

AC 2009-185: INTEGRATION OF SOFTWARE ENGINEERING GRADUATE EDUCATION AND CONTINUING PROFESSIONAL DEVELOPMENT

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Integration of Software Engineering Graduate Education and Continuing Professional Development Programs

Abstract

Monmouth University offers a thirty-six credit graduate program in software engineering. In support of the US Army's Software Engineering Center at Fort Monmouth, New Jersey, the program has accommodated a group of new Army employees every year since 1988, giving them an opportunity to earn a master's degree in software engineering during the first few years of their employment. In addition to providing an opportunity for new employees to earn a master's degree the Army makes available a Continuing Professional Development (CPD) program for their new employees. In a recent study, the CPD program and its links to the graduate program were reviewed by the authors from the perspective of the combined ability of the master's program and the CPD program to meet the ongoing needs of technical professional employees. In this paper, we present a summary of the literature relevant to future trends in graduate software engineering education, a description of the study method, results, and several recommendations regarding potential revisions of the continuing professional development program and its relationship to the master's program.

Background

The US Army's Software Engineering Center (SEC) at Fort Monmouth, NJ provides the US Army with state-of-the-art software engineering products and services from the development of new software applications to world-wide technical support for deployed systems. The technical professional workforce in the organization includes engineers, computer scientists and information technologists. Its staff has access to an extensive program of continuing professional development, including an innovative incubator to develop human capital, called the Transformation Cell (T-Cell) Program. In this program, selected new employees are centrally hired and provided with extended rotational assignments across the organization while engaged in a variety of technology initiatives.

Since 1988, SEC has sought to strengthen its capacity to recruit software engineers by sponsoring new employees who study toward a master's degree in software engineering at Monmouth University. To date, over 600 students have graduated from Monmouth University's MSSE program with almost half of them being Army employees. Of those, over one half are still employed by the Army and many of the others are currently employed by US Department of Defense organizations throughout the United States.

Monmouth University is a comprehensive teaching university, with approximately 4000 undergraduate students and 2000 master's students. The Department of Software Engineering is part of the University's School of Science, Technology and Engineering. It established a master's degree program in 1986 and an ABET accredited BSSE program in 2000.

After completing the master's degree program professional employees in the SEC are expected to maintain and expand their expertise through a continuing professional development program.

Employees are required to complete a minimum of 80 Continuous Learning Points (CLP) every two years. A CLP can be thought of as the equivalent of an hour of formal learning activity. Employees have access to an extensive set of professional development offerings from a multitude of sources, including the Defense Acquisition University, the Army Management Staff college, Army E-Learning, Carnegie Mellon University's Software Engineering Institute, the Civilian Education System and the Senior Service Colleges.

Relevant Trends

Enrollment in engineering and computer science programs in the United States, which feed the Army's engineering and science recruiting pool, is not growing robustly. Because the Army's Software Engineering Center will need to recruit new employees from among the stagnant numbers of graduates from these programs during the next several years recruiting may well become more difficult, unless national demand drops dramatically.

Bachelor's degrees awarded in engineering declined in 2006-2007, the last year of reported data by the American Society for Engineering Education. Electrical and Computer Engineering bachelor's degrees fell almost 15 percent from 1999 to 2004. Computer Science degrees awarded by engineering colleges has fallen 30 percent since 2004. The numbers of undergraduates declaring computer science as a major in and out of engineering colleges is also declining.¹ Master's degrees awarded also declined, by almost nine percent from 2005 to 2007. While the number of undergraduates enrolled in software engineering programs is still relatively small, the number of undergraduate software engineering programs in the US is growing. In 2007, there were almost 2,000 students enrolled in software engineering programs and approximately 625 bachelor's degrees were awarded.

Concomitantly, bachelor degree programs in Information Technology (IT) and Information Sciences (IS) are expanding more rapidly. The graduates of these programs will be an increasing proportion of the technical, professional labor force. Their backgrounds will be different from those hired with degrees in either computer science or engineering. They will seek out different continuing professional development opportunities and aspire to different target positions. The increasing popularity of accredited IT, IS and SE programs is reflected in the data of Figure 1.

Many influences affect the curricular content of post-secondary engineering and computer science degree programs. One of those influences is the criteria for specialty accreditation. The Accreditation Board for Engineering and Technology, ABET, which is responsible for the accreditation of academic engineering, computer science, information technology and information systems programs in the United States, has recently adopted a policy change that rescinds a long-standing practice that prohibited dual accreditation. Simply stated, prior to that change in policy institutions were permitted to seek accreditation of either their bachelor's program or their master's program within a specific field, but not both. Most institutions sought accreditation for their undergraduate programs only. Now that universities will be given the option to accredit graduate programs as well as undergraduate programs in the same field at the same institution, some curricular changes may result.

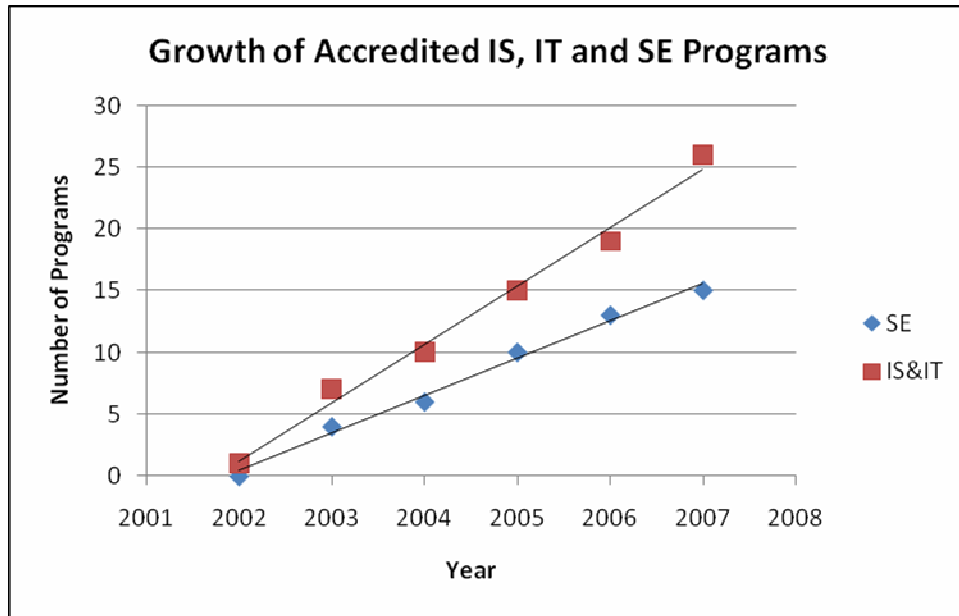


Figure 1 - Trends in Numbers of accredited Undergraduate Software Engineering, Information Technology, and Information Systems Programs.²

The National Council of Examiners for Engineering and Surveying (NCEES), which administers the examinations for professional engineering licensure, has announced that it will change its model law in 2015 and recommend that a bachelor's degree plus a master's degree or 30 additional credits be required for licensure. In time, one could postulate that a combined five-year curriculum would provide the opportunity for all graduates of software engineering master's programs to have a thorough grounding in the engineering sciences (thermodynamics, mechanics, electronic circuit theory, etc.) – a change from the current situation. Such graduates might well be better prepared to address systems engineering problems or software applications that need to communicate intimately with physical portions of systems. In any case, these scenarios are speculative and long-term and will be unlikely to affect decisions regarding continuing professional development programs in the near term.

A movement in graduate science education (physics, mathematics, chemistry and biology) towards applied, hands-on learning aimed at preparation for the workplace instead of research is gaining national support.³ Implications for existing programs in software engineering are minor, because the field turned from a theoretical framework to an applied framework at its outset. But other disciplines may begin to expand master's offerings that are more directly related to the needs of the workplace, including computer science and mathematics, among others. Program elements would be more likely to include internships and industry sponsored projects, interdisciplinary components, business studies, and emphases on communication, teamwork, project management and business ethics. Such program changes may offer the opportunity to better integrate continuing professional development elements with formal academic education through the joint efforts of practicing professionals and faculty in the development of projects, practicums and case studies.

The movement to Professional Science Master's (PSM) programs is now being supported by the President's Council of Advisors on Science and Technology, The National Science Board, the National Governors Association, the Council on Competitiveness, the U.S. Chamber of Commerce, the Association of American Universities, the Council of Graduate Schools and the National Research Council. In early 2008 there were over 120 PSM programs operating, compared to 67 in 2004.⁴ In considering the delivery of MSSE programs for SEC's interns, new educational sources may be enabled by anticipated increases in support from the National Science Foundation and the Department of Defense, among others. Should these trends in the aggregate prove to increase the proportion of SE graduates pursuing MS degrees, then organizations like SEC, which focus on a graduate-level educated engineering workforce, could benefit in the long-term.

A study sponsored by the Office of the Secretary of Defense is articulating the anticipated content of MSSE programs from which both the Department of Defense and private industry will be recruiting graduates in the future.⁵ A draft of the recommendation articulates the level of achievement, as measured against Bloom's Taxonomy, of outcomes in each of nine areas of knowledge within software engineering. Importantly, draft calls for an increased emphasis on systems engineering in MSSE curricula. The publication of this report will provide a possible mechanism for revisiting the mix of technical hires for organizations hiring software engineers, and can serve as the starting point for the design of CPD programs for graduates of MSSE programs. Depending on the emphasis to be placed on systems engineering, a plausible result for software engineering educators may be to limit entrants to MSSE programs only to graduates of accredited bachelor of engineering programs who also have one or more years of software development experience.

Continuing Professional Development programs have several purposes. Among them are: 1) the enhancement of recruitment and retention, 2) investment in the organization's human capital to enhance mission achievement, 3) adjustment of the capacity of the workforce as objectives change over time, and 4) support of succession planning within the organization.

Successful CPD programs are likely to contain spiral learning experiences (offering replication and reinforcement both in terms of content and in exposure to broader areas of the organization, revisiting and expanding both technical and managerial skills and knowledge sets); to be accessible to the learner and relevant to current job performance; and to be cost effective while contributing to the optimal achievement of the organizational mission. In the most general sense, the CPD program should enable a career path available to every employee which allows their contributions to the mission of the organization to be optimal. The implication here is that for the program design to contribute to the mission of the organization, it should be aimed at optimizing the success of the individual employee.

Guidance to professional staff on the desired substance of a personal continuing professional development program is essential to the ultimate achievement of the organizational mission. To this end, the SEC has developed a series of roadmaps of instruction for technical employees. The Systems Planning, Research, Development and Engineering Roadmap, for employees is the most relevant to the current study. The Appendix shows a roadmap of courses which had previously been developed for SEC employees working as computer engineers and computer scientists (which encompasses those trained as software engineers at the master's level). This roadmap

provided a starting point for the current study of the continuing professional development program being described here. One purpose of this study was to look specifically at the preparation of employees obtained through the MSSE program and how that preparation might be more effectively integrated into the organization's continuing professional development program.

A study completed previously for the organization identified the perspectives of the organization's upper level managers regarding the continuing professional development needs of journeyman software engineering professionals. In general, that study concluded that unmet needs in technical areas were easier to address than were the unmet needs for development in the areas of general management, project management, people skills, leadership and systems thinking. It concluded that Army knowledge domain skills are important but are achievable through on-the-job experiences. That study used contents of the SWEBOK (Software Engineering Body of Knowledge)⁷ as expectations for mastery of software engineers with four years experience in each knowledge area, and articulated the achievement levels expected to have resulted from formal education programs upon completion of the master's, based upon an assessment by the organization's management of specific SWEBOK knowledge areas.

It is anticipated that the bachelor's and master's degree programs of technical professionals in the job classifications studied would require that students entering the program already have a background in computer science. Those employees entering the master's program in software engineering will have an undergraduate background equivalent to courses up to and including data structures and algorithms, and they will have had exposure to a high level overview course in software engineering, basic software architecture and design concepts and some form of disciplined (quantitative) software development process. For newly recruited employees who do not have this background a program associated with the master's degree program would have to provide foundation coursework to bring incoming employees up to this level. The MSSE program at Monmouth University, which has been offered for several years, provides this background for newly hired employees who do not have that background.

Core software engineering coursework in software processes, requirements engineering, systems and software architecture, hierarchical and object oriented design, software implementation, and verification, validation and testing are likely to continue as the core of most MSSE programs. Continuing education opportunities need to be made available to sustain currency in these technical areas for virtually all technical professionals. Those employees responsible for system architecture and strategic systems development will need exposure to additional domain knowledge and developing technologies to maintain their expertise.

Study Methodology

Initial Interviews and Survey Design. The authors started by interviewing several managers and employees, discussing topics that included their personal assessments of professional development experiences, plans for the future, technical areas of expertise considered important, issues dealing with management and leadership development, and other topics of importance to the interviewee. These initial face-to-face interviews provided the basis for the development of a detailed survey instrument. In turn, the survey results provide insights into the perceived value of CPD opportunities, the depth of knowledge felt to be needed for specific technical areas of work,

the importance of certification, the importance of domains of application areas, preferences for the methods of course delivery, and other information important to CPD plans for the future.

Survey Distribution and Response. Surveys were distributed electronically to employees classified as Computer Scientists, Engineers and Information Technologists, who were hired into the organization between 1996 and 2007. A preliminary mailing of a test survey was sent to a few employees who were originally interviewed at the beginning of the study. Then the survey instrument was revised and e-mailed to all Monmouth University MSSE graduates in these categories and to several other employees who were not affiliated with the Monmouth University program. In total 78 responses were received for a response rate of approximately 32 percent. The questionnaire developed for the survey was executed on an Excel spreadsheet. Respondents completed the worksheets which were then integrated into a common workbook and summarized on a separate worksheet designed to accumulate the responses and to summarize survey results. A summary of survey results was shared with the survey participants. The following section describes the primary survey findings.

Academic Backgrounds of Respondents. About 1/3 of the respondents indicated that they held bachelors' degrees in Computer Science. About 1/3 of them held bachelors' degrees in computer or electrical engineering and the remaining 1/3 held bachelors' degrees in a variety of other fields of engineering or science. A very small number reported that they did not hold a bachelor's degree. Fifty four percent of the respondents already had master's degrees and 29.5 percent of them were currently studying for their master's degrees, mostly in Software Engineering at Monmouth University. Fourteen percent of the respondents indicated that they held additional degrees, including associate's degrees in a variety of fields, an MBA or a second master's degree in engineering. Eleven percent of the respondents indicated that they are considering studying towards additional degrees at the bachelor's, master's or PhD levels.

Software Engineering Technical Areas of Knowledge. The next section of the survey asked questions about the depth of knowledge for each area in the SWEBOK and the level, or sophistication, which each respondent felt they needed to achieve for each of 11 areas of knowledge. They were then asked to rate each area as it relates to their current responsibilities and to their anticipated future responsibilities. Respondents rated Software Engineering Management and Requirements Engineering at the highest levels with average ratings of 4.7 and 4.4, respectively (where a 1 was the lowest level and 6 was the highest level). Software Construction (e. g. standards, coding style and build methods) was rated lowest, at an average level of 3.7. In all categories of the SWEBOK respondents anticipated that they would need more in-depth capabilities for their future responsibilities than they needed for their current responsibilities. The greatest difference between the levels needed to meet their future responsibilities as compared with their current responsibilities was in the area of Software Engineering Management (e. g. software project management and engineering economics) with a difference of +0.98. That area was followed closely by Software Engineering Process (e. g. process assessments and benchmarking) with a difference of +0.77.

Army Domain Application Areas. The next question asked which Army application domains respondents felt were most important for them to develop a deeper technical understanding. All of the domains that were listed had some respondents indicate that they would like to achieve deeper understanding within that domain. Those which were of most interest were: Information Assurance, Battle Command and Tactical Communications.

Methods of Content Delivery. The next two questions asked which delivery methods were preferred for delivery of course content and which were the least preferred methods. The most preferred method, by far, was face-to-face traditional lectures. Rotational assignments within or out of the respondent's organizational division, mentoring and on-line asynchronous courses were all second choices. The least preferred method of delivery was the use of case studies. Unfortunately, we did not have sufficient time to investigate why case studies were the least preferred method, but future work could examine why this was the case.

Improvements and Changes. Finally, respondents provided a number of suggestions for improving or changing the structure or operation of the continuing professional development program.

Recommendations

It was clear that the number and variety of existing continuing professional development opportunities available to employees in the organization was extensive. The management may wish to consider adding a course in Cultural Diversity to the list of local mandatory training courses, or to include the equivalent coverage in orientation sessions for new employees. The course could address outreach efforts to minority communities as well as effective communications with individuals from different international cultures. There is a significant international diversity among the organization's employees, and the need to improve communications with and among culturally diverse individuals was raised during the study. The continuing professional development course titles that are currently required do not appear to cover these topics.

To facilitate cross-organization collaboration, the management should consider adding CPD offerings related to application domains that were of most interest to survey respondents which are not currently offered. These included: Business Management Information Systems, Enterprise Solutions and Software Oriented Architectures; Battle Command; and, Communications. Survey respondents indicated that these were the domains of most interest to them but very few survey respondents indicated that they had taken specific courses in these areas. The other area of great interest was information assurance and data encryption. For those areas many respondents indicated that they had taken courses that appear on the roadmaps. However, it was not clear to us whether they had taken simple awareness courses or if they had taken in-depth technical courses on those subjects.

It should also be noted that a majority of the respondents indicated some dissatisfaction with completely on-line asynchronous course delivery, actually preferring face-to-face lectures. If possible, consideration might be given to cost-effective ways of increasing face-to-face experiences in the overall mix of offerings available to the organization's personnel. One suggestion would be precede or follow each on-line course with a group session on the relevance of the material to the organization's mission or examples of applications of the material by others after the course was taken. Modern learning theory suggests that it would be valuable for supervisors and employees to identify opportunities to apply material learned as soon after taking each on-line course as is practicable.

The organization has put a considerable amount of work into development of the CPD training roadmaps for its employees. These roadmaps are very thorough and, if employees and their supervisors study them carefully and make appropriate use of them, they should provide a solid basis for continuing professional development. They are also readily available on the organization's Human Resources "splash page." However, they require some time for reading and study to make them meaningful. A possible supplement to the roadmaps for new employees might be a brief explanation of why the first several courses should be taken and what would be accomplished by doing so.

For the comparatively young workforce represented by survey respondents, beyond the basic courses required for all employees, very few have taken advantage of the many opportunities for management and specialty technical training. Although understandable, and while senior management may not want to create totally separate career paths for technologists and managers, we recommend that selected employees be guided by their management toward specialty technical training and others be directed towards additional management and leadership training after they finish their required coursework. This may result in differences in the comparative development of individuals, but it would allow the organization to better meet its short-term goals and also to meet the short-term preferences of employees.

As part of the Department of Defense Base Closure and Realignment Commission (BRAC) program the organization is scheduled to move from Fort Monmouth, NJ to Aberdeen Proving Ground, MD by 2011. When the organization relocates, there will probably be a need to fill some supervisory positions with employees who are currently non-managers, and to fill some higher level management positions with people who are currently lower level managers. While most employees understand that promotional opportunities are likely to occur as a result of the move, very few indicated that they have been participating in continuing professional development opportunities that will prepare them for management positions. Employees who have been nominated for "bench" positions should be advised, if they have not already been advised, to take some of the courses identified in the roadmaps as courses that address development of leadership, management and communications skills for technical professionals and, perhaps, even some courses from the supervision and leadership specialty tracks for supervisors earlier than they otherwise would.

With the relocation, the organization may well lose domain expertise and may wish to select the best short service employees and put them in key domain positions either instead of current domain experts or to shadow current domain experts who are known to be leaving with the move to Aberdeen.

There is a need for most technical professionals in the organization to have a systems perspective of their work, technically and organizationally. Technically, the roadmaps already identify the appropriate Systems courses (Information Assurance, Systems Engineering and Software Architecture/ Design) that would develop this expertise to necessary level. Organizationally, there does appear to be a need to provide a broader professional exposure to the organization's divisions beyond that of the employee, through rotational assignments, participation in the T-Cell program, and collaborative, cross-organization team assignments. In the longer term, coverage provided by the existing CPD courses, and an increased exposure to the complexity of the organization's work, coupled with the increased emphasis on systems engineering concepts

anticipated in MSSE programs should provide a broad cadre of employees with a systems perspective.

Selected new employees who are hired as Transformation Cell employees receive a substantive exposure to a broad cross section of work in the organization. However, most employees never get this exposure. It appears that if the T-Cell program is retained in its current form it will give only a small number of employees the desired broad exposure. Because of the benefits to participants, the organization should consider reducing, to the extent possible, the total time that each T-Cell individual spends doing rotational assignments and spread the experience more broadly across a larger number of employees. One way to do this would be to have all interns treated the same and, during their first three years of experience in the organization, make arrangements for each to spend 2 or 3 short (8 to 12 weeks in duration) rotational assignments with parts of the organization other than their own. Additionally, management should consider the possibility of coordinating the T-Cell assignments with the MS Program practicum. This would require careful selection of project assignments to assure that the needs of the hosting Directorate and the educational objectives of the MS faculty are both achieved. Such an arrangement would benefit the interns significantly, and also serve as a long-term mechanism to better integrate the MS program into the continuing professional development program.

Supervisors should articulate specific courses identified as electives in the master's curriculum should be chosen if that is what best meets the needs of the organization. Many employees who go through the MSSE program at Monmouth University seem to select their elective courses at random, to avoid subjects that they do not like or to take courses in which their friends are registered. We recommend that employees and their direct supervisors take time to review the electives available to participants in the MSSE program and choose courses that are closely linked to the work that the employee is likely to be doing in their organization.

Efforts at integration of the organization's continuing professional development opportunities with the master's program, either through coursework or project work, would help develop an increased understanding of the organization's functions. The courses offered by a master's degree program should be different from the ones provided by a CPD program to avoid duplication. A first step in this direction might be taken in concert with Monmouth University faculty to collaboratively review the content of the offerings specified in the Roadmaps to see if some master's degree curricular offerings can be substituted for required CPD courses. This would free up the selection choices of interns and eliminate possible duplication of material.

The academic leaders of the Software Engineering Masters' degree program(s), which the organization will use in the future for its software engineering interns, should be invited to a briefing with the organization's management and a small cross section of employees so they can better understand the daily functions of the organization. A short panel session with organizational management followed by an open Q&A session and, perhaps, one-on-one discussions with a cross section of individual employees could substantially increase the understanding faculty would have of the interns' academic needs.

There is a very diverse range of continuing professional development courses and opportunities available to the organization's employees. The depth of the existing Continuing Professional Development program and its breadth of coverage make it a potentially powerful recruitment

tool for new hires. The organization should consider marketing the program prominently as part of its recruitment efforts.

We would encourage supervisors to become more deeply involved in mentoring for CPD. The organization could hold an annual discussion session at which supervisors describe their best people and what they have done during the past year to provide an opportunity for sharing best practices and for self-assessment regarding managerial nurturing.

There is a need for a systems-of-systems perspective to lead the organization toward appropriate technological innovations. This level of systems concepts is not attainable through CPD or university educational offerings, but is usually attained through decades of experience. Such technical leadership could be provided by a Chief Technical Officer (CTO) who would take responsibility for leading a team of organizational technical managers to identify the most promising new technologies that have potential for future applications within specific domains, for leading project management audits of large scale projects currently underway, for providing informal advice to the leadership of those projects, for identifying best practices that could be used more broadly, and for spearheading efforts to advance the level of technology used by the organization through activities like visits to other software development intensive organizations and companies to observe what is working best for them.

Summary

This paper has described a somewhat unique relationship between the Monmouth University master's degree program and the continuing professional development program of the US Army's Software Engineering Center at Fort Monmouth, New Jersey. It outlined some of the external factors influencing the continuing development of education in the field of software engineering and described interviews and a survey that was done among Army employees. Finally it described several recommendations that were made for consideration by the management of the Software Engineering Center.

Acknowledgements

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Appendix - CPD Training Roadmap for Engineering and Science Classifications

DB - 02

Assignment to sponsor/mentor

SEC briefing by Director or Deputy Director

Your Place on the Army Team – 4 Hours

Tutorial on the CE-LCMC New Employee Asset

SEC Introduction to CMMI – OL – 3 hours

*Fundamentals of Systems Acquisition (ACQ 101) - OL – DAU**

Action Officer Development Course – OL – AIPD

Business Writing Essentials – OL – 30-hours – Army E-Learning

Delivering Successful Presentations – OL – 11-hours – Army E-Learning

Greening Course – 5-days – CERDEC

Planning, Programming, Budgeting and Execution – 9-days – USAFS

*Intermediate Systems Acquisition (ACQ 201 A&B) A-OL B-5-days**

DB – 03

*Systems Planning, Research, Development and Engineering (SYS 101) – OL – DAU**

Basic Software Acquisition Management (SAM 101) – OL – DAU

*Intermediate Systems Planning RD&E Part I (SYS 202) –OL - DAU**

*Intermediate Systems Planning RD&E Part II (SYS 203) - 5-days - DAU**

Software Cost Estimating (BCF 208) – 9-days – DAU

Effective Business Meetings – OL 10-hours – Army E-Learning

Beginning Project Professional – OL 10-hours – Army E-Learning

How to Excel at Customer Service – OL 40-hours – Army E-Learning

DB – 04

How AMC Runs – 5-days AFMS

Intermediate Software Acquisition Management (SAM 201) - 5-days – DAU

*Advanced Systems Planning RD&E (SYS 303) – 10-days – DAU**

Advanced Software Acquisition Management (SAM 301) – 5-days – DAU

Notes:

DB – 02, DB – 03 and DB – 04 refer to organizational levels for individual employees. The courses listed are those that employees should complete before reaching the levels shown.

DAU – Defense Acquisition University

CERDEC – Communications-Electronics Research, Development and Engineering Center