RESPONDENT	RESPONSE
SEPG 1	There has been some resistance but the longer we go the less we see.
SEPG 2	No.
Project 1	N/A
Project 2	Not sure which factors you're talking about.
Project 3	Too early to tell.

Append x C: ALC Number 2

This appendix contains a complete listing of the questionnaire responses for ALC Number 2.

Section 1. Motivation for Process Evaluation/Improvement (ALC Level)

a. What factors led to the initiation of a process improvement program?

RESPONDENT	RESPONSE
SEPG 1	Mandate
SEPG 2	A couple of years before the AF ECS PMP, our branch chief read some papers on process improvement and what was going on at the SEI. He thought it sounded like a good idea, so he had us get involved. We did a self assessment at the time (Follow-Up Conversation - there was never any action taken as a result of this 7 Nov 90 internal assessment)
Project 1	N/A
Project 2	A need to cut costs to become competitive

b. What factors led specifically to SEI involvement?

RESPONDENT	RESPONSE
SEPG 1	I don't know
SEPG 2	The AF ECS PMP initiative
Project 1	N/A
Project 2	?

c. What is your overall opinion of the SEI assessment process/methodology?
   (1) Advantages

RESPONDENT	RESPONSE
SEPG 1	Conceptual framework and educated, helpful people
SEPG 2	Organize the evaluation process and define the evaluation criteria
Project 1	N/A
Project 2	Good, a thorough job done in a brief period

   (2) Disadvantages

RESPONDENT	RESPONSE
SEPG 1	Distance
SEPG 2	Systems engineering is missing. Human resources also. Takes a long time to show change to management
Project 1	N/A
Project 2	Don't think our customer realized how important their participation was

d.   Is maturity level viewed as a legitimate representation of your organization's ability
to produce/support software?

RESPONDENT	RESPONSE
SEPG 1	Yes
SEPG 2	No, sometimes the customer does not want to incur the cost. Could go for years without a change in level
Project 1	N/A
Project 2	Yes

e. For which reasons is it valuable to strive for higher-level ratings? (Circle all that apply)

(1) Perception (of improvement)
(2) Improved Product (Quality, Cost, etc.)
(3) Headquarters Mandate (Required to stay in business)
(4) None/Other

Explain your answer:

RESPONDENT	RESPONSE
SEPG 1	(2) Improved Product - we know we need to improve our capability, (3) Headquarters mandate makes it essential
SEPG 2	(2) An example, we delivered a piece of software in which the tape could not generate the executable (configuration management)
Project 1	(2) and (3). We need higher-level ratings, not to say ware are a level II or III, but because we improve ourselves at each level
Project 2	(2) Quality and cost of our product is more important than mandates and perceptions

Section 2. General Process Improvement/Assessment Issues (ALC and Project Level)

a. Was the evaluation accomplished entirely by the SEI, through an SEI-assisted team, or
a self-assessment?

RESPONDENT	RESPONSE
SEPG 1	SEI-assisted team
SEPG 2	SEI-assisted team
Project 1	The evaluation was conducted by an SEI-assisted team
Project 2	SEI-assisted team

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b. What process improvements/actions have been taken solely as a result of the assessment process?

RESPONDENT	RESPONSE
SEPG 1	1. Established management steering council for process improvement 2. Established executive center group for customer forum 3. Developed written software engineering policy
SEPG 2	1. Action teams started on assessment results 2. Strategic and tactical plans in development 3. Project Reviews 4. Reorganization 5. Software engineering policy statement
Project 1	We have looked at our process. We have started documenting and have taken steps to improve program management and testing methods
Project 2	1. Implemented TPS development guide 2. Implemented new procedures to track costs

c. What other process improvements/changes have been undertaken within the same time frame?

RESPONDENT	RESPONSE
SEPG 1	1. Project reviews 2. Reorganization to establish formal SQA, CM, and independent test and evaluation
SEPG 2	Several steering councils have been formed
Project 1	Improved Software change control process (i.e. submitting/approval of Form 75)
Project 2	Reporting of projects more frequent to our customers

d. What benefits have been realized through the SEI Assessment Process?

RESPONDENT	RESPONSE
SEPG 1	Increase awareness of software engineering requirements
SEPG 2	Management involvement, especially in problem resolution and status reviews
Project 1	Better tracking of software changes and improved testing methods
Project 2	TPS costs have been baselined and high cost phases have been identified

e. What process problems have been identified?

RESPONDENT	RESPONSE
SEPG 1	Inadequate or non-existent requirements specification, planning and management oversight. Virtually no CM or SQA.
SEPG 2	Role of middle management in improvement effort Takes a long time to get going Better defined improvement process effort definition for planning purposes
Project 1	Need more team approach to software management Need to better track costs Management needs to take a bigger role
Project 2	Customer not involved with process Certain phases of TPS development were high cost

Section 3. Impact on Project Success (ALC and Project Level)

a. At what level was the organization rated?

RESPONDENT	RESPONSE
SEPG 1	Level I
SEPG 2	Level I
Project 1	Level I
Project 2	Level I

b. What actions taken as a result of the SEI assessment(s) have been part of this project?

RESPONDENT	RESPONSE
SEPG 1	N/A - however, a number of projects we have observed have increased emphasis on SOWs and CM.
SEPG 2	N/A
Project 1	Project 1 tends to be the guinea pig for any changes/investigations that the SEPG need.
Project 2	Implemented TPS development guide to have repeatable results across the project

c. How successful was (is) this project? (Please address the following areas)

    (1) Customer satisfaction
    (2) Cost
    (3) Schedule
    (4) Other areas?

RESPONDENT	RESPONSE
SEPG 1	Too early to tell
SEPG 2	N/A
Project 1	1. customers are more satisfied because we are able to produce better quality software. 2. The costs are being tracked now, so we can better estimate future software releases. We can not compare software releases and their costs (before we had no way of doing so) 3. Our schedules are being tracked and we can now set realistic time lines for future software releases
Project 2	Customer satisfaction seems to be high especially since we can more effectively predict costs and schedule

d. How have the post-SEI assessment actions affected the success of this project in the following areas? (Please address the following areas)

    (1) Customer satisfaction
    (2) Cost
    (3) Schedule
    (4) Other areas?

RESPONDENT	RESPONSE
SEPG 1	Marginally to date - although management interest in project reviews have helped, especially when management offers to help resolve problems
SEPG 2	N/A
Project 1	See 3c for answer
Project 2	See 3c for answer

e. Do you feel the proposed improvements will directly result in benefits to this project? Why?

RESPONDENT	RESPONSE
SEPG 1	Can't really comment on specific project
SEPG 2	N/A
Project 1	Yes. If the schedules and costs can be predictable, and if our process can be "standardized" (formalized), the customer will be satisfied - which should always be our goal.
Project 2	Yes, higher quality and lower costs of TPSs will be the big benefit.

Section 4. Human Factors (ALC and Project Level)

a. What was the worker level feeling concerning the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	Skepticism followed by surprise at final report. Currently taking a wait and see approach. Progress has been slow
SEPG 2	Lots of good stuff, but needs to be realistic/usable (more paperwork must show added value, SQA should not just be a check list group, more costly to improve can we remain competitive?) concern on management oversight
Project 1	Just another formality, nothing would come out of it
Project 2	They were viewed as another inspection by folks who were self-proclaimed experts

b. How did management react to the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	For the most part, constructively
SEPG 2	Check to box, so we can get to level II, in the beginning. They are slowly changing
Project 1	The were all behind it. Management always gets behind these kinds of things - it's their follow through that makes people skeptical. In other words - they usually don't do any follow through.
Project 2	Something that had to be done and the outcome (Level I) was not surprising

c. How thoroughly has management embraced the SEI assessment results/suggestions (active or just filling a square)?

RESPONDENT	RESPONSE
SEPG 1	Some see value. To others, it is just another fad.
SEPG 2	Slowly becoming active. Our forming of the management steering council has really helped to get their involvement.
Project 1	It was active for a while, now some managers are just going through the motions
Project 2	Active, but their plans are slow to implement

d. What, if any, negative effects have been realized as a result of the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	Fear of unproductive management involvement
SEPG 2	Hidden agendas are coming out in an attempt to use the improvement effort as a piggyback mechanism
Project 1	Workers are upset that we wanted the assessment to mean something, but overall there have not been many changes.
Project 2	We are more concerned about satisfying the SEPG, than about our customer

e. Has the non-attributive environment been maintained? (or has head-hunting taken place)

RESPONDENT	RESPONSE
SEPG 1	No head-hunting
SEPG 2	Practitioners and managers are still very concerned about non-attribution. (Practitioners are also concerned about advancement if they get involved in a long-term improvement effort that uses 50% of their time)
Project 1	For the most part.
Project 2	Yes

f. Has the status of these factors changed since your process improvement efforts were initiated?

RESPONDENT	RESPONSE
SEPG 1	Fear has decrease, but skepticism about value of process improvements remains.
SEPG 2	N/A
Project 1	No, no really. Management will support most anything, especially if they don't have to do anything about it.
Project 2	No

Appendix D: ALC Number 3

This appendix contains a complete listing of the questionnaire responses for ALC Number 3.

Section 1. Motivation for Process Evaluation/Improvement (ALC Level)

a. What factors led to the initiation of a process improvement program?

RESPONDENT	RESPONSE
SEPG 1	It was mandated by the Air Force. If it hadn't been mandated, it wouldn't have been done.
SEPG 2	SEI self-assessment in June 1992 indicated that no SQA function was present
SEPG 3	Directorate commitment
SEPG 4	N/A
SEPG 5	Don't know
Project A-1	N/A
Project A-2	N/A
Project b	Mandated by management
Project C	The need to standardize, which identified areas of duplication
Project D	Trying to cut costs and complete schedule : .ead of time

b. What factoı ˙ led specifically to SEI involvement?

RESPONDENT	RESPONSE
SEPG 1	It was mandated by the Air Force. Nobody formally evaluated the advantages and disadvantages of SEI involvement.
SEPG 2	The SEPG had the help of the SEI in their assessment (June 1992)
SEPG 3	1. HQ AF mandate 2. Directorate/Division decision to measure current state
SEPG 4	N/A
SEPG 5	?
Project A-1	N/A
Project A-2	N/A
Project B	Mandated by management
Project C	The need to be more competitive, hold costs down.
Project D	Our division know ﹀ we must be competitive. SEI is standard private industry uses.

c. What is your overall opinion of the SEI assessment process/methodology?
   (1) Advantages

RESPONDENT	RESPONSE
SEPG 1	If used, the CMM provides the correct methodology for managing a project, not just a software project. Involving SEI in an assessment means that the assessed organization benefits from SEI's experience and obtains a legitimate assessment.
SEPG 2	The opinions come from the working level
SEPG 3	Consistent
SEPG 4	N/A
SEPG 5	It is a set method
Project A-1	N/A
Project A-2	N/A
Project B	It allows us to better define requirements and sets a well-defined path in which to follow in our process
Project C	N/A
Project D	I feel it will show us our weaknesses so we can improve

   (2) Disadvantages

RESPONDENT	RESPONSE
SEPG 1	The CMM isn't a cookbook and it isn't all that easy to understand. The project managers must spend considerable time studying it before they can implement it in their projects.
SEPG 2	Management can justify the position of the organization and paint a rosy picture.
SEPG 3	Some criteria very vague to subjective
SEPG 4	N/A
SEPG 5	Does not address systems (hardware)
Project A-1	N/A
Project A-2	N/A
Project B	We have a tendency to improve things to the point that they don't work after the improvement (KISS - keep it simple sir)
Project C	N/A
Project D	N/A

d.   Is maturity level viewed as a legitimate representation of your organization's ability to produce/support software?

RESPONDENT	RESPONSE
SEPG 1	Both management and the workers put heavy stock in maturity levels, but they tend to over estimate their own maturity levels. Management's estimates are higher than the worker's.
SEPG 2	It definitely is a metric to be considered - but not solely
SEPG 3	More as a measure of consistency, repeatability, and predictability
SEPG 4	N/A
SEPG 5	Yes
Project A-1	N/A
Project A-2	N/A
Project B	I feel that for the most part it does. Except that we may not be as formalized and documented as we should be.
Project C	What is maturity? The idea does not represent a company's ability to be profitable and perform work for the customer
Project D	Yes

e. For which reasons is it valuable to strive for higher-level ratings? (Circle all that apply)

   (1) Perception (of improvement)
   (2) Improved Product (Quality, Cost, etc.)
   (3) Headquarters Mandate (Required to stay in business)
   (4) None/Other

Explain your answer:

RESPONDENT	RESPONSE
SEPG 1	For me personally, it is only to improve the product. Both as an aircraft software design engineer and as the MEG chairman, I worry about our software's quality; but for many division employees, it is simply mandated by the Air Force. If it hadn't been mandated, it wouldn't have been done. As a member of the SQA team, I feel a heavy obligation to help institutionalize the CMM.
SEPG 2	The higher level ratings should show improved efficiency and quality of the end product
SEPG 3	1. To improve morale 2. Competitiveness and less maintenance 3. Self-explanatory
SEPG 4	N/A
SEPG 5	N/A
Project A-1	N/A
Project A-2	N/A
Project B	Improved product and headquarters mandate. We are all professionals, which means that quality and cost are the only options to stay in business
Project C	Headquarters mandate. A committed level III organization should be adequate
Project D	Improved Product. By improving our processes, we cut costs and schedules plus put out a better product.

Section 2. General Process Improvement/Assessment Issues (ALC and Project Level)

a. Was the evaluation accomplished entirely by the SEI, through an SEI-assisted team, or a self-assessment?

RESPONDENT	RESPONSE
SEPG 1	An SEI assisted team. This approach has two advantages. First, SEI involvement brings SEI's vast experience to the assessment. Second, having employees from the assessed organization on the assessment team gives the organization insight and a buy-in into the assessment process
SEPG 2	It was a self-assessment, but it had representation from the SEI and other ALCs
SEPG 3	SEI-assisted team
SEPG 4	SEI-assisted team with members from the other four ALCs
SEPG 5	SEI-assisted team
Project A-1	Local SEPG assessment. I was not sure about this, but asked someone else that knew.
Project A-2	Self-assessment by a local SEPG team
Project B	I think though an SEI-assisted team
Project C	Assessment team
Project D	Through a SEI-assisted team and self assessment

b. What process improvements/actions have been taken solely as a result of the assessment process?

RESPONDENT	RESPONSE
SEPG 1	Organized eighteen Implementation Teams to determine the actions each project must perform to satisfy all of the Level II and Level III KPAs
SEPG 2	SQA team formed - 18 implementation teams formed from working level employees
SEPG 3	SEPG and independent SQA groups formed
SEPG 4	We have initiated approximately 18 improvement efforts
SEPG 5	Implementation teams have been organized for each of the KPAs in Levels II and III of the CMM
Project A-1	More formal peer reviews have been encouraged
Project A-2	Peer reviews have been pushed by management
Project B	We now track our peer reviews where before, we would hold them but no record was kept.
Project C	An attitude shift toward the SEI standards
Project D	Better peer reviews, weekly status meetings

c. What other process improvements/changes have been undertaken within the same time frame?

RESPONDENT	RESPONSE
SEPG 1	None.
SEPG 2	Peer reviews have been standardized, and process definition has begun.
SEPG 3	Process baselining, metrics enhancement
SEPG 4	None.
SEPG 5	Human resources, software metrics, management reviews, test equipment, project resources, organizational policies and procedures
Project A-1	Configuration management process has been improved and is continuing to be improved
Project A-2	Configuration management of software process has been evaluated and improved
Project B	We work closer with our customers. We attend a team meeting with them twice a month.
Project C	The formation of implementation teams
Project D	Using a project management program to track each task

d. What benefits have been realized through the SEI Assessment Process?

RESPONDENT	RESPONSE
SEPG 1	The SQA team and the implementation teams have been organized and are functioning. Other than that, it's too soon to determine the impact these teams will have.
SEPG 2	The net results haven't really surfaced yet - were still in the pain stage
SEPG 3	Process awareness. metrics awareness
SEPG 4	Increased awareness of the need for process improvement within the organization. Helped to focus process improvement effort.
SEPG 5	Implementation teams organized.
Project A-1	Nothing specific, other than a vision for change and more (formal) peer reviews
Project A-2	Clear understanding of our own processes and looking for ways to improve them. Changing and evaluating the process improves quality
Project B	We try to solve stumbling blocks before they develop into real problems
Project C	Awareness of SEI
Project D	Better understanding by everyone - what our processes are.

e. What process problems have been identified?

RESPONDENT	RESPONSE
SEPG 1	None yet.
SEPG 2	Peer reviews are not consistent - SQA is non-existent
SEPG 3	Configuration management of processes
SEPG 4	Refer to the assessment report findings and recommendations
SEPG 5	Listed in questions 2b and 2c
Project A-1	The need to identify a specific process
Project A-2	First major problem, people don't know what the process is and that it can be changed
Project B	I feel that our processes are solid
Project C	N/A
Project D	We haven't allowed enough time for some areas of our processes. (i.e. fabrication, lead time for parts)

Section 3. Impact on Project Success (ALC and Project Level)

a. At what level was the organization rated?

RESPONDENT	RESPONSE
SEPG 1	Emerging Level II. As far as I'm concerned, that's a polite way of saying Level I.
SEPG 2	Emerging Level II. (by the old standards)
SEPG 3	Emerging Level III
SEPG 4	Emerging Level II, e.g. some of the Level II and Level III KPAs satisfied, but not all.
SEPG 5	Division
Project A-1	Level I
Project A-2	One
Project B	Level I-II
Project C	1.8
Project D	Level II

b. What actions taken as a result of the SEI assessment(s) have been part of this project?

RESPONDENT	RESPONSE
SEPG 1	The SQA team and the implementation teams have been organized and are functioning.
SEPG 2	SQA team formed - with the goal of ensuring SQA functions are performed as part of the development cycle.
SEPG 3	Better SQA, process configuration management
SEPG 4	We are implementing the activities/functions necessary to satisfy the SQA KPA goals.
SEPG 5	Organization of implementation teams
Project A-1	None that I know of.
Project A-2	None
Project B	?
Project C	Peer reviews initiated
Project D	As a result of the assessment, we started using a project management program

c. How successful was (is) this project? (Please address the following areas)

    (1) Customer satisfaction
    (2) Cost
    (3) Schedule
    (4) Other areas?

RESPONDENT	RESPONSE
SEPG 1	The SQA team and implementation teams take people away from the projects. It is too soon to determining what impact this will have on quality.
SEPG 2	The team was just formed two months ago - the attitude ranges from encouraging to neutral throughout the division at this time.
SEPG 3	1. Good 2. Fair 3. Very Good
SEPG 4	Too early to tell right now. We just started this project/effort in May 93.
SEPG 5	Not far enough to know.
Project A-1	Customer satisfaction is good, cost is within budget, and schedule is on-target
Project A-2	The customer is satisfied with product. The project is within budget and on schedule.
Project B	We now work much closer to our customer. Cost and schedule have had no change this close to the end of the assessment. We have better equipment to do our jobs.
Project C	Customer satisfaction is good and we are able to manage costs. Our schedule has been blown out of the water by contractor involvement
Project D	Customer is pleased, cost is average for the complexity of these programs

d. How have the post-SEI assessment actions affected the success of this project in the following areas? (Please address the following areas)

(1) Customer satisfaction
(2) Cost
(3) Schedule
(4) Other areas?

RESPONDENT	RESPONSE
SEPG 1	It is too soon to tell. As the SQA team, we need to develop metrics to show how the software quality improves as the KPAs are implemented. I'm not sure how we do this yet.
SEPG 2	Same as 3c
SEPG 3	1. No change 2. Higher 3. No change
SEPG 4	See question 3c
SEPG 5	It got us started
Project A-1	It has not directly affected customer satisfaction, cost, or schedule.
Project A-2	The SEI assessment has not really affected any of these areas
Project B	See 3c
Project C	N/A
Project D	It showed us what we were doing could be improved by showing customers the status of their projects. It also showed how we might cut costs and improve schedules.

e. Do you feel the proposed improvements will directly result in benefits to this project? Why?

RESPONDENT	RESPONSE
SEPG 1	Definitely, I strongly believe the CMM provides the structure to manage any project. The closer the division follows the CMM, the more successful it will be.
SEPG 2	This project hopes to result in benefits to the developmental units in the division as SQA is implemented
SEPG 3	Yes. Improved quality and better design
SEPG 4	Yes
SEPG 5	This project is an improvement effort
Project A-1	This project will be completed by the time any proposed improvements would affect it. They may benefit the use and maintenance of the station developed by this project.
Project A-2	I think SEI assessment has had us look at our processes, but I can't see anything that will improve or benefit our project that we were not already addressing
Project B	Yes, only if management will mandate all to get involved in the improvement. The few can not move us to the next higher level alone.
Project C	To establish a method and procedure for handling the unexpected.
Project D	Yes, because we have better tracking in place, and everyone on the project understands the part they play.

Section 4. Human Factors (ALC and Project Level)

a. What was the worker level feeling concerning the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	It was positive. The workers believe that the assessment was realistic and they support the implementation teams. They think the assessment is one way to get management to listen to their problems. The SQA team has an excellent relationship with the engineers because we worked with them for many years.
SEPG 2	Some think it will go away like other government programs, others are grasping onto the principles
SEPG 3	Good
SEPG 4	Not sure what the benefit/result of the assessment would be
SEPG 5	Most were unaware or uninformed
Project A-1	Not well informed about the SEI assessment or how it related to this project
Project A-2	We got a Level I, now what?
Project B	there were not many involved. Input was not given. I feel that the feeling was just "its another quality program being forced upon us"
Project C	They have a cautious idea of the SEI (A wait and see attitude)
Project D	They now feel like a better part of the team and realize everyone must do their share

b. How did management react to the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	They took it very seriously and understood they must create the corporate culture required to satisfy the KPAs
SEPG 2	All managers think it was their section who is Level III - to bring the rest of the division up to Emerging Level II (a very scary assumption)
SEPG 3	Responded with improvement plans
SEPG 4	Used it as a tool to provide insight on where to focus our process improvement efforts.
SEPG 5	Business as usual
Project A-1	Management has begun to discuss the need to improve and be a Level III by next spring.
Project A-2	We got to get a better level next time - management hasn't said much since the first few weeks after the assessment.
Project B	I think some management had a good reaction, but there are still many that support it just to satisfy the requirement. I don't see any push of excitement.
Project C	Some felt cheated, others were relieved.
Project D	Disappointed we weren't at a higher level. But determined to do what they have to tot get a higher level.

c. How thoroughly has management embraced the SEI assessment results/suggestions (active or just filling a square)?

RESPONDENT	RESPONSE
SEPG 1	Management appears to be totally committed to implementing the SEI assessment suggestion. They are more serious than just filling a square.
SEPG 2	Because the division has committed to become Level III by August 1994, the management is taking a more serious approach than in the past.
SEPG 3	Active, but slow
SEPG 4	Seem to have fully embraced them
SEPG 5	Filling a square
Project A-1	I feel management has or is beginning to embrace the results/suggestions, but lacks understanding on how to get the process functioning.
Project A-2	Just filling the square. They push the ideas and suggestions, but we receive no training or help in implementing them, except for a 1-hour class on peer reviews
Project B	See 3b
Project C	Yes and no. Most are attempting to initiate SEI standards and others are filling squares
Project D	Management is very actively involved in us reaching our goals

d. What, if any, negative effects have been realized as a result of the SEI assessment?

RESPONDENT	RESPONSE
SEPG 1	We've just changed division chiefs. The old division chief, who is not the department head, held the assessment's final report because he didn't want the consequences included in the findings. The new division chief doesn't appear to have these problems.
SEPG 2	None - I believe everyone thinks there is always room for improvement - just how far management will support it - only time will tell.
SEPG 3	Unknown
SEPG 4	Some people felling overwhelmed with the process improvement efforts that have resulted from the assessment.
SEPG 5	The result was an "emerging Level II." We were really Level I and this gave overconfidence
Project A-1	None that I know of
Project A-2	The concern appears to be in getting a higher level in the next assessment, rather than seeing how the model applies to a project and see if it will ad value to it.
Project B	I think that not enough training and motivation have been pushed
Project C	None
Project D	N/A

e. Has the non-attributive environment been maintained? (or has head-hunting taken place)

RESPONDENT	RESPONSE
SEPG 1	Yes
SEPG 2	No head-hunting has occurred, but management is denying that certain realities did in-fact surface.
SEPG 3	Yes
SEPG 4	Yes
SEPG 5	Yes
Project A-1	Have not seen any head-hunting, assume a non-attributive environment has been maintained
Project A-2	Yes
Project B	Yes
Project C	Yes, the head-hunter's attitude has not surface yet
Project D	By better tracking, you don't need to head-hunt a person can see quickly how their performance as a team member is.

f. Has the status of these factors changed since your process improvement efforts were initiated?

RESPONDENT	RESPONSE
SEPG 1	I think the worker/management relationship will improve as they cooperate to implement the CMM and SEI suggestions
SEPG 2	If management denies that a problem exists! How do you fix something that is not broken?
SEPG 3	Morale is slightly higher.
SEPG 4	What factors?
SEPG 5	No
Project A-1	It is being discussed more, but I feel there is a great need for training on what exactly is expected and how it will be implemented. There is a lack of understanding on the process and there is no road map on moving from Level I to the next.
Project A-2	No
Project B	No
Project C	No
Project D	N/A

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13. ABSTRACT (Maximum 200 words)

This research sought to determine whether a relationship exists between the maturity level of the software process, as determined by the Software Engineering Institute's Capability Maturity Model (SEI CMM), and the actual success of particular software projects at three US Air Force Air Logistics Centers. Project success is defined in terms of cost, schedule, and quality criteria. In addition, each organization's acceptance of the SEI assessment as well as its effectiveness in setting up follow-on process improvement programs were evaluated. Finally, the process improvement programs were reviewed individually inasmuch as these programs are the mechanisms for achieving improved quality, lower cost, and on-time software projects. The research was accomplished through a combination of information gathering techniques and data analysis. A literature review, both within and external to the Department of Defense, summarized current software process research, discussed the CMM in detail, presented case studies using the SEI CMM, and introduces software project success criteria. Using information gathered from three Air Force software organizations, we addressed each research objective.

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