Session 3325

Industrial Collaboration in an Undergraduate Computer Aided Design Course

MAJ Brett A. Barraclough

United States Military Academy

Abstract

For the past two years, the Department of Civil and Mechanical Engineering at the United States Military Academy has been improving a multi-disciplinary design course called EM370, Computer Aided Design (CAD). Based on student feedback and advances in technology, goals were established to ensure the computer design tools were compatible with the top-down design process and that the course content and Engineering Design Problems (EDPs) were linked by a common theme. In 1998, the department began coordination with the Army Tactical Missile System (ATACMS) to use the weapon as a thread of continuity to show how all the topics taught in EM370 are related to real-world problems. The new series of ATACMS EDPs demonstrated how design information could be shared in a collaborative engineering environment. Moreover, the course improvement project included an opportunity to incorporate the way the Department of Defense (DoD) uses top-down design in the acquisition process. Simulation Based Acquisition (SBA) is a proposed system to apply top-down design and ensure that product data can be transferred across all the phases of the acquisition process. One of the main goals of the SBA initiative is to develop collaborative environments to speed the design process. In order for the initiative to succeed, the engineers across all disciplines must understand its goals and work to improve the way we develop weapon systems. Student assessments showed that the collaboration effort including the ATACMS and SBA improved the course content, instructor performance and student outcomes. Additionally, EM370 could serve as an educational baseline for other multi-disciplinary undergraduate CAD courses and the Defense Acquisition University curriculum.

I. Introduction

This paper documents the impact of collaboration with industry on EM370 and shares lessons-learned about SBA and the connectivity of leading commercial software tools. First, the goals and an overview of EM370 will be discussed. The parallel development of methods to improve EM370 and recommendations made by the SBA Joint Task Force will be presented. Then, the improvements made to the course by collaboration with the ATACMS Project Office and Lockheed Martin Vought Systems

(LMVS) will be explained. An overview of the four major Engineering Design Projects will be presented. Finally, the results of the latest EM370 student assessment will be presented with recommendations on the course's utility to serve as a baseline for the integration of SBA into education.

II. EM370 Course Development & Overview

EM370, (CAD) was originally developed in 1989 as a design course taught to juniors which covered four major topics in Computer-aided Design: traditional computer-aided drafting, finite difference methods, numerical solutions to differential equations and finite element analysis. The goal of EM370 was to explore the use of the computer in the engineering design process. In a constant effort to improve the course, the faculty sought student feedback. Some student assessments indicated the course made bold leaps from concept to concept. One solution proposed the incorporation of a series of design projects focused on one system that could show the integration of course concepts and how technology supported the top-down design process.

Over the last two years, efforts were made to update EM370 based on the advances in engineering design software and hardware. One goal was to reduce the number of non-compatible, specialized software tools used in the course. In 1997, advances in PC technology allowed the Academy to purchase Windows NT workstations that would run fully associative, 3D modeling software. Fully associative CAD software allows changes made to the database to propagate to the part, assembly, drawing and layout files. The USMA engineering program adopted two such computer tools, Pro/ENGINEER and Pro/MECHANICA for solid modeling and finite element analysis, respectively. Then, EM370 was restructured (Figure 1). The course began with 10 lessons

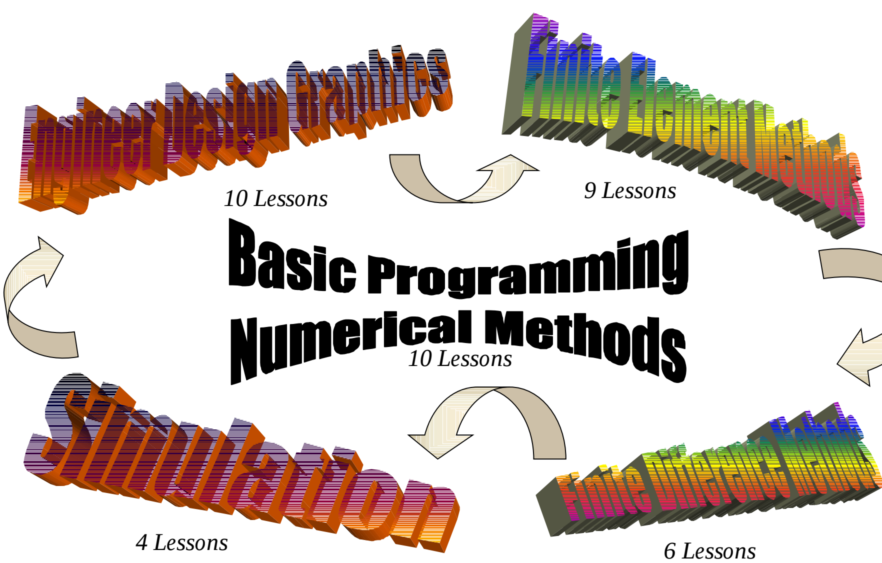

Figure 1. EM370 Course Overview

on Engineering Design Graphics where solid modeling was taught using Pro/ENGINEER. After reviewing linear algebra, the course transitioned to a study of finite element methods. Next, cadets studied finite difference methods and solved a design problem involving 1D, transient heat transfer and MATLAB programming. A design problem involving a simple shock absorber was the capstone to a series of lessons on dynamic simulation involving numerical solutions to ordinary differential equations. Additional lessons on numerical methods and basic programming helped students to understand how the computer helps engineers solve complex problems.

III. EM370 Shortfalls prior to Collaboration with Industry

Although the software used in the restructured course was fully associative, it did not seem to support the top-down design process as taught in many of the undergraduate classes using Pro/ENGINEER. For example, many freshmen courses in Engineering Design Graphics (EDG) that use parametric CAD software like Pro/ENGINEER start by teaching students the basics required to make a simple solid model or part[1]. The next logical step is to teach a novice CAD user to combine the parts into an assembly. Some instructors and textbooks prefer to create drawings from the solid models as intermediate steps in the process[2]. In this manner, students learn how to apply powerful CAD software in violation of the essence of top-down design. Top-down design is defined as "a methodology that proceeds from the highest level to the lowest and from the general to the particular, and that provides a formal mechanism for breaking complex process designs into functional descriptions, reviewing progress, and allowing modifications[3]." To a student, it would appear that modern CAD software does not support the top-down design process commonly taught in ABET undergraduate programs. Industry suffers from the same misconceptions in the initial phase of incorporating CAD programs into their design process[4].

In order to provide the students a thread of continuity for the course, the instructor attempted to generate a series of projects without the support of engineers working on a real system. Initially, the projects were not well received by the cadets. It took a tremendous amount of time to brainstorm for ideas, develop problem statements, create graphics and experiment with example solutions. Since the EDPs were concocted, they tended to lack realism. Also, it was difficult to ensure the EDPs were related to demonstrate the importance of top-down design. In short, the time the instructor spent in course organization and problem development was disproportional to the gain. Other areas of teaching suffered because of the unbalanced effort.

IV. Simulation Based Acquisition Initiative and Industry Shortfalls

SBA is the way the DoD plans to employ modeling and simulation in the top-down design process in the next century. The goal of the initiative is to cut the acquisition cycle time for new systems by 50%. In order to save time and money, the new process will modify the current system of specialized, non-compatible computer tools and establish collaborative environments to pass data about a weapon system across the four major phases of the Acquisition Management System[5]. The focus of the initial SBA road map is on the first two phases. The report provides a detailed plan and guidelines to establish a collaborative environment across the Concept Development and Program Definition phases of the acquisition cycle. Consequently, the Joint Task Force left the integration of design tools with models and simulations of other functional disciplines to future initiatives. Since 1990, industry has demanded integrated CAD tools to speed work in the Engineering and Manufacturing Development (EMD) phase. Most modern CAD software allows engineers to share information in the design phase and could be expanded by industry to be more collaborative. Soon, engineers could develop and test products in collaborative, virtual design environments. In order to be successful, government, industry and academia must work together to encourage the cultural adjustments, teach engineers and management about the process and develop the appropriate technical environment incorporating tested engineering science.

V. Implementation of Collaboration with Industry in EM370

The general project that the cadets worked on as the thread of continuity for EM370 was the development of an ATACMS variant called the Block II (Figure 2).

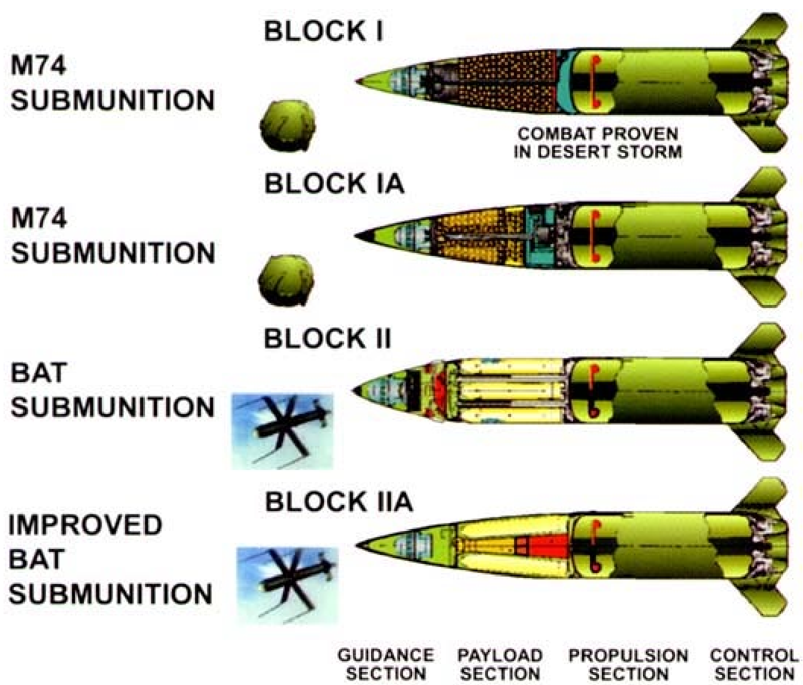

Figure 2. ATACMS Block I and Block II Comparison

Block II is a tactical missile whose purpose is to penetrate behind enemy lines to deploy 13 Brilliant Anti-Armor (BAT) weapons. Once deployed, the BATs seek out and destroy enemy armored vehicles. The complex system offered numerous design opportunities appropriate for undergraduate engineers.

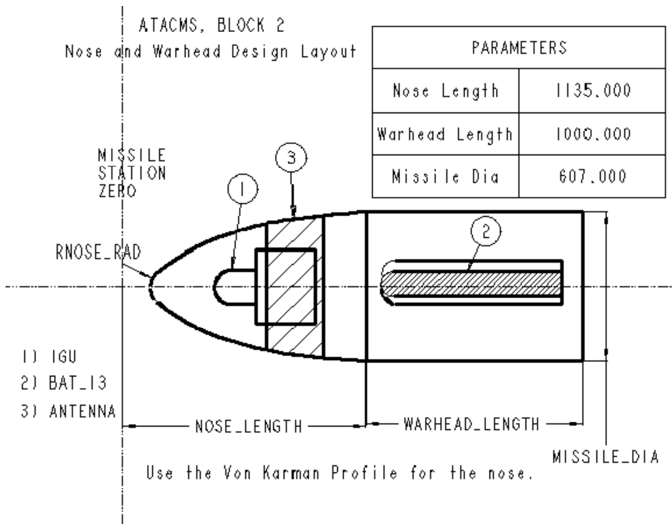

Figure 3. Block II Layout

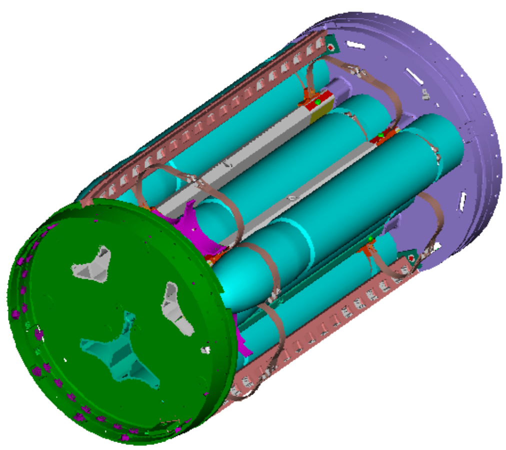

Figure 4. Block II Warhead

The Engineering Design Problem sequence for the Block II ATACMS consisted of four major projects. The first design project (EDP1) allowed the cadets to use Engineering Design Graphics to create a solid model of the Block II ATACMS nose and a wrap-around antenna. A layout file helped cadets see how their work fit into to the top-down design of the missile (See Figure 3). They ensured that the nose followed a low drag profile and justified the thickness of the material. Both the nose and the wrap-around antenna are related to the work the cadets do on the third design project. Next, the cadets designed a strap to hold the BATs inside the ATACMS (EDP2). The BATs are secured in the warhead with aluminum straps (see Figure 4). The straps must hold the BATs during ground handling and break when the airbags deploy to push the BATs away from the ATACMS. The students had a very narrow design space and used finite element analysis (FEA) to confirm their concept met the design requirements. In the third project (EDP3), students redesigned the wrap-around antenna so that it will not peal due to the heat load in flight (see Figure 5). The problem involved a finite difference method program for 1D, transient heat transfer. Once students determined the appropriate thickness for the outer layer of duroid in the antenna, they updated the model they created in EDP1. This project showed the challenge of using computer tools in an iterative design process. Note that the heat load used in EDP3 is a function of the shape of the nose of the missile they created in EDP1. In the last project, cadets redesigned the skid for the ATACMS ground handling system (EDP4). In cold weather, the rubber feet on the skid froze and failed the ground-handling test. The cadets modeled the system using an ordinary differential equation and found the appropriate spring constant and damping coefficient for a new mechanical shock absorber (Figure 6). This final project is directly related to the boundary conditions the cadets used in their FEA of the strap in EDP2. The collaboration effort allowed the instructor to quickly develop a series of design projects linked by a common theme.

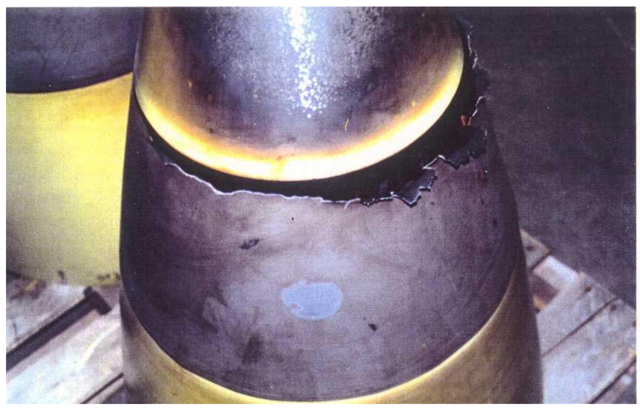

Figure 5. Antenna Failure for EDP3

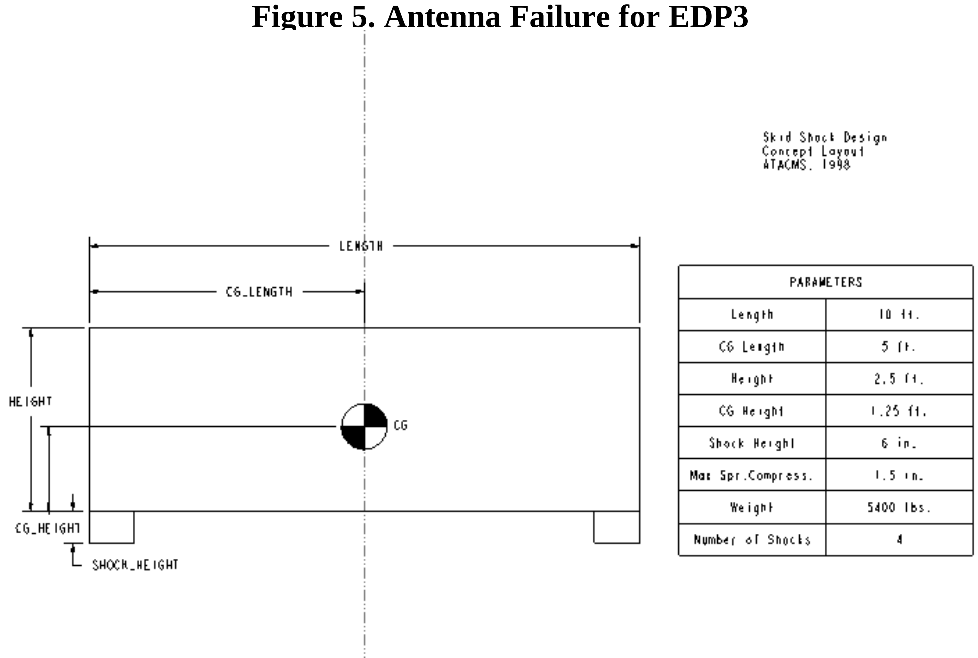

Figure 6. ATACMS Skid Layout

VI. Impact of Collaboration with Industry

Like many other universities, USMA places great confidence in the results of student evaluations as an assessment tool[6]. Data collected from the last semester's student assessment (28 students) showed the collaboration with industry made a positive impact on EM370 in three main areas. The collaboration effort improved the course structure, instructor performance and student outcomes. Collaboration with ATACMS enhanced the EM370 organization and content from the previous year. The cadets' approval rating for the course's contribution to their critical thinking ability increased by 10% between first semester in Academic Year 1998 and 1999. Also, the approval rating for critical thinking was 8% higher that the Academy average. Moreover, the approval rating for course organization was 11% higher than the previous year. Additionally, the same instructor's rating by the students increased dramatically over the year. The cadets' assessment of the instructor's enthusiasm for the material increased by 9% in a year. Also, students indicated the instructor was 8% more effective at demonstrating the course's practical significance. His ability to communicate effectively and provide timely feedback to students also increased by 8% and 12% respectively. In short, the collaboration effort allowed the instructor to shift focus from teaching engineering to teaching students. Finally, the students perceived direct benefits from EM370 in four key criteria evaluated by the Mechanical Engineering Division (Figure 7). Students rated CAD 23% higher than the average ME course in pertinence to their field of study. Moreover, cadets stated that they were able to develop their creativity and confidence in applying the engineering design process at a rate of 20% and 8% higher than the ME average respectively. Also, cadets indicated they understood the engineering thought process 12% better based on taking EM370 than they did from the average ME class. Granted, these conclusions are based on limited data from one instructor; however, the data clearly shows increased approval ratings in the three areas mentioned with the collaboration effort as the only major change to the course.

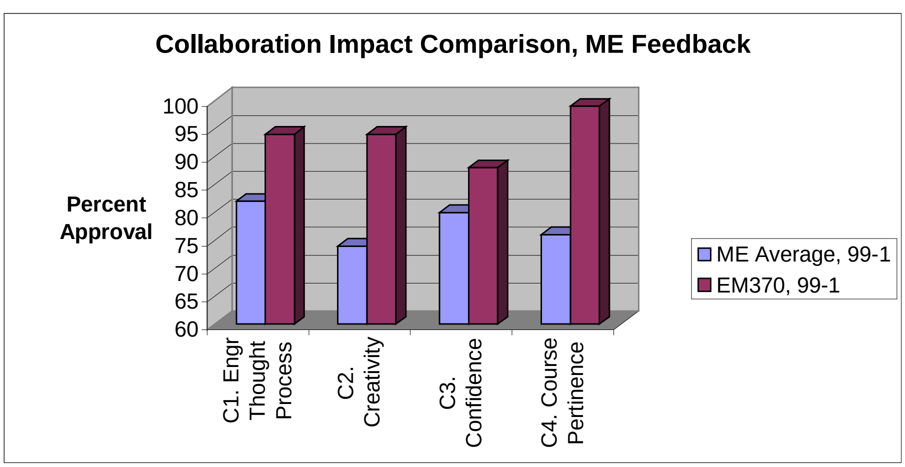

Figure 7. EM370 and ME Average Comparison

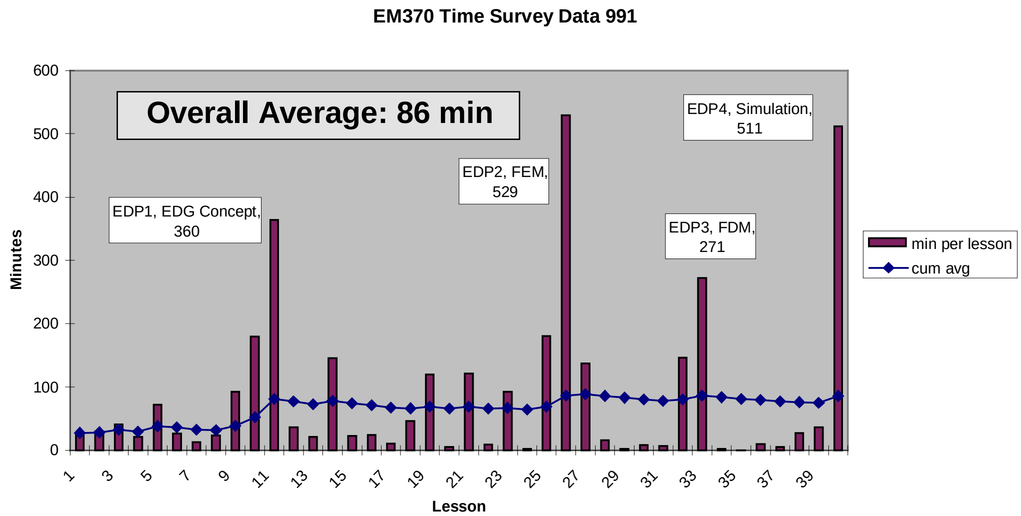

Figure 8. EM370, AY99-1 Time Survey Data

One other aspect of the collaboration was the impact on student time. The cadets reported they nearly doubled the amount of time spent on EM370. Each lesson, the instructor took a time survey of the amount of time cadets reported they spent preparing for class or completing projects. Cadets using 100% of their allotted time by Academy policy would average 120 minutes of homework. In AY99-1, cadets reported they spent nearly twice as much time on CAD as students did in AY98-1. However, cadets still spent 14% less time on CAD than required. One would have expected the amount of time to decrease if the promise of using compatible computer tools to speed the design process were true. Clearly, the learning curve for applying technology to the design process is steep. It gets steeper when students mismanage their time and "peak" for major requirements. The results of the time survey show that students have a tendency to wait until the last moment to work on major requirements (see Figure 8). A future course improvement may be to require intermediate project submissions to flatten the time curve and improve work quality.

Conclusion

Clearly, there is more to developing a successful computer-aided design class than collaboration with industry. Even before the collaboration effort, EM370 helped cadets to prepare to work in the summer intern program. One sponsor said, "…the CAD classes that they had at West Point proved to be an invaluable asset, and helped them contribute to the program they were assigned to…" However, collaboration can make a good course great. The student assessments demonstrate that collaboration with industry made dramatic improvements in a time-tested, multi-disciplinary computer-aided design course. Students loved the opportunity to put all the pieces together in one class. Moreover, government, industry and academia will benefit from collaboration and critical thinking focused on the SBA. I believe this paper demonstrates the potential improvement of any engineering design course through a coordinated collaboration effort.

Bibliography
1. Barr, R.E. & Juricic, D., *Extending Engineering Design Graphics Laboratories to Have a CAD/CAM Component: Implementation Issues,* The Engineering Design Graphics Journal, 60, (2), 27.
2. Bolluyt, J.E., Design Modeling with Pro/ENGINEER, 3rd edition, Schroff Development Corporation, Mission, 1998.
3. McGraw-Hill Dictionary of Scientific and Technical Terms, 5th edition. McGraw-Hill, New York, 1994, p.2043.
4. Barraclough, B.A., Memorandum, *Army Tactical Missile System (ATACMS) Simulation Based Acquisition Summary, 1998*. PM ATACMS-BAT, ATTN: SFAE-MSL-AB-EA, Redstone Arsenal, AL 35898-5650
5. URL: http://www.dmso.mil, *Simulation Based Acquisition Road Map,* Document under SBA Special Interest.
6. Lowman, J., Mastering the Techniques of Teaching, 2nd edition, Jossey-Bass, San Francisco, 1995.

BRETT BARRACLOUGH
Brett Barraclough is an Assistant Professor at the United States Military Academy and a Systems Development Officer in the Army Acquisition Corps. He was commissioned as an Infantry officer upon graduation from USMA in 1986 with a B.S. in Mechanical Engineering. In 1996, he received his M.S. in Aerospace Engineering from Georgia Institute of Technology. He teaches Computer Aided Design.