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OUR CONTRIBUTIONS BEYOND THE ACADEMIES

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EDITOR'S NOTES

We have some very interesting articles for you in this issue of *Mathematica Militaris*. We are all very proud of our accomplishments in the classroom, and rightfully so. The academies are known throughout the academic arenas as innovative thinkers and proponents of new curricula and reform in the traditional methods of teaching. In this issue we explore another facet of the academies with some wonderful examples of how our faculty and students have made an impact *outside* the classrooms and halls of the Academies.

The first article by CPT Ray Eason and Dr. Fred Rickey reviews a recently published book entitled *West Points Scientific 200*. This fascinating book written by BG (Retired) Chris Arney does a wonderful job of reviewing the accomplishments of the finest scientists and engineers in 200-year history of the US Military Academy.

Dr. Kenneth Seigenthaler describes in the second article how two of his student capstone projects succeeded in helping the community. Their efforts made an undeniable positive impact on the lives of their "clients".

Next, Major Gerald Kobylski goes into great detail describing the research opportunities available to rotating faculty members who might find themselves at one of the four Intermediate Level Colleges (ILC). Major Kobylski provides a wonderful analysis of the curricula at all four service ILCs along with some of his personal research endeavors.

BG (Retired) Chris Arney provides some excellent insight and discussion in his article entitled *Why the World Needs America's Service Academies.* His wealth of experience at the US make him uniquely qualified to offer his opinion on Military Academy and years as the Department Head for the Department of Mathematical Sciences the subject, and his article provides excellent reading.

One method to make an impact that is certain to carry beyond the walls of the Academies is to create life-long learners. By incorporating methods that spark the mathematical interests his cadets, CPT Bart Stewart has done well to do just that. His article entitled *Movie Madness* discusses unique methods to inspire and challenge students while removing some of the math anxiety that is often seen by instructors.

The final article contributed by Dr. Deborah Arangno demonstrates how students can master the same mathematics used to solve some rather complex problems for defense agencies. She successfully incorporated some sophisticated differential equations and modeling techniques in the classroom that were used in some recent research efforts for the Strategic Defense programs. These students saw first hand how the faculty reaches beyond the boundaries of the Academies.

I hope you take the time to visit our updated website that includes copies of past issues of *Mathematica Militaris* at the following site: http://www.dean.usma.edu/math/pubs/mathmil/ .

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Editor, *Mathematica Militaris*
Department of Mathematical Sciences
United States Military Academy
ATTN: MADN-MATH
West Point, New York 10996

Book Review

CPT Ray Eason and Prof. Fred Rickey, USMA, Department of Mathematical Sciences

West Point's Scientific 200: Celebration of the Bicentennial. Biographies of 200 of West Point's Most Successful and Influential Mathematicians, Scientists, Engineers, and Technologists by Chris *Arney (Lexington, SC: Palmetto Bookworks, ISBN 1-887301-15-1)*

Crafting a quilt of history, General Chris Arney's latest publication engages the imagination of those interested in learning more about 200 West Point graduates who have advanced mankind and made a difference in the scientific world. Their unique lives are woven together with several common threads. These scientists, engineers, technologists, and mathematicians had an impact on our world that spans two centuries. All two hundred gave us a gift of knowledge and prosperity. The entire group helped build America as a world leader in the pursuit of science. The publication that pays tribute to their lives is entitled *West Point's Scientific 200: Celebration of the Bicentennial*. Not only is this work a celebration of 200 biographies, but it also offers the reader a chance to view the past from different historical lenses. One can also find interesting historical connections between the service academies.

For example, do you know which Air Force Academy Department Head was a West Point graduate? His name was Monty Coffin (a 1950 USMA graduate) and he served as head of the Air Force Academy Mathematics Department from 1967 to 1971. Earlier in his life, Coffin had combat duty in the Korean War and staff duty in Turkey. He had a colorful collage of experiences in his Air Force career – a journey that took him from the Lawrence Livermore Laboratory to the Air Force Missile Laboratory where he served as the Research Director. His biography celebrates the diversity of contributions made by West Point's *Scientific 200*.

The journey of William Fenn Hopkins (1825) offers another interesting example. Hopkins served both as a West Point Professor from 1825 to 1835 and as a US Naval Academy Professor from 1850 to 1859. Somewhere in between, he found ways to make academic contributions at the Norfolk Academy in Virginia, the Western Military Academy in Kentucky, and William and Mary College also in Virginia. The reader would not expect one person to have such a broad range of influence between the Army, Navy, and civilian worlds. But as the reader uncovers more within the pages of *West Point's Scientific 200*, one discovers that this pattern is not unique.

Choosing these 200 graduates must have been a difficult task, for a large proportion of the graduates of the military academies have made substantial contributions to American science. The *Scientific 200* were chosen from the deceased graduates of West Point, less than 16,000 men – the first women graduates were in 1980 and none are included here. The earliest graduate included was the very first one, engineer Joseph G. Swift (1802), and the latest was Thomas Johnson of the class of 1965. Johnson joined the Air Force upon graduation, earned a Ph.D. in physics, and then joined the Department of English at USMA, where he taught poetry, physics, mathematics, mechanics and engineering – perhaps no one else taught as many subjects at USMA. During 1981-83

Johnson served as assistant to the President's Science Advisor.

Not surprisingly, since the author is a mathematician, four of the top ten are mathematicians. Sylvanus Thayer, the "father of the military academy" is ranked fourth, but his classification as "mathematician" is based on but two years of teaching mathematics at the Academy. Charles Davies – a name that all should know, but few do – is deservedly in the top ten. He was the foremost writer of mathematics textbooks in the nineteenth century, writing 49 textbooks that appeared in almost 500 editions.

Edward Courtenay (1815) is fifth on the list of 200, just behind Davies. He taught at the University of Pennsylvania and then at the University of Virginia, where he replaced J. J. Sylvester after he left because of an altercation with a student (the rumor that Sylvester killed the student with his sword cane is false). The fourth "mathematician" in the top ten is Ormsby Mitchel (1929) who is better known as an astronomer who charmed "thousands as he traveled around the country" giving lectures, but he did teach mathematics both at West Point and at the long defunct Cincinnati College.

That all of these individuals graduated early in the history of the Academy reflects the fact that there was no other place in this country to obtain a scientific education. While none of these have the name recognition of a Sylvester, they were the best in the country and also illustrate how a mathematical community has to develop before a few can flourish.

There are other surprises in the "mathematician" category. What did Omar Bradley (1915) and Dwight Eisenhower (1915) have to do with mathematics? Bradley taught mathematics at West Point for four years – because he was so good at it, he was extended for a fourth year to train the new instructors – and claimed that it was important in his development as an officer and problem solver. It is encouraging to hear him say this, for the claim has been made since the inception of the Academy that mathematics is a crucial skill for an officer to have. Claims like this are the primary reason why cadets should read this book. They will be officers soon and need to understand that what they are learning now in mathematics will be of benefit to them later no matter how their life threads through the fabric of our society.

Eisenhower is included, not because he taught mathematics, for he didn't, but because he did "analytic and quantitative studies" for the Army. While we welcome these great individuals into the college of mathematicians, it would be good to have more documentation for these claims. An honorable mention to the *Scientific 200* wanted to be a professor of mathematics, but Professor Albert Church (1828) turned him down. That was U. S. Grant (1828). His mathematical ability is attested by several of his cadet drawings in descriptive geometry that survive in the USMA Archives. It would be nice to have included Grant in the long chalky line of USMA mathematics teachers, but it is more fun to say 'It is easier to become President of the United States than to teach mathematics at West Point.'

While the bulk of this volume is devoted to the *Scientific 200*, there is a fifty-page section at the end that deals with the connections between various scientific organizations and West Point. Since the Corps of Topographical Engineers, the

Ordnance Corps and the U. S. Coast Survey are all heavy users of mathematics, it is not surprising that many West Pointers have been involved with these organizations. One expects a section on the Army Corps of Engineers since West Point was founded to educate engineers. Among the engineers is 'Whistler's Father,' George Whistler (1819), who built railroads in this country and in Russia. Also included is George Goethals (1880) who supervised the building of the Panama Canal. Leslie Groves (1918) oversaw construction of the Pentagon, which remarkably took only took sixteen months to build, and used his considerable organizational and interpersonal skills while heading up the Manhattan Project, so he is deservedly in the top ten of the *Scientific 200* along with Goethals.

As West Point celebrates 200 years of existence, it is fitting that this publication celebrates the contributions of 200 of its most successful and influential scientists, mathematicians, and engineers. Perhaps the strongest cord that unites these 200 individuals is the long gray line, but the most interesting aspect of *West Point's Scientific 200* is the hidden threads and connections that lie waiting for you to discover.

RAMPS AND RACE CARS: APPLIED MATHEMATICS IN A PUBLIC SERVICE PROJECT

Dr. Kenneth E. Siegenthaler, USAFA, Department of Mathematical Sciences

The Air Force Academy has a capstone course, Engineering 410, Engineering Systems Design, which is a core course required for graduation. About half of the students who take this course are non-technical majors. The projects for these courses are selected from proposals submitted by various nonprofit organizations. In the Spring Semester of 2001, I taught two sections of this course. Each section had one engineering and one science major, and all of the other students were non-technical majors.

The project for one of my sections was to design, build, test and deliver a collapsible ramp that could be used to drive an electric cart/wheelchair into a vehicle. The ramp was for a handicapped spouse who liked to travel on the airlines. She wanted a ramp that would fold up and meet the airline requirements to be checked as luggage. Then when she arrived at her destination, she could drive her rented electric cart into her rented pickup and go anywhere she wanted. It would also allow her to drive her electric cart into the back of the family pickup, enabling the family to go camping and participate in other outdoor activities that are popular in Colorado. The design constraints required cadets to perform extensive research and development to produce an efficient design using lightweight materials. This not only required the use of specific aluminum alloys, it required the use in some cases of perforated aluminum. The aluminum had to have the proper perforation design to still maintain the required strength. An example of one of the unique requirements imposed in this project is the fact that the ramp had to be 11 feet long. This requirement was not dictated by the amount of power available in the electric motor in the cart. It was dictated by the safety switches that are located behind the rear wheels of the cart to prevent it from tipping over backwards when power is quickly applied to the drive wheels. The entry angle to the ramp had to be small enough so that these switches were not activated. Although, the final ramp was 11 feet long, the completed ramp only weighed 70 pounds. When in the folded position, the ramp had wheels and a handle so that it could be pulled along in a manner similar to many of the large suite cases presently used by travelers. I was particularly pleased with the rugged design and construction. Under normal use, the completed ramp should last almost indefinitely. Except for the welding, all of the activities required to take this project from conception to delivering a finished product, were performed by the cadets.

The project for the second section, was to design, build, test, and deliver a complete Pinewood Derby race track system for a Cub Scout Troop. If you are not familiar with the Pinewood Derby program, it involves each Cub Scout being given a kit containing the basic materials necessary to make a model race car. Within the guidelines provided, the scout carves the body of the car from a block of wood, and then adds the accessories needed to make a completed model race car. The cars are then raced for time on an approved Pinewood Derby race track system. A very accurate electronic timing mechanism is obviously an important component of the race track system. The system produced by this cadet section was a complete approved Pinewood Derby race track system. This system required the construction of a track that was 32 feet long, which included a starting mechanism, an electronic timing mechanism and a storage/carrying case. The completed system, packaged in the carrying case, weighed nearly 200 pounds. The storage/carrying case was a wooden cabinet that was finished to the quality standards you would normally expect of a piece of furniture. In this case all of the activities required from conception to delivering a finished product, were performed by the cadets.

The course was structured so that the cadets formed a company that was contracted with the government, (Course Instructor), to satisfactorily design, construct, test, and deliver a finished product to the customer by the end of the course. I think it is a credit to the value of the core course program at the Air Force Academy that both sections produced very professional, worthwhile products that will be put to good use for many years. In addition to the satisfaction of doing a good deed to help someone, the projects also create a very positive image of the Air Force Academy in the local community. Because of the end use of their product, the cadets took this course very seriously.

Since the Air Force prides itself in being the “technical service”, I felt that the value of the core course concept at the Air Force Academy was demonstrated in the quality of work on an engineering project performed by non-technical majors. Of course, our non-technical majors are different from the “normal” non-technical majors at a civilian university. The average English major at a civilian university has not taken a year of calculus, a semester of probability and statistics, and 13 semester courses of science and engineering. The point is that without the mathematical foundation, the science and engineering portion of the core curriculum is not possible. Because the Mathematical Sciences Department is usually a service department, the fundamental value of its contribution to the ability of cadets to provide meaningful service in nearly all aspects of their professional and personal lives is sometimes lost. In addition to the mathematical mechanics, there is the influence of the discipline and analytic thought process required in completing calculus courses. I was pleased to see this demonstrated by non-technical majors in these two sections as they developed their finished product.

Another added benefit for the cadets, is that they were required to learn how to use hand and power tools that many of them had not been exposed to before this course. It is always good for an officer to have gotten their "hands dirty" before having to lead others. With today's urban society, many people have not become familiar with the normal hand and power tools in common use in rural society.

The emotional expression of joy by the handicapped person and her family for the efforts of the cadets was a great motivator for the cadets to extend their skills to be better equipped to help someone in the future. Of course the Cub Scout Pack had enough enthusiasm to motivate anyone. It is evident that the practical application of applied mathematics is one of the most effective methods of teaching and reinforcing fundamental principles. When a very worthwhile public service is part of that practical application, the reinforcement is all the more dramatic.

"Major" Research Opportunities After an Assignment at the U.S. Military Academy

MAJ Gerald C. Kobylski, USMA,
Department of Mathematical Sciences

Many majors assume that there are few research opportunities at the Intermediate Level Colleges (ILCs). This is true of course, unless one pursues research on personal time in addition to the rigorous academic requirements. As a result, some of those officers who teach at the U.S. Military Academy and who will soon begin intermediate level education might shy away from involved research near the completion of their teaching tour. A reason for this is that they think that they will not be able to complete it before departing for further schooling.

I have found that there are many opportunities for conducting a broad range of research activities at the ILCs. In this paper I will point out some of these research opportunities and applications of analytical skills that exist at the various ILCs. I will also briefly explain some research that I have been involved with at the College of Naval Command and Staff (CNCS). Finally, I will discuss how an officer can utilize potential research opportunities as leverage in requesting a service command and staff college that they would like to attend.

<u>Research Opportunities at the ILCs</u>

The CNCS in Newport, RI, offers opportunities for research analysts to continue previous research, to begin new research, or simply to apply analytic skills. During each of the academic program's trimesters, students are required to take a ten-week elective course. Students can substitute for this elective an individual research program on a topic of their choosing. Two of the basic requirements for any individual research are to select a military topic that would enhance one's professional development and to select an advisor. Advisors can have as much or as little oversight as you and they agree to and they do not have to be from the CNCS. The elective courses, or the research substituted for them, are on a pass / fail basis.

Another research opportunity at the CNCS is to substitute a research program for one of the three core courses taught. The requirements for this are a more stringent than for the ten-week program. One must define a specific plan of study and then obtain approval for it. This opportunity can offer 12-16 weeks of focused research time.

The final opportunity for an analyst to contribute at the CNCS is during one of the three core courses called National Security Decision Making (NSDM). During this block of instruction, students are presented with such analytical topics as uncertainty and risk analysis, probability and expected value, decision theory, and modeling (weighted, deterministic, inventory, and stochastic). All of these topics are tools taught for use in the NSDM arena. Students with prior experience in these topics can offer to teach or assist with many of these classes.

The Army's Command and General Staff Officer School (CGSOC) at Fort Leavenworth, KS, requires students to take 12 different elective courses in the latter half of the year in addition to its core courses. There are many choices for the students to choose from, several of which include operations research topics. One such course involves case studies with applications of analytical techniques; another course covers several modeling techniques. Like the CNCS, students also have the opportunity to conduct / continue independent military research as a substitute for an elective.

This summer's CGSOC class (June 2002) may be the last year for officers who are not in the Army's Operations Career Field to be able to attend resident staff school at one of the four ILCs. However, under the "universal" intermediate level education plan, every officer may have the opportunity to attend resident schooling at some location. Although the specific staff school programs for these officers have not yet been finalized, there should be a multitude of opportunities to continue or develop research particular to ones own field so be on the lookout! For those Operations Career Field officers who continue to attend resident ILC, there should be the same research opportunities mentioned above.

Similar to the CNCS and the CGSOC, the Air Force Command and Staff College at Maxwell Air Force Base, AL, offers research opportunities as a substitute for one of its three elective courses. The Marine Corps Command and Staff School in Quantico, VA, offers research opportunities for those officers desiring to pursue a Master's Degree. These officers are required to conduct research on a topic of interest and then produce a graduate level thesis.

My Personal Research

While a student at the CNCS, I conducted research in three different areas. The first area was in one of the three core courses given in the Department of Joint Military Operations (JMO). This research involved an analysis of the current Joint Professional Military Education (JPME) at the ILCs.[1] Admiral Dennis Blair, a former Director of the Joint Staff, stated that a key goal of Joint Professional Military Education (JPME) is that officers "come away with an understanding of how the other Services think, what their strengths and weaknesses are, and ideas on how they can build synergy of their forces with the

[1] The paper describing this research is scheduled to be published in the Defense Technical Information Center.

other Services in the joint fight."[2] Joint Vision 2020 states that a key to successful joint operations amongst the Services is joint education.[3] Despite much emphasis by the senior leadership of our services on joint education, many leaders strongly believe that our JPME programs are inadequate.

Upon receiving the syllabus for the JMO course, where the majority of the joint education credit for CNCS is provided, I noticed that many of the objectives were vague and began to wonder about the problem of inadequacy in JPME suggested by some leaders. Having had some experience at USMA in setting course objectives, I realized the importance for the student of clearly defined and obtainable objectives in a course. This interest motivated me to determine if the ILCs provide the necessary skills for officers to be successful in joint assignments. To determine this would require an analysis of the education our officers receive at every level from pre-commissioning through general officer courses, an analysis beyond the scope of my research. I decided to focus my effort on the JPME that O4s receive at the ILCs, like CGSOC and the CNCS, and determine if the ILCs are teaching what is important.

In order to meet his Joint Vision guidance in joint education, the Chairman of the Joint Chiefs of Staff created the Officer Professional Military Education Policy (OPMEP). This policy contains five learning areas with several sub-categories for each ILC to cover in its curriculum. Like the JMO objectives, to me many of these seemed vague. Before determining if the ILCs are teaching the skills that are important, I first had to determine what skills are important. In order to determine the important skills, I developed a survey containing 56 knowledge areas that O4s might require in a joint assignment. A survey conducted by the Requirements Team of the Joint Professional Military Education 2010 Working Group served as a starting point or base for my survey.[4]

My survey's target was a group of officers who had served in joint assignments while in the grades O4-O6. The survey asked the officers to rate the knowledge areas and skills required to perform effectively in a joint operational environment. For each skill, officers could respond very low, low, average, high, very high, or leave it blank if they were not sure of an area. Having analyzed the results of the survey, I determined 19 areas to be very important.

The next step in my research was to determine if the four service ILCs, Army, Navy, Marine, and Air Force, give appropriate coverage to these areas. To do this I analyzed three areas, feedback from graduates, comments from the course directors, and the syllabi from each of the ILC's joint curriculum. My findings indicated that O4s do not receive sufficient joint education from the ILCs in all of the necessary areas that would make them successful in joint assignments. I have enclosed a summary of this analysis in Table 1, which is provided at the end of this article.

[2] Michael Carney, "Joint Professional Military Education 1999: Where to Now?" (Army Command and General Staff School, Fort Leavenworth, KS: 1999), 16.

[3] United States Chairman of the Joint Chiefs of Staff. Joint Vision 2020. (Washington, DC: June 2000), 15.

[4] United States Chairman of the Joint Chiefs of Staff. Joint Professional Military Education 2010 Study. (Washington DC: 1998), B-7.

Also while attending the CNCS, I was able to conduct research during two 10-week periods that substituted for two required electives. During the first, I assisted an analyst in the Naval War Gaming Department in analyzing the cost effectiveness of Theater Ballistic Missile Defense (TBMD). Just as missile defense costs the U.S. a certain amount of money, missile offense also costs our adversaries. The goal of this research, which is still underway in the Naval War Gaming Department, is to determine a ratio of the cost for missile defense verses missile offense in an offense / defense arms race. Some of the variables in this model are the probability of kill of an interceptor, the probability of finding Scud mobile launchers, commonly referred to as transporter, erector, launchers (TELs), factors contributing to the saturation of missile defenses, and the optimum mix of offensive and defensive TBMD assets. My primary role in this endeavor was to investigate some of the factors that contributed to these variables. These factors focused on the enemy's concept of operations for employing TBMs, which included procedures for planning, movement, firing, and command and control. A majority of my contribution in this effort was classified.

Currently, I am completing my second research elective with a focus on the U.S. Army Future Combat System (FCS). In this research I am coordinating with the Department of Systems Engineering at Stevens Institute of Technology, the Mitre Corporation, and the Department of Systems Engineering at West Point. The Department of Systems Engineering at Stevens currently has a grant from the Mitre Corporation for analyzing and improving Command, Control, Communications, Computers Intelligence, Surveillance, and Reconnaissance (C4ISR) using current technological capabilities. My plan is to continue this research as part of my doctoral studies in my next assignment.

Requesting Attendance at Different ILCs

If officers are interested in attending another Service's ILC, they can increase their chances of being selected by coordinating a research program with the desired school before formally requesting the assignment. The Army's branch managers recommend that any officer requesting attendance at a specific ILC other than CGSOC submit a personal statement on why the officer would like to attend that ILC. They also recommend that the letter emphasize how attending this school better supports the requestor's career goals and how the requestor can benefit the ILC. If officers are already working on some research and would like to continue it, they should coordinate this with the desired school. If they are not working on any current research, they should still coordinate with the desired school in order to determine a potential research program. The results of this coordination should be emphasized in the personal letter sent to the branch manager.

Conclusion

In conclusion, the purpose of this article was twofold: first, to share some of the rewarding research experiences I have had at the CNCS; second, to make officers attending intermediate level education, regardless of the service school or the location (this will not be Fort Leavenworth for Army officers who are not in the Operations career field), aware of the research opportunities that are available. With some coordination at the service ILC for a research program, officers can make significant contributions to the institution, to the service, and to their own professional development, all during a year in their military career when they probably did not expect.

Table 1. Curricula Analysis

TOPICS	Army	Navy	Marine Corps	Air Force
B. JOINT ORGANIZATION AND STAFF FUNCTIONS				
B1. Organization for national security (National Command Authorities, NSC, DoD, military departments)		M		
B2. Sister service organization				
B3. Joint staff organization (composition, authority, responsibilities)	M			
B4. Combatant commands (for example, missions, unified command plan relationships, command authority)				
B5. Roles of the joint staff officer (briefings, papers, staff studies)	X			M
C. JOINT PLANNING PROCESS				
C1. Joint Operation Planning and Execution System (JOPES)				
C2. Deliberate Planning process				
C3. Deliberate plans (for example, OPLAN, CONPLAN, functional plan, theater engagement plan)				
C4. Crisis Action Planning process (for example, initiation, concept development)				
D. FORCE PLANNING CONSIDERATIONS				
D6. Time Phased Force Deployment Data (TPFDD) refinement	M			M
E. MULTINATIONAL PLANNING AND OPERATIONS				
E1. Organization and command relationships				
G. JTF MISSIONS				
G1. Event flow during situation development (OPREP-3, Commander's Estimate, etc.)				
G2. Types of orders (Warning, Deployment, Execution, etc.)	M		M	
H. JTF ORGANIZATION				
H1. JTF Types	M	M	M	
H3. Functions of an Operations Planning Team (OPT) / Joint Planning Group (JPG)	M	M		M
J. JTF COMMAND RELATIONSHIPS (unity of command/unity of effort)				
J1. Authority	M(5)		M(5)	
J2. Command relationships [Combatant Command (COCOM), Operational Control (OPCON), Tactical Control (TACON)]		M(1)	M(1)	
J3. Liaison officers and their responsibilities	X	X	M	M
L. JTF STAFF SPECIFIC RESPONSIBILITES AND CHALLENGES				
L5. Interagency coordination, host nation and multinational coordination				M

X: No Coverage **M: Marginal coverage** **Boldface: Confirmed by graduates**
(number): reflects the ranking of this area if in the top five

Why the World Needs America's Service Academies

BG (Retired) Chris Arney, College of Saint Rose, Albany, NY[1]

In my opinion, the math departments of the Service Academies and their brother and sister departments fall into the category of national or world-wide treasures. That is a very bold statement, so I better have some good reasons to back it up. First off, the United States for some time now, has been an important player on the world's stage in terms of nearly every perspective one could take –– economically, politically, militarily, culturally, and morally to name a few. But, I believe, most importantly, the United States undergraduate education system is the centerpiece of its role in the world. We now live in an age, when the vast majority of Americans go to college, and almost all, during their younger days, expect to go on to higher education and change the world. Why is this so -- because college education paves the way for success no matter how you measure it and it really is the way to change the world. I happen to think that our nation's only nationally supported undergraduate schools (the five Service Academies) have an obligation to set the standards in teaching and learning and set the tone for our entire nation's undergraduate program.

On the world stage, we have come to realize that education is the only way for us to make any inroads in terms of peace and prosperity for all people. So the entire world (including the previously called 3rd world) is embracing advanced, college-level education for its citizens. And the world is looking at our country for help and guidance on how to do this. There is little dispute that we have the world's best undergraduate colleges and universities, even if our elementary and high schools are sometimes criticized. Therefore, the influence of the Service Academies through our nation's undergraduate education system is world wide and critical at this time of great need.

While some could argue that this influence may be real in the areas of technical and military schooling, since the academies are generally technically oriented, their influence doesn't extend into the liberal arts and social service schools of the country. I believe this argument is wrong. First of all, the service academies are as much liberal arts as technical. All the programs at the academies can and do influence national standards and the academic culture. Faculty members at other schools notice how the Service Academies teach English and language as well as math and physics. Did you ever notice how many more people attend conference sessions where Service Academy faculty present and how they listen and ask questions? There is real national level outreach and influence in all areas of academics –- curriculum, pedagogy, values, faculty professional development, standards, faculty, and research.

Historically, we know of the tremendous effect West Point had in the early and middle 19th century as the nation's first engineering and science school. For over 50 years, it was the nation's primary source of math,

[1] Chris Arney currently serves at a liberal arts college that looks to the Service Academies for help and guidance in establishing good math & science programs for future school teachers of these important subjects.

engineering, and science faculty, textbooks, and curricula for dozens if not hundreds of academic programs. West Point graduates literally set in place the national undergraduate teaching culture. We have US postage stamps honoring Thayer, Partridge, and other Service Academy graduates for their role in establishing quality programs and catching us up with Europe. The other Service Academies did the same as they began their own influence across the nation. Jefferson bestowed this responsibility on West Point because our country needed this leadership and all the Presidents (along with our congresses and citizenry) ever since have expected this leadership and service from all the Service Academies. The influence of the Service Academies goes way beyond the military forces they serve; they reach into every neighborhood of the United States, and because of America's influence, into every country of the world. Why else would there be dozens of academies in China modeled after our Service Academies, teaching dynamical systems and asking cadets to recite at the boards –- because they notice, follow, and want to succeed.

America's Service Academies have tremendous resources (best facilities, faculty, and students) and tremendous potential for influence and leadership. With such assets comes tremendous responsibility. The world needs America's Service Academies to do a good job and be successful leaders in order to help give us hope for peace and prosperity. So I speak on behalf of all citizens of the world, when I say "Good Luck!"

Movie Madness: Improving Conceptual Learning in the Classroom

CPT Bart D. Stewart, USMA,
Department of Mathematical Sciences

With the advent of technological advances, not only are the rigors of "chalk and blackboard" drills continuing to fade, but classroom learning environments are also changing. Much more than number crunching, mathematical science programs are shifting, or should be, to produce creative thinkers who can relate mathematical theory and practice to real-world applications. In the battle to educate today's student accordingly, motion pictures can serve as force multipliers!

Motion pictures tap our imagination, and our imagination helps to make abstract concepts clear. Concepts, when grasped, promote creative and critical thinkers. Hence, incorporating motion pictures in to the classroom appears to be a good idea. It is a good idea for many reasons, to include, affecting classroom atmosphere, sparking our imagination, and presenting math's applicability to real-world phenomena.

Whether students come with few or several tools in their mathematical toolbox, nearly all experience some sort of math anxiety within the classroom. Math alone isn't always the trigger though. Unfamiliar terms, such as, eigenvalues, eigenvectors, related rates, work, hydrostatic force, or forced harmonic motion, can quickly unsettle a student. In the end, math anxiety can quickly erode the classroom learning environment.

Despite the presence or absence of any math anxiety, the challenges of teaching the mathematical sciences are not easy ones. Unfortunately to some, concepts remain ambiguous and the math cryptic. Our imagination, however, helps us to make sense of the ambiguous. In fact, “imagination is more important than knowledge, for knowledge is limited whereas imagination embraces the entire world….”[5] Consequently, igniting students’ imagination should come first and foremost, and then the expectation that the mathematical knowledge will follow may not be too far fetched.

In an effort to reduce math anxiety and present more than what may appear to simply be arbitrary concepts, I fire-up my students’ imagination by using motion pictures as my tool. Students’ relate well to them, and their familiarity with them reduces their anxiety and opens their minds. With their minds open, and hopefully confidence up, my students prepare an in-class essay tying a key concept to a motion picture of their choice, and occasionally, a mathematical solution follows. Hence, the concept of imagination followed by knowledge may work.

Here are few abbreviated examples of the students’ essays without the supporting math:

In Star Wars: The Phantom Menace, one character sabotages another’s pod racer, and it forced the damaged pod to “wobble” – or become unstable to some degree. If we were to model it, and change coefficients in the model after the repair, our model would generate an eigenvalue where stable equilibrium occurs.

[5] Albert Einstein. “Ideas and Opinions” Crown Publishers. New York, 1954.

In Outbreak, a diseased monkey is illegally brought in to the U.S. It infects one person, and then another. The disease is highly contagious, and it spreads exponentially. When the military predicts its growth rate, it resembles a population growth model.

In the movies, The Matrix, Mission Impossible II, Top Gun, and The Princess Bride, the concept of work is illustrated through various lifting problems. In the Matrix, one character lifts another up the side of a large building. In Mission Impossible, the thief needed the appropriate equipment that would lift him and the weight of the cable out of a secure area. Top Gun offers the same example with a helicopter rescuing pilots floating adrift in the sea. And in the Princess Bride, the problem was a bit more difficult, but simplifying the model made it possible to calculate the work done to climb the Wall of Insanity.

In Star Trek IV, the earth needed to respond to an alien vessel searching for humpback whales. They were extinct. In an effort to save the planet, an engineer had to manufacture a “whale tank” within their spaceship that could withstand time travel. To do so, the engineer had to properly calculate the hydrostatic force of the tank to ensure a safe return of the whales.

In Crossroads, the characters sought off on a cross-country trip. Up until now I thought the movie had little to no value, but it illustrated the difference between distance and displacement.

Admittedly, motion pictures aren’t the save all. But they do help reveal the significance and applicability of the mathematics we teach. In closing, motion pictures, or any popular culture for that matter, can be a value-added option to enhance the classroom learning environment. In fact, the Mathematical Association of America (MAA) recognizes the importance of adding popular culture within the classroom (Mathfest 2002). Perhaps it is time that we all consider incorporating some popular culture in to our own classrooms as well?

Some Simple Math in the Analysis of Orbits

Dr. Deborah C. Arangno, USAFA,
Department of Mathematical Sciences

After half a semester of the theory of Differential Equations and Linear Algebra, it was difficult convincing my students of the utility of the concepts and methods they'd mastered. I reassured them of the relevance to so many pressing and practical problems. But it was my reference specifically to my work on Strategic Defense programs, (both at NORAD with the Directorate of Astrodynamics and on the so-called "Star Wars" program), that interested them most. I realized this was a wonderful opportunity to help them appreciate the power and relevance of mathematics. So I presented to them as a project a real-world application: that of the three-body problem in formulating the effects of solar and lunar perturbations on artificial earth satellites.

First, as way of motivation, I discussed with them the objectives of a space-based missile defense system, and then explained the basic principles of orbital analysis; such as they would study in an elementary Celestial Mechanics course. I also explained the various perturbative forces, which cause satellites to accelerate out of its intended (or predicted) orbit, including forces which arise from Earth harmonics, atmospheric drag, solar radiation and the gravitational attraction of other celestial bodies. I convinced them how essential it is, for the accurate prediction of a satellite's orbit to apprehend the magnitude of the effect of all such perturbations. I explained that analysis of an orbit incorporating these forces involved high-order differential equations.

Their assignment was to understand the perturbative effects of the sun and the moon on three specific orbit types: A) the *deep-space satellites*, such as probes (which at their farthest distance from earth – apogee - may be five or six earth radii, or more); B) the *½ -day highly-eccentric*, such as reconnaissance satellites, having perigee as low as 300 km; and C) the circular *one-day synchronous*, which is the most versatile and multi-functional band of orbits, for commercial, scientific and military use, such as communications satellites, Manned space stations, electronic intelligence, early warning, navigation, meteorology, et al. [See Figure 1 below.]

For simplicity, I asked them to ignore the non-homogeneity of the earth (gravitational potential variations, et al), as well as atmospheric drag, and to treat the sun, moon, earth and satellite as point masses in a conservative field. This would permit us to use Newton's Second Law to write a simplistic model of the motion of a satellite. I also asked them to develop a computer program to facilitate a thorough testing of their analysis over a range of orbital characteristics.

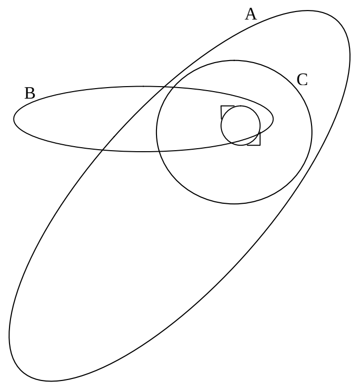

Figure 1: Three different orbit types.

Additionally, I provided an explanation how the sensor was hypothetically employed to track the satellite in the problem (whether Baker-Nunn camera, phased-array, mechanical, etc.) would acquire measurements of the satellite's *range(ρ)*, *azimuth (A)*, *elevation (h)*, *range rate*, *azimuth rate*, and *elevation rate*, (see Figure 2 below). This set of measurements is known as an "observation".

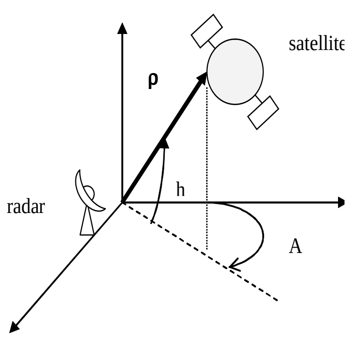

Figure 2: Physical orientation of the satellite in space.

From this data, the students were expected to calculate the position and velocity vectors, and transform the calculations into the set of classical Keplerian elements $\{a,e,i,\omega,\omega,\theta\}$. (See Figure 3).

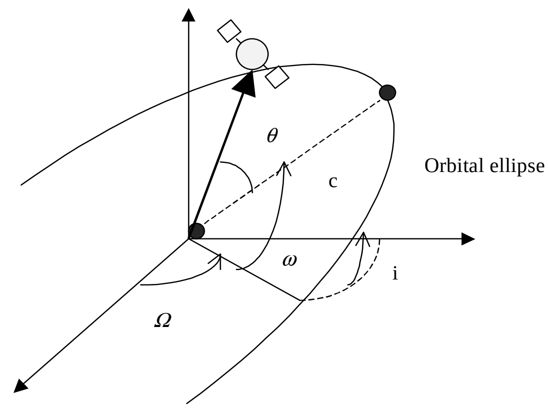

Figure 3: Position and velocity vectors for the satellite in orbit.

Where:

a = semi-major axis (not shown)
e = eccentricity of orbit (not shown)
i = angle of inclination (with respect to the plane of the earth's equator)
Ω = longitude of node (measured from Aries)
ω = argument of perigee
θ = true anomaly
[c = perigee]

From that element set, the students understood they could describe the orbit of the satellite, called the "initial orbit determination", by computing the state vector for position and velocity. But perturbative forces alter the actual orbit from that which they initially predicted from the state vector obtained from the orbital elements. Therefore the students' second task was to apply Newton's Second Law to the four body problem illustrated below, and formulate the satellite's motion.

simulation and appreciate the use of mathematics in the very important area of space defense systems.

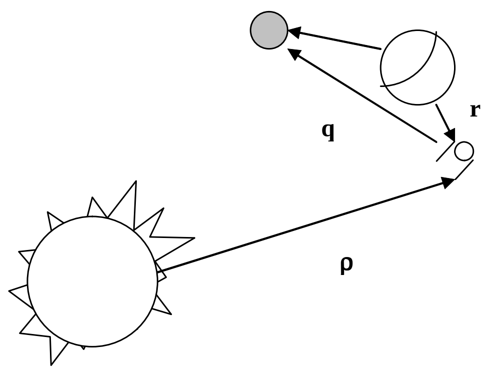

Figure 4: Four body diagram.

The initial coordinate system was taken to be the *helio-centric ecliptic*, which is the most-nearly inertial. This obtains the (overly simplified) principle equation

$$M_{sat}\rho'' = \sum F_{sat} \ .$$

Which becomes

$$\rho'' = \frac{-\mu_{Sun}\rho}{\rho^3} - \frac{\mu_{Earth} r}{r^3} - \frac{\mu_{Moon} q}{q^3} ,$$

where μ_{Sun} , μ_{Earth} and μ_{Moon} are the gravitational constants of the sun, earth, and moon, respectively.

But it was when the students successfully transformed the coordinate system, from helio-centric to geocentric, by means of rotation through the angle of obliquity, making extensive use of matrix transformations, that they recognized a real and practical use for their linear algebra skills. And they observed the power and relevance of the tools they had studied.

In the final analysis, the students obtained a very satisfactory model, which allowed them to build a small-scale