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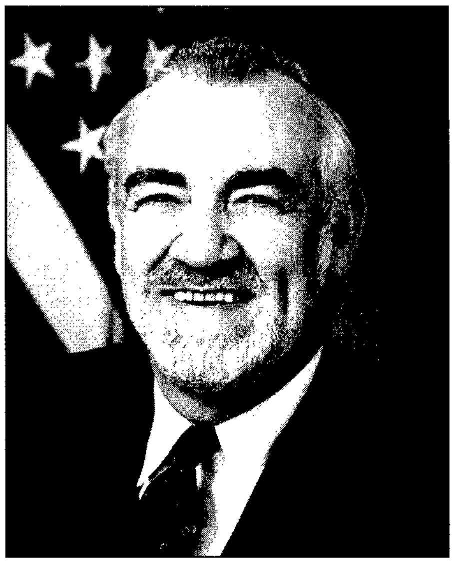
Military Operations Research and Army Force XXI Acquisition Objectives



The Honorable Gilbert F. Decker
Assistant Secretary of the Army
(Research, Development and Acquisition)

America's Army is decisively engaged in a process that aims to conceive, shape, test, and field a force prepared to meet the challenges of the next century. We call this process Force XXI, and military operations research has an essential role to play in equipping our future force. I challenge the operations research community to continue to use and develop techniques that allow us to equip the most capable force in the world far more efficiently than in the past.

Equipping this force is a tough challenge. Tough because our goal is nothing short of transforming an Army currently equipped, trained, and operating with Industrial Age technology into a force that takes full advantage of everything the Information Age offers. Tough also because money for weapon systems modernization is tight.

Our strategy in the near-term is to buy a limited number of new systems, while extending the lives, improving the performance, and adding new capabilities to our existing systems. But ultimately, the Army will reach the point where additional technological improvements to today's systems will provide only marginal benefits. The Army's Big Five heroes of Desert Storm — Apache, Black Hawk, Patriot, Abrams, and Bradley — were not developed, tested, procured, and fielded within four or five years. Each system required more than a decade of sustained investment to provide the battlefield capability we have today.

In short, today's modernization program is tomorrow's readiness. It is clear that we must invest now in new types of systems and capabilities for the Army of 2010 and beyond. But, given our constrained resources, how are we to accomplish our goal?

The Army is looking to all disciplines for tools to identify those technologies and systems that maximize the use of our scarce modernization dollars, and our operations research/systems analysts are key participants. It is clear the application of operations research techniques allows us to leverage designing, testing, and producing new equipment to put more capable systems in the hands of our soldiers.

We can no longer afford to design, prototype, redesign, test, redesign, retest and finally produce and field new equipment. We must quickly design, using computer assisted design and modeling; test, using simulation as an integral part of the testing process; and produce, using computer assisted manufacturing techniques, to reduce equipment costs. In fact, we must use Integrated Concept Teams to hypothesize candidate designs and simulate their performance during the requirements determination process. Only then, can we avoid overstatement or understatement of minimum, essential performance requirements.

While mathematical programming techniques and statistical analysis offer technical tools that have increasing applicability in our technology advancing environment, let me explore one area that offers almost unlimited potential. The current and evolving use of modeling and simulation techniques to reduce the time, resources, and risks of the acquisition process is crucial to our future success.

Modeling and simulation tools and processes have expanded rapidly. This is largely due to more powerful, less expensive computers combined with advances in modeling and simulation technology that make simulations more powerful and less expensive. Expanded use of modeling and simulation in the acquisition process allows us to find better, more efficient ways to field weapon systems.

In fact, the use of modeling and simulation has benefits in all areas of system acquisition. Using them in the design phase helps to rapidly evaluate concept designs and even address producibility and affordability issues. A goal in the system development process is to use simulations to reduce or eliminate physical prototypes.

(See **DECKER,** *p. 34)*

THE ISSUE TODAY

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MORS 1996-97 a Year for "Reestablishing the Foundations of Analysis"

Fred Hartman
MORS President

By the time you read this issue of *PHALANX* we will be into the holiday season, and our "MORS year" will be almost half over. We have made great progress in a number of areas this year, yet there is much to be done before the **65th MORSS** in June of 1997 in Quantico!!

Communications

In the September issue of ***PHALANX,*** I discussed your Board of Director's concerns that we achieve wider, more active participation from the membership at large. There is time for you to start making plans now for attendance, presentation and volunteer participation with the 65th MORSS on 10 - 12 June, 1997. The MORSS team is led by **Harry Thie**, our Program Chair who has put together an impressive group of hard working volunteers to prepare for and pull off a first class meeting. The names, phone numbers and e-mail addresses of the entire 65th Program Staff were included on page 19 of the September ***PHALANX***. The very timely and appropriate theme for next summer is "Analysis for Complex, Uncertain Times."

Our Vice President for Meeting Operations, **Kerry Kelley,** working with **Stuart Starr**, Committee Chairman for Special Meetings, has also provided us with a very rich set of topics for Workshops and Mini-Symposia for the next year. More will follow on each of these topics later, but back to communications.

The main sources of MORS' communication have, in the past, been largely through the written word and also, of course, our slate of special meetings and the annual symposium. During the last year we installed two excellent new editors for ***PHALANX*** and our journal ***Military Operations Research***, and their impact is now being felt. The ***PHALANX***, edited by **Julian Palmore** with a host of volunteers as Associate and Department Editors, authors/contributors and **Michael Cronin**, Editorial Assistant, has been turning out both professionally produced and very informative and readable products. No longer are we searching for articles to fill the allotted pages of ***PHALANX***; we are now trying to screen through a queue which contains good quality articles for publication. I will try to keep the word count down on my article to allow more of those good words to be included!! An excellent suggestion came to me following the last issue, that might offer a solution and bring us more into the electronic age. In September, Dr. Palmore indicated that "shorter is better" in the submission of your articles for publication. This is necessary for meeting our page limits, but on the downside, may impact on the quality and completeness of the author's work. Perhaps we could solve both these problems by providing a more condensed or even an executive summary version of the article in ***PHALANX*** with a more complete, detailed version on our MORS homepage. Let us know what you think of the idea. My congratulations to each of you who made the September issue such an outstanding, informative and thought provoking publication.

The journal, ***MOR***, should also have arrived in your mailboxes during the month of October. Congratulations to editor, **Greg Parnell,** also a past president, and his Associate Editors for producing such a quality publication! The Spring 1996 Volume includes a call for papers to be included in a special issue, "Military Operations Research Methods for Future R&D Concept Development." This topic fits well with our MORS theme for this year and should be an excellent forum for your ideas on getting the most "bang" in terms of potential operational benefit for our selection of the most promising concepts for future R&D spending.

By the way, if you have not visited the new MORS homepage at **http://www.msosa.mil.inter.net/mors/** you owe it to yourself to do so!! Our ad hoc Committee for Electronic Media is under the leadership of Secretary, **Joe Tatman** and chaired by CAPT **Lee Dick**. Congratulations to the Committee, MORS Staff and in particular to our new part time computer assistant, **Jason Watkins** for the hard work involved in upgrading the web page, and keeping it up to date. They are making great progress incorporating and improving our electronic communications for MORS. We are still exploring the concept of conducting one of our special meetings as a hybrid that includes an e-mail/internet-type "news group" of progressive comment on a given topic for say 30 days followed by a more standard workshop. Let us know your thoughts if you would like to lead or participate in the electronic workshop.

Special Meetings

Completed: October got off to a running start with an outstanding Mini-Symposium, *Quick Response Analysis Requirements and Methodologies (QRAM),* held at Booz, Allen & Hamiltion in Tyson's Corner, VA on 1-3 October. A big **thank you** to **Jackie Henningsen,** who served as the General Chair and also to **Bob Statz** and **Roy Rice** as co-chairs and **Doug Williams** as the technical chair. A very special vote of appreciation is also in order for the support of Booz Allen in hosting the meeting in their beautiful new Conference Center. Read Jackie's article in this issue of ***PHALANX,*** so you can get early feedback as the formal report/proceedings is being prepared for publication. Our keynote speaker, Mr. **Bill Lynn**, Director, Program Analysis and Evaluation, Office of the Secretary of Defense, traced the history of the impending Quadrennial Defense Review (QDR) from the earlier Bottom Up Review (BUR) process and is incidentally the responsible individual for the accomplishment of the QDR. The QDR is a very timely topic for MORS attention, and offers us the ability to provide near-term contribution in the form of analysis of real "operational" issues.

One of our MORS Fellows suggested that the real key to QRA is having the right

(See **MORS PRESIDENT** *p. 20)*

Spotlight on Society Services

Dr. **Stephen J. Balut**
MAS President

Elections are just around the corner, and we are doing our best to smooth out some bumps in the road. In addition, the MAS homepage is coming of age, our journal is more readily accessible, and we are upgrading the books in the "Topics" series.

Elections

In a few months, MAS will elect a new set of officers. **Tom Gulledge**, Chair of the Nominating Committee, is working with other members of his committee to put the final touches on the new slate of candidates for office. The slate was announced at the INFORMS meeting in Atlanta and will be posted on the MAS Bulletin Board. You will receive your ballots in the spring.

MAS Homepage

If you haven't already, please take a look at the MAS homepage. You'll find it at **http://www.ida.org/ida/organiz/card/mas-home.htm**. **Tom Frazier** of IDA has taken it over and is keeping it up to date. Click on the Meetings icon and you will find a complete list of MAS-sponsored sessions and papers scheduled for the San Diego meeting. Our Cluster Chair for that meeting, **Philipp Djang**, who did an outstanding job of coordinating MAS's contribution to the San Diego meeting, made the information available for publication on our homepage. Other new items under the Meetings icon include information on upcoming meetings of both INFORMS and MORS. By the time you read this, we hope to have our slate of candidates for office listed under the News icon, along with their position statements and credentials.

MOR an Affiliated Journal

The journal of MORS and MAS, *Military Operations Research*, has been designated an affiliated journal of INFORMS. What's more, it is now available at reduced subscription rates. You can order *MOR* when renewing your membership in INFORMS (see the reverse side of the membership renewal sheet). Through negotiations involving **Matt Goldberg**, MAS's Publications Committee Chair, and **Dick Wiles**, Executive Vice President of MORS, we are now able to offer MOR to MAS and INFORMS members at the reduced rate of $34 per year, rather than the regular rate of $40.

Topics in Operations Research Activities

I am pleased to announce that **Al Washburn** has produced a new edition of his book *Search and Detection.* This third edition is now being printed and should be available for purchase by the time you read this article. Al is the author of another book in the "Topics" series titled *Two-Person Zero-Sum Games.* This volume was updated and reprinted several months ago. After sales of the new volume commenced, Al learned that the disk he provided with the revised edition would not work under certain circumstances. Al provided a corrected version of the disk and the INFORMS Business Office sent copies of it to all who had purchased the new edition. If, by chance, you purchased this volume within the past few months, are having trouble with your disk, and were not contacted by INFORMS, please call. We'll send you a new disk.

PHALANX Mailing List

Several months ago, **Mary Magrogan**, INFORMS Director of Subdivision Services, discovered that some MAS members were not being mailed their copies of *PHALANX.* Her investigation revealed that the source of the problem had its genesis in activities associated with the merger of ORSA and TIMS. Those of you who were affected received a letter of acknowledgment and apology from Mary and me and were given complementary membership in MAS for the 1997 calendar year. INFORMS graciously picked up the tab for the added expense.

As you can see, your Society is working hard to provide you with the best services possible. Your participation in the leadership and management of MAS is encouraged and welcome. We have many places for you to fit in and take part. If you would like to take part, send me e-mail at sbalut@ida.org or contact any member of the Council. ✪

Military Operations Research Journal

Call for Papers – Special Issue On

Military Operations Research Methods for Future R&D Concept Evaluation

Interested authors should submit abstracts to the MORS office by 15 January 1997.

We are also seeking volunteers to serve as guest editors, associate editors, and referees for this special issue.

Please contact the MORS office if you are interested in authoring a paper or serving as an editor/referee for this special issie.

Sharing New Techniques and Approaches to Analysis

CDR **Dennis Baer**
Vice President for Professional Affairs

This year in MORS is promising to be both professionally challenging and rewarding. Our main purpose is to provide our membership with the opportunity to take advantage of sharing new techniques and approaches to analysis with our peers. The new MORS homepage will be the main tool to distribute information concerning the professional items in this society. Each of the four committee chairs listed below will provide a section on the homepage. Questions and suggestions can be directly provided to them via the internet.

Education Committee

Dr. **Yupo Chan** of AFIT is continuing the efforts from last year's Education Colloquium. This colloquium's afternoon discussion centered on the pros and cons of continuing education. To summarize, the colloquium felt there were many benefits of continuing education, but there was also considerable time and cost to administer and oversee continuing education. Everyone agreed that continuing education was needed — it was a matter of how much and in what form. We received feedback from the 64th MORSS attendees at the beginning of the symposium by asking three basic questions: (1) Would continuing education in OR be beneficial to you? (2) Are you interested in earning Continuing Education Units (CEUs) pursuant to a program of professional OR certification? and (3) Would your company/organization support OR Continuing Education? The conclusion from this sample poll is that the majority feels continuing education would both be beneficial to the individual and supported by their company or organization. The members feel that we should not go as far as setting up a certification program for continuing education. Education sessions in the Washington, D.C. area will begin at a later date and will be announced on the MORS homepage. The tutorials at the 65th MORSS will consist of three one hour tutorials on the same subject for continuing education needs.

Other areas the education committee will concentrate on this year include the 12th Education Colloquium, 65th MORSS Education Session, and the Junior/Senior mentor program. The 12th Education Colloquium will be held in the D.C. area in spring of 1997. We would like more participation this year from the various contractors, and government agencies like CNA and CAA. A panel discussion vice a recap of the last Education Colloquium will be the forum for the 65th MORSS Education Session. The topic of this panel discussion will be certifying analysts vice models. The Junior/Senior mentor program is still in the design stage. Recruitment of "first time" analysts is the goal of this program and will hope to eventually complement the Junior/Senior analyst session.

Heritage Committee

With the help of the Fellows, the history of Military Operations Research will be preserved via the normal paper archives and electronically on the homepage. A bibliography of these archives will eventually be maintained on the homepage. Any articles on Military Operations Research that should be archived, please contact the committee chair.

Prize Committee

The Prize Committee will be headed by Mr. **Jim Duff** this year. Mr. **Howard Whitley** and Mr. **Roy Rice** will co-chair the Rist and Barchi Prizes respectively. We greatly appreciate the several non-board members and advisory directors who have volunteered to read the papers this year. The winners will be announced at the 65th MORSS at Quantico. Selection criteria and description of each prize are given on our homepage.

Publications Committee

Besides this great publication, LTC **Jim Armstrong** will lead the entire publication's effort. This effort includes products resulting from: (1) our annual and special meetings, (2) publications produced in intervals, and (3) special publications. Summaries of our annual symposia and special meetings are published in a bound format. Items produced at scheduled or unscheduled intervals include this *PHALANX,* the *Military Operations Research* Journal, and the *MORS Analyst's Handbook* (soon to be renamed). Editors of these publications are listed below. *Military Modeling for Decisions* and the *Warfare Modeling* are a few examples of our special publications. Preview our new homepage for a description of each publications, how to order, and how to contact the editor.

The professional state of the society is in great hands, when run by those listed below. Please contribute to these efforts by providing suggestions and volunteer time to anyone listed below or the MORS office. Again, thanks to those Advisory Directors and non-board committee members who have shown commitment of their free time to help with the society. Visit our homepage (http://www.msosa.mil. inter. net/mors/) on a regular basis to stay in tune with the professional items of interest to the Military OR analyst.✪

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Modeling Joint Mobility Problems – Part I: Current State-of-the-Art

Dr. **Yupo Chan,** Air Force Institute of Technology
James L. Johnson, Office of the Secretary of Defense

Introduction

Since the Joint Requirement Oversight Council process was initiated in 1995, there has been a whole flurry of responses outlining analyses to support the process in the "New World Order." Mobility is one of such analyses. Over this past year, one has witnessed Workshops organized by MORS and outside MORS. An example is the workshop entitled "Developing a Framework for Joint Mobility Analysis" that took place this past fall. A white paper is being prepared to summarize the findings at this workshop. This article is a by-product referenced by the white paper and represents a more in depth look into the operations research analysis issues facing the mobility community today and in the future.

Background

In the "New World Order," there has been a lot of interest recently in revisiting the mobility needs in the defense community. The vision is to have global reach as our overseas presence has diminished due to base closures triggered by either geopolitical considerations or budget cuts. The problem is particularly cogent in the joint operating environment, not only between the services but also among coalition forces. In response to this, we have witnessed the Joint Requirements Oversight Council (JROC) process started in 1995. In this two-part paper, we wish to accomplish three goals. First, we would like to review briefly the existing knowledge base in modeling joint mobility problems—which is really transportation problems in general—facing the Department of Defense. Second, we wish to lay out the research agenda to further the art and sciences of transportation analyses. Finally, we lay out some future activities for the consideration of those in the mobility community. The first goal is accomplished by the Part-I paper below, with the second and third goals to be achieved by the Part-II paper in a subsequent issue.

Importance of Jointness

To motivate the need for transportation analyses, we would like to cite the *Braess' Paradox* (Catoni and Pallotino 1991) which is well known to transportation researchers. The following numerical example would show a mobility problem on a theater level. This is to be contrasted with strategic mobility which is concerned with pre-planning to put assets in place ready for a campaign. Suppose we have two separate and distinct objectives, one is catering to the needs of individual services, while the second is for the joint community. We call the former the *user-optimizing* objective and the latter *system-optimizing* objective.

Figure 1 shows that six units are to be moved from the origin 1 to the destination 2. There are two routes available for the movement. One on the left consisting of nodes 1-3-2 and the other one on the right consisting of 1-4-2. To fix ideas, we will resolve the user optimization problem by simulation, resulting in a *descriptive* model of how individual services may act if left to themselves. We will solve the problem of system optimization via mathematical programming, which represents a *prescriptive* solution to the problem, or how a centralized decision-maker may lay out as a grand plan.

Let us consider the first unit that wishes to move. The unit can take either the left path or the right path. Once the first unit has been deployed, however, the second unit would take whichever path that the first unit does not use, since it would save time to do so. For example, if the first unit goes via 1-3-2, the amount of time to reach the destination is exactly (10)(1)+(50+1), or 61 units of time. Should the second unit follow the same path, the travel time for the two units would jump to (10)(2)+(50+2), or a total of 72 units of travel time. On the other hand, if the second unit would go via the right path it would enjoy a faster travel time of only 61 units of time. This results in moving two units, each at 61 units of time. The third unit can now go either on the left or the right path at a travel time of 72 units. If we keep on doing this for the fourth, fifth and sixth units, one will find that three units will follow path 1-3-2 while the other three would go via 1-4-2. All of these units would experience a travel time of 83 units. We call this travel pattern an *equilibrium*, since any deviation from three units via the left path and the other three via the right path would be unstable, in that one of the "users" on the more congested path would find it easier or faster to go on the less congested route. This equilibrium-flow pattern has a total cost of 498, which is the result of multiplying 83 by 6.

Similarly, one can obtain the result of system optimization by inspection. Keeping in mind that the objective is to minimize the overall unit-minutes of travel cost. It can be shown that again we obtain three units of flow via 1-3-2 and the remaining three via 1-4-2. One can also check this answer by perturbation. Suppose 4 units go left and 2 go right. This yields (4)(94)+(2)(72)=520 unit-minutes (say), which is bigger than the existing 498 and hence not acceptable for a solution that seeks to minimize the overall unit-minutes of travel cost. Formally, one can formulate the system-optimizing problem in terms of a *quadratic program.* Here the system-optimizing model yields the same exact solution as the user-optimizing: the user optimum is also the system optimum. But the total travel costs in unit-minutes are different, 498 for system optimization compared with 552 for user optimization.

Now an engineering unit in the field suggests that the closure time from start (node 1) to finish (node 2) can possibly be shortened if we build a bridge from 3 to 4 (Figure 1). Upon completion of the bridge one of the three units that used to travel on the left path finds it advantageous to follow the path 1-3-4-2, utilizing the new bridge. Instead of 83 units of travel time, it can reach its destination in a mere 81 units of time. It would also lighten the traffic on the left path enough to allow users x_3 to reach the destination in 82 units of travel time. Meanwhile, those on the right path experience traffic congestion, causing the travel time to increase to 93 units. This poses an incentive for one of the three units travelling on the right path to switch to the path using the new bridge. One can verify that the end result, after the two switches in total, constitutes the new equilibrium. This consists of two units on each of the three paths, or $x_1 = x_2 = x_3 = 2$ with a travel time of 92 each. The new equilibrium has increased the travel time between origin to destination from 83 minutes to 92, or a total cost of 552. Instead of shortening the travel time, the new bridge prolongs everybody's travel time by 11%!

Even though the problem has been solved by simulation thus far, it can be shown that the same problem can be solved by optimization techniques. The model consists of a minimization objective-function and conservation-of-flow as well as non-negativity and integrality constraints (Catoni and Pallotino 1991). The solution $x_1^*=x_2^*=x_3^*=2$ and $f^*= 552$ confirms earlier (simulation) results. As suggested earlier, one can obtain the solution to the system-optimizing problem also by a quadratic-programming formulation, subject to the same constraints. System optimization yields the result of $x_1^* = x_3^* = 3$, with $x_2^* = 0$. In other words, the joint perspective—to be contrasted with the individual services—suggests that no such bridge be built, it leaves the travel times at 83 units and a total cost of 498.

This simple example shows that analyses can unveil counter-intuitive results. A seemingly good idea of building a bridge to speed up the movement results in more congestion for the users. It also shows the merits of joint operations, wherein a global viewpoint would prevent tragic mistakes from happening. Finally, we have illustrated the two main streams of operations research modeling, namely simulation vis-a-vis mathematical programming. This simple example also shows some very fundamental *transportation-modeling* techniques (Manheim 1979). The above example can be extended to a *dynamic* version (instead of its current static form), wherein the units stage at different times—one following another instead of close to simultaneously as implied by the example. It also illustrates the simplest of the *spatial gaming-models* (Chan - forthcoming), or war gaming in a spatial dimension, wherein the precise geographic location of a unit is accounted for. More involved examples can be constructed to show the *Cournot-Nash equilibrium* in a spatial context. Instead of competition among services or coalition forces, adversaries are now vying for dominance in the battlefield. While this simple case shows there exists an equilibrium, other cases can be constructed where the solution is unstable. More advanced studies of this class of problems shows that both user and system optimization can be analyzed in terms of *variational inequalities* (Miller et al. 1996), the general mathematical condition governing the existence of an equilibrium solution. We have already shown in the simple example above that the user-optimizing solution can be solved by both simulation and optimization techniques, both of which mimic the myopic decisions facing an individual unit at one point in time. Put in the framework of variational inequalities, the debate between simulators and optimizers may be tremendously toned down by recognizing this common basis between the two techniques as evidenced by optimizers built into current simulation computer programs. At the same time, the schism between mobility and combat models is greatly narrowed by way of spatial gaming.

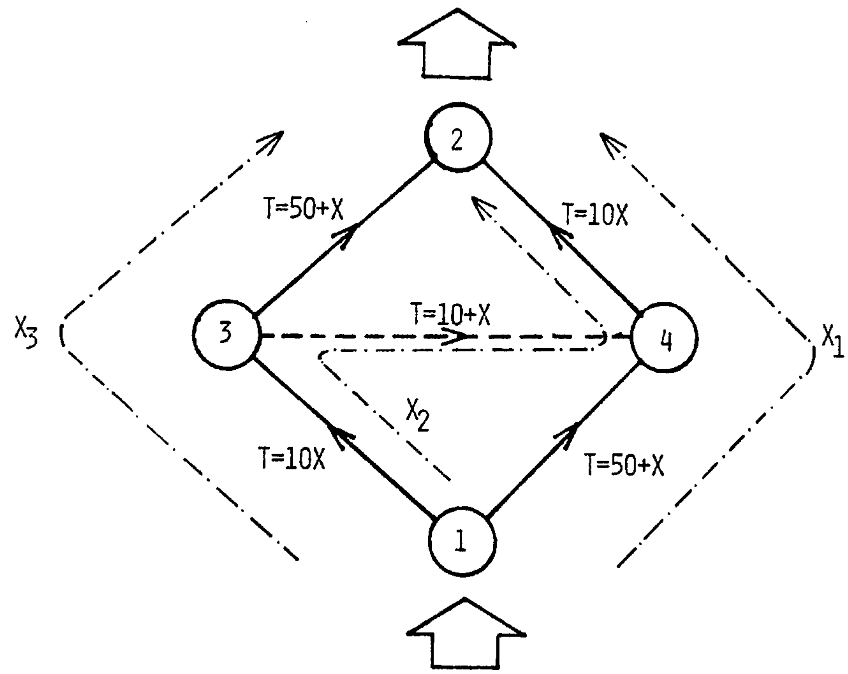

Figure 1: Network Flow

	Before	1-switch	2-switches
x_1	3(83)	2(82)	2(92)
x_2	0(-)	1(81)	2(92)
x_3	3(83)	3(93)	2(92)

Setting the Stage

Mobility requirements range today from relief missions to major regional conflicts, which can surface at a moment's notice. As mentioned, there is collaboration not only among services but among coalition forces as well. Because of the stochastic nature of such conflicts, we no longer have the luxury of *strategic* mobility where we can determine the timing of a campaign. Rather, we face *tactical* mobility issues such as the real-time determination of movement speed and resupply rates to contingencies around the globe, and to sustain our mission. We have already mentioned more than once that single-service mobility plans and operations are no longer sufficient. Coordinated services are the key. There are also requirements to consider mobility together with logistics and combat models. Inter-theater lift capacity has to be complemented with intra-theater deliveries. Instead of routine decisions, we need innovative ways to accommodate last-minute changes. Aside from *multi*-modal transportation systems there needs to be explicit consideration of *inter*-modal operations, defined as an end-to-end process that employs (say) airlift in one leg and sealift in another. Figure

(See **MOBILITY,** *p. 31)*

Complexity, Simulations, and Emergent Law

Dr. Joseph L. McCauley
University of Houston

Both deterministic chaos and maximum computational complexity have been discovered within low dimensional Newtonian dynamics. We examine the evidence that *new* dynamical laws of motion may emerge from empirical studies of complicated motions. Socio-economic "motions" are considered as well as a well-defined example from fluid mechanics.

Mathematical Laws of Motion

"Laws" of economics, "laws" of human behavior, and the Darwin-Wallace "laws" of fitness, competition, selection and adaptation are sometimes discussed in the same context as laws of motion of inanimate matter[1], although since the time of Galileo the word "law" in the first three cases does not have the same significance as in the case of physico-chemical phenomena. Confusion over what constitutes a law of nature is ancient: Aristotle invented a purely qualitative, holistic approach to the description of nature. Recognizing no distinction between the different uses of the idea of natural law, he lumped together as "motion" the rolling of a ball, the education of a boy, and the growth of an acorn[2]. Attempts to mathematize "motions" in Aristotle's sense are prevalent in our own age.

In the first chapter of his text on elementary economics, Samuelson tries to convince both the reader and himself that the difference between the socio-economic fields and the laws of physics is fuzzy, and that economics can be treated as if it would also be a science subject to mathematical law[3]. Samuelson argues that physics is not as lawful as it appears to be, that the laws of physics depend subjectively on one's point of view. His argument is based on a nonscientific example of ambiguity from the visual perception of art and is related through only a very slight academic mutation to a viewpoint that has been advanced by the postmodernist and deconstructionist movement in art, literature, philosophy, psychology, and sociology. Postmodernists and deconstructionists use "literary theory" to argue that a "text" has no more meaning than the symbols on a printed page, that there is no universal truth, and that there are therefore no universal laws of nature.

Samuelson notes that physics is based on controlled experiments, but asserts that in the socio-economic fields it is generally impossible to perform controlled experiments. We note that controlled experiments are also impossible in astronomy, where mathematical laws of nature have been verified with high decimal precision. I will argue that economic and other social phenomena lie beyond the bounds of understanding from the standpoint of dynamical modelling that attempts to describe the time-evolution of systems, *even if the goal is merely to extract the crudest features like coarsegrained statistics.*

Deterministic Chaos

The digitization of a system of time-evolution equations in any integer base of arithmetic defines an "artificial automaton", an abstract model of a computer. The digitized initial condition is the computer program. In a chaotic dynamical system the part of the program that directs the trajectory into the distant future is encoded as the end-string e_{N+1}... of digits in an initial condition $x_o = .\, e_1.e_2...e_N...$. This is the meaning of a positive Liapunov exponent, and of "sensitivity with respect to small changes in initial conditions[4]."

Merely by varying initial conditions, even the simplest chaotic dynamical systems can generate every histogram that can be constructed[4]. Therefore, statistics can not be used to distinguish one dynamical system from another. The generating partition forms the support of every statistical distribution and characterizes the particular dynamical system[4,5]. *It is the generating partition, not statistics, that must be reconstructed from empirical data like a time series if an unknown dynamical law is to be discovered from complicated empirical data.*

Both critical[6] (meaning at a transition to chaos) and chaotic[4,5] dynamical systems may have a generating partition, but not every nonintegrable dynamical system admits a generating partition. *For a system with a generating partition, topologic universality classes can be defined that permit one to study the simplest system in the class* [7]. For unimodal maps of the unit interval, both the symmetric and asymmetric logistic maps peaking at or above unity belong to the trivial universality class of the binary tent map[4]. The two dimensional Henon map belongs to the universality class of chaotic logistic maps of the unit interval peaking beneath unity[5].

If a deterministic dynamical system has a generating partition then the symbolic dynamics can in principle be solved and the long-time behavior can be understood qualitatively and statistically *in advance*, so that the future holds *no surprises*: the generating partition and symbol sequences can be used to describe the motion at long times, to within any desired degree of precision. Multifractal scaling laws show how finer-grained pictures of trajectories are related to coarser-grained ones. *In other words, universality and scaling imply relatively simple dynamics.*

Complex Dynamics

There is a much greater variety of complicated motions possible in nonlinear dynamics than criticality (transition to chaos) or deterministic chaos: systems of billiard balls combined with mirrors[8,9], and even two-dimensional maps[10], can exhibit universal computational capacity via formal equivalence to a Turing machine. A system of nine first order quasi-linear partial differential equations has been offered as a computationally-universal system[11]. It has been speculated that a certain three degree of freedom Newtonian potential flow may be computationally complex[10].

For a dynamical system with universal computational capability there is no generating partition: there is no computational compressibility that allows us to understand the system's long-time behavior in advance, either statistically or otherwise. In contrast with the case where universality classes exist there is no symbollic dynamics that allows us to relate the fine-grained structure of an orbit to the coarse-grained structure via scaling laws, or to look into the very distant future. We do not know whether either fluid turbulence or Newton's three-body problem fall into this category.

Some degrees of complexity are defined precisely in computer science[12] but these definitions, have not satisfied many physicists[13,14]. According to von Neumann[16] a system is complex when it is easier to build than to describe mathematically. Under this qualitative definition the Henon map is not complex but a living cell is. No one knows if universal computational capability is necessary for biologic evolution, although DNA molecules in solution apparently are able to compute[17], but not error-free like a Turing machine.

Can Laws of Motion "Emerge" From Studies of Complicated Behavior?

We have stated above that the statistics that are generated by an unknown dynamical system are inadequate to infer the dynamical law that generates the observed statistical behavior[4]. Instead, it is necessary to extract the generating partition of the map from the empirical data, *if there is a generating partition.*

Given a time series generated by a low dimensional deterministic dynamical system with a generating partition, our inherent restriction in data analysis to *finite precision* and *finite time* is physically significant: given the most accurate existing data on a fluid dynamical system near a bifurcation to chaos, the unique extraction of the universality class of an iterated map from a critical or chaotic time series has yet to be accomplished without physically-significant ambiguity[18].

For truly complex dynamical systems, the lack of a generating partition suggests that the extraction of laws of motion from empirical data is a hopeless task.

Is Socio-economic Behavior Mathematically-lawful?

Is it reasonable to expect that mathematical laws of socio-economic or other mathematical laws of human behavior exist objectively and can be discovered? Economists and system theorists[1,19,20], and sociologists [21,22], uncritically assume that this is possible.

Billiard balls and gravitating bodies have no choice but to follow mathematical trajectories that are laid out deterministically, *beyond the possibility of human convention, invention, or intervention*, by Newton's laws of motion. The law of probability of a Brownian particle also evolves deterministically according to the diffusion equation *beyond the possibility of human convention, invention, or intervention.* In contrast, a brain that directs the movements of a human body makes willful and arbitrary decisions at arbitrary times that cause it to deviate from and eventually contradict any mathematical trajectory (deterministic models) or evolving set of probabilities (stochastic models) assigned to it in advance. Set onto a collision course, two billiard balls or two planets have no choice but to collide. Two tanks operated by two people, however, can be made to collide or not to collide on the basis of conscious decisions. Dynamical systems are represented by fixed automata with fixed programs. Human behavior is not that simple.

Mathematical-lawlessness reigns supreme in the socio-economic and legal fields, where nothing of any social or economic significance is left even approximately invariant by socio-economic "evolution", including the "value" of the dollar. This is the reason that artificial law ("law") is instituted by governments and central banks in the attempt to regulate and control economic behavior. Socio-economically, everything that is significant changes completely unregulated in the absence of either artificial law (the Roman model) or strong community traditions (the tribal model).

Rather than assuming that laws of human behavior exist objectively like the mathematical laws of physics, we should instead ask: why should *any* part of nature behave mathematically? Why does the mathematics of dynamical systems theory accurately describe the motions studied in classical mechanics, but not the "motions" in Aristotle's sense[23] studied in economics, political science, psychology, and sociology?

Reductionism, Invariance Principles, and Laws of Nature

Since Galileo, we understand reductionism as the arbitrary division of the study of nature into laws of motion and initial conditions, plus "the environment". We must always be able to neglect "the environment" to zeroth order, because if *nothing* can be isolated then a law of motion can never be discovered. Following Wigner, laws of motion themselves obey laws called invariance principles, while initial conditions are completely lawless[24].

"It is not necessary to look deeper into the situation to realize that laws of nature could not exist without principles of invariance. This is explained in many texts of elementary physics even though only few of the readers of these texts have the maturity necessary to appreciate these explanations. If the correlations between events changed from day to day, and would be different for different points of space, it would be impossible to discover them. Thus the invariances of the laws of nature with respect to displacements in space and time are almost necessary prerequisites that it be possible to discover, or even catalogue, the correlations between events which are the laws of nature."

The experiments that Wigner had in mind are the parabolic trajectories of apples and blocks sliding down inclined planes, the two physical systems originally studied by Galileo in his empirical discovery of the local versions of Newton's first two laws of motion. Without translational and rotational invariance in space and translational invariance in time (at least locally, on earth and within our solar system), simple *mathematical laws of motion* like the Keplerian planetary orbits and the Galilean trajectories of apples could not have been discovered.

Socio-economic phenomena are not invariant. Socio-economic time-development and the corresponding statistics depend upon *absolute position* and *absolute time*, which is the same, for all practical purposes, as admitting that socio-economic "motions" are not reducible to a well-defined dynamical system.

Universal laws that are determined by regularities of nature differ markedly from human-created systems of merely conventional, invented, or expected behavior. The latter consist of learned, agreed-on, and communally- or politically-enforced behavior, which can always be violated by cleaver or at least willful people. No one can violate the laws of inertia and gravity, however. In Wigner's language, all socio-economic initial conditions matter because of the lack of invariance, so that it is

(See **LAW,** *p. 30)*

Cost Integration and Normalization Issues

Dr. Francois Melese
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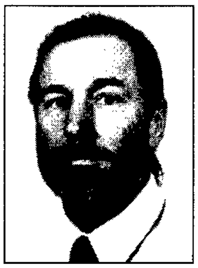

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Introduction

In a useful article ["On Measures of Effectiveness," *PHALANX,* Dec. 1995], Drs. Pinker, Samuel and Batcher (PSB) offer a brief history and introduction of effectiveness analysis. In a simple illustration of an effectiveness evaluation, PSB construct an "overall index (or MOE)" to help choose among three different alternatives.

The authors propose a five-step decision-making process:

1. First, the decision maker (DM) "identifies a group of factors that he [she] considers to be of crucial importance."
2. Second, "[t]o each factor a weight [between 0 and 1] is assigned; and the sum of the weights has to equal 1."
3. Third, "[t]o overcome the problem of differing units and conflicting objectives, a normalization...is performed."
4. Fourth, "an index (or MOE) can be computed for each alternative as a weighted average."
5. Finally, that alternative with the "largest index (or MOE)...[is] selected."

This note examines two critical assumptions made by PSB. These assumptions appear in steps two and three of the decision-making process summarized above. In step two, PSB assume that costs should be integrated directly into an "Overall Measure of Effectiveness (MOE)." We disagree. Assigning a weight to cost and combining it directly into an Overall MOE needlessly restricts your options. In step three, PSB claim that "little is lost if [the baseline alternative used to normalize data] is arbitrarily selected." (p.9) This note demonstrates that a baseline cannot arbitrarily be selected, and offers an alternative normalization procedure, also mentioned by PSB.

Combining Cost and Effectiveness

Leaving the normalization issue aside for a moment, consider how PSB arrive at their "Overall MOE." Table 1 reproduces PSB's raw data. Assuming the "crucial factors" in the evaluation are measured correctly (a comment on the kill probability calculation appears in a recent issue of Phalanx), PSB report the scores for four factors for each alternative, together with an assessment of each factor's relative importance (or weight).

Assigning costs a weight of 0.4, PSB then directly combine cost with the other weighted factors (normalizing the values in Table 1 using Alternative 1 as a baseline) to obtain the "Overall MOE's" reported in Table 2. On this basis, alternative 2 is preferred, followed by 3 and 1. Unfortunately, this calculation of an overall MOE eliminates several interesting approaches to the decision problem.

A different strategy is to combine the Kill probability, Reliability measure, and Space requirement into a separate effectiveness measure. Then costs can be integrated with that effectiveness measure in one of two ways—both of which can be revealing: We call the first, the "Level Playing Field" (LPF) approach, and the second the "Opportunity Cost" (OC) approach. However, neither approach is possible if one insists on calculating the "Overall MOE" proposed by PSB.

Set PSB's data aside for a moment. Now consider the simpler problem of choosing between two alternatives. Suppose the first alternative gives you lower effectiveness but costs less, while the second offers higher effectiveness but costs more. Which one should you choose? PSB's approach is to integrate cost directly into an "Overall MOE" and choose the alternative with the highest MOE. Unfortunately, this calculation of an overall MOE eliminates two attractive approaches to the decision problem: the LPF and the OC approach. The LPF approach requires an *intra-program* adjustment to the proposed alternatives. The OC approach requires an *inter-program* adjustment.

TABLE 1: Raw Data

Factors	Alternatives 1	Alternatives 2	Alternatives 3	Weights
Kill	15	10(9)	12	.3
Reliability	.8	.9	.8	.2
Cost	1800	1000	1200	.4
Space	500	700	800	.1

TABLE 2: Using Alternative 1 as a Baseline

Factors	Alternatives 1	Alternatives 2	Alternatives 3	Weights
Kill	1.00	.67(.60)	.80	.3
Reliability	1.00	1.13	1.00	.2
Cost	1.00	1.80	1.50	.4
Space	1.00	.71	.63	.1
Overall MOE	1.00 (1.0)	1.22 (1.20)	1.10 (1.10)	

(Note: Numbers in brackets assume alternative 2 has a Kill value of 9 instead of 10)

The LPF *intra-program* adjustment can be achieved in two ways: 1) Adjust the alternatives to equalize effectiveness (design each so they give you the same program capability), and then choose the low-cost option; or instead, 2) Adjust the alternatives to equalize costs (see what you can buy of each with the **anticipated budget** for the program), and then choose the option that yields the highest program effectiveness.

The OC approach offers additional insight, but requires a more challenging *inter-program* adjustment. Now, rather than modify the alternatives to level the playing field, the OC approach accepts both lower cost, lower effectiveness and higher cost, higher effectiveness alternatives, but employs the concept of "opportunity cost."

Opportunity costs can briefly be defined as the next best alternative use of funds. A challenge to implementing the OC approach is that the DM is asked to reach beyond the immediate program into higher level inter-program considerations. The OC approach asks tough questions such as: Could the difference in dollars gained by going with the low-cost alternative be better used in some other program and thus raise overall national security?

Alternatively, if we choose the higher cost, higher effectiveness alternative: first, where is the difference in dollars likely to come from? and second, is this inter-program transfer likely to raise overall national security? These are tough, but useful, questions that break through the sub-optimization nature of many effectiveness analyses. Such questions also encourage critical communication between different layers in an organization.

The bottom line is that it is often more revealing to develop effectiveness measures that are independent of costs. Moreover, both the budget forecasted for the program, and the concept of opportunity cost, can play important roles in effectiveness analyses. A further investigation of these approaches appears in an article entitled "Cost and Effectiveness Integration" by Henry and Hogan in the March 1995 issue of *PHALANX*.

Normalization Issues

Having made the point that costs are more usefully treated separately in an effectiveness evaluation, we now follow PSB and ignore this problem to focus on another important issue—normalization. In step three of their decision-making process, PSB claim that "little is lost if [the baseline alternative used to normalize data] is arbitrarily selected." (p.9) However, two simple counter-examples indicate that a baseline cannot arbitrarily be selected to normalize data. Rank reversals are obtained with different choices of the baseline alternative. Although PSB use the arbitrary baseline, Alternative 1 (see Table 2), to normalize, they also discuss (but do not demonstrate) another method of normalization that avoids the problem of rank reversals.

As stated by PSB, normalization is performed "to overcome the problem of differing [measurement] units." For example, in Table 1, suppose for simplicity (instead of .3 and .2) that the same weight, 0.1, is attached to Kill and Reliability (and that the other weights are adjusted accordingly). Even though equal importance was attributed to both factors, the magnitude of the Kill measure will dominate Reliability in the (non-normalized) MOE. For example, that portion of the (non-normalized) MOE for Alternative 1 contributed by Kill is 1.5 (0.1x15), while the portion contributed by Reliability is only .08 (0.1x0.8). Hence the requirement to normalize.

TABLE 3: Using Alternative 2 as a Baseline

Factors	Alternatives 1	2	3	Weights
Kill	1.50 (1.67)	1.00	1.20 (1.33)	.3
Reliability	.89	1.00	.89	.2
Cost	.56	1.00	.83	.4
Space	1.40	1.00	.88	.1
Overall MOE	0.99 (1.04)	1.00 (1.00)	0.96 (1.00)	

(Note: Numbers in brackets assume alternative 2 has a Kill value of 9 instead of 10)

TABLE 4: Normalizing by Best-of-Factor

Factors	Alternatives 1	2	3	Weights
Kill	1.00	.67	.80	.3
Reliability	.89	1.00	.89	.2
Cost	.56	1.00	.83	.4
Space	1.00	.71	.63	.1
Overall MOE	0.80	0.87	0.81	

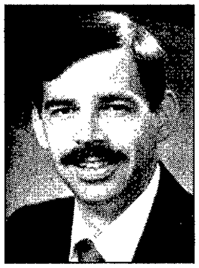
From Table 2, if Alternative 1 is selected as the baseline, then alternative 2 is preferred, followed by 3 and 1. However, a rank reversal occurs when Alternative 2 is selected as the baseline: (from Table 3) alternatives 1 and 2 are separated by only .01, while alternative 3 is now ranked last.

To highlight this problem, consider a trivial change in the raw data for Alternative 2 for Kill, from 10 to 9. This change and its subsequent impacts on the calculations are reported in parentheses in Tables 1-3. With Alternative 1 as the baseline, the rankings remain unchanged: alternative 2 is still preferred, followed by 3 and 1. However, a rank reversal occurs when Alternative 2 is selected as the baseline. Table 3 indicates that alternative 1 is now preferred, with 2 and 3 tied for second.

The problem with using a randomly chosen alternative as a baseline for normalization is that this method violates the requirement for independence among factors. As we have demonstrated, the result is that rank orderings can change as a function of the alternative selected as a baseline.

(See **COST-INTEGRATION,** *p. 17)*

Using Constructive Simulations and ALSP for Training in UFL 92†



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Introduction

The Korean War ended with a truce, not a treaty. The level of combat is currently low (occasional raids and fomentation of civil unrest by North Korea); however, a major conflict is possible at any time. Both Korean and U.S. troops are trained in individual and group skills by various means; however, training the commanders and their staffs is a particularly difficult problem. Commanders and staffs at the theater level are concerned with coordinating vast quantities of men, material and information. The command is supposed to formulate plans that drive a conflict in satisfactory directions and to react to an uncooperative foe. In Korea, this problem is exacerbated by language differences and constant turnover of U.S. personnel.

The only solution is practice. At the top level, this includes an annual exercise called Ulchi Focus Lens (UFL). This exercise involves a majority of the Republic of Korea (ROK) forces, all of the U.S. forces in Korea and a large number of U.S. forces located outside of Korea, such as Japan and the continental U.S. (CONUS). Actually moving all of these forces and employing them in a wargame each year would be prohibitively expensive. The alternative is to use a constructive simulation or simulations to generate the problems (caused both by the enemy and poorly coordinated friendly forces) that the generals need to solve.

Prior to UFL in 1992, this exercise was driven by a set of independent models and extensive manual scripting and communication among models (e.g., "the enemy air just sank that ship [in the air model], so quit using it [told to the naval model controllers]"). This worked, but not as well as desired. The U.S. Forces Korea (USFK) wanted something better. A single model covering the entire domain of training for war (at the desired level of detail) would have been preferable. However, there was no single combat model that simulated all areas. In addition, there were several individual areas for which there was no functioning, credible model. The staff at the Oak Ridge Department of Energy facilities were asked to help solve the problem. We put together a team of over 50 people, most located in Korea, to identify a technically feasible solution and implement a prototype Battle Simulation Center (BSC) to manage the exercises.

Training Program

The Korean BSC training program is composed of three core elements; the training audience, training materials/methods, and the support personnel. The exercise training audience consists of military personnel (players) operating from Tactical Operations Centers. The players prepare plans and issue orders to the personnel (gamers) who input the requirements into the BSC computer workstation.

As the echelon of the training audience increases, so do the exercise support requirements. Any exercise supporting a division or above training audience requires augmentation from outside the BSC staff. These additional support personnel need training in their functions prior to running the exercise. Training materials and methods must be tailored to meet the needs of the training audience and the additional support personnel. The detail and focus of instruction will vary between players, gamers, scripters, and controllers. In addition to the mix of trainees, the Korean BSC incorporates a variety of models to accomplish the command training objectives. Each model requires unique training materials, certified instructors, and instructional methods. Although most model developers provide user documentation, it is generally very basic and must be extracted from and expanded to create a suitable program of instruction. When training gamers, scripters, or controllers it appears that the most effective instruction methodology is one that minimizes lecture and maximizes hands-on training time. Instilling confidence in the trainee that the simulation is efficacious can only be accomplished through intense practical exercises at the workstation.

When selecting individuals for instructor positions, functional expertise should be a primary consideration. Without it an instructor may be able to teach the mechanics of the simulation model, but he will not fully understand the player unit organization, mission and capabilities - information that is critical when assisting gamers as they translate player orders into appropriate computer commands and computer output into realistic tactical reports.

Opposing Forces (OPFOR) players, gamer/controllers and scripters have training requirements which differ from their friendly counterparts. The OPFOR players perform command and staff functions comparable to that performed by the training audience player commanders and staffs. A significant difference is that the training audience players are performing familiar tasks while the augmentation OPFOR players are performing in a new or unfamiliar operational environment. The instructor must work closely with the OPFOR Operations Officer to ensure that the training is focused on the systems, tactics, and capabilities of the OPFOR. There are two competing views of OPFOR activities:

1 During the OPFOR gamer/controller training, the instructor must emphasize that the OPFOR's role is not to win the war but to support the Blue Force training audience. On occasions during an exercise, the OPFOR may be required to deploy personnel and equipment in a manner that is uncharacteristic or doctrinally incorrect in order to support emerging, Exercise Director mandated, training objectives.

2 The OPFOR gamer/controller training focus is on ensuring that the training audience objectives are realized through the realistic portrayal of OPFOR doctrine, tactics and capabilities. The OPFOR must play to win, even when constrained by scenario

input designed to allow attainment of the exercise goals or objectives.

It is the job of the Exercise Director to reconcile these two views.

Exercise Operations

Typically, the BSC will not own sufficient equipment to operate a theater-level exercise, such as UFL, nor will it staff all of the remote sites that will be used in running the exercise. A quality site-survey will greatly facilitate all subsequent exercise activities. The exercise facilities can range anywhere from fully equipped permanent buildings to temporary collections of tents with mobile generator power.

Exercise support and battlefield simulation is a fast paced environment and extremely mobile. Commanders prefer the simulation hardware and technical control to be close to the command posts it supports. In certain ways, this makes sense but there are good reasons to isolate the technical support activity from the bustle and chaos of the exercise site. Although commanders like the ability to walk into the Technical Control cell to receive status on simulation operation and stoppages, excessive interruptions impede the ability of Tech Control to respond to and resolve operational problems. Furthermore, many of the types of questions brought to the Tech Control staff actually pertain to the functional aspects of the simulation model and are better directed to Senior Control staff. The main argument for location of Technical Control at the exercise site stems from the legitimate need for close communication between Technical Control and Senior Control. Proper planning for adequate telephone lines and well formulated policy articulated in a standard operating procedure may alleviate the need to collocate Senior and Technical Control.

Pre-exercise activities begin when the decision is made to support an exercise and continue until its start. The key document prepared to plan the pre-exercise activities and forecast operational support of the exercise is the Technical Support Plan. The primary reference for its formulation is the Exercise Support Plan, the formal statement of the functional requirement to conduct the exercise. The Technical Support Plan must embody this functional requirement while describing the details of the areas required to technically support the Exercise Control Plan. The Simulation Control Plan specifies the requirements for gamers, scripters, and controllers. The ability to meet the objectives of the training audience is, in part, attributed to the scope and detail found in the Plan. Additional pre-exercise activities include an exercise plan review, configuration planning, and equipment inventory and packing.

Exercise deployment activities take the approved Exercise Plan and Technical Support Plan and execute the steps necessary to station equipment and personnel at the remote exercise sites. Activities include determining staffing requirements, insuring equipment delivery and accountability, installing the equipment, configuration testing, and operational support during the exercise. These activities must begin early enough to ensure readiness to perform the Communication and Simulation Test on the designated dates.

The training audience (players) consists of commanders and staffs of real units using go-to-war communications systems and existing unit standing operating procedures (SOP). Habitual unit relationships, an existing chain of command, and personnel performing normally assigned duties enables the training audience to concentrate on tactical planning and employment and attainment of specific training objectives. USFK OPFOR gamers do not have this luxury. The USFK BSC relies upon combined ROK/US augmentation to perform the required OPFOR gaming, acting as the enemy commanders.

During an exercise the Analysis Section conducts an intensive data collection effort in preparation for the exercise After Action Reviews (AARs).

Models

The desired UFL 92 set of models included the Corps Battle Simulation (CBS) as the basic ground combat model, the Air Warfare Simulation (AWSIM) as the basic air combat model, the Research and Evaluation Systems Analysis (RESA) model as the basic naval model, and the Theater Transition and Sustainment Model (TTSM) as the basic logistics model. Because there was overlap among these models, the detailed choices for which code would be used for each event depended on close analyses. Two smaller models (of subroutine size compared to the major models) performed specialized functions: the Joint Electronic Combat/Electronic Warfare Simulation (JECEWSI) performed electronic warfare functions, and the Combat Base Assessment Model (CBAM) assessed damage to air bases. The Tactical Simulation (TACSIM) was used in the exercise as an intelligence driver; however, its classification prohibited full electronic linkage to the other models. Its connection to the confederation was maintained by manual interface.

The Aggregate Level Simulation Protocol (ALSP) is now a proven success in connecting the logic and timing of constructive simulations. In 1991 and early 1992, when we were planning UFL 92, ALSP was unproven technology. ALSP was a Defense Advanced Research Projects Agency (DARPA) sponsored effort, being developed by the MITRE Corporation. The goal was to develop a protocol for interfacing multiple combat simulations. The description of ALSP might lead one to conclude that it is a simple protocol for allowing multiple (similar or dissimilar) combat models to communicate with each other. This is analogous to a Local Area Network (LAN) connecting PCs. A little bit of software and hardware would be added to each PC, allowing each to communicate. Similarly, a little code would be inserted into each model and external code modules added, allowing each model to communicate. However, the changes go deeper than implied by the analogy: the models are REQUIRED to communicate. The implementation of this philosophy in ALSP required profound changes to the operation of models that run under it.

Figure 1 illustrates the effect of ALSP on the CBS model. The CBS model is shown residing on a computer and connected to several distribution computers, each connected to CBS workstations. The ALSP Common Module (ACM) is shown residing on a workstation (avoiding an overload on the CBS computer), with a link to the CBS computer. The ACM provides the protocol connection to other models in the confederation and is virtually identical to the ACMs for the other models. The ALSP Translator is shown

*(See **ALSP,** p. 22)*

MORS Mini-Symposium: Quick Response Analysis Requirements and Methodologies (QRAM)

Introduction

Dr. Jackie Henningsen, OSD PA&E Mini-Symposium General Chair

On October 1-3, 1996, a MORS mini-symposium called *First Order Analysis: Quick Response Analysis Requirements and Methodologies (QRAM)* was held at the Booz Allen Hamilton Conference Center in Tyson's Corner, Virginia. I served as general chair for this meeting, and **Mr. Bob Statz** of Booz Allen Hamilton and **Dr. Roy Rice** of Teledyne Brown Engineering were co-chairs. **Mr. Doug Williams** of Booz Allen Hamilton was Technical Chair.

QRAM Statistics

One hundred, fifteen participants were involved in QRAM. This is the second meeting in the last two years that was prepared as a quick response to a key decision maker or sponsor's request. The Joint Requirements Oversight Council Workshop in Fall of 1994 was the first. QRAM was developed in just over three months in response to the suggestion of **Mr. Bill Lynn**, Director, Program Analysis and Evaluation, Office of the Secretary of Defense with the concurrence of the other MORS sponsors. The long-standing efforts of the Joint Staff sponsor, **Mr. Vince Roske**, to develop a framework for quick-response analysis provided the foundation for the organization of the QRAM mini-symposium. A draft report was completed in early November, and is now in review. The objectives of this special meeting were

- To use the skills of outstanding analysts across DoD to explore senior leaders' requirements for quick response analysis of major issue categories.
- To develop a taxonomy and categorize available methodologies to apply to these and similar issues.
- To use an organized analytic approach to frame these issue categories and to provide demonstrations of the application of this approach using existing case studies.
- To apply the organized analytic approach to specific issue questions within the issue categories, to identify applicable QRA methodologies, or to identify shortcomings in current response capabilities.
- To hold guided discussions on the uses and misuses of QRA methodologies.
- To provide a report of the results of the mini-symposium and a preliminary catalog of methodologies.

MORS, President **Fred Hartman**, provided the opening comments and introduced the keynote speaker, **Mr. Bill Lynn**, Director, Program Analysis & Evaluation, OSD. Mr. Lynn reviewed the Base Force assessment by the Bush Administration and the Clinton Administration assessment known as the Bottom-up Review. He went on to describe how the Commission on Roles and Missions of the Armed Forces had recommended that a quadrennial review of the defense program be initiated at the beginning of each newly elected Presidential administration. The general guidance for this review is provided in the *1997 DoD Conference Report* "The Military Force Structure Review Act of 1996".

Mr. Will O'Neil, Vice President of the Center for Naval Analysis, provided a framework and set of "antinomies" for problem solving to include the differences in private versus public analysis. He was followed by **Dr. James Ignizio** of the University of Virginia, who discussed **Intelligent Decision Systems** and presented techniques for framing issues in terms of reasoning categories. He suggested that identifying issues as questions of induction, deduction, or other categories would help analysts determine the best assessment approaches.

Major General Mark Hamilton, Deputy Director Force Readiness and Resources, Joint Staff/J-8 used the questions identified by decision makers prior to the planning meeting to discuss some of the analytic challenges of the QDR. For example, MG Hamilton's response to the question "What is the value of investing in "tail" economies?" was — "what do you call a military airlift mission to deliver grain to a starving population?" "It's not tooth and it's not tail — maybe", he suggested, "it's lips." He opined that "we need more body parts." He challenged the assembled analysts to creatively consider new viewpoints."

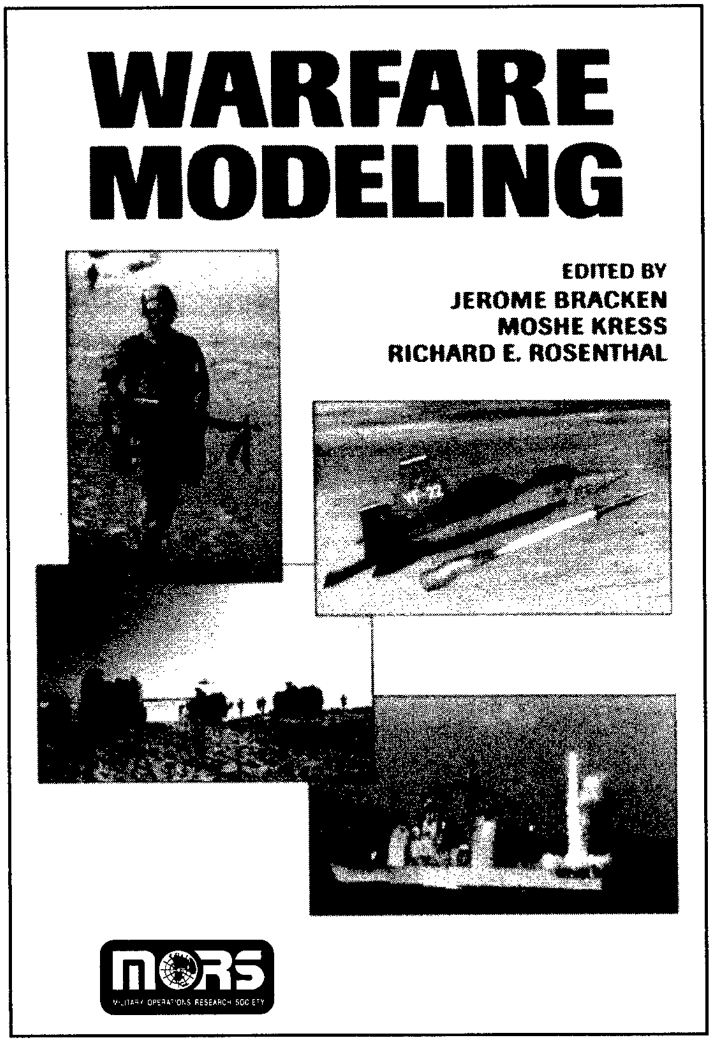
Dr. Paul Davis of RAND presented thoughts from his recent report **Adaptiveness in National Defense** to describe the use of portfolio analysis to examine future force structure requirements. He cautioned that we must look at multiple scenario options including a review of the current two MRC policies with a more rigorous investigation of uncertainties that have been previously considered lightly.

Mr. Bob Statz, QRAM co-chair, provided a road map that included the key elements for quick response analysis. He was followed by **Mr. Doug Williams**, QRAM Technical Chair who described how a difficult question on the value of BDA in the air tasking order cycle was framed in a few days by using a simple visual model starting from a cold base. **Dr. Roy Rice**, QRAM co-chair, presented an insightful and humorous look at the role of the analyst in supporting the decision maker. He pointed out that decision making involves choosing among alternatives. It is a role of the analyst to (a) insure that there is an adequate range of alternatives, (b) establish meaningful criteria to distinguish among alternatives, and (c) insure trackability and traceability.

Following the presentations, participants attended two of eight groups in two different sessions and helped to develop a report on the status of the base (warm/cold) for a specific issue category. The experts who led these groups and their issue categories were as follows:

A synthesis group met throughout the meeting. This group was led by **Dr. Paul Davis, Dr. Stu Starr**, and **Mr. Clayton Thomas** with support from **Ms. Susan Iwanski, Dr. Richard Hayes, Mr. Richard Helmuth, CDR Dennis Baer,**

(See **QRAM,** *p. 33)*



The book is comprised of seven sections:

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Warfare Modeling was edited by Jerome Bracken of Yale University, Moshe Kress of Israel's Center for Military Analyses, and Richard E. Rosenthal of the US Naval Postgraduate School. The Foreword is by Wayne P. Hughes, Jr., a retired Navy captain and MORS Fellow.

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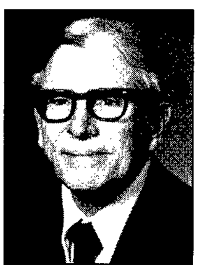
Phour Phine Fellows Join the Phlock

Jack Walker, FS

During the past year, the MORS Board of Directors elevated four outstanding analysts to the honorary status of *Fellow of the Society.* What is striking about this class of inductees is that each individual occupies a very responsible and demanding position in the defense community, yet each one continually finds time and energy to devote to the betterment of our professional society. It is this splendid characteristic of sharing wisdom and encouraging peer development that nurtures professional excellence. *PHALANX* joins the military operations research community in congratulating these outstanding leaders:



Walter W. Hollis, FS, currently Deputy Under Secretary of the Army (Operations Research), has served MORS and the military operations research community in a wide variety of significant ways. He has been a participator, mentor, advocate, critic, leader, author ... always constructive and ever supportive. His observations and suggestions form the basis for many of the recent initiatives and advances in Societal activities — workshops, mini-symposia, and special activities at MORSS.

After graduation from Northeastern University, Mr. Hollis taught physics there while pursuing graduate studies at Boston University. He entered Civil Service in 1951 at Frankford Arsenal, PA., rising to become Chief, Combat Vehicle and General Instruments Fire Control Laboratory. In 1968 he became Scientific Advisor to the Commanding General, US Army Combat Developments Experimentation Command at Fort Ord, CA. After graduation from the National War College and receiving an MS degree in International Affairs from George Washington University in 1973, he became Scientific Advisor to the Commanding General, US Army Operational Test and Evaluation Agency in Falls Church, VA. He moved up to his present position in 1980 where he establishes policy guidance and monitors Army operations research activities. He initiates, conducts, reviews, and monitors studies and analytical reports basic to the justification of Army requirements and programs. He has been a frequent contributor of lead articles for *PHALANX.*

Dr. William G. Lese, Jr., FS, now associated with LOGICAN in Arlington, VA, was the moving influence in establishing the Organization of the Joint Chiefs of Staff as a Co-Sponsor of MORS. He has participated in recent symposia as a panel member, discussant in outstanding paper sessions, and presented papers including the Sponsor's presentation on "Research Directions" and an earlier examination of "OR Needs for the 80s." He served a four-year term as a thoughtful and active member of the MORS Board of Directors.

He graduated from California University of Pennsylvania with a BS in Mathematics, and from the University of Delaware with an MS in Statistics and Computer Science and a Ph.D. in Statistics. He attended the National War College, the Executive Manager Program, the Federal Executive Institute, and Harvard University's Senior Managers in Government Program. Lese is an Adjunct Professor of statistics for The American University.

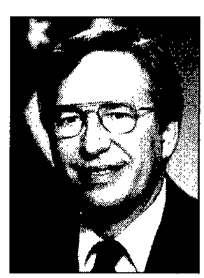
He entered government service with the US Army Ballistic Research Laboratory, Aberdeen PG, MD after which he was Scientific Advisor to the Deputy Chief of Staff for Operations, US Army Europe. Subsequent service was with the Office of the Secretary of Defense for Program Analysis and Evaluation, and as the Scientific and Technical Advisor, Studies, Analysis, and Gaming Agency (SAGA) in OJCS.

Among the many recognitions of his contributions, Dr. Lese has received the Meritorious Presidential Rank Award, an OSD performance Award and Bonus, and an Illustrious Graduate Award from California University.

James J. Sikora, FS, is Senior Vice President/General Manager for BDM International, Inc. He has been a hyperactive participant in MORS affairs and activities for a score of years, serving on the Board of Directors and in almost every symposium operational and administrative position. He was General Sessions Chair for the 46th MORSS and is a leader or advisor of most of MORS' test and evaluation activities. Concurrently he has presented numerous papers at MORSS and was the facilitator for the Air Defense Modeling and Simulation Workshop (ADMAS) in 1987.

Jim has been and continues to be a driving influence in the MORS Simulation Validation (SIMVAL) Series. Since the Series was initiated in 1990, he has cochaired all activities including three major workshops and a mini-symposium. He is a member of the Verification, Validation and Accreditation (VV&A) Subgroup for the DIS Workshop, and is a member of the DMSO Technical Working Group and Technical Support Team for VV&A.

Sikora has been a frequent contributor to *PHALANX* over the years. And he coauthored an article in a recent issue on "Advanced Distributed Simulation (ADS) Distributed Interactive Simulation (DIS)."



Edgar B. Vandiver III, FS, is the Director of the US Army Concepts Analysis Agency in Bethesda, MD. He has served twice on the MORS Board of Directors and was the

MORS President in 1992-93. Through the years at one time or another, he has filled almost every leadership position in the Society and had been instrumental in maintaining a search for excellence in the MOR community. He was a prime influence in the establishment and advancement of the MORS Educational Colloquium, a precursor in the wave of MOS workshops and similar meetings. He has initiated or cosponsored numerous topics and sessions of special interest to MORS Sponsors. And as MORS Vice President for Professional Affairs, he provided special support and guidance in the evolution of *PHALANX*. He was the 1995 recipient of the prestigious MORS Wanner Award.

He graduated from the University of Missouri with a BS and later an MS in Physics, and has done graduate work at The American University. He attended the Federal Executive Institute Senior Executive Education Program and the Harvard University Program for Senior Executives in National and International Security. His special interest in military history led to courses at Northern Virginia Community College in Russian History, Military History, and Data Processing.

His distinguished career started at the US Army Chemical Corps CBR Combat Developments Agency, then through some years with the Combat Operations Research Group (CORG) at Fort Belvoir, VA, a brief tour with CVA, Inc. in Alexandria, and then to the Pentagon. In Headquarters, Department of the Army, he served first as Chief of the Scientific Advisor's Force Planning Division, Office of the Assistant Chief of Staff for Force Development. Then he was Research Analyst for Systems, Office of the Deputy Under Secretary of the Army (Operations Research), and finally he was Technical Advisor to the Army's Deputy Chief of Staff for Operations and Plans. He has been Director of CAA since 1984.

EB's performance of these duties has been recognized by many US and foreign awards including three designations as Presidential Rank of Meritorious Executive, two Senior Executive Service Performance Awards, and the DOD Distinguished Civilian Service Award.

Despite extremely busy schedules demanded by the above duties and associated domestic and international requirements, these leaders consistently have applied time, energy, and resources to materially enhance the structure and pith of MORS activities. It is for this long dedication and timely significant contributions that each of these professionals has been designated a ***Fellow of the Society.*** ✪

COST INTEGRATION

(continued from p. 11)

Rather than normalizing based on a particular alternative, a preferred method would be to normalize across alternatives, using the best value of each factor as a baseline for that factor. This is equivalent to constructing a so-called "ideal alternative" that is given the best scores for each factor. The actual alternatives can then be normalized using the ideal as a baseline.

This ideal normalization process involves identifying the maximum (minimum) value for each attribute if more (less) is better, and then dividing (multiplying) each alternative's score for that attribute by the maximum (one over the minimum) value. This approach guarantees a consistent ranking and is insensitive to the addition of new alternatives i.e. "the best [actual] alternative [does] not change because of the addition of a new alternative that is itself not best." (p.9) Table 4 presents the normalization of the raw data (from Table 1) using this method.

Conclusion

This note examines two critical issues in effectiveness analyses: 1) how to integrate costs in an overall evaluation of comparable alternatives, and 2) how to normalize raw data to obtain a consistent MOE. We argue that assigning a weight to cost and integrating it directly into an effectiveness measure restricts your options. It is often more revealing to develop effectiveness measures that are independent of costs. Then costs can be integrated with the effectiveness measure in one of two ways—through a level playing field (LPF) approach, or an opportunity cost (OC) approach. The first approach has an intra-program focus, while the second has an inter-program focus. The budget for the program can also play a critical role. Finally, it is confirmed that a baseline alternative cannot arbitrarily be selected for normalization. Instead we propose the use of a so-called "ideal alternative."

Biographies

Donald E. Bonsper *is a Senior Lecturer at the Defense Resources Management Institute (DRMI), at the Naval Postgraduate School. He is a graduate of the U.S. Naval Academy, the Marine Corps Command and Staff College, and the Naval Postgraduate School. He was also a Fulbright Scholar in Costa Rica. Prior to his retirement from the Marine Corps, Professor Bonsper served in a variety of command and staff assignments including tours in Vietnam, Okinawa, Venezuela, and Panama. As an operations research analyst, Professor Bonsper served with the Marine Corps Development Center where he worked in the field of long-range planning. in addition to his teaching duties, Professor Bonsper is the International Programs Coordinator at DRMI.*

Francois Melese *is an Associate Professor of Economics at the Defense Resources Management Institute (DRMI), at the Naval Postgraduate School. He has published articles on the defense industry, military medicine, the role of benefits in military compensation, and gain-sharing and transfer pricing in DoD. He received his BA from the University of California at Berkeley, MA from the University of British Columbia, Canada, and Ph.D. from the University of Louvain, Belgium. He was previously an Assistant Professor of Economics at Auburn University.* ✪

WG/CG Updates

Kerry Kelley
Vice President for Meeting Operations

The 65th MORSS will consist of programs for thirty-three Working Groups and eight Composite Groups to address topics specific to each group while incorporating the 65th MORSS theme: "Analysis for Complex, Uncertain Times." The small Working Group format allows for the presentation and discussion of either complete or in-progress work to peers within the military operations research community. The result is an exchange of ideas and perspectives on the problem, the analysis and the solution which serves to enhance the quality and usefulness of military operations research. In addition, the working groups meet in Composite Group sessions to address a wider spectrum of topics which are of interest to their associated composite group. The *Announcement and Call for Papers* provides a prospectus with details on the particular areas of interest for each working group.

For those familiar with the Working Group and Composite Group format, a few changes deserve highlighting. Working Groups 2 (Missle Defense) and 12 (Air Defense) have been combined into one Working Group named "Air & Missle Defense" and identified as Working Group 2. There is a new Working group 12 called "Analysis in Support of Training." Finally, Composite Group III has been divided into two sessions: (1) "Airland Contingency Operations" which will retain the Composite Group III identifier and encompass topics of interest to Working Groups 7, 8, 9, 10 & 14, and (2) "Force Protection Measures" which will incorporate Working Groups 2, 11 & 13 and be identified as Composite Group VIII. ✪

65th MORSS Spouse/Guest Tour

Virginia Wiles
Spouse/Guest Tour Coordinator

The 65th MORSS Spouse/Guest Tour, June 10th and 11th, will include visits to historic homes in Fredericksburg, VA. A tour of Stratford Hall and lunch in the Director's Dining Hall, recently featured in *Southern Living* Magazine, are also on the schedule. There will be plenty of time for shopping on "antique row" near the Rappahannock River in Fredericksburg, VA.

Watch this space for more details in the March *PHALANX*!

65TH MORSS

10-11-12 June 1997

Marine Corps Combat Development Command

Quantico, Virginia

65th MORSS Working & Composite Groups Chairs

Theme: *Analysis for Complex, Uncertain Times*

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CG I:	**STRATEGIC**	**Dr Robert Batcher, US ACDA**	**202-736-7396**
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WG 3:	Arms Control & Proliferation	Karen Stark, BDM Federal	703-848-6258
WG 4:	Revolution in Military Affairs	Michael Miller, Aegis Research Corp	703-610-9360
CG II:	**NAVAL WARFARE**	**CDR Kirk Michealson, OSD (PA&E)**	**703-697-0064**
WG 5:	Expeditionary Warfare/Power Projection Ashore	CDR Steven Barnes, CNO (N815)	703-697-0059
WG 6:	Littoral Warfare/Regional Sea Control	CDR Michael R. Shumaker, CNO (N81)	703-697-8078
CG III:	**AIRLAND CONTINGENCY OPERATIONS**	**Robert Statz, Booz • Allen & Hamilton**	**703-902-5875**
WG 7:	Nuclear Chemical Biological Defense	Michael O. Kierzewski, OptiMetrics, Inc	410-893-9714
WG 8:	Mobility	Denis Clements, GRC International	703-602-2917
WG 9:	Air Warfare	Thomas Lillis, McDonnell Aircraft Company	314-234-2737
WG 10:	Land Warfare	Thomas J. Iten, Raytheon E-Systems, Inc	703-413-5335
WG 14:	Joint Campaign Analysis	Rich Morris, McDonnell Douglas	703-412-3944
CG IV:	**SPACE/C^{3}I**	**Professor William G. Kemple, NPS**	**408-656-2191**
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WG 17:	Operational Contribution of Space Systems	LtCol Gerald Diaz, AFMC/OAS/DRA	505-846-8214
WG 18:	Operations Research and Intelligence Analysis	Dr. Allan S. Rehm, MITRE	703-883-7802
CG V:	**RESEARCH AND DEVELOPMENT**	**John M. Green, Lockheed Martin**	**609-722-4516**
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WG 21:	Unmanned Systems	Thomas W. Haduch, Army Research Lab	410-278-5870
WG 22:	Analyses of Alternatives	COL Robert Clemence, Jr., OSD(PA&E)	703-697-1600
WG 23:	Weapon System Acquisition	Terrence J. Cooney, Veda, Inc	513-476-3506
CG VI:	**RESOURCES AND READINESS**	**Dr. Patrick D. Allen, Cubic Applications, Inc**	**360-438-6078**
WG 12:	Analytic Support to Training	Brian R. McEnany, SAIC	703-734-5849
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WG 25:	Social Science Methods	Dr. Jock Grynovicki, ARL	410-278-5917
WG 26:	Logistics	Alan Cunningham, USA TRAC	804-765-1830
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WG 28:	Resource Analysis and Forecasting	LCDR Timothy P. Anderson, NCCA	703-604-0296
WG 29:	Readiness	John E. Leather, DMDC/TREAD (ext 4046)	408-583-2400
CG VII:	**METHODOLOGIES AND TECHNOLOGIES**	**LTC David Hutchison, OCSA-PAED**	**703-695-9377**
WG 30:	Decision Analysis	LTC Daniel T. Maxwell, US Army CAA	301-295-1082
WG 31:	Computing Advances in MOR	Maj William S. Murphy, TRAC-MTRY	408-656-4056
WG 32:	Advanced Analysis, Technologies and Applications	Dr. Michael R. Anderson, TRAC-FLVN	913-684-9192
WG 33:	Modeling Simulation and Wargaming	John R. Winkelman, Lockheed Martin	609-722-7479
CG VIII:	**FORCE PROTECTION MEASURES**	TBD	
WG 2:	Missile and Air Defense	Robert J. Fleitz, Coleman Research Corp	703-607-1908
WG 11:	Special Operations and Operations Other Than War	Greg Jannarone, Consultant	813-677-9498
WG 13:	Electronic Warfare and Countermeasures	TBD	

OR AT THE SERVICE ACADEMIES

LTC **Michael McGinnis**
CPT **Liz Lind**
United States Military Academy

The United States Military offers an undergraduate Operations Research Major and Field of Study degree program jointly sponsored by the Department of Mathematical Sciences and Department of Systems Engineering. West Point cadets now have their own student chapter of INFORMS and conduct monthly field trips and tours as well. The Academy has over 70 faculty positions coded as operations research billets (FA49). The Departments also jointly sponsor the **Walt Hollis** Award for Excellence in Operations Research presented annually for the best cadet, or cadet team, OR project.

In September, the cadet INFORMS chapter took a field trip to Pictinny Arsenal. The tour included briefings on shaped charges, computer simulation, Distributed Interactive Systems (DIS) and virtual reality, as well as, a tour of an armament technology laboratory, various simulation exercises, and a short, live fire demonstration. Pictinny Arsenal also supports many cadet capstone systems engineering projects. For example, then Cadets **Ben Marlin** ('96) and **Warren Sponslor** ('96) headed up a cadet group that studied lethality enhancements for the M1A2 Abram's Main battle tank for PM-TMAS, ARDEC, that was supervised by MAJ **Rocky Gay** and Dr. **Jeff Goldberg**. The 1996 Walt Hollis Award winning project, by Cadets **Matthew Champion** ('96), **Jonathan Darr** ('96), **Paul Ferrigno** ('96), **Hernan Ruiz** ('96) and **Kyle Towns** ('96) under the direction of LTC **Jack Marin** and Dr. **Don Barr,** examined the effectiveness of intelligent, Wide Area Munitions (WAM). Another notable study by Cadets **Mary Ashworth** ('96) and **Tim Alden** ('96), under the guidance of LTC **Bill Fox**, developed a SINCGARS model for the Army Research Laboratory.

Academy faculty are also involved in operations research projects. LTC **Patrick Driscoll**, jointly with Dr. **Sherali** of Virginia Tech, is developing a Lagrangian algorithm for scheduling activities at the Academy for the Army Research Laboratory. LTC **Jack Marin** and Dr. **Don Barr** are designing a passive theater missile defense assessment system for the U.S. Army Chemical School. MAJ **Mick Smith** is looking at a time-dependent reliability assessment of steel miter gates for the US Army Corps of Engineers in Vicksburg, Mississippi. LTC **Dave Thomas** and Dr. **Don Barr** are providing statistical support to the US Army Recruiting Command. CPT **John Zornick** is supporting USSOCOM with a modification of the Special Operations cost-benefit model.

The Operations Research Center (ORCEN) continues its work with Army clients under the direction of LTC **Michael L. McGinnis**. Recent efforts by MAJ **Todd Sherrill** and Dr. **Don Barr** to develop an information gain measure of effectiveness was awarded the David Rist Prize by the Military Operations Research Society (MORS) for significant contributions to military OR. MAJ **Bob Phelan** and LTC **Mike McGinnis** are developing a computer simulation model for analysis of Force XXI C^2 alternatives. CPT **Mick Sanzotta** has been investigating the optimal mix of military assets in an MOUT environment for TRAC and Marine Corps Combat. CPT **Liz Lind** is developing the Installation Decision Support Model (IDSM) for ASA (FM&C); an installation-level budgeting priority tool that utilizes Installation Status Report (ISR) data. Finally, COL **James Kays** and LTC **Mike McGinnis** are supporting the Army Chief of Staff and ASA (FM&C) with OR and business process reengineering of the Army's installations. ✪

MORS PRESIDENT

(continued from p. 3)

data and tools available to commence work quickly in any given key functional/analysis area. We are now making progress in identifying the critical areas, data, tools and methodologies to provide an expanded capability into more functional areas. Perhaps we also need to develop a logical plan to identify what we have and what we need to round out that tool set!

Next: A draft Terms of Reference is in preliminary coordination for a workshop on *OOTW Analysis and Modeling Techniques* planned for early next year (January 28-30, 1997). This is certainly an area ripe for MORS involvement and analyses. The number and complexity of the OOTW missions continues to increase in the new world order. There is a broad range of OOTW events that are both different and in some regards very much like the more traditional military missions. This session will build on two meetings at the Naval Postgraduate School (NPS), held earlier this year, that provided an opportunity for operational commands and the Services to identify their requirements for OOTW analyses and tools. The NPS meetings also developed approaches for framing the OOTW mission area by categories, attributes and component tasks. As an aside, less than two years ago, while working on an Army Science Board study looking at the supportability aspects of OOTW, members of the operational community confessed to starting the planning for OOTW each time with a "blank sheet of paper"! There really is a better way, and hopefully this workshop will help us bring more analytic rigor to the process!

A planning meeting took place on 1 November for a special meeting on *Complexity in Models and Simulation*. This meeting will be Co-Chaired by Dr. **Marion Williams,** FS, and **Jim Sikora,** FS and is scheduled for 25 and 26 February 1997. It will be held at Sandia Lab's Technology Transfer Center on Kirtland Air Force Base in Albuquerque, NM. Look for more information on this ery timely topic on page 26 of this issue.

One last thought on **communications.** If you would like to have more information on MORS, contact the MORS Office for your copy of the new, updated fact-filled brochure, ***The World of MORS***. This short, ten page publication is a wealth of information for both seasoned, new and prospective MORS Members (an excellent marketing tool for recruiting new MORS members!). The topics include everything from the history of our founding to details on membership and our awards and prizes for excellence in our profession. Get your updated copy today, and remember that communication implies a two-party dialogue. We want to hear from YOU! ✪

A Case Study: The Creation of a High Level Architecture

Dr. Randy Garrett

The previous year has seen a rising interest in something called the "High Level Architecture" (HLA). As with anything new, different people have different degrees of understanding. This column will give some historical insight into the creation process. Since a variety of people were involved, this account is only my version of the story, but hopefully the "author's intent" will become clear. Finally, it might be informative, amusing, or scary to hear a "case study" from an insider's viewpoint of how all these puzzling developments came to transpire.

The HLA began life as an Advanced Distributed Simulation (ADS) architecture within ARPA. Early in 1993, COL **Robert Reddy**, the Advanced Systems Technology Office (ASTO) Assistant Director for ADS had just completed an extensive review of the Synthetic Theater of War program. The ASTO Office Director, **Ron Murphy** — presumably now convinced that we had a better than even chance to actually accomplish the objectives of STOW — asked about the next ARPA program to follow STOW. Or were we planning to turn out the lights, close the doors, and go home? In the finest ARPA tradition, we assured him that we would be glad to present a detailed plan, at a meeting to be scheduled later. At which point, we all went back to our offices and panicked!

One critical element that rapidly emerged from our thinking was the need for a simulation framework or architecture that would unite all the future ARPA simulation programs, so that future programs could build on a common infrastructure. A common infrastructure would enable future programs to maximize ARPA research dollars by leveraging earlier investments. A common infrastructure would also facilitate interoperability among diverse programs, further promoting a synergy of efforts. To meet these goals, the ADS architecture would need to cover a variety of DoD mission areas, scale over a wide range of applications, be highly extensible, push the state-of-the-art in design, and offer extremely high performance in a multiple dimensions. Other than that, there were no stringent requirements! Given these criteria, we resorted to our normal approach, which was to turn to industry to ask someone else to solve our hard problems.

As we were preparing our Broad Agency Announcement (BAA) to solicit industry ideas, another group was beginning to meet that also had some problems. All four Services were planning to initiate new simulation programs to replace their current training models, which were reaching the end of their life cycle. Furthermore, given the continually increasing priority of Joint operations, the Services had a requirement for interoperability. The difficulties of achieving high levels of interoperability among independently created simulations were becoming notorious. An earlier ARPA program, Aggregate Level Simulation Protocol (ALSP), led by LTC **Mark Pullen** had very successfully whetted appetites for interoperability, but only so much could be achieved using existing models without extensive re-engineering. This group would later form a Joint Program Office known as the Joint Simulation Systems or JSIMS.

During the time JSIMS was formulating their plans, COL Reddy went to a meeting via helicopter with Dr. **Anita Jones**, the Director for Defense Research and Engineering (DDR&E). Since presumably no one had furnished Dr. Jones with a parachute, she had little alternative but to listen. The plan was reasonably elegant — okay, some people might say simple. The timelines for the development and deployment of all the Service programs were in reasonably close proximity. One critical element for JSIMS would be a common architecture. Since ARPA was in the process of developing an architecture for themselves, why not create a team effort to design an architecture that would not only form a foundation for future ARPA efforts and could be built upon by the Services for JSIMS? ARPA had already begun the procurement process, so could move quickly, and, to sweeten the deal, ARPA would pay for most of the initial effort. Finally, ARPA would transition this effort at some mutually agreed stage to another Agency and become a customer of their own process.

(See **CASE STUDY,** *p. 22)*

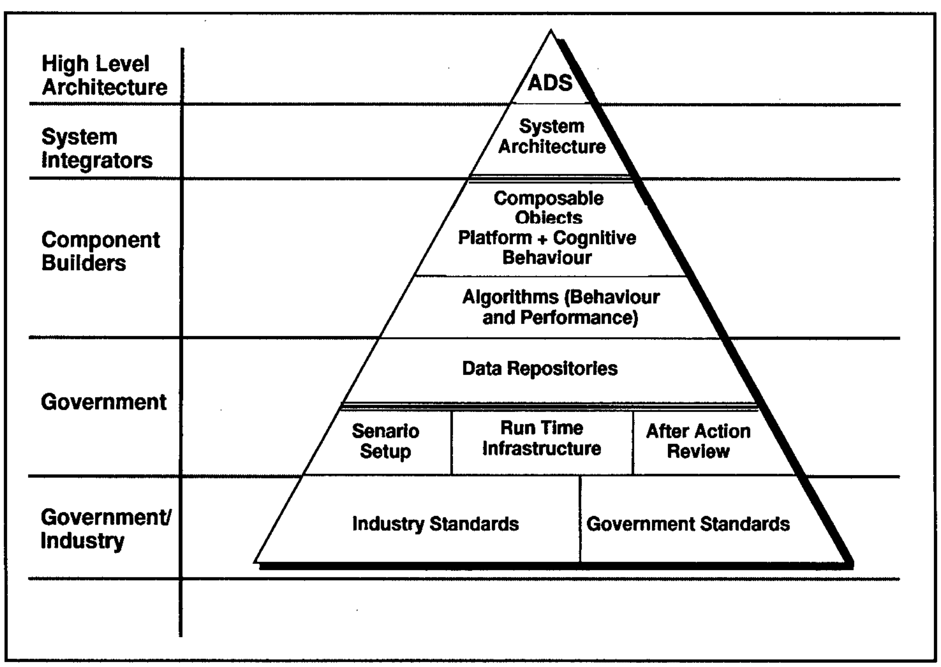

Figure 1.

CASE STUDY
(continued from p. 21)

And so, a deal was struck — Dr. Jones did not throw COL Reddy from the helicopter. Instead the BAA solicitation was modified to include JSIMS requirements and a combined evaluation team was formed. After an initial white paper review, approximately 30 proposals were received. A thorough review and critique resulted in three contracts being awarded. The winners were: **John Balisteri**, ETA Technologies; **Jim Cantor**, Science Applications International Corporation (SAIC), and Dr. **Karl Lindberg**, SRI International. COL **Jerry Wiedewitcsh**, formerly Deputy Director of the Defense Modeling and Simulation Office (DMSO), graciously contributed enough funding to fund one of the proposals. Perhaps being thrown from a helicopter would have been less painful in the long run!

A critical element of the architecture development process was the formation of a Program Evaluation Team (PET), organized by **George Lippencott** from the Institute for Defense Analyses. An extremely astute and capable retired Air Force Colonel, George had previously been a key advisor during the procurement of the ARPA WarBreaker program, then led by LtCol **David Neyland**, and would later be invaluable during the STOW Systems Engineering, Integration, and Development (SEID) creation. Members of the PET were carefully chosen to cover a variety of technical fields relevant to simulation plus represent the interested Service programs. By early August, all three contractors were vigorously working on a very intense schedule.

As the ARPA Program Manager, I provided the PET and the contractors with appropriate guidance — the figure looks much more intellectual with the original crayon colors. The sketch is based on a diagram in a newspaper tabloid I once read while waiting in a grocery checkout line (admit it; you look at them, too!), then thoughtfully modified during a boring meeting. Since the diagram was transmitted by aliens from outer space to John F. Kennedy, who used it to revive Elvis Presley — with the help of Marilyn Monroe, I figured it had to be good. Anyway, the intent of the pyramid is to show the relation of the HLA to the system architecture and assorted subcomponents, but is probably so unintelligible that I actually hope it serves as a cliffhanger for the next column. Will he actually be able to provide a halfway sensible explanation, or will he continue to sound totally ridiculous — the more likely outcome? Tune in next time!

References:

1. For a comprehensive statement of current HLA specifications, papers, and notes: see www.dmso.mil under the Architecture Management Group (AMG). ✪

ALSP
(continued from p. 13)

sitting on and rooted in the CBS model. The Translator converts messages from other models to the format understood by CBS. The root-like extensions shown in the figure are changes to CBS that cause CBS both to react to these messages and send its own messages to other models.

ALSP was promising technologically and enjoyed external funding support. This external funding was critical to USFK because the model interface task was too large for USFK to fund alone. However, the ALSP choice would not solve the USFK problem immediately. Only two models, CBS and AWSIM, were to have been modified for ALSP use by the end of Fiscal Year (FY) 92. Additional models could be modified subsequent to that time; however, no more than one to two major models were likely to be modified in a given year. The implication for USFK was that a complete confederation of five or six major models and two smaller models, interfaced through ALSP, might not be available until FY 96. Clearly hybrid solutions would be required to meet the USFK requirements for operations from FY 92 until the complete confederation is available. Human interfacing was the only immediately available supplemental option.

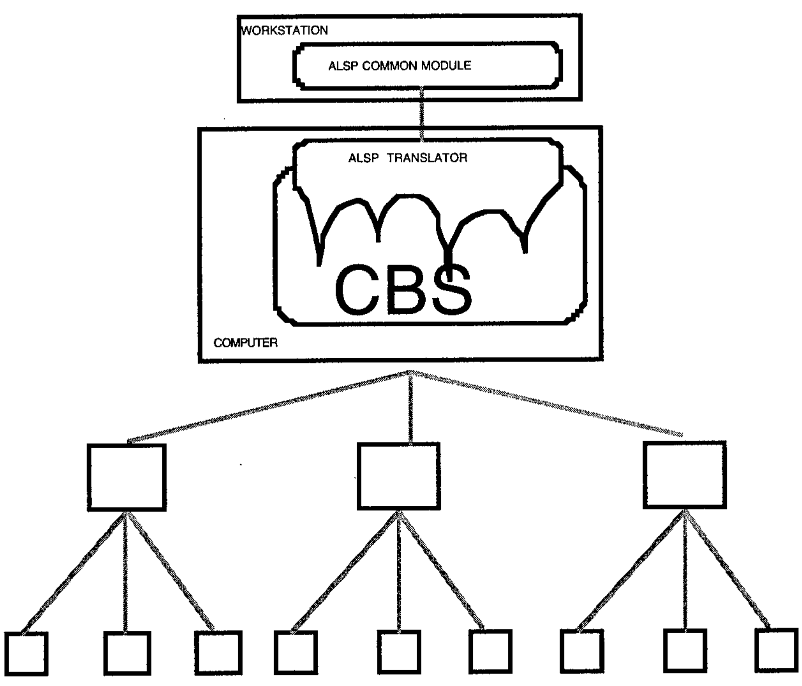

Figure 1. CBS under ALSP.

Several immediate and long-term concerns about using ALSP to solve the interface problem for USFK were apparent. USFK would require confederations of large numbers of models (a different configuration for each use). Would the message traffic become excessive? How extensive and expensive would the model modifications be? Many of the models are subject to configuration control by their owners. How receptive would the owners be to the modifications? Differing requirements might require differing confederations with corresponding differences of attribute ownership. How difficult would it be to modify the models to accommodate this? How extensive and

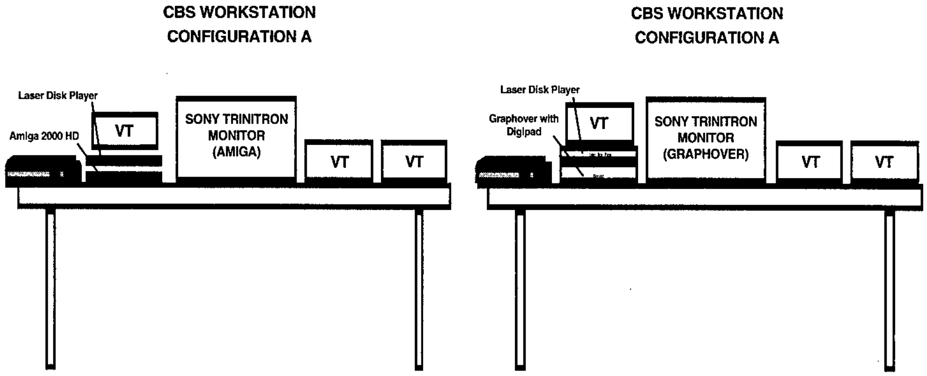

Figure 2. CBS Workstation Alternatives.

expensive would the aggregation/disaggregation problems be and how many versions would be required based on multiple confederation sets? Although DARPA was funding the initial modifications to AWSIM and CBS, DARPA was to step out of the picture, leaving other agencies to fund the modifications to other models (and further modifications to AWSIM and CBS required to communicate with new models). Despite the risks, USFK chose to use ALSP for UFL 92.

Physical Facilities

Running the models and especially running the exercise required physical facilities. The practical matter of the availability of facilities and funding to modify what is available placed restrictions on what could be done, requiring an iterative design process.

One starting point is an appreciation of the physical size and configuration requirements for the workstations for each of the models. Figure 2 illustrates the two types of CBS workstations that were used in Korea, each occupying a standard 6 foot long table.

Site layouts depend on equipment configurations. They also must be designed to accommodate functional team activities. An example site layout is illustrated in Figure 3. Notice that the workstations are arranged and labeled by functional team. In addition to the space requirements, space availability must be considered and compromises arrived at.

The design of the communications connections begins with the models' logical data flows. The logical data flows are realized as communications lines with named and sized circuits. In addition to model circuits, supporting communications lines must be added, such as video teleconferencing circuits to permit high data-rate personal interactions for solving problems quickly. All of the communications circuits are brought together to produce a set of overall circuit diagrams. Naturally, system security procedures also

(See **ALSP,** *p. 24)*

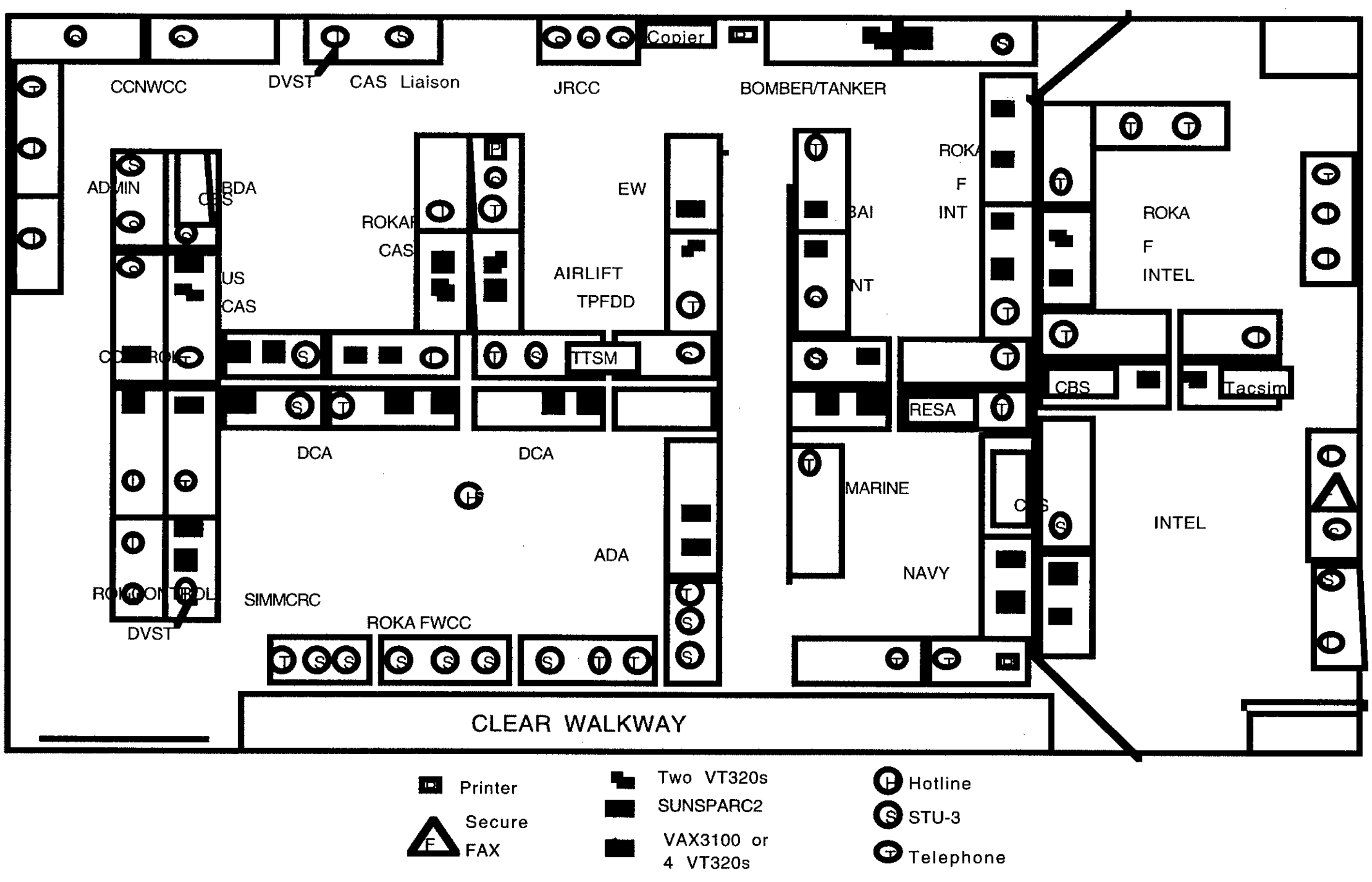

Figure 3. Osan Layout.

ALSP

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had to be addressed and solved.

The confederation's logical data flows are shown in Firure 4. ALSP was used to connect AWSIM in Europe at the Warrior Preparation Center (WPC) and CBS in Korea at the BSC. CBS terminals were remoted to I Corps at Fort Lewis, WA in the U.S. JECEWSI and RESA were connected to AWSIM with the WPC point-to-point connections. Similarly, TACSIM was connected (with a one-way link) to CBS in Korea. The resulting confederation was not perfect, but was an improvement over all manual links.

The overall communications architecture for simulation support to UFL 92 is illustrated in Figure 5. This figure illustrates a worldwide distributed architecture that includes communications networks with sites in Korea, the CONUS, and Germany. This linkage supported voice, data, and limited video interface between the simulation centers, the USS Blue Ridge, TACSIM user sites, and the Yongsan simulation technical control facilities in Buildings 2386, 2552, and 2555.

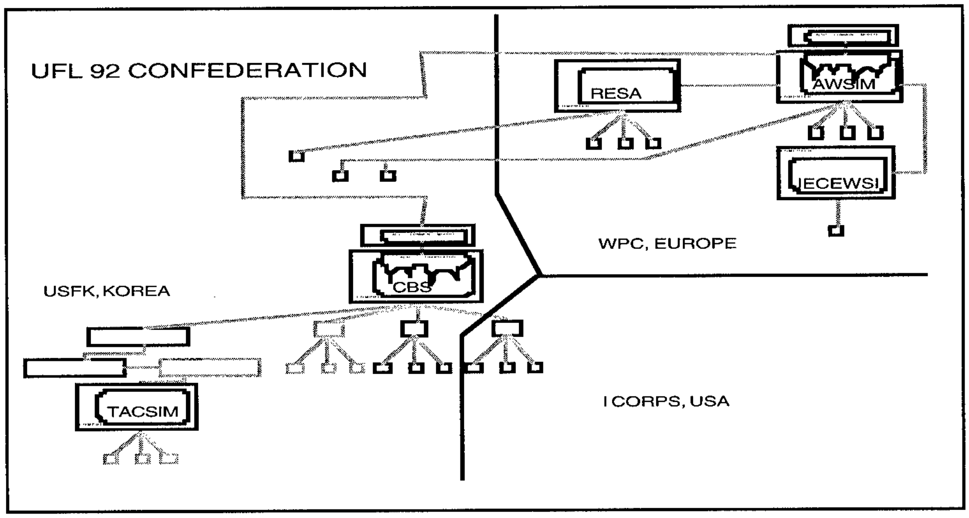

Figure 4. Model Connections for UFL 92.

More than 180 workstations were used in UFL 92, supporting AWSIM, CBAM, CBS, JECEWSI, the Joint Intelligence Model (JIM), the Joint Military After Action Reporting System (JMAARS), the Joint Strategic Target Acquisition and Reporting System (JSTARS), RESA, TACSIM, and TTSM. A total of eleven simulations and support software were employed in support of UFL 92, requiring a wide variety of computer hardware and supporting communications and networking.

Database

Although each model comes with a database for test purposes, those databases did not describe Korea, any Korean scenario, or even the weapons likely to be employed in Korea. Databases for the exercise needed to be constructed.

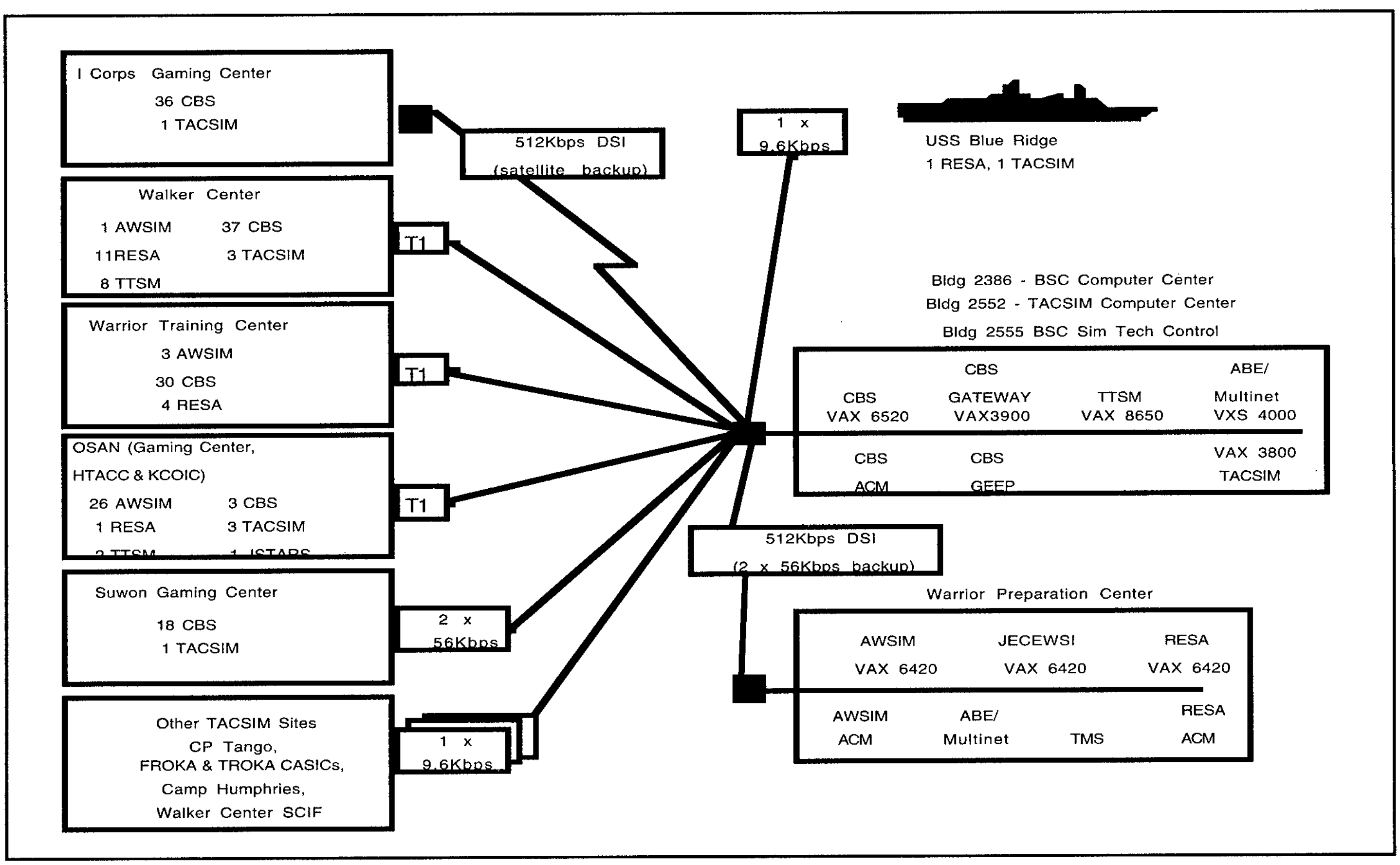

Figure 5. Communications Architecture.

Each of the models has its own database design and set of tools for handling the database. For example, a typical CBS database holds around 4 megabytes of data. The most visible data are the unit data. Unit data will include the specific unit's name (4th Battalion, 3rd Brigade, 4th Division), its size and type (battalion, infantry) and its make up (400 troops, 2 tanks, 1 flame-thrower, 3 anti-tank missiles, 10 jeeps). These are the data which are of most obvious and direct relevance to the players and they spend inordinate amounts of time ensuring that it is exactly the way they want it. These data will typically change significantly for each exercise. New weapons are particularly troublesome. The database manager only has limited capability to make the model adapt to new weapons. Every time that a new version of CBS is released, the database structure is modified as well. A typical upgrade may take several days of intensive work to complete a single database. When the model reads incorrectly formatted data, it will either crash then, or worse, wait until you are in the middle of the exercise and then crash! Further, some or all of the utilities which the database manager depends upon may need to be upgraded with a version change. Finally, it should be pointed out that with every upgrade, hidden anomalies in the model tend to surface.

The USFK BSC initially started with an unclassified generic Soviet type database. The organizations portrayed were made to look like the USFK threat forces by changing their names. Initially, little was done to modify the composition of the units to more accurately reflect the real world threat forces other than to refrain from using certain units which were dramatically different. For example, if an air defense brigade in the database was not extant in real life, it was not used or was moved far out of the competitive playbox. This type of solution was not totally satisfactory. The unit would still shoot at Blue air assets and print the reports associated with acquiring the tracks and the subsequent firing as well as any observable results of that weapons firing. The units not being used, regardless of where they were positioned or located, were still subject to normal attrition, which resulted in automatic resupply actions being generated by the model. Realism of the information contained in the database quickly became an issue when the generic Soviet type units displayed greater capabilities than the real world threat being played.

In addition to the simulation specific requirements for databases, the confederation of simulations imposes a requirement that the databases need to be logically consistent across the simulations. This does not mean that a similarly named data element should have the same value in each simulation, but rather that the values (based on the specific process models within the simulations) generate comparable results. Units sizes need to match or at least be interpretable by the interface. Weapons names have to match and expected results need to be compared. Agreements have to be reached on operational areas. When there simply is no match between weapons, "work-arounds" need to be devised.

A good example of this is the Marine's requirement for off-shore naval gunfire support. CBS didn't allow for such an implementation. To get around this, the CBS ability to make "on the fly" islands was used. The naval gunfire work-around was to create islands at the spot where ships should be and then move artillery pieces to those islands. However, the artillery pieces had to have weapons characteristics that closely matched naval weapons.

Conclusions

UFL 92 was a success and ALSP played a part in enabling the success. Technology improvements in computers made the first simulation centers possible by producing computers with sufficient capacity to handle significant sized battle simulations for use in military training. Further improvements, such as ALSP, have driven the costs down sufficiently for all major commands to consider the advantages of having their own BSCs. Budget constraints are forcing reductions in fully manned and equipped training exercises, shifting the emphasis in the direction of simulation based training exercises.

Unfortunately, simulation training requires a substantial overhead in support manpower: that is, personnel who are not part of the training audience. These support personnel operate the computers and convert actions by the training audience into inputs for the simulations and convert simulation activity into stimuli for the training audience. Major commands can afford the personnel to support division level training, which occurs frequently during the year. However, the personnel requirement for the once or twice a year theater exercises is not sustainable. New technology such as ALSP is enabling distributed simulation support, in which one or more simulation centers provide support to a simulation center undergoing a major exercise. They would, in turn, receive support during their major exercises.

It should be noted that, while ALSP provides the possibility of better exercises, it is not a panacea. Planning and executing an exercise of the magnitude of UFL requires much more than a model or a set of models. Actual use of constructive simulations for training requires careful consideration of a series of factors. The training needs specify the model requirements and the physical requirements. The model inventory specifies the input space, logical links, and computer hardware requirements. The locations, input space, logical links, and computers specify the electronic links. The locations, input space, and electronic links specify the facility design. Any (and there are bound to be some) restrictions on model inventory, input space, computers, or facilities will specify physical BSC connections. The BSC connections will modify the implementations of the designs.

Despite the complexities of designing and employing a confederation of simulations for training, there is a significant reward. Training can be more meaningful and thorough and can engage a larger proportion of the command and staff functions required in a real war. A better trained command structure produces better results in war and a more credible deterrence to potential adversaries.

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† Work sponsored by U.S. Forces Korea under DOE Project Number 1947-E096-A1 with the U.S. Department of Energy and performed by Lockheed Martin Energy Systems, Inc. ✪

FLASH: Just Added!

Tutorial on High-Level Architecture (HLA) will be given by Dr. **Judith Dahmann** on Monday 24 February from 1330 - 1700 immediately preceding the workshop. Details will be in your registration packet.

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Modeling and Simulation Operational Support Activity (MSOSA)

Marcus R. Erlandson, MSOSA

Today, DoD M&S activities demand considerable effort in event design, planning, and execution. A special task force, as well as several independent studies, concluded that duplication of effort in developing M&S assets and general lack of knowledge about already existing assets were prevalent among DoD activities. In response to the perceived need for better coordination and asset sharing within the DoD M&S community, the Executive Council on Modeling and Simulation (EXCIMS) approved the establishment of a prototype activity to provide expert assistance on the operational employment of Modeling and Simulation.

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- C4I Systems
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The MSOSA is presently providing its services free of charge to DoD customers. At the direction of the EXCIMS, it has focused its support on the training community, but, within the limits of its resources, it has been responding to requests for assistance from activities in the analysis and acquisition communities as well.

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Dr. **Robert Helmbold,** CAA

Contributions and comments are welcome and may be addressed to: US Army Concepts Analysis Agency, ATTN: CSCA-TA (Helmbold-Combat Analysis Editor), 8120 Woodmont Avenue, Bethesda, MD 20814-2797.

Well, lets start off by reviewing where we are in this series on the defender's advantage parameter, $ADV = \ln(\mu)$, as a measure of effectiveness in combat. Previous PHALANX Combat Analysis columns have taken up the following topics. In March 1993 we gave necessary and sufficient conditions for the validity of Lanchester's square law. In September 1993 we presented our version of the solution of Lanchester's square law, and showed how it naturally led to consideration of the lambda (λ) and mu (μ) parameters. We also noted that these are good indexes of the intensity and defender's advantage, respectively. In December 1994, we showed in detail that the advantage parameter governs a remarkably wide variety of qualitative properties related to possession of the advantage in combat operations. All of these results were based on theoretical considerations.

Our first column testing this theory against historical combat data appeared in March 1995. It used the SP128 data base to show that the advantage parameter is empirically a much better predictor of victory in battle than the logarithmic force ratio (the logarithm of the force ratio). In March 1996, we showed that this is also true for the much larger and more accurate CDB90DAT data base.

This column continues this series of empirical tests using different data bases. Here we use data from Bodart's massive dictionary of battles.[1] Bodart gives both side's strengths and losses for over 1,000 land and sea battles that took place between 1618 and 1905. Bodart also indicates which side won the battle. Unfortunately, Bodart does not say which side was the attacker and which the defender. So we lack the information needed to prepare graphical displays of the kind we used in earlier empirical tests and are forced to use tables instead of graphs. All of Bodart's numerically complete data on battles have been reduced to electronic data base format for convenience in performing analyses.[2]

We first consider Bodart's land combat data base in electronic form (BWSH). It has 1,087 entries for battles that occurred between 1619 and 1905, inclusive. We use the ADV parameter to predict which side won. This is done by computing from Bodart's strength and loss data the value of the ADV parameter favoring one of the sides. If the ADV parameter favoring that side is greater than zero, then we "guess" that Bodart will identify that side as the winner; otherwise we "guess" that Bodart will identify that side as the loser. We do the analogous thing, using force ratios (FRs) greater than one as the basis for guessing the winner. We then ask how often these guesses are correct. Some of Bodart's battles are sieges, which we treat separately because the theory that predicts victory based on ADV may apply better to nonsiege battles than to sieges. The following table gives the results. One of the 1,087 battles lacked the information needed to compute the ADV parameter, so only 1,086 battles are used here. The ADV parameter correctly predicted the winner in 946 (87%) of these battles. The FR parameter got 718 (66%) of them right. When we deleted the sieges, we were left with 973 battles. The ADV parameter correctly predicted the winner in 845 (87%) of these battles; the FR parameter got 626 (64%) of them right.

We now turn to Bodart's sea battles. The BODASHIP data base gives data on 120 naval battles that occurred between 1638 and 1905, inclusive. As for the land battles, Bodart identifies the winning side, but does not say which side was the attacker and which the defender. Now, for naval battles, one might argue that the ADV parameter computation ought to be based on the numbers of ships present and sunk on each side. However, we will not take that approach. Instead, even for naval battles, we continue to base the ADV parameter on the personnel strengths and casualties on each side. This is consistent with what was done for land battles. It also avoids the very difficult task of seeking an index that adequately rates the comparative "fighting strength" of different types and sizes of ships. Those who would rather base sea battle ADV parameters on the numbers of ships can consider that our

(See **COMBAT ANALYSIS,** *p. 30)*

Percentage of Bodart's Land Battle Winners Correctly Predicted by the ADV or FR Parameters

Data base	Number correct based on ADV	Out of total	Percent correct based on ADV	Number correct based on FR	Percent correct based on FR
BWSH-All	946	1086	87%	718	66%
BWSH-NoSiege	845	973	87%	626	64%

Percentage of Bodart's Sea Battle Winners Correctly Predicted by the ADV or FR Parameters

Data base	Number correct based on ADV	Out of total	Percent correct based on ADV	Number correct based on FR	Percent correct based on FR
BODASHIP	86	96%	90%	56	53%

COMBAT ANALYSIS

(continued from p. 29)

approach results in a particularly stringent test of the theory. The following table gives the results. Only 96 of Bodart's sea battles have enough information to compute the ADV parameter, but 105 of them have enough data to compute the (personnel) force ratio. The ADV parameter correctly predicts the winner in 86 out of 96 battles (90%). The force ratio got 56 out of 105 battles (53%) right.

So we have now shown that the ADV parameter is quite successful at predicting victory in battle for the SP128, CDB90DAT, PARCOMBO, BWSH, and BODASHIP data bases. In a future column we will discuss its application to a data base of wars, as distinguished from battles.

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LAW

(continued from p. 9)

impossible to discover any underlying correlations that could be identified as mathematical laws of socio-economic "motion".

Holistic Theories

The Aristotelian dream of a holistic approach to physics, biology, economics, history, and other phenomena was revived by Bertalanffly in 1968[25] under the heading of "system theory". System theory proposes to use mathematics to describe the time evolution of "the whole", like a living organism or a money-economy, but generally in the absence of adequate information about the local correlations of the connected links that determine the behavior of the whole[26].

Attempts to quantify the Aristotelian style of thought can be called "reductionist holism", or "holistic reductionism", because any mathematization whatsoever is an attempt at reductionism. Quantification necessarily ignores all nonquantifiable qualities, and there are many qualitative and quantitative considerations to ignore if we want to restrict our considerations to a definite mathematical model.

Every computer model of a society or an economy represents the invention of an artificial simulation of a society or economy. Mathematical simulations cannot adequately describe real societies and real economies, although through adequate politico-economic enforcement (selection) we can be constrained to simulate an economist's simulation of society and economics (recall Marxism). Every economic system represents a selection based upon a limited set of human needs, wants, resources, and illusions. According to Adam Smith, an unrestricted free market system is supposed to be regulated by an "invisible hand", a vague idea inspired in part by Calvinism and in part by the Newtonian example of Watt's flywheel governor.

Darwin's ideas of "natural selection, fitness, and adaptation" may make sense in sports and financial life, *but they also are not mathematically-defined.* That they remind us of the description of a market economy is not accidental: Darwin was very strongly influenced during the cruise of the Beagle by his second reading of Malthus[27], who was both a protestant preacher and theoretical economist.

There are two main sources of Darwin's undefined phrase "natural selection". The social-Darwinist origin of the phrase is Malthusian socio-economic doctrine, which derives from Calvinism and can be traced through the late medieval revival of puritanism by the religious reformers Luther, Calvin, and Zwingli back to the neo-Platonist St. Augustine[23], who bequeathed to western civilization a notion of selection called "predestination".

The only scientific motivation for Darwin's notion of natural selection came from plant and animal breeding, which he mislabeled as "artificial selection". Plant and animal breeding constitute the only known case of selection in biology because they proceed via manipulating certain initial conditions in order to try to achieve a desired result.

The scientific foundation of biologic evolution (or change) was established in Darwin's time by Mendel, who chose to become an Augustinian monk out of financial necessity[28] and was trained more in mathematics and physics than in biology. Mendel was not Augustinian in education and outlook: he was a lecturer in experimental physics who approached the problem of heredity via isolation of cause and effect in the spirit of a physicist.

Darwin and his contemporaries accepted a holistic picture of heredity that made the understanding of genetics impossible[29]. It was only after the rediscovery of Mendel's (ignored) discovery that a few biologists began to dislodge themselves from the teleological notion of organic evolution as progress toward a goal predetermined by a "selector". By ignoring "the whole" in favor of the most important parts inferred from performing simple, controlled experiments, Mendel found the key that divorced the study of heredity from unsystematic tinkering and socio-economic doctrine, and changed it into a precise mathematical science[30]. Economics has never had a Galileo or a Mendel.

Acknowledgement

I am grateful to my colleague and good friend Julian Palmore for the invitation to contribute this article, which summarizes parts of references 31 and 32 and also reflects the viewpoint of a forthcoming text on classical mechanics[33].

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Biography

The writer is professor of physics at the University of Houston with research interests in nonlinear dynamics, computability theory, porous media, statistical mechanics, and superfluidity. He has written two texts on nonlinear dynamics for Cambridge University Press, the second of which is scheduled to appear later in 1996.✪

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(continued from p. 7)

2 shows a schematic of a multi-modal transportation network. It shows the entire Reception, Staging, Onward movement and Integration (RSOI) process, starting from the ports of embarkation to the ports of debarkation, all the way to the foxhole. It also shows offshore pre-positioning involving aircraft carriers or some other land-based pre-positioning schemes. The Figure illustrates intermodal operations and the entire gamut of planning, deployment, execution, sustainment and training issues. Recently, the manufacturing process is included as part of the process, wherein the Global Transportation Network now encompasses the factory/fort to foxhole process. Correspondingly, we have the Force Projection Model of the Uni-

(See **MOBILITY,** *p. 32)*

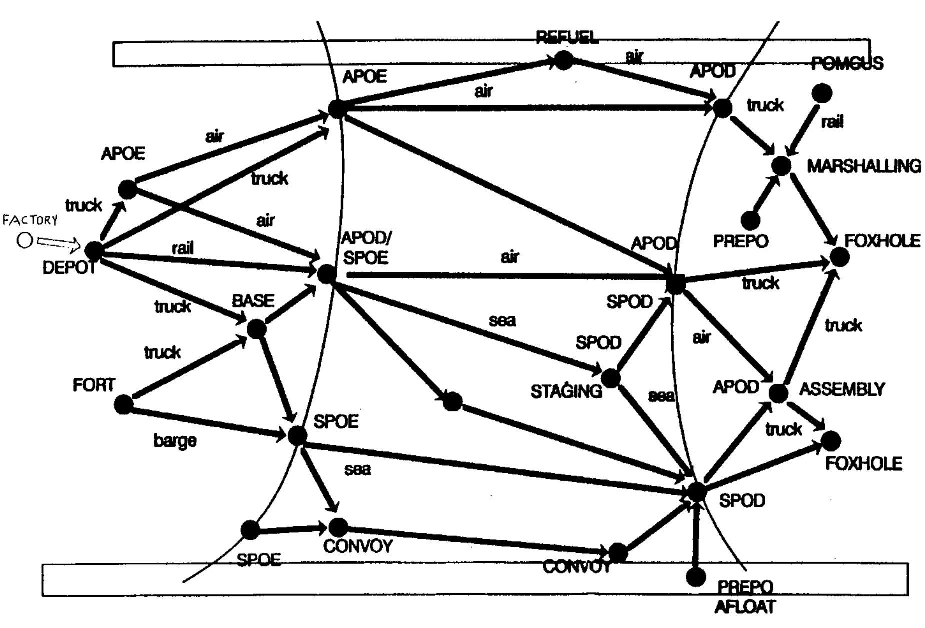

Figure 2: Multi-Modal Transportation Network (CAA 1995)

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(continued from p. 31)

fied Transportation Command and the Army's Transportation Engineering Agency (USTRANSCOM-TEA), the Force Deployment Estimator of the joint community, and the USTRANSCOM/DARPA Logistics Anchor Desk to respond to the challenge of RSOI. DARPA's Transportation Analysis, Modeling and Simulation program also addresses, among other things, the manufacturing logistics. At the present time, it is unclear whether there is a model constructed for training purposes.

Earlier we have already defined today's mobility problem as the integration of mobility issues with campaign analyses. For example, the current family of Air Force wargaming models do not realistically simulate logistics and other combat-support "show stoppers". To address this, the army recently has complemented their Mobility Model GDAS and Combat Concepts Evaluation Model (CEM) to include the Mobilization Capabilities Evaluation Model (MOBCEM). With today's emphasis on *object-oriented programming*, the ultimate goal is to define a common set of *objects* to be used in both mobility and combat analyses. We will come back to this point a bit later.

Modeling Disconnects

Current mobility models have a number of well recognized shortcomings (Yost 1985). In air-mobility models, utilization (UTE) rates are mystical numbers at best. UTE rate is defined as the number of operating hours per aircraft per day. Ideally, such a rate needs to be estimated by a model. But most mobility models require as input these rates as well. To the extent that most mobility models are executed sequentially, this poses a tautological dilemma: Is UTE rate a model input or model output? Another mystical number is maximum-on-ground (MOG). Ideally, MOG should be a combination of parking spaces, refueling and service time, and flow intervals between aircraft arriving at the terminal. They reflect both the ground-side and air-side capacity of a terminal, as pointed out in the Airfield Capacity Estimator of RAND Corporation.

In the joint services, the Time-Phased Force-Deployment Document (TPFDD) is yet another mystical number. TPFDD is beguilingly simple to define: who is moving to where and when they have to be there. Technically speaking, transportation analysts refers to this as a *demand function*, rather than a fixed number. It is a function because TPFDD varies depending on the level and quality of the lift capability. If the lift capacity fails to deliver personnel and supplies on time, we would lose the war and all TPFDD would be "zero". Straightforward as it may sound, TPFDD is viewed by the user community as an irrevocably rigid set of requirements. Only very reluctantly would the command structure allow these numbers to be edited and changed. We will try to connect these three disconnects—UTE-rate, MOG, and TPFDD—in our modeling proposal later.

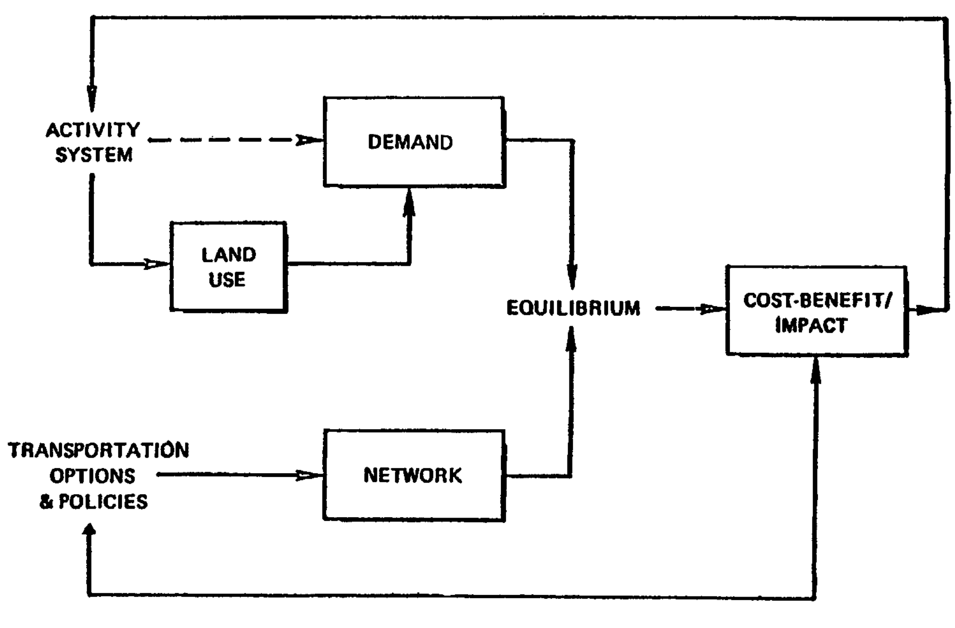

Figure 3: Relationship Between Different Classes of Models

In the Braess'-Paradox example, we have put into perspective the commonality between simulation and mathematical-programming approaches to modeling. However, the debate continues between simulators and optimizers. Simulators often suggest that the problem is too big and too complex to be cast into a mathematical program. Optimizers, on the other hand, suggest that the serial processing of data in simulation disallowed the look-ahead capability to optimize this system globally, as also illustrated by the myopic decisions made in the user-optimizing model. The two camps show little sign of easing up on their views. Meanwhile, simulation and optimization come in and go out of favor between decades, with simulation on the rise in recent years.

Much of the disconnects cited above are attributable to the sequential execution of models, as mentioned. Figure 3 shows a way to overcome this difficulty. Used in urban-transportation planning for a few decades by now, the feedbacks between models as shown in the Figure permit us to iteratively converge upon an equilibrium solution. Under *activity system* in the Figure we have included major regional conflicts, operations other than war, and war gaming in general. Under *land-use models* (or facility-location models), we account for base closures and pre-positioning strategies. Under *demand*, we have TPFDD as well as modal share among airlift, sealift and ground transportation. Under *transportation options and policies* we include such technologies as the C17 cargo-plane and information technology. Operations plans are also part of these options. Under *networks*, we have routing and scheduling of vehicles—together they give rise to vehicle UTE rates and MOG numbers. Under *equilibrium* is the capacity of the "lift" to satisfy the demand and hence the outcome of spatial games, whether it be stable or unstable. Under *cost benefit/impact* would be all the measures of effectiveness. Perhaps the most important message that comes out of Figure 3 is that— because of all the feedback loops—demand (TPFDD) is variable instead of fixed; failure to deliver for example will result in zero demand, inasmuch as the war has been lost!

The feedback between the different classes of models in Figure 3 has fascinated urban-transportation researchers for decades. It is clear that an iterative (rather than sequential) execution of these models is no trivial task, particularly when one wishes to compute spatial equilibrium by balancing lift capability against demand. But recent research progress has been encouraging, as admirably documented by Oppenheim (1995). Aside from theoretical challenges, it is clear that the equilibrium process is computationally intensive. While special cases have been worked out thoroughly, the general problem remains unsolved. Even for special cases, the problem of model verification and validation remains evasive at best. In spite of this, the state-of-the-art in urban-transportation modeling is a fertile ground for cross fertilization to the defense mobility community. Setting aside the different contexts from which civilian and military transportation originate, there are more commonalities than one would imagine. For example, the Intelligent Transportation System advocated by the civilian sector addresses many of the real-time, logistical decisions faced by the military. The civilian community has also refined the art in predicting *modal share*, or the relative split between various transportation modes (air vs. ground transportation, etc.)—an issue that has only been picked up by the joint defense community.

There has been a perceived chasm between the applications community and the research community involving the ways and means to resolve mobility and transportation problems in general. While there is a need for high-quality analysis to be performed on a day-to-day basis, the state-of-the-art technologies are often not brought to bear upon the problem. At the same time, the research community is equally frustrated about the lack of sophistication in analysis performed on a real-time basis, which prevents important insights to be gained. It has been said that many of the technological advances of operations research and transportation science are at least twenty years ahead of applications. In response to this problem, Part II of this article is geared toward narrowing the gap between research and applications by having a meaningful, structured dialogue between the two sides.

While the Mobility Requirement Study (MRS) and Bottom Up Review Update (BURU) examine strategic mobility, recent efforts strive to integrate mobility issues into existing campaign analysis. This will bring mobility to the theater level, in which real-time, stochastic events are explicitly modelled. Also of importance is multi-modal transportation systems, wherein lift capacity is provided by a combination of aircraft, trucks, rail, as well as water-borne vessels. This is in response—once again—to the "new world order", wherein the strategic confrontation between the East and the West is now replaced by regional conflicts which can flare up at a moment's notice. Strategic-mobility requirements are now over shadowed by tactical transportation demands. Furthermore, increasing emphasis is placed on joint operations as mentioned.

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Biographies

Yupo Chan *is Professor, Department of Operational Sciences, Air Force Institute of Technology. Dr. Chan received all his three degrees from MIT. His 25 years of post-doctoral experience encompasses industry, academia and government, including an honorary assignment as a Congressional Fellow. He is currently a Director of the MORS Board.*

James L. Johnson *is currently Director of Projection Forces, Program Analysis and Evaluation, Office of the Secretary of Defense (OSD) in the Pentagon. Mr. Johnson is the OSD sponsor of MORS.* ✪

QRAM

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Ms. Christine Fossett, and **Dr. Roy Rice.** This group met with the issue category leaders at the end of each session and prepared a high-level report of cross-cutting ideas. Mr. Thomas also prepared a meeting feedback report for MORS.

Observations

In the QRAM mini-symposium, participants focused on the analytic processes

(See **QRAM,** *p. 34)*

QRAM Synthesis Group

C4ISR	Mr. John Osterholz	Deputy Director, CISA
	Mr. Mark Herman	Booz Allen Hamilton
Readiness	Mr. Joe Angello	Dep Director, OUSD(Readiness)
	Mr. Bob Holz	Army Research Institute
MOOTW	RADM Gary Wheatley	Evidence Based Research
Infrastructure	Mr. Dan Barker	OD/PA&E/Resource Analysis
Force Structure	Mr. Bob Statz	Booz Allen Hamilton
Modernization	Dr. David Graham	Institute for Defense Analyses
WMD	Dr. Bruce Bennett	RAND
	Mr. Pat McKenna	USSTRATCOM/J53

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and methodologies required to gain a first order understanding of seven issue categories. The organizing concept for their explorations was the matrix that compared the availability and significance of a cold versus warm base for analysis, given a suspense of two days, two weeks, or two months. There is the obvious point that the warmer the base the more readily and competently quick response analysis can be accomplished, however, during the mini-symposium planning, the idea of a warm base primarily focused on tools and data bases. Discussions about what different organizations were doing to prepare for the QDR pointed out that quality analysis in support of efforts like the QDR, required that the intellectual/analytical base and the organizational base should also be kept warm.

In terms of the intellectual/analytical base, it was observed that we have tended in the last few years to assume that investment in research means investment in technology demonstrations and distributed simulation enhancers. In addition we have tended to equate the capability to use spreadsheets and computer models with analytical capability. Careful consideration of the requirements for warming up the intellectual/analytical base will focus on how we educate new analysts, how we upgrade the skills of current analysts, and how we invest in basic intellectual research. In the latter area, an important follow-up to this mini-symposium would be the development of a list of critical research topics.

The organizational base must also be warm to insure that quick response analysis is also quality analysis. In the world of business, the most recent leadership model in vogue focuses on *connectedness.* A related term in venture capital circles is the Japanese term *Kereitsu* which is used to describe an interlinking group of organizations that share common information, data sources, and goals. The focus of *kereitsu* is on investing to build industries as opposed to working individually to build companies. The Department has mirrored the trend toward connectiveness in recent efforts for collaborative analysis on weapons mix studies. The extension of this effort to a major activity like the QDR requires an escape from the traditional large review stovepipes. Rather than each defense component preparing to defend its interests every four years, participants suggested building a connected structure that keeps the whole organizational base warm. Notice the use of the word WARM, not HOT. Keeping the base warm with connectedness doesn't mean that components can't appropriately defend their interests. In fact, as RAND's David Chu and Paul Davis have both pointed out, competition is worth encouraging, but only after first building a solid common knowledge base.

Issue category sessions were individually structured by the issue leaders to explore options to support quick response analytic requirements. For example, C4ISR participants developed two week study plans for the question, "In support of POM "XX" what is the most cost effective balance of weapon systems/platforms and C4ISR capabilities to accomplish the Prevision Strike Mission." The *Recapitalization/Modernization/Life Extension* group explored intergenerational tradeoffs vs new missions, cross area tradeoffs, and process and institutions for modernization. The *Military Operations Other than War* team noted the lack of integrated data bases for MOOTW analysis as well as the need for multi-dimensional readiness measures that capture PERSTEMPO concerns. The *Weapons of Mass Destruction* participants explored the current analytic capability to address the question: Would NBC make a difference operationally and strategically? The *Force Structure* team investigated a process to evaluate the force structure requirements under risk and uncertainty using an investment portfolio approach. The *Infrastructure* group considered how to analyze of what is needed (capacity)! and what is the most cost effective (efficient) way to provide it. Cost drivers, data issues, incentives and impediments were explored. The Readiness/Sustainability/ Supportability participants looked at analysis processes for PERSTEMPO, Tiered Readiness, Peacetime Demand, and Logistics-sustainment.

Follow-on activities for this mini-symposium will include a report, a session at the annual symposium, and forther exploration of quick response analysis methodologies.

The general session presentors, issue category leaders, participants and the synthesis group did an outstanding job of considering quick response requirements and methodologies in light of the QDR. As ususal, this meeting would not have been possible without the professional support of **Natalie Addison**, MORS Vice President for Administration, **Cynthia Kee LaFrieniere**, **Michael Cronin**, and the leadership of **Dick Wiles**, MORS Executive Vice President. ✪

DECKER
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Testing benefits through increased use of simulations by eliminating costly repetitions and assessing what may not otherwise be testable. Using simulation in manufacturing can develop or validate a manufacturing plan and reduce cost/schedule risk. Logistics requirements can be better assessed by integrating these requirements into simulation models. When a system is fielded, the use of simulators and simulations may reduce the cost for maintaining training proficiency.

The Army is currently using simulations and simulators in the acquisition process. Advanced simulators are now being used in the development of the RAH-66 Comanche helicopter. These simulators integrate six degree of freedom motion simulation with computational and display power. Actual flight control laws can be programmed into the simulator and validated through many extremes before flying the aircraft. In the missile community, hardware-in-the-loop simulation is not only proving out better designs and creating efficiencies in designing new missiles, it is vital to ensuring that we can design the missile at all within any amount of affordability.

What is important here is that modeling and simulation techniques are being included in our acquisition strategies early on to achieve maximum benefits. In fact, as I stated earlier, we can gain even larger payoffs by having these techniques employed earlier in the requirements determination process.

Over the last year and after detailed study, the Army adopted a new process methodology for determining its requirements and translating them into Mission Need Statements and Operational Requirements Documents. This process is essentially an integrated product team called the Integrated Concept Team (ICT). Here, not just the doctrinaires, but members from the acquisition community, including technologists and simulation members, are part of the ICT. Together they work to understand the implication of suggested requirements in terms of system design difficulty and potential cost. Once concepts and requirements are decided, engineering design and manufacturing trade-offs are considered.

The ICT approach should take full advantage of the military operations research techniques which will allow us to pursue not only operational concepts and requirements, but also consider engineering design and manufacturing trade-offs in a stimulating environment. Together, the ICT works to understand the implication of suggested requirements in terms of difficulty of system design and potential cost. This same documented process introduces cost as an independent variable (CAIV) as part of the requirements process. At this early stage, modeling and simulation are the primary vehicle for conducting effective analyses for use in the CAIV approach to weapon systems design.

In order for the ICTs to clearly understand difficulty, risk, affordability, and the statement of warfighting requirement, they will need to do early-on system design in a rapid manner and place that system design in simulations to determine warfighting effectiveness. A key tool of military operations research is virtual simulation techniques which have been instrumental in developing "Synthetic Theaters Of War" (STOW) — realistic synthetic battlefields where the ICT can "experiment" on virtual prototypes to maximize effectiveness at reasonable cost.

In fact, this electronic agility allows us to see the system design, use its parameters to design it into the simulation, and then display it in different operational settings to determine the critical variables and cost drivers. This has enormous potential because, at present, we determine the requirements based almost exclusively on envisioned military needs. It is only later that we find out that some requirements are just not affordable or are far more risky than envisioned originally.

Simulation is also important to our efforts to improve our capability to prove out and test designs and systems integration. At present, test design, planning, and rehearsal are limited because of the time and cost inherent in "live" test and evaluation. As weapons become more expensive and lethal, some attributes of systems are best tested by simulation due either to safety or affordability issues. The cycle of "test-fix-test" is a strain on our modernization resources and increases the time it takes us to field more capable equipment. When possible, we must reduce costly live repetitive testing and capitalize on the capability of simulations.

Integrated virtual models and simulations offer an opportunity to test new equipment in a full spectrum of synthetic environments, a "Virtual Proving Ground" (VPG) of sorts. The VPG synthetic environment encompasses both hardware-in-the-loop and man-in-the-loop simulations. Ultimately, VPG will allow us to link our knowledge of weapon systems performance within synthetic environments directly into constructive models, design and engineering models, and virtual prototypes.

Advances in Distributed Interactive Simulation (DIS) offer significant savings not only in concept formulation and testing, but in operations and support costs. System-specific embedded training devices can employ actual weapon systems software and operational command and control networks to accomplish training. For example, through DIS, the Crusader advanced field artillery system will link an embedded training capability at the force level with the advanced Family of Simulations (FAMSIM) and Warfighter's Simulation 2000 (WARSIM 2000) to exercise and train multiple tasks, conditions, and leading-edge concepts.

There are other examples of applications, but the main message is that simulation is like software and computing power. When software and computing power became used routinely, it revolutionized the world, moving it from an industrially-based world to an information-based world. Simulation, in my opinion, is an aggregation of this technology. It offers great insight into where we might be in the future, not just in defense but in other areas as well. Simulation will revolutionize our thinking and certainly have a major impact on our military operations.

My challenge in the modeling and simulation arena is for the operations research community to take the lead in the integration of simulation tools and technologies across all acquisition functions and programs. Simulations must be seamlessly integrated to provide our program managers with the ability to reduce time, resources, and risks while increasing the quality and productivity of our weapon systems.

Military operations research is an integral component of the Army's process to build a force ready to meet the challenges of the 21st century. Our plans will not become a reality without the powerful analytical tools and techniques that our operations research/systems analysts bring to the table.

Biography

*Mr. **Gilbert F. Decker** graduated from The Johns Hopkins University in 1958, with a degree in electrical engineering and a commission in the U.S. Army as an Armor Lieutenant. He attended flight school and served on active duty as an Army Aviator until 1964. Upon leaving the service, he attended Stanford University earning a Master of Science Degree in Operations Research in 1966.*

From 1966 to 1982, Mr. Decker was employed by ESL, Incorporated, rising to the Presidency of that firm in 1977. Since then, he has headed the New Ventures Department of TRW, served as President and CEO of Penn Central Federal Systems Company, and as President and CEO of Acurex Corporation.

Mr. Decker served on the Army Science Board from March 1, 1983 to November 1989. He served as Chairman from March 1987 until the end of his appointment on the Board. Mr. Decker retained his commission and remained active in the Army Reserve until 1988, at which time he retired from the Reserve as a Colonel.

Sworn in as the Assistant Secretary of the Army for Research, Development and Acquisition on April 21, 1994, Mr. Decker serves as the Army Acquisition Executive (AAE), the Senior Procurement Executive, the Science Advisor to the Secretary, and the Senior Research and Development (R&D) official for Department of the Army. ✪

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THE LAST WORD

PHALANX Special Issue on VV&A of M&S

Jim Sikora, FS
BDM Federal

The June 1997 *PHALANX* will be a special issue on verification,validation and accreditation (VV&A) of models and simulations (M&S). It will contain articles which provide an overview of M&S VV&A status and current issues and concerns. The issue will also cover other facets of VV&A including the verification, validation and certification (VV&C) of data, the cost of VV&A, VV&A policies, and VV&A in an advanced distributed simulation environment. If you have a special interest in another VV&A area you would like to see addressed, or would like to contribute an article or other input to one of the VV&A facets shown above, contact Jim Sikora, FS at e-mail at **jsikora@bdm.com** or telephone at (505) 848-5650. ✪