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EDITOR'S NOTES

Mathematical modeling is highlighted in this issue. This is a natural area of interest for many of the students and faculty members at the service academies given the applied nature of the mathematics departments. Over the last decade, there have been tremendous strides in the interest and teaching of mathematical modeling throughout the undergraduate curriculum. The service academies have helped lead the way in this area. Please enjoy reading more about mathematical modeling in the columns throughout this issue.

With this issue, Mathematica Militaris has entered the 20th century. We have used desk-top publishing in the form of Aldus Pagemaker™ to produce this issue. We are not experts yet, but, hopefully, this technology makes for a more aesthetic and readable Mathematica Militaris.

With this issue, we bid farewell to our managing editor, MAJ **Mark Wroth**. His new duty station is Fort Sill, Oklahoma. CPT **Dave Olwell** becomes the new managing editor. We also welcome Professor **Peter McCoy**, who replaces Professor **William Withers** as the USNA Associate Editor, and Dr. **Joseph Wolcin**, who is taking over from LT **Tim Henry** at the USCGA.

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ARMY

The Mathematical Modeling Course at USMA has an enrollment of 425 cadets per year. The course director this year was Major **Mark Wroth**, and the instructors were Major **Jack Kloeber**, Major **Mike Bumbulsky**, and Captain **Chuck Clark**. What follows is their description of their course.

Mathematical modeling is the process of constructing mathematical representations of some phenomenon. As such, it underlies almost the entire "math-science-engineering" field. Cadets enrolled in MA391, the Military Academy's course in mathematical modeling, are given the chance to see this process in action in examples ranging from the nuclear arms race to predicting the weight of a fish.

Along the way, they also create their own models in open-ended Special Problems that allow them to apply the techniques they are studying in class and challenge them to solve a problem based in real data. These special problems cover topics in modeling with proportionality, model fitting, empirical modeling, and computer simulation, giving an overall perspective of some of the major techniques used in modeling. They are also many cadets first experience with problems where defining the question is part of the problem. Predictably, this causes some anguish in the cadets.

One of the unusual feature of the special problem requirements is that they require the cadets to write about the

problem and their solution. While this sound like a common practice, for most cadets enrolled in the course the special problems are the first time they have ever attempted to combine the skills in writing they have gained in English course with the analytical skills they are attempting to master in a math course.

Based on the critiques conducted at the end of the course, this approach is quite successful in integrating the course material for the cadets, which is a useful side effect. As the special problems progress in difficulty over the course of the semester, this increasing mastery of the material parallels an increased ability to attack problems with a variety of tools.

The current year has been a challenging one for the faculty, as the student population has more than doubled, with the majority of the increase being cadets who are taking the course as part of the required engineering sequence. This commonly means that their mathematics skills are not their strongest area. This is both challenging and rewarding to the instructors, as some students discover for the first time that mathematics can actually apply to the "real world."

NAVY

The course in mathematical modeling at the U.S. Naval Academy was developed by **Professor Thomas J. Sanders** and **LCDR Fred Lynn**. It was first taught during the fall semester of 1985. The prerequisites for the course include algebra, probability and statistics, calculus, differential equations, and computer programming. It is an upper level course, being taken by first and second class midshipmen. Students who take the course generally state that it is one of the most useful and enjoyable courses they have taken.

The course consists of a sequence of 4 to 6 "real world" problems that the midshipmen model and solve, while working as part of a 2 or 3 person team. Teams are required to either write a formal technical report on the problem and its solution, or to give a non-technical oral briefing on the problem.

Problems that have been used include the economics of towing icebergs, an optimal launch range problem involving a naval platform and attacking aircraft, and a "data poor" problem on population growth. The problems are selected so that the teams should be able to attack a problem with the mathematics they have learned previously, but their statement is not in the context of mathematics just learned.

AIR FORCE

The Air Force Academy offers several applications oriented mathematics courses. Math 310, Mathematical Modeling is an introductory course in mathematical modeling intended for basic sciences, engineering and space science majors. Course grade is weighted heavily on student team projects which require creative solutions to Air Force oriented problems. Math 359, Design and Analysis of Experiments is an introduction to the philosophy of experimentation and the study of statistical design. OR 495, Operations Research Problems is for technical majors who want to apply operations research solution techniques to real world problems. Math and OR majors work together in teams to solve four real world problems.

Additionally, all AF Academy math majors take either a Math 495 (special topics) or Math 499 (independent study). These courses for first and second degree cadets vary from semester to semester. The Math 495 offering for Spring 1991 is Applied Reliability. This course will cover concepts used both in the AF and industry. Examples will include estimation of mean time to failure, component reliability, system reliability, reliability confidence intervals, and hypothesis tests on reliability. The course will also cover state-of-the-art techniques and the Air Force Reliability Program.

COAST GUARD

The mathematical modeling course at CGA is a 3 credit hour elective course for mathematics majors. The catalogue of courses describes the course like this:

> "First course in the development of mathematical models with application to social science, life science, engineering, physical science and management. Emphasis on problem definition, creative mathematical formulation, identification of assumptions, and model validation. "

The objectives of this course have been satisfied using several different teaching approaches. One approach was to use of the MAA TEAM case study modules. These case studies provide students with the necessary background information about some industry related applied mathematics problem. The students, over a period of three or four weeks, must then use their reasoning, writing and mathematical abilities to construct and present a solution to the problem. Another approach which is being used for the course being taught during the spring 1990 semester is a class project. The students are investigating the wind drift or leeway drift problem. This problem is defined as follows:

> "Given the location of a disabled boat, or liferaft along with present environmental conditions determine how drift of the craft will be affected by the wind."

This problem is of great interest to the Coast Guard. There is currently a significant effort being made to improve the Computer Aided Search Planning (CASP) program and wind drift is one component of this search planning process. The students are reviewing current search and rescue doctrine along with several prior studies which have been conducted on the wind drift problem. The goal of the class is to develop a mathematical model which provides good wind drift predictions in real time. As the cadets work towards this goal all facets of the modeling process are being addressed.

WHO'S WHO

Lt Col **Steve Schmidt** is Director of Research, Tenure Associate Professor, in the Department of Mathematical Sciences at the USAF Academy. He received his BS in Mathematics from the USAF Academy. His MS in Operations Research is from the University of Texas. He earned his PhD in Applied Statistics from the University of Northern Colorado.

He has served as an instructor pilot in T-37s,and as a B-52D aircraft commander, flight commander and instructor pilot. He served his first tour at the Academy as an Assistant Professor from 1980 to 1982. His second tour began in 1984.

His background includes extensive instructional and consulting experience for academia, industry and government, primarily in design of experiments and Taguchi methods. He has presented his management overview and short course in experimentation to over 3000 managers, engineers and university students from over 100 international companies, government agencies and universities. He has published numerous papers and is the co-author of *Understanding Industrial Design Experiments*, 2nd Edition 1989. This is a unique book which blends the Taguchi and classical approaches to experimentation.

NAVY

Visiting Research Professor **Daniel H. Wagner** joined the USNA Mathematics Department August 1989. He received a Ph. d. in group theory from Brown University in 1951 after a B.S. from Haverford College. His subsequent career has been operations research. He was with the CNO Operations Evaluation Group 1951-56; his field assignments included Korean duty afloat. After a consulting partnership, Kettelle and Wagner, 1958-63, he founded Daniel H. Wagner, Associates and was its CEO 23 years. This firm was staffed mostly with Ph.d. Mathematicians and served primarily naval clientele, including numerous on-site Fleet field assignments.

As an adjunct professor in OR at the Naval Post Graduate School, 1988-89, he authored a text, "Naval Tactical Decision Aids." At the USNA he has organized a team of midshipmen doing senior projects and faculty advisors to develop a tacaid to do target motion analysis at short range, for Commander Submarine Development Squadron Twelve. He also chairs a committee to prepare a successor text to "Naval Operations Analysis." In 1987, Professor Wagner was commended by the Chief of Naval Operations for over 35 years of contributions to naval warfare analysis.

He as served on the Council of the American Mathematical Society and the Board of Directors of the Military Operations Research Society. He has published in group theory, optimization, measure theory, reliability, and OR practice. He gave a survey on measurable selections at Oberwolfach. His appointment at USNA is sponsored by the Tactical Development and Evaluation Program of CNO (OP-73).

COAST GUARD

LT **Mark B. Case,** USCGA Class of '79, has been teaching in the Mathematics Department at the academy since 1984. He was originally a member of the rotating military faculty, but in 1988 was selected to the Permanent Commissioned Teaching Staff (PCTS). As a PCTS member, he provides continuity between the professional and academic programs.

LT Case received his M.S. degree in Operations Research and Statistics in 1984 from Rensselaer Polytechnic Institute. He is currently working on his Ph.D. in Applied Mathematics at the University of Rhode Island.

Before coming to the academy, LT Case served as Operations Officer aboard the buoy tender USCGC Sassafras, Governor's Island, N.Y., and as Commanding Officer of patrol boat USCGC Point Francis, Sandy Hook, N.J.

LT Case is a volunteer women's softball coach at the academy, and he enjoys participating in both softball and basketball (he recently led the Math Dept. intramural basketball team to its second straight title).

ARMY

COL **Frank Giordano,** Head of the Department of Mathematical Sciences, has been instrumental in the implementation of mathematical modeling in the USMA curriculum. He helped design and teach the first course in mathematical modeling at USMA in 1978. Under COL Giordano's guidance, modeling concepts have been introduced in many of the other applied mathematics courses offered at USMA. He and **Maurice Weir** of the Naval Postgraduate School wrote the textbook *A First Course In Mathematical Modeling,* published in 1985. The same authors will have the text *A First Course in Differential Equations with Mathematical Modeling* published this year.

COL Giordano has been an advocate for mathematical modeling in the national mathematics community as well. He has given many presentations and mini-courses on mathematical modeling throughout the nation. He serves as a grader and member of the advisory board for the Mathematical Competition in Modeling. He also serves on the National Council for COMAP which is very active in the issues and programs involving mathematical modeling.

RESEARCH NOTES

NAVY

Professor **John C. Turner** has been actively involved in several research projects at David Taylor Research Center, Annapolis. One current project involves modelling the effect of using non-MILSPEC fuels in Navy engines. The current work centers on the effect t of the performance of diesel engines. Later stages will address endurance of diesels, as well as performance and endurance for other power plants, such as gas turbines and boilers. Various fuel properties are altered from the current standard and the performance of engines using this fuel is measured. The change in performance is then modeled as a function of the change in fuel property.

The second current project involves classified work in electromagnetic signature reduction. This is a joint US-UK project. Different aspects of electromagnetic signature are modelled as a function of shipboard parameters. This has involved both sea trials, as well as scale model experiments.

COAST GUARD

Professor **Janet McLeavey** of the USCGA is currently doing research on dynamite fishing and its effects in the Philippines and other third world nations. Her research involves modeling repopulated blast site ares. The model should give an indication as to how many species have reentered an area at a point of dynamic equilibrium. It is important to determine such parameters as rate of immigration and extinction of species. The usefulness of queueing theory is being investigated and compared to other models.

Professor McLeavey is also working on a lower bounding procedure for determining optimal configuration for certain classes of reliability systems with stand-by redundancy. This procedure can be used alone as a heuristic which will usually obtain the optimal. However, when combined as an initialization procedure with other search methods, it will always achieve the optimum as well as significantly reduce the number of nodes evaluated by the search routine.

AIR FORCE

At USAFA, six DFMS professors and 21 cadets are engaged in testing and validation of the State Department's Interagency Working Group (IWG) AIDS model. The model (developed by Los Alamos) is a set of over 100 first -order differential equations that describe the rates at which various population groups mix. To examine the sensitivity of the model forecasts to inaccurate input data, DFMS scientists developed a computer program that generates Hadamard matrices up to dimension 200x200. The matrices are used in Plackett-Burman designs that minimize the number of computer runs necessary to find the first-order gradient of the response surface. This allows the variables driving the epidemic to be ranked in order of importance. Results of the sensitivity analysis have been published in the United Nations Proceedings for December 1989. The model was installed in Uganda in February 1990 and is being used by 23 government agencies to analyze the spread of the AIDS epidemic.

ARMY

The Department is actively involved in research and consulting in a very broad spectrum of subjects. The Department is very proud that a member of the rotating faculty, Major **Kevin Beam**, was recently awarded his Ph.d. in Operations Research from Rensselear Polytechnic Institute with the completion of dissertation work involving multivariate distributions. The research work of the

tenured faculty includes time-series, sequences and tiling, chaos theory, acoustics, and economic forcasting.

Several members of the department are performing consulting work coordinated through the USMA Science Research Laboratory and the USMA Operations Research Cell. A primary initiative is work on simulation models which will allow the Army to determine the impact of proposed personnel changes on the inventory of officers.

Four officers in the Department spent the previous summer at the Los Alamos National Laboratory. Their investigations there involved neural-like networks, modeling of strategic targets, vulnerability and risk assesment, and conventional munitions management modeling.

Majors **Thomas Pijor** and **Mark Wroth** spent the summer guiding the work of four cadets involved with the Voluntary Summer Training Program. They worked on the Minefield Attrition, Delay, and Mobility Model, a sub-module of the Vector-in-Command Model (VIC) which is the Army's primary low-resolution model.

The Department places great emphasis on the importance of research activities for all rotating faculty during their normal three-year tour. Recently, summer research fellowships were established so that all the rotating faculty will be able to apply their skills to solving Army problems.

NOTED

USAFA

Congratulations to C1C **Frickenstein**, C2C **Bishop** and C2C **Levine** who received perfect 4.0 GPA's in the fall semester. Also, special thanks to our competitors who volunteered a Saturday to take the National Putnam Math Exam. Welcome back to C1C **Dennis** from the French Academy Exchange Program.

Our annual spring Pi Mu Epsilon membership drive is well under way. Pi Mu Epsilon is the national honorary society created for undergraduates in mathematics. Juniors and seniors with a math and cum GPA of 3.0 (or higher) are eligible to join. Faculty members interested in supporting the goals of Pi Mu Epsilon may also apply for membership.

Approaching events include the spring math major's dinner and the math department golf tournament. The math major's dinner is an opportunity for our math family to mix in a fun, informal atmosphere and benefits both the faculty and students. The spring golf tournament includes novel prizes and a special "math rules" format that allows even no-skill players to compete.

USCGA

A faculty seminar in "Hypothesis Testing/ Signal Detection" was recently conducted in the Mathematics Dept. by Dr. **Joseph J. Wolcin**. Attendees were from the Math Dept., the Electrical Engineering Dept. and the Coast Guard Research and Development Center. The seminar covered classical, sequential, and robust methods, and examined several real world problems in order to illustrate the application of the techniques.

Dr. **Ernest Manfred** offered a workshop for public school teachers on "Chaos and Dynamical Systems". The workshop was made possible by a government grant to the Thames Science Center. Dr. Manfred also incorporated this same topic into the course Advanced Engineering Mathematics.

The Math Department has been selected by the CUPM Subcommittee on **Calculus Reform and the First Two Years** to contribute its computer projects to a book to be soon published (funded by the National Science Foundation and the Mathematics Association of America).

The department entered a team in the national Math Modeling Competition in February. The team consisted of Cadet 1/c **Robert Quinn**, 1/c **Matthew McDonald** and 1/c **Christopher Hayes**. The faculty advisor was Dr. Ernest Manfred.

USNA

The Department has been holding a weekly applied mathematics seminar since the fall semester of 1988. One of the goals of this seminar has been to acquaint the faculty at the USNA with the ongoing activities in mathematics in the Greater Baltimore - Washington area. To this end, many of the invited speakers have been from the academic institutions and the government laboratories in the metropolitan area. In addition, each year about half a dozen prominent applied mathematicians from across the country and abroad have been invited to speak about some of the most recent developments in their fields. The emphasis of the talks has been in the areas of differential equations and modelling, scientific computation on parallel processors, bifurcation theory, and operations research. A special effort is made to make some of the talks understandable to the more advanced Midshipmen in hope of introducing the students to the elements of research.

This seminar is organized by Assoc. Prof. **R. Melek-Madani** of the Mathematics Department in collaboration with Assoc. Prof. **Peter R. Turner**, Asst. Professors **John F. Pierce** and **Sonia Garcia**, and Asst. Prof. **Gabriel Karpouzian** of the Aerospace Department. The seminar is funded by a grant from the Faculty Development Fund of the USNA.

Professor **Stucker** has an interesting way of starting his topology course. His students separate into pairs and play tic-tac-toe on a torus by using a 3X3 square and identifying the edges. Although the screens are flat, the playing board of many video games are not planes but in fact cylinders (Pac Man) or tori (Asteroids). After the students play the game each pair is asked to analyze it topologically and strategically.

This form of tic-tac-toe had many interesting differences from the original version. All the first moves are equivalent in this version since any square can be viewed as the center square. Topologically, there are only two distinct responses for the second player, but surprisingly they both lead to equivalent games. Hence, the first two moves do not affect the game at all. It is interesting to watch students who have not initially realized this fact carefully planing their first two moves. Furthermore, the first player has a winning strategy, and unlike the original, this game cannot possibly be played to a draw. The students enjoy this opportunity to apply topology in a game situation.

This problem comes to us courtesy of Professor **Gaglione**, USNA.

Find the units digit in the decimal expansion of

$$(15 + 220)^{19} + (15 + 220)^{82}.$$

No calculators or computers allowed!

Best answer will be printed next issue!

SUBSCRIPTIONS

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USMA CRAFTY ABSTRACT

The CUPM Committee on the Reform of the First Two Years (CRAFTY) is publishing a book of abstracts of Calculus Reform Projects. We are printing a portion of the USMA CRAFTY Abstract as a service to our readers. We will reprint the other academies' abstracts as we receive them.

...We are this year abandoning our current core curriculum of two semesters of calculus, followed by a semester of ordinary differential equations and a semester of probability/statistics. We are moving this fall to a sequence of one semester of discrete dynamical systems, followed by two semesters of calculus with a 'lean and lively' focus, and capped by a semester of probability/statistics.

All our cadets who enter after this summer will take the new sequence. We will have approximately 20 faculty members teaching the sequence this fall, and that will increase to about 40 the second year. Our class size will be at most 18 cadets.

Each cadet purchases an IBM PC/386 compatible computer, as well as an HP-28S advanced scientific calculator. We support the hardware with a mandatory issue of Derive, Mathematics Plotting Package, Quattro, Minitab, and several local products.

For our Discrete Dynamical Systems text, we will use *Discrete Dynamical Systems*, by James Sandefur. For our two semesters of calculus, we will continue to use *Calculus, One and Several Variables*, by S.L. Salas et al. For our probability and statistics course, we will continue to use *Probability and Statistics for Engineering and the Sciences*, by Jay L. Devore....

...Discrete mathematics progressing from algebra to matrix algebra to discrete dynamical systems provides a logical transition from high school mathematics and can be used to preview the more difficult concepts (for example, the limit) that underlie continuous mathematics. The DDS course will have a heavy modeling emphasis to motivate both the study of solution techniques for difference equations and the eventual study of calculus. Concepts and techniques will be discussed for first order and nonlinear equations, and higher order equations. Instructors and students will use computer software to demonstrate and solve problems in both the matrix algebra and the discrete dynamical systems sections of the course. We also will instruct our cadets on the use of Derive and the HP28-S in this course.

Our second and third semesters will be Calculus I and II. Calculus I includes the differential and integral calculus through techniques of integration. Calculus II introduces differential equations; parametric equations; series and sequences; and the study of multivariable calculus including: 3-dimensional geometry and vectors, functions of two variables, partial derivatives, and multiple integrals. We rely heavily on computer software and advanced scientific calculators throughout the course to aid the student in computation.

Our final semester of the core curriculum is Probability and Statistics. Coverage includes descriptive statistics; basic probability concepts; discrete, continuous and joint random variables and their distributions; point and interval estimation; and hypothesis testing. Students complete written case studies to motivate concepts and to develop the ability to communicate quantitative results. Heavy use of computer capabilities for statistical analysis is required.

As a service to the other departments, we will offer several different fifth semester courses, tailored to different majors and fields of study. These courses have been developed in close cooperation with the other departments at USMA. We maintain permanent liaison officers with every other department.