# The Fire Support Software Engineering Division Achieves CMMI Level 5

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*The U.S. Army Communications-Electronics Command (CECOM) Software Engineering Center (SEC) Fire Support Software Engineering (FSSE) Division and its prime contractor, Telos·OK, have attained the Capability Maturity Model Integration (CMMI®) Level 5 rating in systems and software engineering. After 13 years of continuous pursuit and practice of a software and systems improvement program, the CECOM SEC FSSE has become the first Department of Defense organization to attain CMMI Level 5.*

The U.S. Army Communications-Electronics Command (CECOM) Software Engineering Center (SEC) Fire Support Software Engineering (FSSE) Division and its prime contractor, Telos·OK, achieved an unprecedented milestone on Aug. 6, 2003. The appraisal team leader from the Software Engineering Institute (SEI) announced that CECOM SEC FSSE had achieved Capability Maturity Model Integration (CMMI®) Level 5. They are the first Department of Defense (DoD) agency to achieve this rating, and only the second organization within the United States to do so.

In August 1990, the U.S. Army's Army Material Command (AMC) began an affiliation with the SEI. The purpose of this affiliation was to generate methods to continually improve the software engineering capability of all U.S. Army software development agencies.

The SEI introduced the AMC to the Capability Maturity Model® for Software (SW-CMM®), which provides a model of software engineering key practices accepted by the software industry. The AMC selected the CECOM SEC to take the lead in implementing the methods associated with this model. The SEC subsequently selected the FSSE Division, which is located at Fort Sill, Okla., to initiate formal software engineering process improvement in accordance with the guidelines set forth in the CMM.

The team of the SEC FSSE and Telos·OK has been a partnered organization since the founding of the FSSE by the predecessor to the AMC in 1976. This partnership has survived and thrived through six full and open five-year contract competitions during the intervening 26-year period. The processes are owned by the government, and practiced, controlled, and changed by the government and contractor team.

The FSSE began its software engineering process improvement program by establishing a benchmark activity to determine its current state of software engineering maturity, as described in the CMM for Maturity Levels 1 through 5. This appraisal was conducted in February 1991, and identified the organization as a CMM Level 1 with a large portion of the Level 2 key practices in place. Members of the FSSE, the SEC Ft. Monmouth, the Mitre Corp., and the SEI conducted this appraisal.

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Subsequent to this first appraisal, the FSSE immediately developed and implemented a plan for process improvement, which primarily focused upon key practices associated with organization and system-level process documentation, personnel training, managing process improvement, and technology innovation. The implementation of this plan was completed in September 1994, and the FSSE conducted its second benchmarking activity. Members of the FSSE, the SEC Ft. Monmouth with full participation of representatives from Mitre, and the SEI conducted the appraisal.

The actual appraisal methodology had become significantly more rigorous over the past three years; however, the organization was appraised at a solid CMM Level 3. This was the first time that any organization affiliated with the SEI had moved from Level 1 to Level 3 without an interim appraisal of Level 2. The Level 3 placed the FSSE in the top 15 percent of software development organizations around the world.

## Level 4: The Next Step

Following this second appraisal, the FSSE refined its process improvement plan to move next to CMM Level 4. The refinements to this plan focused primarily on establishing a viable management-through-measurement program. The key attribute of a CMM Level 4 organization is its ability to quantitatively control the process performance and product quality of its software development efforts. However, there were no other Level 4 organizations in the world from which to draw lessons learned for moving from a Level 3 to a Level 4 process maturity level. It took quite a bit of study to gain an adequate understanding of what the CMM actually intended with its Level 4 key practices.

We turned to Lockheed-Martin, a CMM Level 5 organization, and the SEI to assist in deciphering the Level 4 key practices. The SEI and Lockheed-Martin provided excellent guidance and assistance in identifying methods and means for the FSSE to adequately plan for the Level 4 process changes. The following bullets elaborate upon some of the major implementations identified for the move to Level 4:

- A formal methodology was documented that described how the organization collected, displayed, and analyzed software engineering data.

- A new tool was created to provide real-time visibility to managers and developers into the progress, process performance, and product quality of all software engineering efforts.
- Training in statistical process control (SPC) was provided to managers and engineers across the organization. Subsequently, SPC was tagged to those critical processes used for software development.
- Additional reviews and reporting methodologies were employed within the organization's standard software process.

The implementation of the process improvement plan was completed in November 1997, and the third benchmarking activity was conducted. During this appraisal, the FSSE was identified as meeting the criteria for CMM Level 4. Members of the FSSE, Lockheed-Martin, and the SEI conducted this appraisal. This newest rating placed the FSSE in the top 2 percent of software development agencies around the world.

The FSSE then implemented plans to improve its Level 4 process and advance toward CMM Level 5. During this important process upgrade, the SEI, the DoD, and the software community established the CMMI project, and a new model was released in the latter part of 2001. The accompanying, and more rigorous, Standard CMMI Appraisal Method for Process Improvement (SCAMPI[SM]) was released in early 2002.

This new model provides for an integration of software and systems engineering. Level 5 means that process improvement is a way of life for an organization. Improvements flow naturally from the work force, and through the exercise of the organization's development processes. The key attributes of a Level 5 organization are predictability, efficiency, and high quality. The FSSE adjusted its improvement program to adopt the new model, as well as the new SCAMPI appraisal methodology.

The latest appraisal was concluded on Aug. 6, 2003 with the achievement of CMMI Level 5. A notable aspect of this newest appraisal method was the length of time needed to complete the event. The appraisal, which was led by members of the SEI, actually began with a mini-appraisal on March 12, 2002. The organization conducted three mini-appraisals from March 2002 through June 2003. These mini-appraisals were used as a means to facilitate the gathering, review, and rating of a tremendous amount of documented evidence. This mini-appraisal technique was found conducive to the increased rigor of the SCAMPI method, and allowed the appraisal team to prepare and conduct a smooth one-week on-site interview period.

The achievement of this benchmark exemplifies the seriousness the FSSE holds for developing and maintaining mission-critical, highly reliable, tactical software used in support of the nation's fire support warfighters. Fire support is the collective and coordinated use of indirect fires, target acquisition data, armed aircraft, and other lethal and nonlethal means against ground targets in support of the maneuver force operations.

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## Characteristics of the Level 5 Process

CMMI Level 5 requires advanced project management, which gives increased visibility into and control of the software and system engineering process. The following traits are indicative of this level of management:

- Evidence of decisions based upon *quantitative* analysis.
- Evidence of *formal* decision analysis.
- Evidence of identifying *root causes* of problems – not just software defects.
- Evidence of *measuring* improvements against projected outcomes. These are process and technology improvements.
- Evidence of *institutionalization* across all projects.

Most importantly, a culture exists that invites ingenuity and creativity from the work force. This culture is evidenced through the documented involvement of the work force in process improvement.

## Missions Supported by the Level 5 Process

The FSSE was among the first Life-Cycle Software Engineering Centers established to support mission critical software for the U.S. Army. The center performs diverse work in all areas of the fire support domain to include command and control, target acquisition, tactical fire control, and technical fire control. Supporting work includes fire support automated testing, validation (regression, ballistics, stress, and interoperability, using a mix of tactical equipment and simulation), systems integration, system emulation, or porting and training. The knowledge base required to accomplish the mission includes system and software engineering, NATO, joint and Army interoperability, software training and fielding, doctrine, tactics, radar, cannon, missile, auxiliary equipment, and embedded systems.

Within the joint service community, the Joint Variable Message Format Bit-Oriented Message (BOM) standard used between services for interoperability was base-lined using a core set of 63 Army Variable Message Format BOM that were invented, developed, and matured by the FSSE. This advanced messaging capability is a direct result of the processes that were used in the FSSE's system-of-systems package development and maintenance methodology.

The FSSE has successfully fielded 73 major fire support weapon system software versions. We have transitioned eight weapon systems, developed 20 new fire support weapon systems, performed 68 major weapon systems upgrades, developed 27 major programming support and automated test systems, and developed 18 major prototype systems. Currently, we are responsible for more than 9.5 million source lines of code (SLOC). This includes over 600,000 in-house developed Ada SLOC for new systems and 2,197,000 SLOC transitioned and updated or reused in new systems.

The FSSE has supported the Army's transformation through Task Force XXI and the current First Digitized Division. The FSSE accomplished this support by providing more updated systems (10 systems in all) to Task Force XXI and the First Digitized Division than any other

[SM] SCAMPI is a service mark of Carnegie Mellon University.

government agency or contractor. The FSSE performed the additional task without impacting on-going Army operational needs, doing it under cost and on schedule.

## Return on Investment

Since the advent of the original AMC initiative for process improvement, thousands of organizations and projects around the world have instituted formal software engineering process improvement programs. The FSSE continues to be at the forefront in industry in process improvement, leveraging the CMMI Level 5 processes to develop and maintain mission critical, high reliability, command and control, real-time acquisition fire control and fire direction tactical systems. A significant return on investment has been realized through increased product quality (reduced defects) and increased productivity (decreased cost to the customer). The following details some of these returns:

- **System Growth.** The organization has gone from maintaining over 1.5 million LOC in 1993, to over 9.5 million LOC today. This has been accomplished without any increase in staffing. As the process has matured, process efficiencies and new technology have provided the increased maintenance ability. One of these process efficiencies is advanced reuse of components.
- **Size Stability.** The organization's ability to accurately predict the size of the projects at the beginning of development has improved 250 percent. As most companies realize, this ability is critical in estimating staffing and other resource needs.
- **Software Quality.** Defects found during formal testing have decreased by over 80 percent.
    - Defects found on previous version = 2,881; LOC = 2,050,739 for a rate of 1.40 defects per KLOC.
    - Defects found on most recent version = 457; LOC = 1,966,702 for a rate of 0.23 defects per KLOC.
    - Decrease in defect rate = 83.57 percent.

This provides engineers time to do valuable follow-on efforts, instead of concentrating on rework and retest.

- **Productivity.** The organization's LOC/hour rate has increased by 48 percent. This is even more significant when considering the increased quality.
- **Cost.** For the 13-year period encompassing the FSSE's current process improvement efforts, the average inflated 13-year operating cost would have been approximately $59 million per year. Because of continuous process improvements, the average inflated cost per year is approximately $30 million. This represents significant savings attributable to process improvement efforts.

## Specific Improvements

We have seen in similar reports a lack of specific improvements identified, which were actual implementations through the maturing of the process. Here are several that have been implemented here:

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- **Improved Software Development Model.** The organization has implemented the Incremental Software Development process, which provides for finding defects earlier in development, as well as better handling of requirements and requirements changes. For some smaller projects, or as needed, the process still allows for use of the Waterfall Model.
- **Advanced Reuse.** As mentioned earlier, maintaining a reuse repository, administering its use, and wiring it into the process has provided significant gains in efficiency and quality. This advanced reuse capability is fully supported by the processes and is made possible because the FSSE has software responsibility for numerous related domain-specific systems.
- **Automated Tools.** The organization has developed automated tools that provide significant improvements in project management, software development, and testing. Some of these are the following:
    - TRACKER: A locally developed tool used to manage the contract dependencies between the government customer and its support contractors.
    - CMDB: A locally developed tool used to control the creation of software systems and their components. This tool has numerous features in one product, which can only be found through multiple products on the market.
    - ABTCS and TSS: Locally developed tools that provide fast and thorough means for testing software and validating a system's software baseline capabilities as the system's software continues to evolve.
- **Formal Inspections.** Although implemented years ago, the organization continues to refine this process, and looks deeper into the various products to identify and eliminate errors. These inspections begin during requirements development and go through the testing and training products.
- **Numerous Development Platforms.** The organization has moved from numerous program support environments (PSEs) into a single PSE, thereby reducing procedural and technical training burdens associated with the PSE and allowing engineers and programmers to move quickly and easily between systems as needed. In addition, we pursue and continue to move toward standard unified tactical platforms for all pertinent systems. This allows multiple tactical systems to use a common hardware platform and to reduce the maintenance cost of maintaining the hardware through volume usage and use of parts of common items.
- **Open Systems Operating System.** The FSSE is one of the first to move all tactical systems from vendor-specific operating system solutions to a

solution based on a free and open system operating system kernel (i.e. Linux). This has relieved the FSSE from being held hostage to external vendors and their market-driven desires, and provided uniform processes, tools, and engineering methodologies to be applied across the multiple systems that the FSSE is responsible for maintaining and enhancing for the Army and Marine Corps.

- **User Interface.** The organization has found that one of the most significant advances came through the establishment of local and worldwide interface/interoperability boards. These groups provide for the direct involvement of user representatives in the details and decisions throughout software and system development. These groups are proving extremely critical in a world that is moving more toward common interfaces.

## Conclusion

The CECOM SEC FSSE now looks forward to sharing its accomplishments and experience with others within the federal government, DoD, and the software industry. There are numerous areas where this organization could provide benefit to other agencies:

- Technical assistance in the primary areas of software development (configuration management, quality assurance, testing, engineering, etc.).
- Tool development and maintenance.
- Formal inspections.
- Process improvement guidance (Level 2 to Level 5).
- Formal appraisal conduct and assistance.

It is realized that CMMI Level 5 is not an end but simply another step in the evolution of the software process. Establishing this benchmark provides the organization the ability to see the promise for the future.◆


## About the Authors

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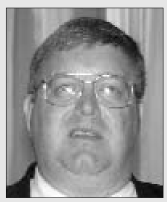

**Phil Sperling** is principal process engineer for Telos·OK, a software development contractor for the U.S. Army. He has successfully guided his organization through several stages of process improvement using the Capability Maturity Model® practices and the Capability Maturity Model Integration (CMMI®). Most recently, his organization achieved CMMI Level 5 using the System Engineering/Software Engineering Staged Version 1.1. Sperling retired from the U.S. Army in 1992. He served as a software-engineering officer and was deployed to support Intelligence and Electronic Warfare, Communications, and Field Artillery Systems during Operation Desert Shield and Operation Desert Storm. He also served a combat tour in Southwest Asia, and held leadership positions in Armor and Field Artillery. Sperling has a bachelor's degree in business from the University of Arkansas and a master's degree in business administration from Cameron University.

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