The Use and Impact of Earned Value Management on Software Projects

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Abstract

The Software Division at Tinker Air Force Base has used Earned Value Management (EVM) methods for approximately 20 years. The management method has had significant influence in the improvement of the software development and maintenance practices of the organization. This article, in a story telling manner, describes the use of EVM for managing software and how its system of management facilitated a natural evolution which lead to recognition, awards, and more importantly ....on time, at cost, quality software.

This story spans more than 20 years. There has been a considerable amount of excellent work throughout this entire span of time, performed by several dedicated and persevering people. Although the period of the Earned Value Management (EVM) application covers two decades, it is not meant to imply that employing EVM for managing software requires an exorbitant time to implement. Rather, what is described is an evolution of practice from the experience of project failure to a desire to do better, and subsequently improvement and success. Included in the discussion are the outside influences which impacted the actions taken.

In describing the Software Division's (SD) use of EVM, we'll cover the topic chronologically. The beginnings cover a period of time from 1979 to 1985. The effort to understand the software process occurred during 1987 through 1989. The period of significant, measured, process improvement was from 1989 to 1996. Then a period of evolving and refining the process is described, beginning in 1997 and continues today.

Before EVM and its influence upon the software practices are described, an introduction to the mission of the Software Division and its products is helpful to understanding. Tinker Air Force Base is an Air Force Depot, which performs maintenance and modification to several aircraft and jet engines, including their electronic systems. The SD supports the automated processes used during the maintenance actions. The primary products of the SD are Test Program Sets (TPS) and industrial automation software. For clarification, a TPS is used along with automatic test equipment to execute the testing process for an item requiring maintenance. A TPS consists of software, an electrical-mechanical interface, and instructions for its use. The portion of the Division supporting Depot maintenance has annual revenue of approximately $40 million. The Depot support functions of the Division employ approximately 360 people of which 300 are electronics engineers.

Beginning

You can just never predict how something may influence your future. In 1979 I attended the 22 week Program Management Course (PMC) at the Defense Systems Management College located at Ft Belvoir, Va. A portion of the course was dedicated to EVM, termed at that time "Cost/ Schedule Control Systems Criteria," or "C/SCSC." The EVM course was taught from the perspective of its application to major acquisitions of the US Department of Defense. At the time, I could not visualize its application to the maintenance performed at the Depot. Thus, upon returning to my job, EVM was more or less forgotten.

In 1981, two years after the PMC learning experience, the SD was to develop several TPSs for the avionics from a cargo aircraft. The project performance was disastrous, and the subsequent reputation created nearly doomed the organization.

During 1985, a major acquisition program provided the SD the opportunity to develop several TPSs. With the cargo aircraft project still in work and suffering from a poor reputation, the SD was very fortunate to have this second chance. We knew that a better way was needed to plan the acquisition project and to track its progress. Gantt charts had

proven to be insufficient for the cargo project. We turned to EVM and created a very rudimentary Work Breakdown Structure, using the "waterfall" model of software development with its system of phases and progress reviews. Earned Value was accounted on the safe side so that there was no fooling ourselves that progress was being made, when it wasn't.

The acquisition project was a resounding success! Among all of the developers on the program, including the contract sources, the SD completed the first two TPSs and was the only developer to complete on time and within budget. Certainly, the success wasn't solely due to implementing EVM, but using its methods did play a significant part.

Capturing the Lessons

One thing leads to another. In 1987, before the acquisition project (A) completed, we began another project, TPS development for a newer cargo aircraft (N). In many respects the N project was simply an extension of the A project; there were many similarities. The lessons we learned from A were applied to the new project. Not only were the cost, schedule, and performance requirements met, the execution of the N project was considerably more efficient. The rework was reduced, impressively, from approximately 45 percent for A to about 25 percent for N.

During the new project, some of the teachings of the Total Quality Management classes, which we reluctantly attended during the 1980s, were applied. Before the close of 1990, three documents were prepared to capture the processes, and a management steering team was established to maintain control of them. The three documents were: The TPS Development Guide, The TPS Project Management Guide, and The TPS Developer Training. Imbedded in the documents and the training were methods for applying earned value. Over the period of time they were used, these process and training documents served the SD well.

Process Improvement

In 1989 I attended the Software Engineering Institute (SEI) Symposium, and was swept up by the discussions of process maturity and improvement. By this time, due to the success on two projects, the SD had developed a good reputation. Therefore, egotistically, it was decided to conduct a SEI led self-assessment to validate that the SD processes were maturity level 3. The assessment was premature to the Secretary of the Air Force edict of 1993, requiring organizations to be Level 3 by 1998 or risk not being able to do business with the Air Force (AF). The SD was under no pressure to perform the capability assessment; however, we believed it was needed to baseline the organization.

The first SEI process maturity assessment was performed for the SD in 1990. The organization showed some Level 2 tendencies, but overall, the SD was Level 1 …..the lowest level of software engineering process maturity. As an organization, we were extremely disappointed with this result. However, being affirmed as Level 1 did serve as the impetus to the organization for the subsequent improvement efforts.

Occurring about the same time as the assessment the Federal government initiated several things to streamline and reduce cost in its operations: "downsizing," Base Realignment and Closure (BRAC), and competition with industry. All of these things said essentially one thing to government workers, "No longer are your jobs secure." With all of these pressures, it was believed that the performance and reputation of the SD would have to be much better than its competitors, within both government and industry, to obtain additional work and retain jobs. Also, we thought that new work opportunities would come from large acquisitions, and would involve winning a competition. Because large acquisitions oftentimes had EVM imposed, an assumption was made that it could become a contract requirement for the software competitors.

To better grasp EVM, we took a class. As we knew more, it was seen that EVM facilitated improving software process maturity. Clearly, the earned value approach provides a good mechanism for the Level 2 key process area, Project Tracking and Oversight. Certainly, having a recognizable work breakdown structure provides structure for another Level 2 area, Project Planning. Seeing other relationships between EVM and the SEI software engineering capability maturity model, we more rigorously applied earned value management.

In 1993, the second SEI maturity assessment was scheduled. Virtually the entire SEI process staff came to Tinker AFB for the assessment. The assessment of the Software Division was the prototyping of a significantly revised assessment process for the SEI. Although the SEI staff was unfamiliar with EVM, they recognized the improvement made in our methods. The organization was assessed as SEI software process capability maturity Level 2, the first Air Force organization to achieve the rating.

Because of the notoriety from achieving the Level 2 rating, and Mr. Mosemann's commitment to software process improvement, the Software Division was chosen to be the subject of a study of its economic benefits, i.e. return on investment (ROI). Mr. Mosemann, at the time, was the Deputy Assistant Secretary of the Air Force for Communications, Computers, and Support Systems; he wanted evidence that the SEI model for software process improvement provided "real results." Software Productivity Research was selected to perform the study; they surveyed four of our projects, spanning the years 1988 through 1994 [1]. Mr. Mosemann obtained the evidence he sought: the conclusion of the study was that the SEI model has validity. The ROI from the improvement efforts was determined to be 7.5 to 1. The application of EVM contributed greatly to the economic benefit from improving the software engineering process.

By 1995, some of the managers within the SD were convinced that the application of EVM should be extended to include software maintenance projects. One group prototyped the maintenance application and demonstrated that it was useful in the same way as it is for the longer software development projects; EVM enforced better project planning and provided several levels of accountability. Consequently, earned value methods for software maintenance were implemented across all of the organization.

In the quest to improve, an organizational set of management indicators was created. Having the standard indicators enforced common reporting and made the periodic management reviews much more productive. During this effort it was recognized that the TPS Development and Project Management Guides were too focused on specific equipment and software tools. Consequently, the processes were generalized with the creation of the TPS Life Cycle Guide (LCG). As part of the LCG, a standard work breakdown structure (WBS) was defined. When applied, the WBS is tailored to the specific needs of a project. Having a standard WBS has facilitated several planning and tracking improvements. Also, from having consistent data elements and standard management indicators, meaningful project history data has been accrued, thereby facilitating improved project planning.

In 1996, the Software Division underwent its third SEI software capability maturity assessment. The result was Level 4, the first in Federal Service! One of the Level 4 process areas is Quantitative Process Management (QPM). Conceptually, satisfaction of QPM indicates that management uses the data from its metrics to make decisions for controlling the process. The indicators from EVM significantly contributed to satisfying this Level 4 process area.

The organization was very nearly assessed at capability Level 5; only one key process area was left unsatisfied, Defect Prevention. As seen later in the paper within the discussion of the Software Process Achievement Award, this process area was very likely achieved; however, it was missed, most likely, because we had not prepared for a level 5 assessment. The hopeful expectation before the assessment was an outcome of level 3 with some level 4 tendencies. Obviously, the result greatly exceeded everyone's expectation — the SD, the lead assessor, and the SEI.

Evolving/Refining

Also during 1996, the SD began the largest software development it had ever attempted. The management reserve (MR) for this effort was larger than the total budget of the vast majority of the division's projects. Because of its size and the criticality of performing well on this project, we formalized the methods for managing MR. Our methods focused on answering two questions:

1) When should MR be applied?

2) What action should be taken, and to what extent?

The methods were published in the March 1999 issue of *CrossTalk* [2]. They are being utilized today for all of the SD's software developments, and have received attention from several organizations, some of which are in foreign countries. In March 2002, the *CrossTalk* article was reprinted with some updates in Projects and Profits, a journal published by the Institute of Chartered Financial Analysts of India [3].

Upon achieving the SEI software process maturity Level 4 rating, it was thought that the SD would be recognized within the US Air Force as a viable, low risk software provider. However, the division performs software work for foreign customers as well as those from the Department of Defense. At the time, the SEI capability maturity model for software process was not that well known outside of the US. Thus, there was some understanding that potential foreign customers might not recognize the meaning of the SEI Level 4 rating as readily as ISO 9001, the international standard for quality management systems. We believed that registration to ISO 9001 would achieve a more recognizable credential to potential foreign customers, thereby providing another avenue to increase our business. Once again, we were driven by the desire to survive as an organization, in turn securing long-term careers for the employees.

An underlying principle of the ISO standard is the manner in which the supplier of the product or service treats the customer. Fundamentally, the supplier must try to satisfy both the customer's written and unwritten needs. With regard to software product development, customers, often times, are uncomfortable specifying the manner of project status reporting. The progress reporting, using the EVM indicators, proved to be an excellent method of providing project status. It portrays to the customer measures of cost, schedule, and technical performance in a very concise, understandable, and meaningful way. Having earned value management methods in place helped the SD achieve ISO 9001 registration in 1998. At the time, there were not many software organizations having a SEI capability rating of Level 4 or Level 5 combined with the ISO 9001 credential. At this point, the Software Division truly became an elite software engineering organization.

In 1999, the Computer Society of the Institute of Electrical and Electronics Engineers (IEEE) and the Software Engineering Institute (SEI) recognized the Software Division for its software engineering process improvements. A primary contributing factor to winning the Software Process Achievement Award is the on site, all day, question and answer session with the IEEE/SEI review team. The 1999 review team was made up of several very recognizable names in the software industry: Dr. Barry Boehm, Watts Humphrey, Dr. Vic Basili, Manny Lehman, and Bill Riddle. Even though the atmosphere throughout the day of the on site examination was very cordial, believe me, it is more than a little intimidating to present and defend your achievements to these gentlemen.

The SEI/IEEE Software Process Achievement Award is unique in that it may not be awarded to the year's nominees; indeed, there have been several years when no award was made. The award is made only when the review team is convinced that an organization has made significant progress. For this reason, the Software Process Achievement Award is regarded as the most prestigious award for software organizations.

The SEI technical report, CMU/SEI-2000-TR-014, is available, describing the software process improvements which earned the award [4]. Figures 1, 2, and

	1993 Level 2 N & A3	1996 Level 4 A3	1997 A3 & A4	1998 A4	Improvement
Effort	1600 Manhours	1200 Manhours	1150 Manhours	1000 Manhours	37%
Cycle Time	13 Months	12 Months	12 Months	11 Months	15%
Defects	3.3/KSLOC	0.3/KSLOC	0.3/KSLOC	0.03/KSLOC	99%

NOTE: Data is based upon an average TPS

Figure 1. Productivity / Defect Improvements.

3 are from the presentation made at the 1999 SEI Symposium; they are included, also, in the cited technical report. These figures illustrate the improvement results. Figure 1, Productivity/Defect Improvements, is a compilation of the improvements over the years 1993 though 1998: effort was reduced by 37 percent, cycle time by 15 percent, and defects by 99 percent. Using the six sigma quality rating system, the defect rate of 0.03 per thousand lines of source code is computed to be 5.5 sigma; i.e., extremely high quality software.

Figure 2, TPS Development Rework, shows the reduction in rework spanning the years 1984 through 1998; rework was reduced from an initial estimate of 75 percent to 45 percent, then to 25 percent, and is now at 3 percent. For comparison, as reported in 2004 by the US Government Accountability Office, rework of 40 percent is not unusual for software development [5]. Figure 3 illustrates the economic benefits derived from the 10 years of US Air Force funding applied to the software process improvement initiative. For the investment of $6 million in software process improvement, the SD can show a reduction of 765 thousand man-hours with a corresponding reduction of cost equal to $50.5 million. There is no question, the use of earned value methods has played a significant role in these achievements; EVM has been a facilitator. Likewise, these achievements serve as a strong endorsement of the SEI and its model for software engineering process improvement.

Things change. Satisfying the quantitative management criteria for Level 4 of the SEI software capability model once meant that the organization used measures in its decision-making process. The criteria have since evolved and have been extended to mean the use of Statistical Process Control (SPC). The Cost Performance Index (CPI) indicator from EVM, and the Schedule Performance Index (SPI(t)) from Earned Schedule [6], provide a means for statistically managing the software engineering process. In the years subsequent to winning the IEEE/SEI award, the SD evolved its use of CPI and SPI(t) into statistical applications. The applications are useful in predicting project outcomes, and have been shown

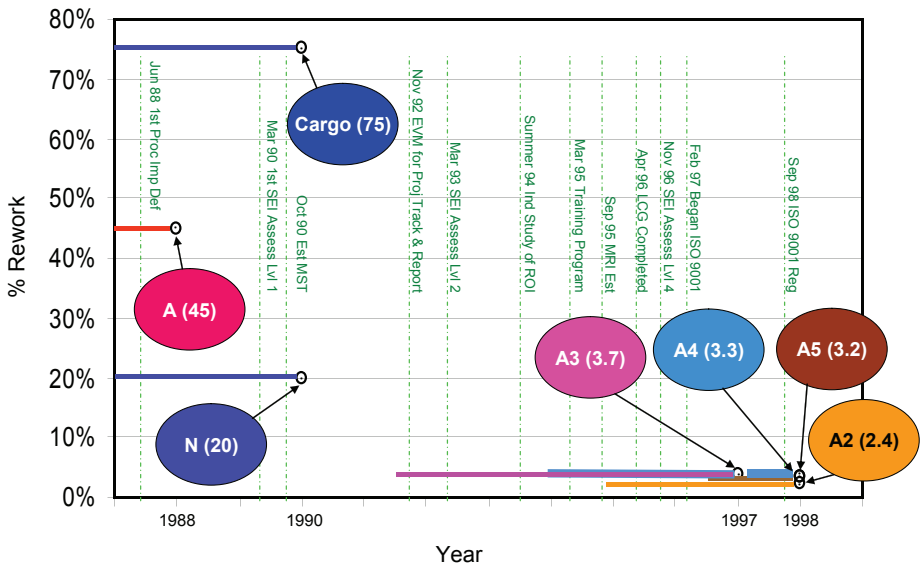

Figure 2. TPS Development Rework.

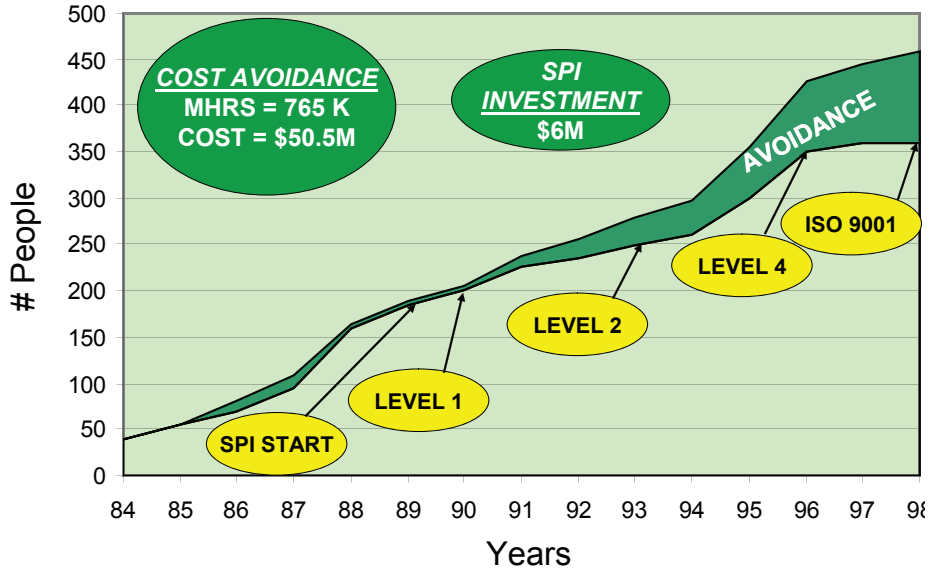

Figure 3. Economic Benefit.

beneficial in project planning. Several papers have been published in *CrossTalk* discussing these methods [7, 8, 9, 10]. Once again, earned value helped meet the challenge.

In addition, the SD is applying a method for strategizing the recovery of a project, which appears headed for failure. Once again, we resorted to the EVM and ES indicators, CPI and SPI(t), for creating the approach. The published technique has shown to be beneficial [11].

Summary

The Software Division has a lot to show for over the years 1985 through 2005. There has been recognizable, quantifiable improvement in the software development and maintenance processes. Integral to many of the software management improvements is the use of earned value methods. The credentials gained from improving, SEI Level 4 and ISO 9001, has placed the organization among the elite in the world. The winning of the 1999 IEEE/SEI Software Process Achievement Award was the final proof that the improvement made is bona fide. And, most important, the "rubber hits the road" proof of the improvement is software products are consistently completed for acquisition and maintenance projects on time, at cost, and with excellent quality, many of which serve today for the US Air Force.

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About the Author

Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base. He has over 35 years of experience in the development, maintenance, and management of software for automated testing of avionics. During his tenure, the division achieved several software process improvement milestones, including the coveted SEI/IEEE award for Software Process Achievement. Mr. Lipke has published several articles and presented at conferences, internationally, on the benefits of software process improvement and the application of earned value management and statistical methods to software projects. He is the creator of the technique Earned Schedule, which extracts schedule information from earned value data. Mr. Lipke is a graduate of the USA DoD course for Program Managers. He is a professional engineer with a master's degree in physics, and is a member of the physics honor society, Sigma Pi Sigma (SPS). Lipke achieved distinguished academic honors with the selection to Phi Kappa Phi (FKF). In March 2007, he received the PMI Metrics Specific Interest Group Scholar Award. In November, Mr. Lipke received the 2007 PMI Eric Jenett Project Management Excellence Award for his creation of the ES method and role in its worldwide propagation and use.