

# Benefits Realized from Climbing the CMM Ladder

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*This article discusses the benefits the Ogden Air Logistics Center (ALC) Software Engineering Division (TIS) reaped from its process improvement efforts. Those benefits are examined from two aspects: the qualitative or the effects on the developer's quality of life and the quantitative or the effects on the organization's development capability measured in cost, schedule, and product quality.*

**W**hy is the comic strip Dilbert® so popular? It makes fun of

- Managers committing to unrealistic costs and schedules.
- Projects being over cost and schedule.
- Poorly managed projects.
- Poorly defined requirements and requirements changing just before delivery.
- Poor quality.

Perhaps Dilbert's popularity lies in its proximity to the truth. Employees complain that management is clueless, whereas management complains that the employees do not give them enough information to manage the project better. But both sides are doing the best they can with the resources and information they have. The solution to end the feuding is simple: a common enemy they can fight together, side by side, and the enemy should be poor processes. Because each side wants to maintain their own ways and wants the other side to change, the proponents of process improvement will have to convince both sides that the process improvement effort should be seen as a friend and not as an enemy. This article will demonstrate the positive aspects of process improvement according to the Software Engineering Institute (SEI) Capability Maturity Model (CMM) for Software.

The original title of this article was "The Return on Investment from Climbing the CMM Ladder." The term *return on investment*, however, has a precise definition within the business community that requires specific knowledge of cause and effect regarding changes to processes or methods and the

accompanying improvements in cost and productivity. Unfortunately, it is only when an organization reaches CMM Level 4 that the employees understand their processes in quantitative terms and can tie specific actions to process capability changes. Although it can be shown that tremendous improvements have been made in the TIS process capability in both the quality of software produced and the cost to produce that software, to correlate each change made over the years to specific quantitative improvements in process productivity or product quality is impossible. Instead, we can show general relationships and overall improvement across the years. A contributing factor to the improvement is the experience gained by the practitioners. This contribution was considered small because most of the core practitioners already had several years experience when significant process improvement began.

We will investigate the improvements in the Ogden ALC software development capability on two fronts. The first will be in qualitative terms, which means the quality of life of the practitioners, changes to their working environment, and general project expectations. The second approach will be in quantitative terms. Although these figures will be exact, we estimate their accuracy to be within 20 percent. Even with this uncertainty, we will show that the savings realized by the Air Force are worth the investment made.

This article is concerned with the overall investment in process improvement and the returns and benefits realized within the two software developmental product lines. In fact, our

experience has been that quantitative gains within the automatic test product line have been difficult, if not impossible, to substantiate. The quantitative portion of this article, therefore, will reflect the savings gained in the Operational Flight Program (OFP) and mission planning product line. The quality of life and schedule issues, however, will reflect gains across the division as a whole.

## Qualitative Benefits

### Practitioner Working Environment

A brief questionnaire was sent to those employees who had been in the organization for the duration of the process improvement effort and who had a long-term perspective on the changes wrought by these efforts. Of 32 questionnaires sent, 18 were returned—a good number for voluntary participation. The questions and responses are summarized as follows:

- *Have you been more constrained or less constrained in performing your job?*

Ten of the respondents felt more constrained, four saw no difference, and four felt less constrained. Of those who felt more constrained, about half saw it as an inevitable side effect of providing beneficial structure to the development process. The constraint was not considered to be negative.

- *Is it easier to perform your duties with respect to tools, working environment, etc.?*

Thirteen of the respondents felt it was much easier, two felt it was a little easier, two about the same, and one said it was a little harder. The one who felt it was harder pointed to more complex and less

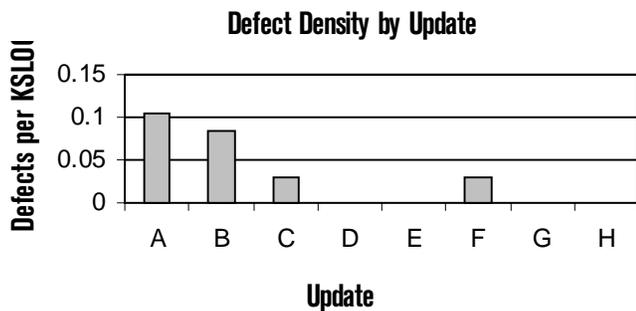


Figure 1. Defect density by update.

user-friendly tools. Of the positive responses, most attributed the improvements to tools and technology, e.g., paperless environment, and some also cited the benefits of better planning and coordination.

- *Are there more project surprises or fewer?*

Thirteen felt there were fewer surprises, four saw no difference, and one felt there were more.

- *Do you now feel that you have more input and control into project planning or less?*

Twelve felt they have more input into project planning, two felt they have a little more, two felt they have the same, and two felt they have less.

- *Do you feel that our CMM efforts have been a positive influence?*

The answer was a unanimous “yes.”

- *Do you feel that you are producing better quality software?*

Sixteen felt that the quality of software produced had improved. Two felt that it was always good and had not changed.

### Project Execution

The ability to control requirements changes, remove defects earlier, and consequently perform better planning and project control has significantly reduced the “fire drill” atmosphere typical of earlier projects. This is especially true of the end of the project cycle when last-minute changes without schedule relief and defects found in final testing wreaked havoc with delivery schedules. The resulting overtime and unhappy customers combined to make life more than a little unpleasant.

### Overall Effect

The working environment and culture within the organization has changed significantly over the years. There are still last-minute glitches and surprises, but they are the exception, not the rule. The engineers do not see much difference in the way they do their work. The constraint on creativity many feared has not materialized. In fact, most still say they dislike process improvement and have not seen many changes. That is because the CMM is, for the most part, a management model. Most changes have been in the way we have managed our projects, not in how the engineers actually do design work. Changes have been slow in materializing, but the resultant change in culture is remarkable.

## Quantitative Benefits

### Quality Improvements

All errors are costly in one way or another, even though some might not believe that quality as measured in conformance to requirements specifications is important. Loss of market share due to customer dissatisfaction or just the increased cost of bringing the product to market have definite financial impacts on the software supplier. Although the latter may be more immediately visible, the former may be the long-term cause of organizational demise.

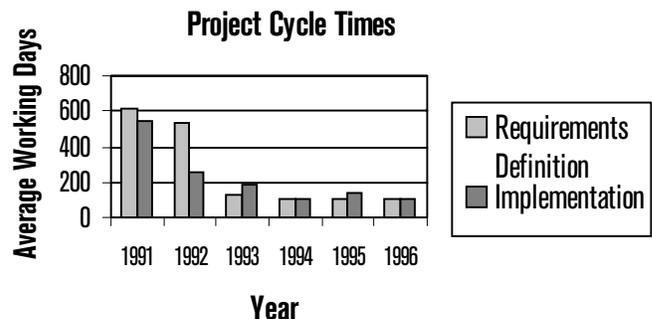
The quality of software delivered to our OFP customers over the years has improved dramatically. In showing this improvement, we chose the metric *defects per thousand source lines of code* (KSLOC) reported after delivery of the production tape. This measure was chosen to compare later projects with earlier projects. As the process improved, our metrics data changed over the years. This measure was available for previous updates. Our defect ratio (Quality Deficiency Reports [QDRs] generated against production deliveries divided by the size of the update in KSLOC) was not as useful as our current metrics. As part of our Level 5 improvement implementations, we now use measurements that show quality at each phase of the project to isolate and remove sources of errors. The defect ratio of production tapes over the years is shown in Figure 1. As can be seen, the quality of product at the point of measure has improved steadily over time. It is now a rarity to receive a QDR on a production tape. Projects D, E, G, and H have had no QDRs submitted. The two QDRs represented by the spike in data at Update F were found by our internal code inspections and testing being done for a later update.

### Schedule and Cycle Time

In the early 1990s, the automatic test equipment (ATE) product line employees focused their efforts on reducing the cycle time. Our assumptions were that if we reduced our cycle time, we would reduce the costs of the projects. This assumption is not necessarily true in every case, but fortunately for us, the assumption appears to have been valid.

The average ATE project cycle times, shown in Figure 2, are the average number of days from the authorization to start work to the delivery of the product. We began our software process improvement (SPI) efforts in 1991 and achieved a

Figure 2. Average ATE cycle time.



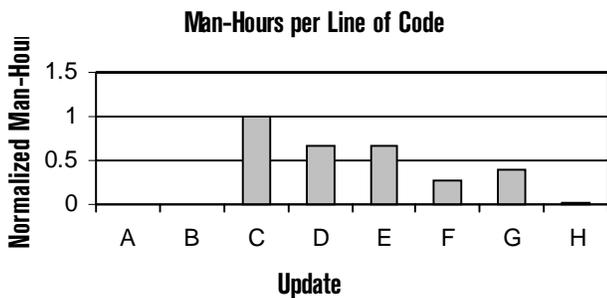


Figure 3. *Man-hours per line of code (normalized).*

CMM Level 3 in 1995. The purpose of Figure 2 is to point out that the improvements need not wait until you are a Level 5 organization. The known inefficiencies were corrected as quickly as possible. These cycle times were reduced by approximately 70 percent each while we worked on the CMM Level 2 and Level 3 issues. The projects are tracked separately as requirements definition (RD) projects, e.g., RD 1, RD 2, or projects to implement the approved enhancements. In this product line, an individual project can reference either new requirements definition or implementation to any one of more than 750 automatic test programs.

Although the cycle time displayed in Figure 2 was only a portion of the lengthy overall response time experienced by the end users of the products, an intangible benefit from the reduced cycle times is greater customer satisfaction. In 1995, the customer joined us in an enterprise-wide action team called the Falcon Software Express (FSE). The FSE was co-chaired by a member from TIS and the customer's lead program manager. The FSE team applied the same high-level process improvement concepts to the overall process, which crossed numerous organizational boundaries. The organizations and people affected by FSE included software engineering, program managers, equipment specialists, item managers, and funding managers. The FSE team achieved a similar reduction of approximately 70 percent for the overall cycle time experienced by the end user.

### Schedule Variance

Mark Paulk, et al., stated, "An unpublished review of 17 major Department of Defense (DoD) software contracts found that the average 28-month schedule was missed by 20 months. One four-year project took seven years; no project was on time." [1] The average schedule variance for the 17 DoD contracts studied showed that, on the average, each project took 70 percent more time than scheduled. In comparison, our average schedule variance is less than 5 percent.

### Productivity Improvements and Cost Reduction

Although product quality may be important and at least highly desirable, productivity and cost per unit of production are the immediate measures that management uses to determine the payback for investment in process improvement.

Savings in our OFP product line is shown in Figure 3, which shows the normalized cost per line of code based on

lines of code produced and man-hours required for each update. (Note that these updates correspond to those shown in Figure 1.) Values for projects earlier than those shown were not available. Those projects with extremely low cost per KSLOC benefited from heavy reuse. Early in the program, our OFP system design engineers learned that they needed to work closely with the pilots to assure that conceptual ideas were understood and defined properly in the system's requirements document. Rapid prototyping and technical interface meetings were established to help assure that the products developed met both the system requirements and the needs of the end users.

Our ATE product line provides a level-of-effort type of support that makes the savings, on a per-project basis, more difficult to solidify. When loaded at the optimum level, the ATE product line now produces the software updates at savings of approximately 70 percent; however, when the workload is at a level less than the optimum level, the cost per project rises. In an effort to stay at the optimum workload level, the ATE product line works closely with the customer to forecast the predicted workload and manpower needs.

### Return on Investment

In an attempt to put a value on the return to the Air Force from the investment TIS made in process improvement, a few basic tenets were established. First, since this and most software maintenance organizations—including those in the private sector—provide essentially a level-of-effort service to the customer, savings were computed based on cost per unit of deliverable product multiplied by the number of units delivered per year, i.e., cost per line of code or cost per test program set times the number delivered per year. Second, based on general business practices, an investment in process improvement for any given year will be assumed to be responsible, in part, for actual and projected savings garnered in the following five years. Third, as previously stated, we assume that most savings realized resulted from the process improvements institutionalized through this program. With these conditions in mind, the estimated return on investment for this division was a ratio of about 19-to-1. In other words, the Air Force received, in the form of additional software enhancements to the F-16 aircraft weapons systems and other weapons systems, nearly 20 dollars for every dollar invested. To date, that is well in excess of \$100 million worth of weapons and test system enhancements and fixes.

We realize that these figures seem unrealistically high. But, as stated before, they are based on investment vs. payback over time, including projected payback over the next five years. This is consistent with management accounting practices used to determine the advisability of making capital investments in process improvements. Further, it is doubtful that doubling our investment would have significantly increased productivity. Likewise, if we had invested the money in process improvement without the management commitment to ensure implementation, our return would have been extremely low. In fact, the money would have been wasted.

We were fortunate to have struck the right balance of resources to move improvement along without waste and yet preserve enough momentum for the organizational culture to undergo the desired change.

## Conclusion

Our end users are the ultimate beneficiaries of our SPI activities. The end users are receiving higher-quality products that perform as envisioned at a lower cost and with minimal project cost and schedule variances. At the same time, most practitioners believe their working conditions have improved or at least have not become worse, whereas management believes that they have better control of the situation.

Remember, the analysis and implementation of process improvement requires patience and time; it does not produce instant feedback. Both qualitative and quantitative metrics show a continual improvement over the years. Although it is difficult to show a one-to-one correspondence to each improvement with the benefits shown in the metrics, it is easy to show continual improvement.

Finally, to quote one of TIS's first-line managers who has several years experience in project management, "We have only been at a CMM Level 5 for a short time. Now that we have the tools in place to really understand our processes, real improvements can now begin." ♦

## About the Authors

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