Building a Better Mousetrap

Advanced Unmanned Ground Vehicle (AUGV) Will Achieve Functional Integration of All Areas Taught in APMC

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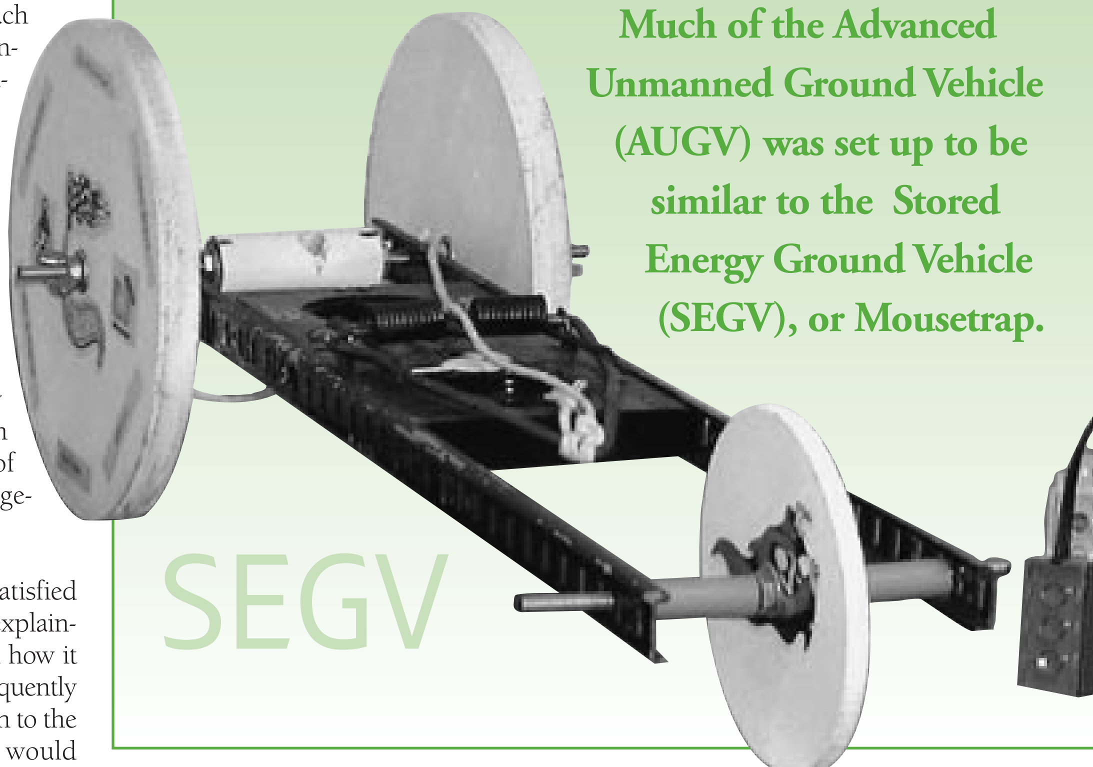
For 11 years, DSMC has used the Mousetrap Exercise to teach Systems Engineering Management to students attending the Advanced Program Management Course (APMC). The exercise started as an elective, but became a coursewide exercise when DSMC reformatted the curriculum from 20 to 14 weeks in 1995. It remains extremely successful in that over 80 percent of students surveyed responded that they were satisfied or very satisfied with the project as the centerpiece of the Systems Engineering Management curriculum.



Much of the Advanced Unmanned Ground Vehicle (AUGV) was set up to be similar to the Stored Energy Ground Vehicle (SEGV), or Mousetrap.

However, those who were not satisfied provided some solid rationale explaining why they did not like it and how it could be improved. The most frequently cited reason was a lack of relation to the type of real-world project they would manage once they returned to the acquisition workforce. One often repeated comment was, "What program today does not have software development and integration as a major part of the Systems Engineering Management effort?"

The January-February 2000 issue of this magazine described the success of using the Systems Engineering Project with Simulation Based Acquisition tools as an integrating mechanism for the APMC curriculum. However, because the Mousetrap Project is a mechanical engineering exercise, it became clear that we could not truly integrate software management into the project in a meaningful way unless we first developed a new project.

Evolving the APMC

Initiation of the Acquisition Management Curriculum Enhancement Program (AMCEP), under the direction of Dr. Bob Ainsley, provided the opportunity for a clean-sheet-of-paper approach to developing such a project. This effort would fully incorporate software and would be directly applicable to the types of real-world technical management issues facing our students as future program managers. A totally new project would also allow incorporation of other acquisition reform initiatives such as spiral development and open systems architectures that did not easily fit into the mechanical Mousetrap Exercise.

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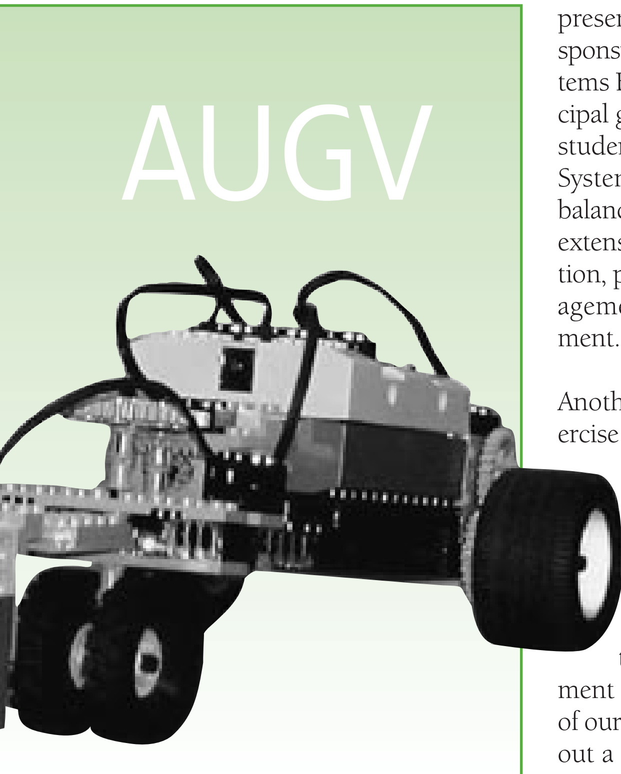
Photos by Navy Cmdr. Dave Brown

With the concurrence of the Acquisition Management Functional Board, the AMCEP IPT began a two-pronged approach to improving the APMC curriculum.

- One major effort involved the introduction of critical thinking Problem Sets (PS). These sets involve multiple functional areas and focus on Problem Based Learning (PBL). The PBL method is purposefully lacking in details and is fraught with ambiguity and complexity. The students are left wondering: 1) "What do we do now?"; and 2) "How do we do it?" This resembles what students will encounter when they return to the working environment. Therefore, case studies provide students with the lessons learned from others' "successes" and "attempts that did not work," while PBL serves as the vehicle by which the students can repeatedly practice critical thinking and problem solving in similar situations they are likely to encounter back in the working environment.



- The second major focus and the subject of this article is the improved integration of the many different functional areas taught during APMC. Because of the need for improved integration, we purposely designed the new exercise to go well beyond teaching the skills of Systems Engineering Management; it was to be an integrated acquisition exercise incorporating all functional disciplines.

While replacing the Mousetrap Exercise with something that could help improve the APMC curriculum held great promise, we took great care to identify and preserve all the elements that were responsible for past success. From the Systems Engineering perspective, the principal goal was an exercise that required students to use all the elements of the Systems Engineering Process such as balanced design through trade studies, extensive use of modeling and simulation, prudent risk taking and risk management, and configuration management.

Another challenge was creating an exercise that fits the educational needs of our diverse student population. In past surveys, some students with engineering backgrounds responded that the Mousetrap Exercise was not challenging for them. However, the purpose of the Systems Engineering Management instructional block is to train all of our students, particularly those without a technical background, in the application of principles of good technical management. Our aim is to train our students to the extent necessary to become effective program management personnel and to understand the relationships between good technical and good business management.

Responding to the need to design the curriculum for the professional engineer as well as the novice, the new project allows each student team to tailor the project to their specific learning needs. To accomplish this, we developed an Operational Requirements Document and draft Systems Specification with a broad range between the thresholds and goals. Meeting the thresholds can be accomplished with minimum difficulty. Meeting all goals simultaneously has yet to be accomplished by any team.

Finding a commercial kit to support such a project proved to be the most difficult challenge associated with development of a new project. Most educational kits are designed to be assembled into a single configuration. The new project required a commercially available kit at a reasonable cost that contained a computer microprocessor and could be assembled into multiple different configurations.

Commercial Market Survey

After conducting a commercial market survey, we chose two kits for purchase and evaluation. They were the Robotix Education Set by Learning Curve International and the Robotics Invention System by Lego. After building projects with both kits, we subsequently selected the Lego kit for use in a pilot project (beginning with one section of APMC 99-2) because of its superior computer microprocessor and easy-to-use programming language. The processor can be programmed with a language called RCX, developed at the Massachusetts Institute of Technology for training engineers in robotics. The kit also comes with an excellent interactive CD-ROM that can train an inexperienced person to program in RCX in about an hour.

As a visual language, programming with RCX is like snapping together Lego blocks on a computer screen (Figure 1). This feature solved one of the challenges of incorporating software integration, which was how to introduce software without consuming hours of valuable teaching time training students to program.

While program management personnel need to understand the technical issues surrounding software development and integration, they do not need to be/become programmers. However, for those students who are familiar with software programming and wish to explore more creative and challenging options, the processor can also be programmed in other languages such as Delphi, Visual Basic, C++, and a variety of custom lan-

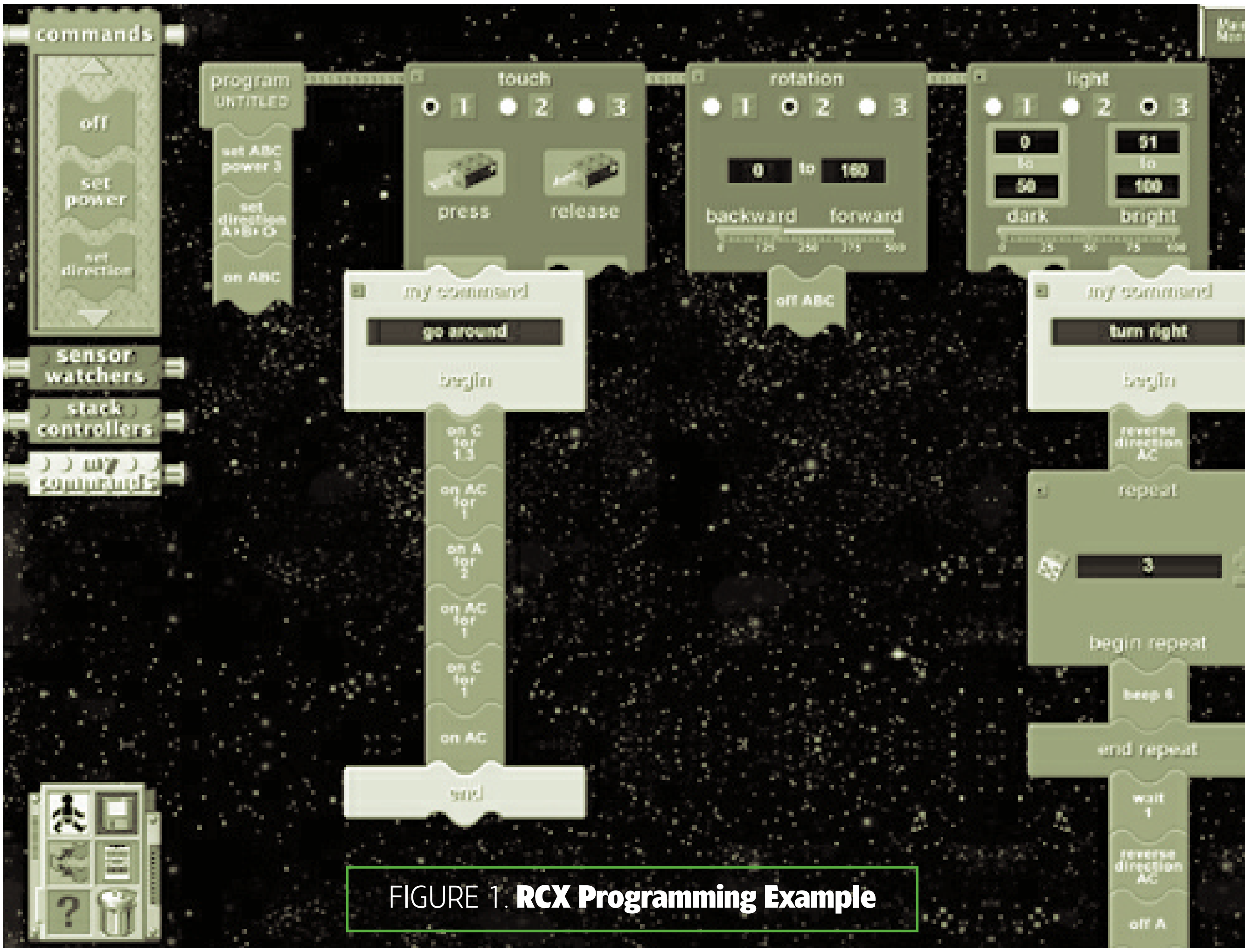


FIGURE 1. **RCX Programming Example**

guages developed specifically for the Lego computer. This information is available on the Internet at **http://www.legomindstorms.com/**.

The Advanced Unmanned Ground Vehicle (AUGV)

The new integrated exercise is called the Advanced Unmanned Ground Vehicle (AUGV) Program. The project is based on the Mission Needs Statement of the Army's Unmanned Ground Vehicle Program. This provides a link to a real-world development program, working with state-of-the-art technical issues. After careful consideration, we chose a ground vehicle since it can easily be tested in a classroom environment.

Acquisition Reform And The AUGV

From the outset, we designed the AUGV project to give students hands-on experience working in an environment where acquisition reform initiatives are reinforced and maximized to the highest level possible within a classroom academic environment. Students gain first-hand experience using these initiatives to complete difficult tasks in a dramatically reduced cycle time. In so doing, our aim is to instill the value of acquisition reform initiatives in our graduates and propagate them throughout future DoD programs.

Keeping Best of Mousetrap

Much of the project was set up to be similar to the Mousetrap Exercise. Leveraging our past successes with Mousetrap allowed us to facilitate a rapid ramp-up to all 12 sections by the summer of 2000. Early in our efforts, we determined that to achieve full implementation, the critical path to success was training instructors to teach the new project and associated integrated lessons. Instructors find the mechanical portions of the project to be very similar to Mousetrap. For example, different size wheels on the Mousetrap require analysis and trades—just like the current AUGV. This is primarily a practical application exercise in Cost As an Independent Variable in that students must work to define "best value to the government." Students trade off number of motors instead of number of rattraps. Different size gears and pulleys replace different size hubs. Students still have to trade between conflicting requirements of speed for one demonstration and power for another.

Introduction of Software

Although the mechanical aspects are similar to Mousetrap, the introduction of software adds an entirely new dimension to the project. Students must develop a vehicle that is capable of both remote control and autonomous operation. Remote control requires students to integrate a "drive by light" control system. The level of autonomous operation is a

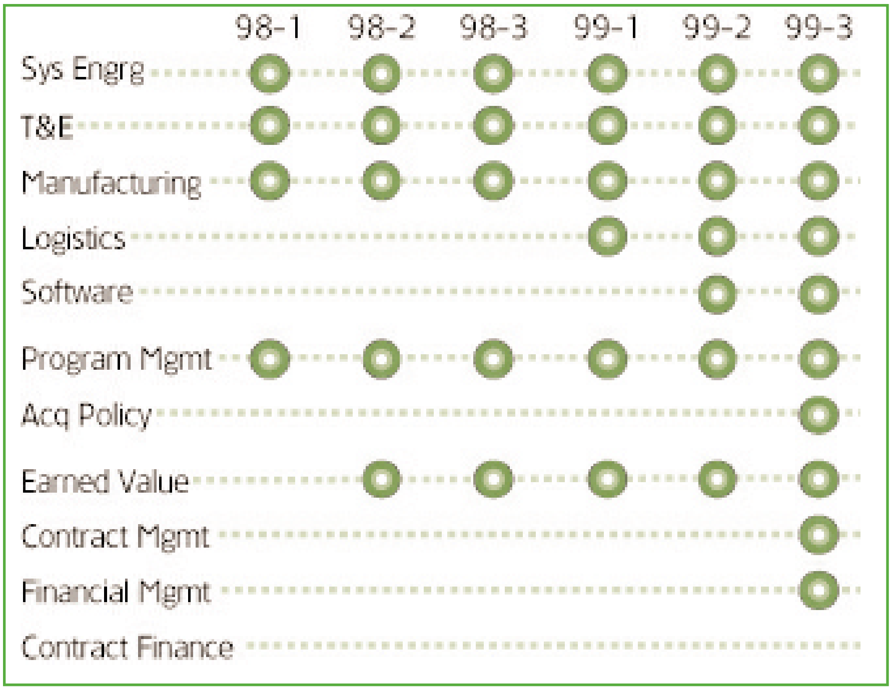


FIGURE 2. **Exercise Functional Integration**

design decision exercised by each student team. As a minimum, each team must demonstrate that their vehicle can be programmed to maneuver over a set course and arrive at a given point within a specified accuracy, in the event of lost communication with the control station. Students looking for a challenge may opt to develop a system that traverses a course without human assistance, including the detection and avoidance of unknown obstacles.

No matter which path the students choose, they must deal with state-of-the-art technology and real-world integration issues. Every Service is working on at least one remote control or autonomous operation vehicle, and many more will likely begin development under the future leadership of our current students.

Student Work Time

Student work time was another major consideration while developing the project. Past student critiques indicated that the Mousetrap Exercise took too many hours to complete. The addition of software to the project added 67 percent more requirements to the AUGV System Specification than the Stored Energy Ground Vehicle (SEGV). To offset the additional workload, we revised contract deliverables to remove items of marginal learning value. In addition, we developed a new, more capable Simulation Based Acquisition (SBA) software package to conduct even more of the trade studies and tests in a virtual environment.

Automated Systems Engineering Tools

Other improvements added were Automated Systems Engineering tools (such as Risk Matrix) to assist in exercises, where practical; and templates to reduce deliverable preparation time. Using the commercial off-the-shelf kit, we made additional reductions.

Students spent many hours in the hobby shop making or modifying the wood and metal parts of the SEGV project. The Lego kit consists of 750 plastic parts that can be rapidly snapped together in an almost infinite number of combinations without modification. The AUGV is designed so that the students spend a higher percentage of project hours on critical thinking and Systems Engineering Management functions as they attempt to manage multiple, conflicting, real-world demands and arrive at a balanced solution.

Functional Integration Crucial

Functional integration was one of the main reasons for changing to a different project. Figure 2 shows how the Mousetrap Exercise has been incorporating lessons and exercises from functional areas outside Systems Engineering for the last two years.. The creation of AUGV completed the integration of all functional areas in the technical block of instruction. Work is currently underway to incorporate all functional areas into the project.

Course Structure

The AUGV exercise for APMC 00-1 consists of 27 lessons and exercises covering 10 of the 11 functional areas taught. Integrating lessons from other functional areas has two distinct advantages.

- The first is a reduction in teaching cycle time. By combining the Systems

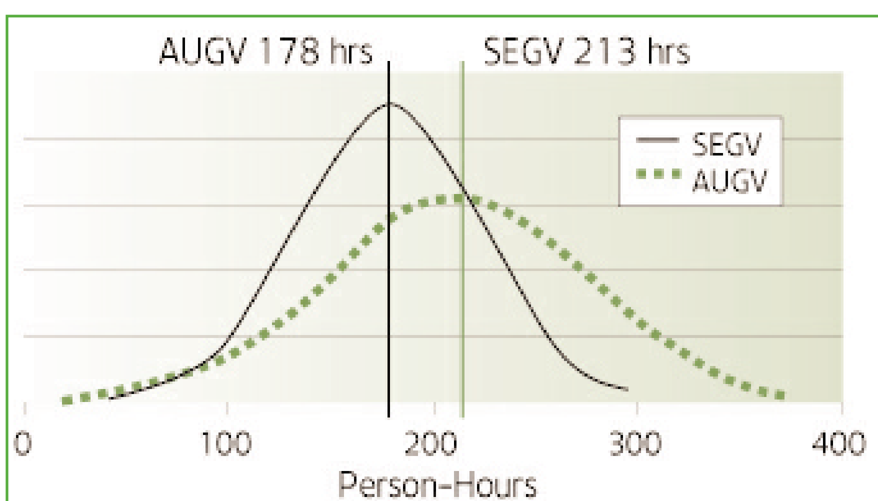


FIGURE 3. **Project Hour Comparison**

1. Course taught at right level?
2. Course enhanced critical thinking skills?
3. Course material well integrated, reinforcing other functional areas?
4. Hands-on learning better than lecture/discussion only?
5. Better at my job because of what I learned in this course?

FIGURE 4. **Student Survey Questions**

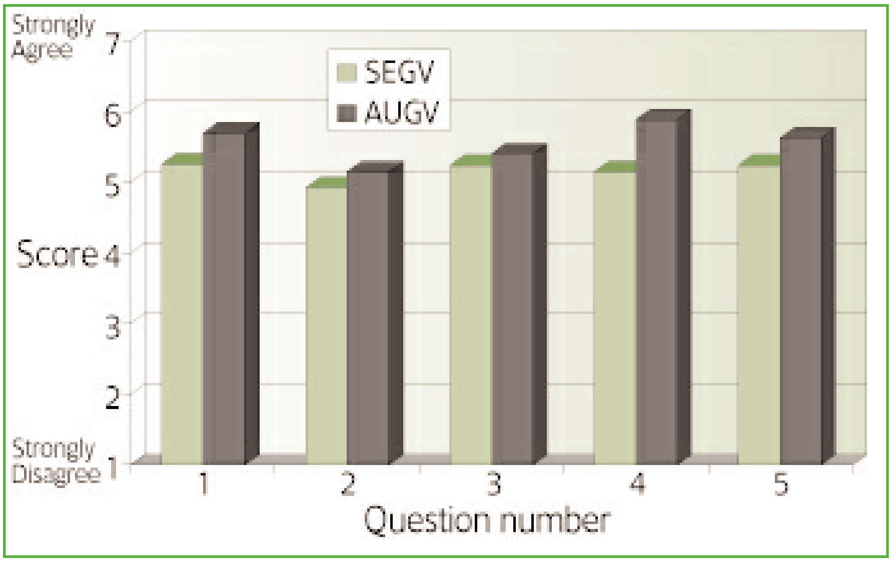


FIGURE 5. **Student Survey Results**

Engineering and Software Management functional analysis/synthesis lessons into a single integrated lesson, we added hardware/software architecture and integration and simultaneously reduced the total teaching cycle time by an hour. This time was then available for addition of the Problem Sets in the AMCEP curriculum. Similarly, the Systems Engineering Department dropped another hour of instruction by replacing the technical risk exercise conducted as part of the SEGV with a total risk analysis exercise (cost, schedule, and performance) of the AUGV in a Program Management lesson.

- The second advantage is that evolving the AUGV to an Integrated Acquisition Exercise provides a common thread to bind together the different functional areas taught in APMC. Successful program management personnel must understand how policy relates to engineering, financial management, contracting, etc.

Project Results

The Systems Engineering Department successfully piloted the first version of the AUGV project in one section during the summer session of APMC 99-2; in APMC 99-3, we taught two additional sections. To measure progress, we established a baseline with respect to the SEGV project in APMC 99-1. At this point, however, a direct comparison between the AUGV and SEGV data is invalid, since the SEGV data contain a fairly large data set while the AUGV data represent only three sections. However, the data are useful as a metric to determine whether or not trends are in the desired direction.

Figure 3 shows the average time to complete the project. Students who worked on the AUGV project completed it in less time than those who worked on the SEGV, despite a 67-percent increase in requirements. This data would also tend to validate Office of the Secretary of Defense policy on the benefits of SBA and streamlined procedures in cycle time reduction.

Figures 4 and 5 show student opinion based on five questions covering the goals of the project. The AUGV showed an improvement in student satisfaction in all areas over the SEGV baseline.

Metrics to date reflect excellent results. In fact, we accelerated the implementa-

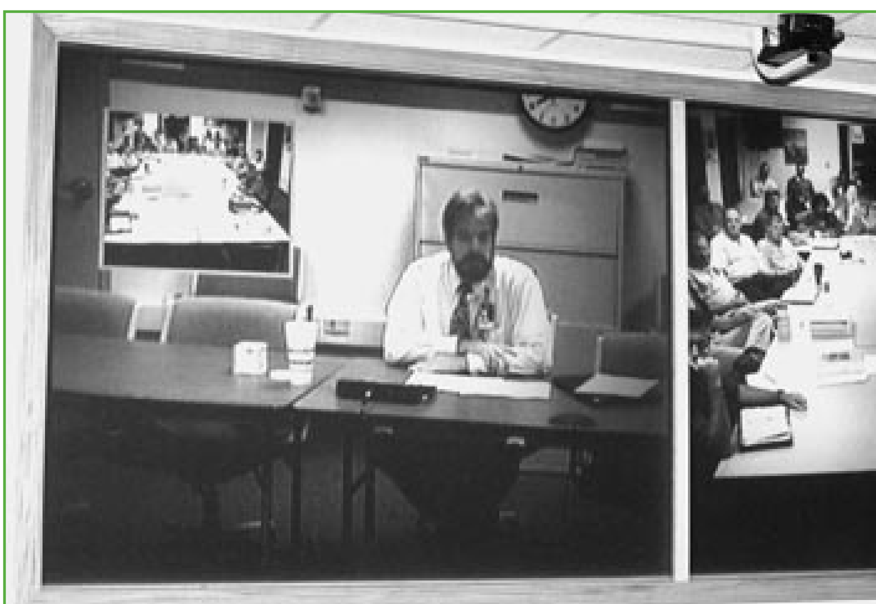


FIGURE 6. **Virtual Field Trip to Pratt & Whitney Engineering Center**

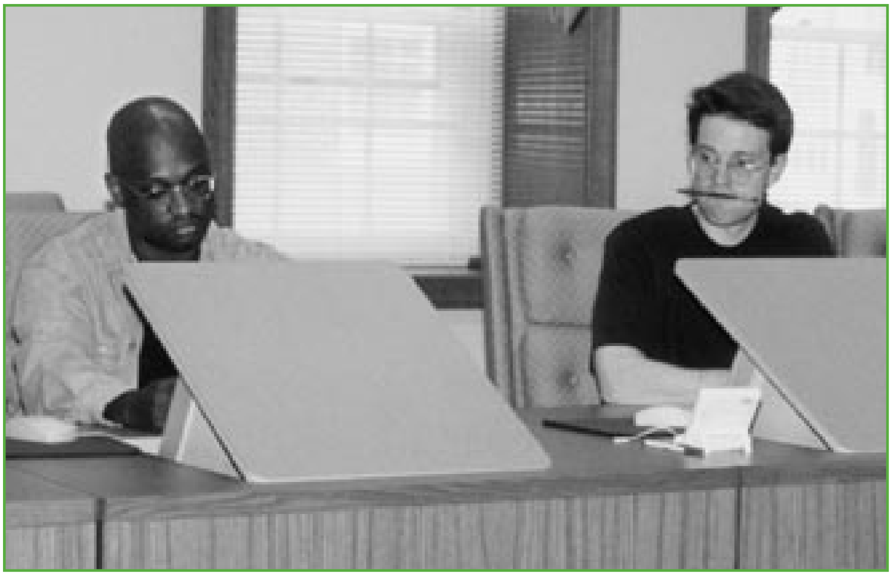


FIGURE 7. **GMU Students Conduct Decision Support Exercise in DSMC's Management Deliberation Center**

tion schedule ahead of the AMCEP implementation schedule, and all sections will use the AUGV in APMC 00-2 and beyond.

Cooperative Efforts

In addition to the AUGV exercise, AMCEP also experimented with cooperative learning efforts outside the college. One pilot effort had the students conduct a virtual field trip to the Pratt & Whitney (P&W) Engineering Center in West Palm Beach, Fla. Using distance learning, the AMCEP section held a video teleconference with a P&W systems engineer (Figure 6). Students gained first-hand knowledge of how industry responds to conflicting government requirements to arrive at a balanced system solution. They also gained insight into how design for producibility and design for supportability are accomplished during the functional analysis/synthesis steps of the systems engineering process.

A second pilot involved cooperative classes between DSMC and George Mason University. During the summer session, GMU students taking a Systems Engineering course taught by Dr. Ruth Buys in Decision Support and Expert Systems conducted an exercise in Group Decision Support using the DSMC Management Deliberation Center (Figure 7).

Clearly, students benefit when different schools are willing to share resources. Since most of the GMU students worked for the government, this second pilot also proved a great way for DSMC to advertise its Management Deliberation Center and other fee-for-service capabilities.

Figure 8 shows a diverse group of vehicles built by instructors as they prepare to teach the new project. Because of a rigorous training program over the summer, the Systems Engineering Department expects to have 12 fully trained instructors by fall 2000. In addition, the popularity of the Lego kit as a teaching tool has spread to numerous high schools and universities because it is an excellent, easy-to-use, low-cost teaching tool.

As we evolve and improve the project, we are able to leverage a wealth of information and work available on the Internet. Students are also encouraged to conduct their own Internet search for best practices, lessons learned, previous designs, and software programs — just as they would in a real program.

The Future

We have successfully expanded the capabilities of the baseline kit by developing our own software programmable controller units within the department (Figure 9). These units provide an option for students to integrate existing software with their concepts within an open systems environment.

Additionally, the kit — with its huge inventory of parts and highly capable computer — has excellent growth potential to support continued evolutionary project improvement and further integration of cross-functional lessons and exercises. Further, the AUGV project can be easily adapted to a spiral development technology demonstration effort to match the new draft of the DoD 5000 series when approved.

As we close out the Mousetrap at the end of APMC 00-1, a sense of loss in retiring something that has served so well

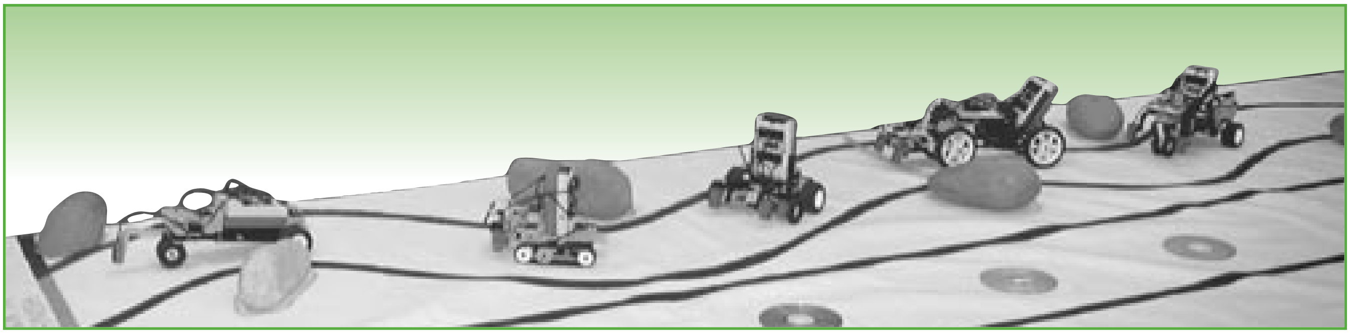


FIGURE 8. **Variety of Instructor-built AUGV Concepts**

for so long will surely remain. However, like a ship or aircraft that has served well, the time must come for older systems to step aside so that newer, more advanced systems may take their rightful place. For those who enjoyed Mousetrap while attending the APMC course, rest assured we took great care to capture and preserve the best in its successor. For those who felt the project needed improvement, we appreciate your feedback and have done our best to act on your comments to create the best possible educational experience possible for our future acquisition workforce.

Ultimately, the new AUGV will allow us to continuously evolve to better learning experiences in support of the acquisition and logistics workforce of the future. This approach, we believe, will be far more effective than either the lecture-based or case-study methods we have traditionally used in the past.

Editor's Note: The author welcomes questions or comments on this article. Contact him at **brown_dave@dsmc.dsm.mil**

FIGURE 9. **Software Programmable Control Units Built In-house by Systems Engineering Department Faculty**

Annual Chemical and Biological Defense Report to Congress Released

The Defense Department announced today [March 22, 2000] that the annual report to Congress on its Chemical and Biological Defense Program is available for distribution. The report provides detailed descriptions of the chemical and biological defense programs, as well as systems that are currently fielded, in production, or in advanced development.

The report is available on the Internet at **http://www.defenselink.mil/pubs/chembio02012000.pdf**.

The report is prepared in Adobe Acrobat, which is available as a free download at **http://adobe.com/products/acrobat/readstep.html**.

For further information for news media, contact Navy Lt. Cmdr. Anthony Cooper at (703) 697-3189.

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