Graduate Computer Science and Engineering Education for the U.S. Army at the Air Force Institute of Technology

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Abstract—This paper describes a joint Army/Air Force professional educational program in computer systems. Included is the motivation for educating military officers in the field of computer science and engineering and a description of a six-month graduate level program for Army officers at the Air Force Institute of Technology. The purpose of the educational program is to develop Army officers who are knowledgeable in acquiring and managing embedded computer systems. The microprocessor is integral to these embedded computer systems and to the student's course work. Projected Army officer assignments are covered to illustrate the means by which this advanced education is utilized.

I. INTRODUCTION

ALTHOUGH the title of this Special Issue is Microprocessors in Education, we believe that the implications of the digital electronics revolution are considerably broader. The development of the microprocessor has led to the integration of computers into all areas of system design and all types of systems. It is this widespread application of computers which impacts education, not any technical details of microprocessors. One of the tendencies which we have observed is to treat microprocessors as a special technology which is taught in a vacuum and covered with an overview and some simple examples and demonstrations. We believe very strongly that designing a system which contains a microprocessor should be approached the same as designing any system which includes an embedded computer, and the proper tack is to teach computer system design and integration into larger systems or particular applications. The details of microprocessor-based systems serve merely as common examples of these types of designs. If a designer wants to be successful at this type of effort, he or she must have a firm grounding in computer systems and the design of computer hardware, interfacing, and software.

One of the key points of United States defense policy is the trading off of numerical strength (i.e., manpower and weapons) for advanced technology. In order to pursue this policy in a cost-effective manner, it is essential that the military services have highly capable personnel to acquire, manage, maintain, and utilize high-technology equipment. In today's world, people with the necessary knowledge and capabilities are a rare and valuable commodity, and it is difficult for the Department of Defense to attract and retain these people. For example, the U.S. Air Force had a shortage of over 3000 military and civilian engineers in 1979, and this shortage is increasing.

One viable approach to meeting these shortages is education, and the military has a long history of educating their own, both to meet immediate needs, and to provide a recruiting benefit for attracting additional manpower. Examples include the health professions scholarship program, used to provide military physicians; funded graduate programs, which include military sponsored Master's and Ph.D. programs at civilian schools, mainly in the physical sciences, engineering, and management fields; and the military graduate and undergraduate schools. These schools include the service academies, the Naval Post Graduate School (NPS), and the Air Force Institute of Technology (AFIT). Additionally, the services provide technical training in specific subjects and weapon systems.

One aspect of the problem of obtaining the best qualified force for the minimum expenditure revolves around cross-training, retreading, and upgrading (or updating) education. This aspect leads us back to the theme of this issue and the subject of this article, graduate computer systems education for Signal Corps officers of the U.S. Army. The Army does not have the funds or the justification for a wholesale increase in the number of M.S. degree positions in the Signal Corps. On the other hand, almost all of the current weapon systems and communications equipment contain embedded computer systems (microprocessors) [1], [2], and need to be dealt with as networks of digital computer systems. Currently, many of the Signal Corps officers have very little education in the areas of computer architectures, software engineering, operating systems, computer networks, and digital data communications. The program which we will describe in the remainder of this paper is a joint AFIT/U.S. Army Signal Center approach to meeting these requirements.

At about the three to four year point in their careers, Army officers receive formal professional military training to better prepare them to function as senior company grade officers. Each of the branches of the Army conducts separate courses tuned to the specific requirements of that branch. The Signal Corps course is held at Fort Gordon, GA, and normally includes communications-electronics doctrine and equipment. The Signal Corps course is further divided into tracks, which address specific job categories or problems in the services areas. Since the current Signal School Commander has identified the areas of computer systems and computer communications as crucial problem areas, Signal Center personnel were searching for a way to offer a track in the teleprocessing area. After considering several options, they chose to use the existing AFIT facilities and courses to meet this need. Students in this program travel to Fort Gordon for a three month version of the standard Signal Corps Course, and then travel to AFIT, Wright-Patterson Air Force Base, OH, for six months of course.
work taken from the AFIT Graduate Computer Systems Program. This approach allows efficient sharing of scarce resources and fosters interservice communication and cooperation.

II. BACKGROUND INFORMATION

The course of study to be described is a new approach to technology transfer in the Army. While the use of a different service facility is not new, i.e., the Signal Corps currently uses the facilities at Keesler Air Force Base, MS; the idea of using a graduate institution for less than a graduate degree is new for the Army. The main concern is for upgrading the skills of officers and selected government civilian employees in modern technology. Relatively few individuals can be selected for fully funded graduate programs under the current policies. There is a need in the Army for officers who are knowledgeable in advanced computer technology. The Air Force Institute of Technology is an accredited graduate institution currently presenting the courses needed by Army students.

AFIT is part of the Air University system under the Air Training Command. The Institute is accredited by the North Central Association of Colleges and Schools. Some of the degree programs in AFIT's School of Engineering are also accredited by the Accreditation Board for Engineering and Technology. AFIT was founded in 1919 as the Air Service Engineering School, and the name was changed to the Air Force Institute of Technology in 1947, after the Air Force became a separate service. The Institute was accredited in 1956, and since that time 25,000 degrees have been awarded.

AFIT's resident School of Engineering graduates some 230 Master's recipients annually in 11 different programs, putting the institute in the top ten percent of the nation's 200 engineering schools in the number of graduate degrees. Most of these are 18-month programs, containing approximately 70 units of quarter work. In addition to meeting the primary AFIT mission of providing education to meet Air Force requirements in the scientific and technological fields, these degree programs provide the resident faculty and facilities to support the conduct of continuing education and specialized training programs.

In the area of computer systems, laboratory facilities range from a collection of single board computers based on 8080 and 6800 family processors, through full development systems for these same processors, and for the 6500 and Z8 processors, to most of the common minicomputers. These minicomputers include the HP21MX, TI 990, Data General Nova and Eclipse, DEC LSI-11 and PDP-11, and VAX 11-780. The rationale for the large number and diversity of machines is to maximize the hands-on experiences of the students and match as much as possible the different types of machines in use throughout the Department of Defense. A special emphasis of the computer system programs is to include hardware modifications, interfacing, and systems design in all laboratory courses. Another aspect of the location of AFIT is the presence of the Air Force laboratories at Wright Patterson AFB. Students are encouraged to participate in active Air Force and Department of Defense (DOD) research projects.

This course of study is designed to overcome a current Army problem in officer development. Under current policies, technical skills for most Army officers are first increased and utilized during the period of the eighth year of commissioned service. This approach does not work well for officers who had technical backgrounds when they entered the Army. Technological obsolescence and poor retention rates are problems often associated with these officers. The state-of-the-art in technology is advancing such that a delay of five to eight years in applying those technical skills makes them obsolete before they can be applied. Such policies have adversely impacted job satisfaction which, in turn, adversely impacted retention. This course of study, therefore, provides: 1) an incentive for individuals with computer-related backgrounds to come into the Army, 2) a means for officers with technical backgrounds to make the transition from academic study to Army-specific practical application, 3) utilization of technical skills early in the officers' career (improving job satisfaction), and 4) the reinforcement of technical skills through advanced study significantly earlier than in the eighth year of service (avoiding technological obsolescence).

The military services have a record of cooperation in computer hardware [3], [4] and software [5], [6]. The services have addressed the technical issues, but a cooperative educational program in computer systems is a new concept. Implementing this course of study also involves the development of a legal agreement between the two services describing requirements that will be adhered to for this program.

One important aspect of this course of study is that the Army students and faculty are fully integrated into the AFIT environment. Army students attend courses with M.S. and Ph.D. students and Army faculty satisfy the same criteria as Air Force faculty.

III. COURSE OF STUDY

A. Entrance Requirements

Acceptance to this course of study is accomplished through a review of an individual's academic and work backgrounds. Army students are not admitted until their college transcripts have been reviewed by AFIT. The criteria for acceptance includes that an individual must possess a B.S. degree in the physical sciences, engineering, or mathematics, with an undergraduate grade point average of at least 2.5 based on a 4.0 scale. An Army officer with a grade point average of between 2.25 and 2.5 and a score of greater than 1000 points (sum of verbal and quantitative aptitude tests) on the Graduate Record Examination or with a Baccalaureate degree in some other field may be considered. This latter group of officers are screened by AFIT on the basis of their work experience, mathematics and science background, and their performance during a prerequisite course conducted at the Signal Center.

B. Course Work

The course of study for this program is heavily oriented toward the system aspects of computer applications. The first quarter consists of three courses, EE 4.50, EE 5.45, and EE 6.89. EE 4.50 is a basic course in digital computer design, covering especially combinational and sequential circuit design, and leading up to register transfer languages and the register transfer description of a computer control unit. The current text for this course is Mano's Design of Computers [7]. EE 5.45 is titled Software Systems Acquisi-
tion, and is intended to address the fact that most software in use in the Department of Defense is purchased rather than written by DOD employees, and the process and regulations covering these purchases are voluminous. Texts for this course include Air Force and Army regulations and guidebooks and Brooks’s The Mythical Man-Month [8]. EE 6.89 addresses two topics, operating systems and data structures. The texts are Madnick and Donovan’s Operating Systems [9], and Wiederhold’s Data Base Design [10].

Four courses are taken during the second quarter, EE 6.46, EE 6.87, EE 6.88, and EE 6.93. EE 6.46 is titled Data Base Systems, and emphasizes the application of various data base organizations to DOD computer systems such as command control, communications, comptroller, and avionics systems. The text is Date’s An Introduction to Database Systems [11]. EE 6.87 is the minicomputer/microprocessor lab which parallels EE 6.88, the computer systems architecture course. This laboratory emphasizes the development of input/output interfacing as a system problem. Successful laboratory projects must demonstrate both good engineering design and good programming style. EE 6.88 emphasizes the relationship between digital system components, performance objectives, and applications in military systems. Specific topics include microprogramming, input/output handling and interfacing, data communications, small machine architectures, and high-performance architectures. The current text is Hayes’s Computer Architecture [12]. EE 6.93 is titled Software Engineering, and is intended to address the period of system development between the initial problem statement and the beginning of coding. Topics include the software development cycle, structured software analysis methods (SADT, ISDOS, CADSAT, SREM, SA), and structured specification development. The text is Composite/Structured Design by Myers [13].

One of the strengths of this program lies in the integration of the AFIT facilities and educational expertise with the practical knowledge of the Army Signal Center. Part of the Army support of the program includes providing AFIT with four active duty officers to serve as instructors. These instructors will have at least Master’s degrees in electrical engineering or computer science, and most will have Ph.D. degrees like the majority of the AFIT faculty. In addition, they are being carefully chosen for their knowledge of Army computer systems and computer communications, and their knowledge of the circumstances and problems which will face the Army officers who complete this program.

As described above, AFIT has quite a number of commercial minicomputers and microprocessor systems, but one of the early goals of this program is to acquire samples of Army computers and communications systems, so that the instructors and students can begin performing in-class experiments and research projects on Army hardware.

One of the important side benefits of this program is the integration of Army officers into the AFIT faculty. These Army instructors are primarily teaching the set of courses described above, but the students include Army officers in this program, military officers and DOD civilian employees in degree programs, and students in other professional specialized education programs.

One of the prime requirements on the type of communications system which we are working with is to communicate with close air support and other tactical aircraft. The Army personnel will be interacting directly with Air Force officers whose jobs after their tours at AFIT may well involve designing or acquiring the airborne counterparts of the Signal equipment.

The standards for admission to this program were described earlier, but it is appropriate to talk in general terms about the student backgrounds, and the anticipated type of student. This is a difficult and demanding course of study, and the student must have a technical background in order to learn this material at the rate it is presented. We will select officers for this program who have the ability and desire for higher education (beyond the baccalaureate degree) but whose undergraduate program was in a less technical field, or who did not demonstrate the performance which they are now capable of. In an effort to reach this goal, we are looking for indicators of ability rather than demonstrated performance in our admission procedures. In an attempt to lower the anxiety level of military officers who tend to perceive (in most cases correctly) that performance in military schooling has a direct and immediate effect on their careers, we are separating academic performance measures from military training reports. The students are working on two parallel, but separate goals. On one hand, they are pursuing military professional education to help them acquire, use, and maintain computer and communications systems, and on the other hand, they will be earning graduate college credits which can be applied toward a graduate degree, either at AFIT, or at another institution.

IV. Army Assignments

The potential job assignments for graduates of this course of study are numerous and varied. These positions require individuals to work with tactical data systems throughout all phases of the life cycle. Positions are available with maneuver units in the employment of fielded systems. A position of this nature involves the daily operation of systems that are actually to be used on the battlefield. These individuals are responsible for effective utilization of the systems, as well as training the user community. Additionally, enhancements to the fielded systems could be accomplished in the development commands from requirements that are generated by technically knowledgeable officers using the systems.

The development commands will benefit with the inclusion of officers that have work experience and technical competence. A significant contribution in Army embedded computer system development is expected in the areas of requirements formulation and system testing. An implied problem throughout this academic effort is that the Army is lacking individuals in the area of technology transfer. Officers who complete the AFIT course will impact the training commands within the Army. These officers can be used to train other Army personnel in installations similar to the Signal Center.

There are many opportunities for these individuals, and as the tactical data systems of the 1980's begin to emerge, the people will be there to deal with the technology. The implementation of this Army/Air Force educational program is a
significant step forward in the utilization of technically educated computer systems personnel in the Army.

V. Future Directions

Several options are available to the Army officer who wants to complete an advanced degree in computer science. This topic is of interest when considering a motivation factor for retaining technically qualified officers. The options available include: fully funded, degree completion, and off-duty education.

Fully funded graduate study can be approved for officers when approved (degree required) positions exist. These positions are limited and quite competitive in nature. Under the fully funded scheme, an individual is projected for a position prior to the start of a degree program.

An Army officer who completes the AFIT course of study will have earned 27 quarter hours of graduate credit. Most universities allow an individual to transfer 12 quarter (nine semester) hours, maximum, toward an M.S. degree. An individual could pursue an M.S. degree on a part-time basis upon reassignment to an area close to a computer science degree granting institution. This approach could be augmented with the degree completion program which would allow an individual to pursue full-time graduate study at the same institution in which part-time work was completed. The degree completion program can be approved for a maximum of six months and there is no requirement for an individual to be projected for a (degree required) position.

In addition to the educational program described in this paper, there is an eight week course for newly commissioned officers which exists at the U.S. Army Signal Center. This Signal Corps course is designed for Army officers who possess an undergraduate degree in computer science or computer engineering. The course consists of four components which are each two weeks in length. The four components include: Army specific material, data base management systems, computer networks and distributed processing, and computer performance measurement and evaluation. The latter three components are each 50 hours in length and designed to be taught at the graduate level.

It is expected that in three to five years many of the eight week Signal Corps course graduates will be eligible for attendance at the AFIT program described in this paper. There are current efforts to ensure that the AFIT program evolves over the next few years in order to accommodate individuals with educational and professional work backgrounds in computer science and engineering, as well as other disciplines.

One major benefit of a joint Army/Air Force educational program is the solution of Army embedded computer systems problems. AFIT has expressed an interest in addressing Army problems within M.S. and Ph.D. theses research in the computer systems degree program. This interest in technical problems of the Army immediately enhances the knowledge base of both services. Additionally, this approach could benefit in the long term from the standpoint of interoperability.

VI. Summary

The joint Army/Air Force program in computer systems education is a unique approach to retreading officers in advanced technology. This effort combines academics and military embedded computer systems in a graduate environment. The program is intended for Army officers who will be utilized throughout each phase of the system life cycle. Finally, the course work in software and hardware meets the current Army requirements.

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REFERENCES


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Microprocessors in Preengineering

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Abstract—The use of microcomputer systems for an elective sequence in our preengineering program at a liberal arts college was motivated by student requests for assembly language programming and for computer courses oriented more toward the sciences. We describe a very modestly priced system and two courses which are based on the Intel 8080A.

Introduction

Recent enrollment increases in our computer science minor have been both a blessing and an imprecation. Administration looks with great favor on courses with broad appeal to the total student community, and broad appeal demands that more general topics be covered and that examples be chosen from a wide spectrum of disciplines. Recently, our three year preengineering and our standard track science majors requested that we teach assembly language programming and include more material related to scientific computing so that summer employability would be increased and postgraduate vocational contacts made.

Prior to the introduction of microprocessors in our program we offered essentially three courses: 1) Computer Culture, a liberal arts introduction to computing and the social issues surrounding it, 2) Introduction to Computer Science, a standard fare of computer language fundamentals, data structures, and programming projects, and 3) Pascal and Structured Fortran, our higher level language course, populated by students from an increasingly wide variety of academic majors.

In addition to the courses described above, our medium sized minicomputer system must support the numerical approximation and graphics needs of various physics and mathematics courses, must provide several statistical packages for social science and statistics courses, and satisfy the rapidly developing demands for word processing and record keeping made by a number of our academic departments. Machine level programming on this system along with the unavoidable student experimentation would have produced a level of instability not acceptable to the majority of users. On the other hand, our administration did not look with favor on a large additional expenditure to provide auxiliary computing equipment to be used by a relatively small number of students, and then for only slightly over one half of the academic year.

In this context we moved toward the purchase of a number of separate microcomputers to support any assembly language instruction we might wish to attempt.

Microcomputer System

We ultimately selected a system which: 1) provides for student-computer interaction by means of a terminal rather than a hex pad and LED display; 2) utilizes our main system for storage and for higher level support, such as editors and cross assembler; 3) employs a small (1K ROM, 1K RAM) microcomputer for execution of student programs; and 4) performs all system communication over standard EIA/RS-232 terminal lines.

In our opinion students learn most efficiently when looking at the industry equivalent of a television rather than an LED display. The use of the main system for storage and for higher level support allows for nontrivial programming on very small and economical systems. Programs generating large amounts of data simply store the data back on the main system.

We have chosen Intel's Systems Development Kit, SDK 80, as our microcomputer. The low initial cost allows us the option of securing technical help for assembling the kits or having students work on the kits as part of their educational experience. The existence of several identical systems also frees us from time pressures that departments often use to rationalize the price of maintenance contracts. Our choice of the 8080A was based on its wide number of applications in industrial and engineering circles.

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