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Using the Quadrennial Defense Review to Prepare for Tomorrow — An Air Force Perspective

Good analysis and intuition based on informed judgment are complementary. And good analysts are key to good analysis. They must establish good relationships with the decision makers or the warfighters they aid, they must seek out relevant data, and they must design requirements for improved models while using and understanding the limits of the models currently in hand.

Most of us understand that analysis is never adequate by itself. Good analysis does not dictate answers, but rather provides insight which informs and supports the decision maker. Decision maker intuition is the key to the process, but it is analysis that confirms the goodness of intuition. Should an analytic result be counter-intuitive, that signals a need for explanation. A check of the scenario, the assumptions, or the data and the model may determine that one or more of these factors should be adjusted. On the other hand, if the analysis has been comprehensive, the seemingly counter-intuitive result could serve as a basis for a decision maker to adjust his or her intuition. Even in this case, it is the decision maker's judgment that drives this adjustment, relying on analysis to provide the appropriate rationale. While the combination of good analysis and good intuition is not necessarily predictive, the results may provide an indication of inherent risk, and that, in itself, provides valuable assistance to the decision maker.

Our recent experience in preparing the Quadrennial Defense Review (QDR) and participating in the National Defense Panel has shown that, more than ever, we need to improve our use of analysis by utilizing



General Ralph E. Eberhart,
Vice Chief of Staff,
Headquarters, US Air Force

good analysts, improving our current models, and creating new and better tools to assist in the analytical process.

Analysis in the Quadrennial Defense Review

The Background. The QDR was the fourth comprehensive review of our military since the end of the Cold War, and was built on the valuable experience of its precursors, including the 1991 Base Force Review, the 1993 Bottom-Up Review, the 1995 Commission on Roles and Missions of the Armed Forces, and the Deep Attack Weapons Mix Study that began in 1995. The Congressional Military Force Structure Review Act of 1996 which mandated the QDR noted that these studies were useful,

but inadequate, given the rapid pace of global events.

The Act directed the Department of Defense to conduct a quadrennial review of the defense program of the United States that would involve "a comprehensive examination of defense strategy, the force structure of the active, guard, and reserve components, force modernization plans, infrastructure, and other elements of the defense program and policies in order to determine and express the defense strategy of the United States and to establish a revised defense program through the year 2005." The Act also established an independent panel to help the Secretary with the QDR, and, starting with the QDR submission to Congress, to do some force structure assessments looking out to 2020. The Secretary was then to consult with the Chairman of the Joint Chiefs of Staff, and pass the Panel report to Congress with his comments.

As the Act provided, Secretary Cohen submitted his QDR-97 report to Congress, and Congress immediately received two assessments. One came from the Chairman of the Joint Chiefs of Staff and was a part of the QDR report. The other came from the Chairman of the National Defense Panel. Both QDR-97 and the independent National Defense Panel called for improvements in all models, partly because most of the far term and "grand strategic" aspects in the QDR had to be based on judgment alone. Although some models now exist which could potentially be used in QDR-01 to address those aspects, we need to continue improving all the tools necessary to prepare for QDR-01 and beyond.

(See QUADRENNIAL DEFENSE, p. 30)

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Creating a Shared Vision and Long-Term Commitment



Dr. Jerry
Kotchka
MORS President

As a team of volunteers, we started this 1997-1998 MORS year with the goal to re-emphasize and revitalize our efforts to capture opportunities, meet challenges, and make change in order to keep Military Operations Research relevant.

We have also strived to create a shared vision and long term commitment to keep our Military Operations Research Society relevant, not only to our membership and their parent organizations, but also to our six Sponsors from the Department of Defense. We started with **Fred Hartman's** results from focusing on the foundations of analysis and went on to develop and implement a two year plan that supported the purpose and strategic objectives of MORS. The definition and execution of this plan took the efforts of each member of the Executive Council, all the remaining Board of Directors, the MORS office staff and many other volunteers.

We pressed forward in many dimensions. The first was to continue to address the analytical underpinnings, emerging technology and tools, and developments in modeling and simulations by conducting special meetings on SIMTECH 2007, Session 1 (by Dr. **Stu Starr** and his team) and on the Analysis Requirements for the Next QDR (by **Mike Leonard** and his team). Plans exist to conduct SIMTECH 2007 Session 2, in August and another in our series on advanced distributed simulation (by Dr. **Hank Dubin** and his team) in February 1999.

A second dimension was the focusing of the operations analysis community on emerging and not necessarily new challenges. This was achieved by conducting our special joint meeting on infrastructure (led by **Dan Barker**, USAF/MORS and Dr. **Dan Nussbaum**, Navy/SCEA). Planning continues to conduct a special meeting in early October to focus on the analyt-

ical basis, tools, and databases needed to analyze information dominance/C4ISR.

Another dimension was critical thinking to challenge the paradigms typically used by our community to generate alternatives for decision makers. The first part of this effort was a special meeting on Warfare Analysis and Complexity (by Dr. **Julian Palmore** and his team). The second part was an expansion of our focus on professional development with a two-day Education Colloquium that would emphasize understanding the problem or issue and thinking about a criteria for measuring outcomes before "running the model" to derive an answer.

Cutting across all these dimensions was the year long effort to plan and execute our annual Symposium at the Naval Postgraduate School in Monterey, CA. **RADM Pierce Johnson**, our Program Chair, and his team are preparing three challenging days that will permit our Society to learn together and laugh together. When the theme for the 66th MORSS is examined, a claim suggests itself: By "Preparing for Military Operations Research in the 21st Century," we are preparing to keep Military Operations Research relevant. We are all looking forward to implementing the new re-engineered working group structure. A footnote to the effort to plan, coordinate, and execute the 66th MORS is the extraordinary effort by **CDR Kirk Michealson** to document an expanded Plan of Actions and Milestones along with detailed descriptions of the processes needed to pull off a superb Symposium. Kirk's effort will have enduring value for many future Symposia. This effort was recognized early by the board and Kirk has already received a "MORS Impact Award" Coin and as important, many "smiles and thanks" from the MORS office staff.

Another thrust that cuts across all MORS activities is the push to interact throughout the year with not only our Sponsors but also our Members. In addition to the Sponsors' luncheons (at Quantico in June and the Pentagon in January), **Dick Wiles** and I have made personal calls throughout the year on eight Sponsors

(General **Campbell** (J-8) and General **Sanderson** (USAF) were added during the year) and the new Navy Sponsor's Representative, Dr. **Susan Marquis**, to share the direction that MORS was taking, solicit feedback, and obtain their views of emerging challenges. We also called on thirteen different analytical groups and talked to over 200 analysts, professors, students and managers (S3I, TASC, Boeing-St. Louis, Boeing-Seattle, Logicon, MCR, SPA, IDA, LMI, CNA, MITRE, AFIT and NPS) — always thanking them for their past support, encouraging future MORS participation, and obtaining constructive feedback. I could not have accomplished these visits from my home base in St. Louis, MO without the strong support and dedication to MORS that **Dick Wiles** showed throughout the year. No task was too big or too small for him to personally support. His keen sense of professionalism will always remain with me, and I thank him for all of us.

If you have read the "VEEP PEEPS" in *PHALANX*, then you have been exposed to the strong members of the Executive Council that we were fortunate to have this year. **Fred Hartman**, our immediate Past President, was available for cogent advice and demonstrated again his dedication to MORS by producing outstanding nominees for awards and a new slate of strong candidates for the next Executive Council. **Denny Baer**, VP (FM) carefully kept his eye on not only the finances but also the development of an integrated Plan of Actions and Milestones for the Board of Directors. **Sue Iwanski**, VP (Meeting Operations), provided effective oversight to our special meetings and annual Symposium. **Bob Sheldon**, VP (Professional Affairs) efficiently pushed the expanded Education Colloquium, along with heritage and publication activities. Our Secretary, **CAPT Lee Dick**, continues to amaze us with the rapid expansion of our electronic media capability. It has been a blessing to work with this team of professionals and to have the daily support of the dedicated MORS office staff.

(See *MORS PRESIDENT*, p. 16)

MAS — Executing the Vision



Tom Gulledge
MAS President

As I reported to you in my last column, it has been many years since MAS has hosted a conference. There is no particular reason, but MAS conferences were quite common in the 1980s, while in recent years we have focused almost entirely on the INFORMS National Meetings. As previously reported, the MAS membership indicated that a MAS conference — independent of the INFORMS National Meetings — was desirable. The idea for a MAS National Conference was proposed by my predecessor (**Steve Balut**), and was executed by our Redstone Arsenal Chapter.

In my last column, I discussed the conference, and by the time that you read this column, the conference will be underway or completed. So, as President of MAS I personally thank all of those involved in organizing and executing the conference at the University of Alabama in Huntsville. The coordinated efforts of many people are required to make a conference of this size a success, but we owe a special thanks to the General Chair, **Tony Brinkley** of Teledyne Brown Engineering, and the Program Chair, **Bruce Fowler** of US Army Aviation Missile Command. We sincerely thank you for helping us execute the MAS membership's vision!

Now, we are soliciting your support for our next National Conference. If you have ideas, or would like to make a proposal to host the next conference, please contact me (gulledge@gm.u.edu) or Bruce Fowler (fowler-bw@redstone.army.mil). The MAS Council wants to continually respond to your professional needs, so we appreciate any feedback that you could provide on the Huntsville meeting, as well as make suggestions for future meetings.

We will host our normal group of ses-



Cadet Dabkowski Receiving Award from COL David C. Arney

sions at the INFORMS National Meeting in October. This meeting will be held in Seattle, and the MAS Cluster Chair is **Pat Murphy** of the US Army Concepts Analysis Agency (murphy@vail.caa.army.mil). Please contact Pat directly for information about the Seattle conference.

I am completing this column with the continuation of our on-going recognition of our award-winning students. The student awards program is a source of pride for MAS, since the students represent our future. As a university professor, I attend many graduation ceremonies, but the service academies are special. Once again, I plan to attend as many of these ceremonies as possible, and personally present the awards.

In this column MAS recognizes Cadet **Matthew F. Dabkowski**, who received the award for outstanding achievement in the Operations Research discipline. Since I was not at West Point for the ceremony (I will be there this year), I thank LTC **Bill Fox** of the USMA Mathematical Sciences Department for helping me with this write-up.

The criterion for the award winner is the highest overall GPA in the required

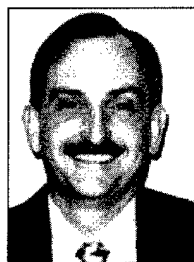
courses for the Operations Research Major. The Operations Research Major is an interdisciplinary major that is jointly administered by the Departments of Mathematical Sciences and Systems Engineering. The 10 required courses are (Mathematics) Linear Algebra, Mathematical Modeling, Nonlinear Optimization, Linear Programming, Applied Statistics and Mathematical Statistics (Systems Engineering) Systems Simulation, Combat Modeling, Computer Aided Systems Engineering, Decision Analysis. USMA uses the following scale for credit hours (A-4, B-3, C-2, D-1, and F-0), but in reality, they internally assign up to an A+, which is worth 4.33 credit hours. Cadet Dabkowski's GPA for these courses was 4.2475. He was a clear winner.

Cadet Dabkowski graduated with a cumulative 4.0 average and was named a distinguished cadet. He graduated in June 1997 and was commissioned as a 2LT in the US Army. He was awarded the cadet Star for academics in each of his four years at the academy. Additionally, he was awarded the Wreath three times for overall achievement within the three domains of physical, military, and academic performance. Congratulations to Cadet Dabkowski.

As usual, feel free to contact me by Internet (gulledge@gm.u.edu). The MAS Council continually monitors the MAS Listserver, and you can always contact the membership or us by this means. If you are not already a member of the list, you can subscribe by sending the following message to majordomo@mat.gsia.cmu.edu: subscribe mas Your Name, Title <yourname@domain.org>

If you have problems, send a note to **Philipp Djang**. He doubles as the moderator of the list. I will use the listserver to provide information of interest to the Military Operations Research community as it is passed to me. I encourage you to do the same. ☺

Financial Report



Dennis Baer
VP of Finance

1997 was a great year financially for MORS. We ended up with almost \$42K addition to fund balance. Last year helped offset our \$28K decrease in fund balance in 1996 and "breakeven" the year before. As most

people are aware, MORS is a non-profit organization. Addition to fund balance in a non-profit organization is similar terminology to "profit." Future reference in this article to "profit" means an addition to funds balance.

The financial success last year was due to lots of hard work by numerous people within the Society. First and foremost, the MORS staff was instrumental in keeping costs to a minimum. The next major rea-

son for financial success was four versus three special meetings. Many thanks to those who planned, executed, and participated in the special meetings this past year. The 65th MORSS staff helped produce a spectacular event, which resulted in great turnout in the D.C. area. Publications were also a great source of "profit." MORS wants to continue to provide quality publications useful to the Operations Research community. ☺

In keeping with US Postal Service regulations, we must publish this "Statement of Ownership, Management and Circulation" information in the *PHALANX*. This will be an annual occurrence.

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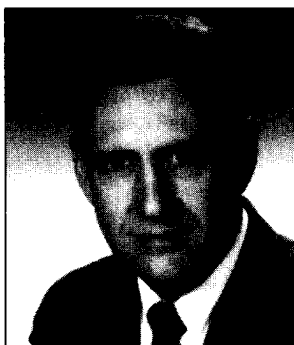
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MORS Election Process



Fred Hartman
Past President

The President and other officers of the Society are elected from and by the Board of Directors at the summer Board meeting. This year the MORS elections are going to be more exciting than ever! At the Winter Board of Director's (BoD) Meeting the new position of President Elect was approved, and for the first time in MORS history, we will be

electing two MORS Presidents during the same election. During the Summer BoD Meeting just prior to the MORSS in Monterey on 23-25 June 1998 we will be voting for the next President of MORS, to serve from June 1998 to June 1999 and the President Elect, who will serve as President from June 1999 to June 2000. In the Summer BoD meeting of 1999, we will be back to electing only one individual who will immediately serve as the President Elect and then ascend to the office of President from June of 2000 to June of 2001. It is appropriate that we move MORS forward into the next Century with a strengthened Executive Council by designating an individual who can work with the Committee Chairs, during the year prior to taking office, to prepare for the MORSS "after next," a full slate of Special Meetings, and other strategic planning issues.

The Past President has the responsibility of chairing the Nominating Committee that nominates the slate of new Board Members and the candidates for MORS Office. Again this year, MORS has an especially strong slate of officer candidates to submit for election at the Summer BoD Meeting. Each has already made important contributions over many years of service to the Society. The candidates for President are **Denny Baer**, **CAPT Lee Dick** and **Bob Sheldon**. Each candidate for President has prepared an article which serves as his platform document and lays out his vision and plan for leading MORS. After one of these individuals is elected to the office of President of the Society, the other two individuals (and any candidates nominated from the floor) will be voted on for the office of President Elect. The other officers elected at this meeting are the Vice Presidents for Finance and Management, Meeting Operations, Professional Affairs, and Secretary of the Society.

Candidates for the other MORS Officers are: Vice President for Finance & Management — **Sue Iwanski** and **Ted Smyth**; Vice President for Meeting Operations — **Dean Hartley** and **Roy Rice**; Vice President for Professional Affairs — **Yupo Chan** and MAJ **Willie McFadden**; Secretary — Col **Tom Allen** and **Howard Whitley**. As indicated above, the Board is free to nominate, from

"Again this year, MORS has an especially strong slate of officer candidates to submit for election at the Summer BoD Meeting.

Each has already made important contributions over many years

of service to the Society. The candidates for President are

Denny Baer, CAPT Lee Dick and Bob Sheldon."

the floor, other qualified individuals who have previously agreed to run, prior to each Officer election. We wish all the candidates well in their up coming elections and feel confident that the Society will be well served by any of the above candidates for office.

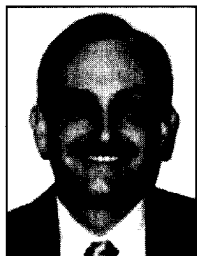
When the Directors complete their four year term, they rotate off the Board and elections are held to maintain the authorized strength of twenty eight elected voting directors. Nominations for newly vacated Director positions are made from within the MORS membership community by the BoD. The Board strives to select Directors for Board membership keeping the representative base of various constituents of the Society in mind and, more importantly, maintaining the Board with the first class leadership, talent expertise and experience necessary to promote the goals of the Society and serve you the membership and Sponsors.

If you are interested in serving the Society more directly and being considered for nomination to the Board, please contact any of the existing Board members or the MORS office for details. The results of both the MORS BoD and Officer elections will be announced at the Symposium in June! See you in Monterey!! ☺

THE PRESIDENTIAL PLATFORMS

"The Younger Analyst — Bridging the Gap ..."

Dennis Baer
Vice President of Finance



It is indeed both an honor and a privilege to be a candidate for President of the Military Operations Research Society this year. Congratulations and sincere thanks go to Dr. Jerry Kotchka for

his leadership and guidance of the Society during the previous year. I will use my two years of Executive Council experience to ensure the momentum built by his team does not "skip a beat" and is further enhanced during the coming year. One of the key roles and almost full-time job of the President is to motivate and reward the almost all-volunteer MORS force to support the twelve goals of this Society. This is where I intend to focus most of my energy.

We must make decisions in a timely fashion so that new ideas from the membership are quickly put into action before they die. To do this, the remainder of the Executive Council must be empowered to make decisions and motivate the remainder of his/her "followers" on an almost weekly basis. I will encourage the Executive Council to communicate between others during the year on general topics of interest to MORS, not only topics relevant to their specific area. Keeping within the guidelines of our by-laws we must make decisions quickly — not quarterly.

Last year's theme was "Keeping Military OR Relevant." This central theme helped focus the Society on keeping our analysis relevant to the changing times. This year I want to focus our attention on the situation of the current workforce, where the average age of our analysts is increasing and soon these personnel will be retiring. The theme "The Younger Analyst — Bridging the Gap Between Yesterday's Analysis And Tomorrow's Solutions" will be used to increase the awareness of this situation throughout the military analytical community. "Younger" is not necessarily defined by age, but by experi-

(See BAER, p. 14)

Pacing Technology for the Analyst

CAPT Lee Dick
Secretary



It is indeed an honor and a privilege to be chosen as a candidate for President of the Military Operations Research Society from among the many highly qualified, dedicated fellow

colleagues on the Board of Directors. Our Society is fortunate, in that we have so many well-qualified volunteers to call on who are willing to give their personal time and energy to become Board members and help to lead the direction for the Society as we turn the corner into the next millennium. In retrospect, I have viewed with admiration and respect the ideas, actions and accomplishments by those whose footsteps I've followed, the Directors and Executive Council members of the past, to whom we all owe a huge debt of gratitude. I am happy to repay some of that debt in whatever capacity you ask, to take my turn to contribute to such a fine group of professionals and to such a well respected and renown organization.

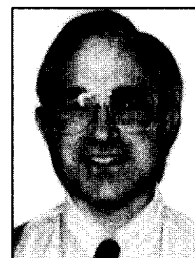
Planning, Programming and Executing

This has been an exciting year for MORS. Starting with the highly successful 65th Symposium at Quantico, relevant Special Meetings such as the "Warfare and Analysis Complexity" in September 1997, the first phase of "Simulation Technology 2007" held in December, "Measuring the Cost and Benefit of DoD Infrastructure" in January, and the "Analysis Requirements for the Next QDR" in April 1998 have kept the activity of the Society at a high level as well as carried forward Jerry Kotchka's theme for the current year. An active management committee, in addition to attending the business end of the Society, has produced a much needed upgrade to the Organization Manual while in the area of Profes-

(See DICK, p. 14)

Teamwork and the Scientific Method: The Pillars of Military Operations Research

Dr. Bob Sheldon
Vice President for Professional Affairs



MORS as a professional Society provides a significant return on investment to its Sponsors and members. The value is evident in our continuing promotion of team-

work and the scientific method as the two pillars of analysis. Military Operations Research (OR) was born as a career field in World War II and continues to prove its relevance today by providing insights and shaping solutions to difficult military operational challenges. We must continue to keep Military OR relevant by sharpening our scientific skills and teaming to apply them to the military issues of tomorrow.

The Foundations of MORS

This year, MORS is republishing the first of a series of classics in Military OR, "Methods of Operations Research" by Philip M. Morse and George E. Kimball, originally written during World War II. In this seminal work, Morse and Kimball provide a working definition of OR: "Operations Research is a scientific method of providing executive departments with a quantitative basis for decisions regarding operations under their control." During the war, OR teams combined scientists with military operational experts (before they were dubbed "subject matter experts" or the ubiquitous "SMEs"). Together, these two communities forged a partnership that serves as the foundation of our organization today.

According to Morse and Kimball, "First of all operations research is a scientific method." Biologist Claude Villee provides perhaps the shortest definition of the scientific method: "Organized common sense."

(See SHELDON, p. 15)

DC Area Tours for Navy Operations Research Graduates: What's Available for Us?



CDR Kirk
Michealson

About four years ago, I was assigned as Executive Officer (XO) on a Guided Missile Frigate and was contemplating what to request on my preference card for my post-XO shore duty. I was completing my sixth straight year of sea duty and my son was an eighth grader at his eighth school. Therefore, I was looking for shore duty that would not only allow me to work in Operations Research, but would also provide my family some needed stability.

Research was essential, since the only shore duty I had previously experienced was my tour at the Naval Postgraduate School. The drawdown added a new wrinkle because the time between a surface warfare officer's XO and command tour had lengthened to as much as 5 years. Knowing that I might have to fit two tours of duty into that time frame and that stability was a family priority, it was essential to locate in an area where it would be easy to get a follow-on tour.

I had studiously avoided Washington, DC up until then. I had heard horror stories of the cost of living and the commute. However, I cannot think of another duty station that offers so many OR billets, and my family and I are extremely happy here. Currently, I'm on my second-straight, post-XO, OR-coded shore duty assignment. This article summarizes my shore duty selection process for DC area OR-coded billets and also discusses how my Master's Degree prepared me for these jobs. Specifically, I plan to describe when Operations Research payback tours normally occur, where the OR-payback tours are located, what the duties of two typical OR-payback assignments are, which courses from my Master's Degree best prepared me for these assignments, and how to get involved with the OR community.

Timing of Payback Tours

When do Operations Research payback

tours normally occur for navy officers? Shown here is not an all-inclusive list, but a snapshot of one class — the eight navy officers that were in my class. What can we observe from this "snapshot?" Basically, there is no exact time for an OR-payback tour. When, or if, the shore duty occurs depends on the specific individual and the primary warfare specialty. Normally after postgraduate school, all navy officers will go back to their primary warfare specialty (aviation, surface, submarines, etc.) for a department head or executive officer tour, and then roll to shore duty, possibly for an OR-payback tour. Let me use my class as an example to explain (the rank indicated was the rank held while at NPS).

The LCDR F/A-18 pilot did not have an OR-payback tour; all of his shore duty assignments were related to naval aviation. As a result of his performance at sea and on shore, he was selected for the prestigious nuclear command pipeline for carriers and is currently an XO of a nuclear-powered aircraft carrier (CVN). The LCDR Helo pilot's shore duty assignments are unknown because our class did not keep in touch with him.

For the Maritime Patrol Aircraft Naval Flight Officers (NFO), we have two cases to consider. The LCDR P-3 NFO's situation does not normally occur: while at NPS, he didn't screen for Department

Head, and as a result, he did not go back to his primary warfare specialty. He completed three OR-related payback tours and then retired from the navy. On the other hand, according to the Navy's Operations Analysis subspecialty manager, the timing for the LT P-3 NFO is fairly normal. After completing the department head job (about 2-3 years after completion of postgraduate education), P-3 NFOs are normally available for shore duty.

Our submarine warfare officer chose to go to the Nuclear Propulsion Examining Board for his first shore duty following his department head tour and then for his second shore duty, to an OR-payback tour following his XO tour. In my 3-1/2 years on shore duty, I've only known two submarine warfare officers in payback tours. The two were the LT Subs listed here and another who completed two OR-payback tours: the first after his department head tours (about four years after completing NPS) and his second after his XO tour.

For surface warfare officers (SWO), we had two Lieutenants with different shore duty timings. The first SWO had an extra long second department head job and was told that he was too "senior" for a shore duty assignment following his department head tour and, therefore, was sent directly back to sea for his XO tour. As a result, his first payback tour was not until the executive officer tour was com-

Naval Officer	Primary Specialty	Years to Payback	Payback Tour(s)	Current Job
LCDR	F/A-18 Pilot	NA	No payback tour	CVN-70 XO
LCDR	Helo Pilot	?	Unknown	Unknown
LCDR	P-3 NFO	0 — —	USCINCPAC J-5 (M&S and wargaming) CINCPACFLT (wargaming) OPNAV, N85 (program assessments)	Civilian Senior OR Analyst - DC
LT	P-3 NFO	2.5	OPTEVFOR (M&S)	OPNAV, N81 (reserves)
LT	Subs	8	OPNAV, N81 (JMA/SA & strategic)	PCO Pipeline (SSN)
LT	SWO	7	OPNAV, N81 (force structure)	OSD, PA&E (forward presence)
LT	SWO	4 —	OPNAV, N81 (surface assessments) OPTEVFOR (M&S)	Civilian Senior OR Analyst - DC
LT	Seal	NA	No payback tour	SOC (acquisition mgmt)

"Snapshot" of OR Payback Tours

pleted. The other LT SWO completed a more typical sea-shore rotation for surface warfare officers, going to his OR-payback tour following his department head job.

The LT Seal did not do an OR-payback tour. Instead he opted for the acquisition management pipeline and was accepted into the program.

What can we observe from this one class?

1. Three of eight, or 38% — all line officers, went to the Navy Staff (OPNAV) first ➔ 37% of the total Operations Research-coded billets for line officers are on the Navy Staff.
2. One of eight, or 13%, went to a Battle Group (BG)/CINC Staff first ➔ 20% of total Operations Research-coded billets are BG/CINC Staff billets.
3. One of eight, or 13% — all line officers, went to the Operational Test and Evaluation Force Staff (OPTEVFOR) first ➔ 13.5% of the total Operations Research-coded billets for line officers are OPTEVFOR billets.

Therefore, not only does having an OR-payback tour depend on the specific individual's desires and their primary warfare specialty, but the timing also depends on where the naval officer is in his or her individual career progression. As an example, the specific initial OR-payback tours for my class are fairly representative of the total opportunities that are available for Naval Operations Research analysts and should provide some general insight when one would expect their first OR-payback tour.

Where are the Operations Research-Coded Payback Tours Located?

If you want to know what types of billets are available (i.e., command, location, designator, rank, Planned Rotation Date (PRD) of incumbent, etc.), you can contact the Operations Research Subspecialty Manager, CDR Steve Phillips, at 703-614-9125, DSN 224-9125, or e-mail phillips.steven@hq.navy.mil. This job is normally held by the OR curriculum Sponsor/reserve assessments action officer in the Assessment Division (N81) on the Navy Staff.

To determine where I wanted to go for shore duty, I used his billet listing to provide a general overview of the possible

payback tours. There are 189 total OR-coded billets, with anywhere from 1-2 billets per BG/CINC Staff (this is 21% of the total billets). Also, about 12% of the total are instructor/war college billets, and about 10% are at miscellaneous commands such as the Naval Security Group or DORA in Richmond, Virginia.

There are 27 billets near Washington DC or currently in the DC area but some are scheduled to move in the near future. For those commands near DC, twelve are Modeling & Simulation/Test & Evaluation billets at OPTEVFOR in Norfolk, Virginia, and five are at the Air Test & Evaluation Squadron in Pax River, Maryland. Commands in the DC area with OR-billets that are scheduled to move out of the area are the Space and Warfare Systems Command, SPAWAR, (5 billets) which is moving to San Diego and the Bureau of Naval Personnel, BUPERS, (7 billets) which is moving to Memphis.

In the DC area, there are 80 billets (42% of the total) available, with the majority of the billets in the Pentagon (OPNAV, Office of the Secretary of Defense (OSD), & the Joint Staff) and in Crystal City (Naval Center for Cost Analysis, NCCA). Over 60 percent of the billets in the DC area (49) are in the Pentagon:

- 31 in the Assessment Division of the Navy Staff (N81)
- 4 in the Expeditionary Warfare Division of the Navy Staff (N85)
- 2 in the Space, Command & Control Directorate of the Navy Staff (N6)
- 2 in the Air Warfare Division of the Navy Staff (N88)
- 4 on the Joint Staff

- 6 in the Program Analysis & Evaluation Directorate of OSD

Also, 15 billets are available at the Naval Center for Cost Analysis, seven are available at the Navy Recruiting Command, seven are available at Bureau of Naval Medicine, BUMED, and there are two other billets available — Defense Information Systems Agency (DISA), and the National Defense University.

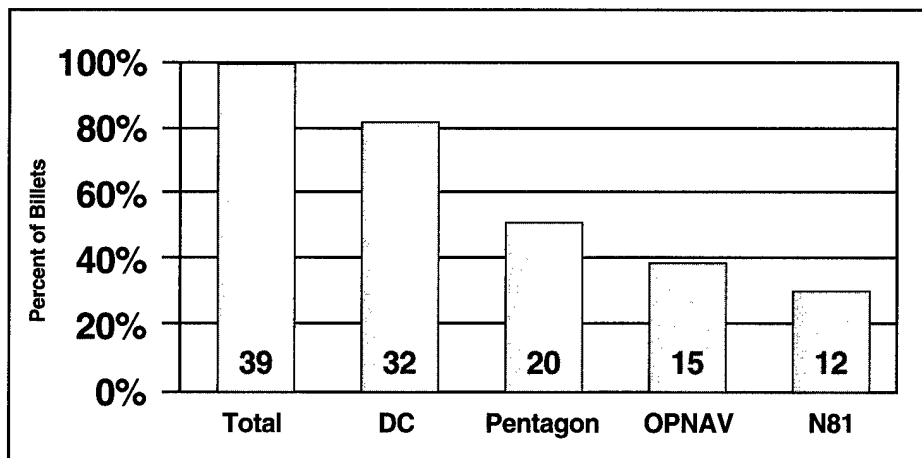
Why the Odds Favored Me Going to DC

When it was time for me to finally roll to shore duty, I used the OR-billet listing to assist me filling out my preference card. Since I wanted an OR-payback tour where I would be able to transfer possibly without moving my family and I didn't want a BG/CINC Staff nor an instructor/naval war college (NWC) billet, I concentrated on billets in the DC area. As a result, I looked at the OR-coded billet listing to determine the percentages of:

- billets that were in the DC area?
- billets that were in the Pentagon?
- billets that were on the Navy Staff?
- billets that were in the Assessment Division?

With a total of 189 OR-coded billets, just over 40% were in DC & about 25% in the Pentagon. When I eliminated the BG/CINC Staff billets and the instructor/NWC billets, there were 126 billets remaining, and of those, over 60% were in the DC area and about half were on the Navy Staff. I then realized that I wasn't

(See TOURS, p. 10)



Eligible OR Billets for Surface Warfare Officers

TOURS

(continued from p. 9)

eligible for all of those billets (i.e., wrong designators), so I next looked at just the line officer billets. Of the 89 billets left, about two-thirds were in the DC area and half in the Pentagon. Since those 89 billets were a combination of all line billets (i.e., submarine, aviation, etc.), I then looked at all billets eligible for Surface Warfare Officers (SWOs). Of the 39 remaining billets, about four-fifths were in the DC area, half in the Pentagon, two-fifths on the Navy Staff, and one-third in the Assessment Division. Similar percentages were discovered when the aviation and submarine billets were examined independently.

Since I didn't want to work on a Battle Group Staff nor be an instructor and based on the above percentages of SWO billets available — I concluded that DC was the place to go, if I wanted to increase my chances of not moving my family between assignments. As a result of my "newly discovered" interest in the DC area, the OR Subspecialty Manager recommended one of the jobs in the Assessment Division (N81).

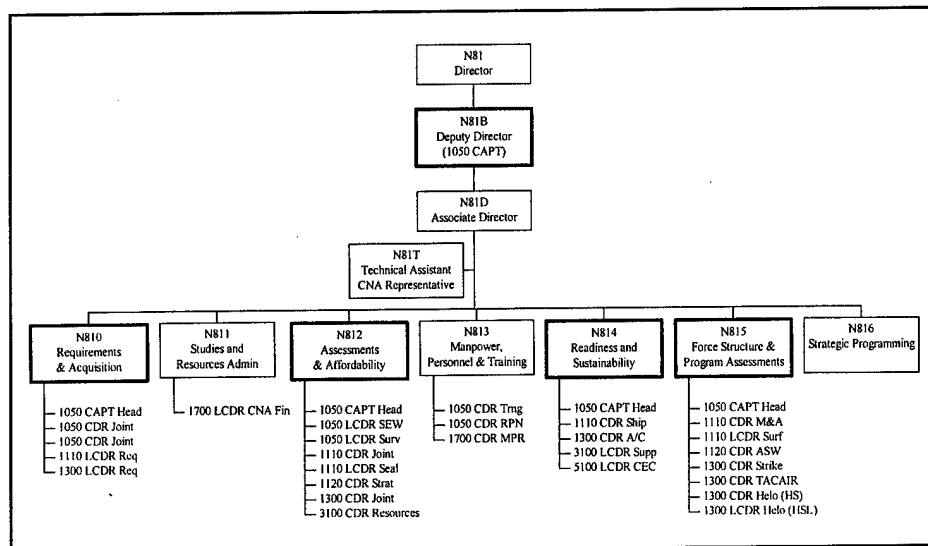
Typical DC Area

OR-Payback Assignments

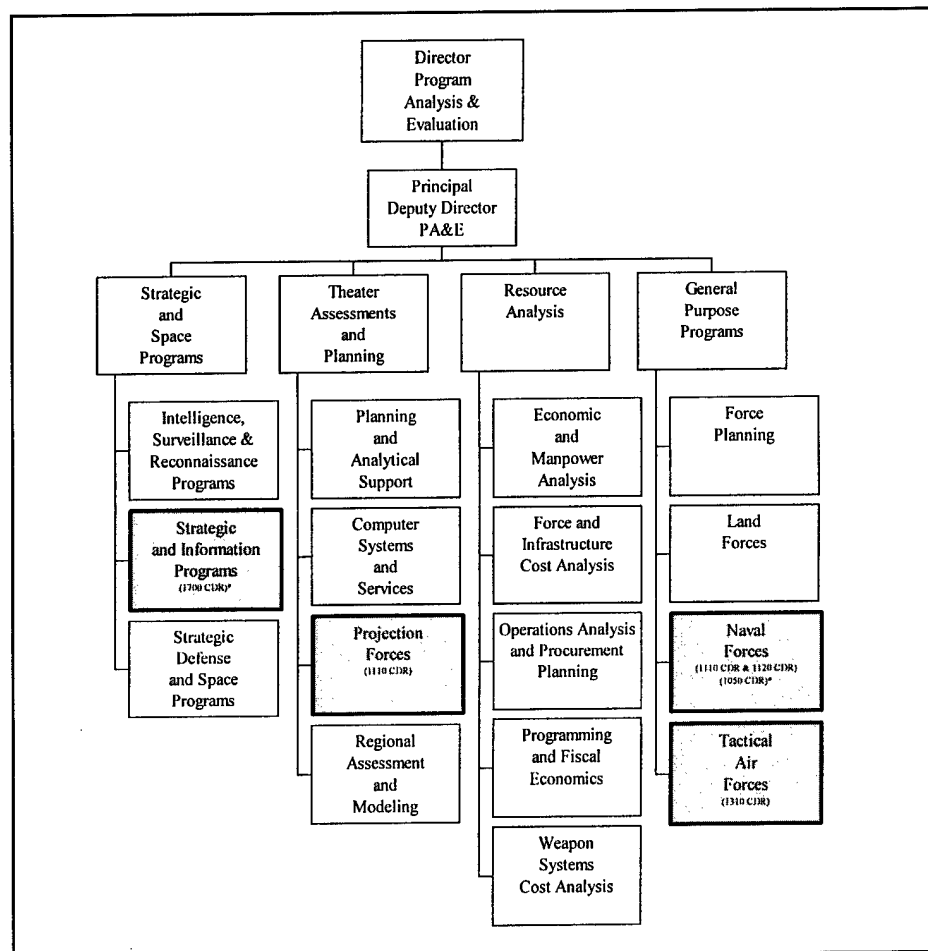
My first payback tour was the exact job the OR Subspecialty Manager recommended in N81. In this division, we were the "honest brokers" for the Chief of Naval Operations (along with the financial management analysts in the Programming Division, N80). We were required to present all of the facts to the Chief Naval Officer (CNO), i.e., present the whole truth. We were not necessarily to agree with our parent warfare division (in my case, the Surface Warfare Division), especially if the facts didn't support their position.

Here is how the Assessment Division is organized. There are seven branches and a total of 31 OR-coded billets. Each billet is listed in its respective branch by designator and rank. The highlighted boxes have positions you can return to for a post-command (O-6) tour. Generally, N81 is responsible for independent assessments, the Joint Readiness Oversight Council (JROC)/Joint Warfare Capability Assessments (JWCA), readiness assessments, requirements/acquisition process monitoring, and other various studies and analyses.

For the CNO & Vice Chief of Naval



OCNO, Assessment Division (N81)



OSD, Program Analysis and Evaluation

Operations (VCNO), N81 provides "honest broker" assessments of various programs (normally on one-page point papers). On these point papers, the background, MAJOR issues/concerns, and recommendations are discussed. These "honest broker" assessments are applica-

ble to all seven branches.

The overall acquisition process is monitored by the Requirements & Acquisition (N810) and the Force Structure & Program Assessments (N815) Branches. N810 is the documentation verification branch. The personnel assigned here ensure all

acquisition-related documentation is developed and written properly, and then they forward the paperwork for proper signatures. N815 monitors individual program status. In addition to reviewing all acquisition documentation with N810, they monitor the overall program status, ensuring each program is ready to proceed to the next milestone.

The majority of studies and analyses for N81 are monitored by the Studies and Administration Resources Branch (N811). Except for the in-house Modeling & Simulation conducted in N812 and the Non-Nuclear Ordnance Requirements (NNOR) analyses performed in N815, all other studies requested by the N81 staff is contracted through N811. Also, N81 is the Contracting Officer's Technical Representative for the Military Operations Research Society (MORS), which is managed by N811.

All branches in N81, except N810 and N811, analyze individual program assessments. The Assessments & Affordability Branch (N812) performs the process control functions for these program assessments. N812 is the Navy point of contact for coordination of Joint Mission Assessments/Support Assessments (JMA/SAs) on the Navy Staff with personnel from N812, N813, N814, and N815 participating on the JMA/SA teams. N812 is also the Navy Staff point of contact for coordination of all Joint Warfare Capability Assessments (JWCAs) with personnel from N812-N815 and the entire Navy Staff participating on the JWCA teams. The Assessments & Affordability Branch coordinates the Integrated Balance Review (IBR) and then sends it to the Programming Division (N80) for POM development (budget) with personnel from N812-N815 participating in issue development.

Finally, N815 conducts all Navy-related force structure analyses (surface ship and aircraft), while all readiness-related issues (including quality of life, reserve, and medical program issues) are assessed by the Readiness (N814) and Manpower, Personnel, & Training (N813) branches.

During my two years in N81, I was the Surface Ship Anti-Air Warfare/Force Structure/Forward Presence Analyst in the Force Structure & Program Assessments Branch (N815). The first 15 months, I primarily conducted program assessments reviewing documentation and attending

meetings (JMA, JWCAs & Analysis of Alternatives (AOA)), but I also maintained the Navy's long range force structure planning estimate for ships and conducted some force presence analyses. During my last nine months, I conducted several independent analyses for N81's technical director on alternate Navy force structures, future surface combatant costing, and forward presence analysis standardization.

My second payback tour was in Naval Forces Division in the Program Analysis & Evaluation (PA&E) Directorate on the Secretary of Defense's Staff. The analysts in PA&E are the "honest brokers" for the Secretary of Defense (along with the financial management analysts in the Cost Analysis Improvement Group or CAIG). Again, PA&E is supposed to tell the whole truth, not necessarily agreeing with our parent service's position, but this time reporting to the Secretary of Defense instead of the CNO.

PA&E is organized into basically four departments with three to five divisions per department. There are only six total OR-coded billets in PA&E; of which two of the six are "on loan" from the Navy Staff (have been for about 10 years). I have highlighted the divisions with the OR-coded billets. In the box, I have listed each billet with its respective designator and rank. The two "loaner billets" are the 1700-billet in the Strategic & Information Programs Division and the 1050-billet (any warfare specialty) in Naval Forces Division. Generally, PA&E advises the Secretary of Defense, the Deputy Secretary of Defense, and the Comptroller on major acquisition and programming items for all services. PA&E also coordinates and reviews the service budget (POM) submissions, evaluates acquisition-related analyses, and conducts/coordinates independent studies on force structure, mission capabilities and industrial base issues.

The Strategic & Information Programs Division works with strategic forces-related issues (ICBMs, SSBNs, SLBMs, long-range bombers, nuclear warheads, arms compliance, counterproliferation of Weapons of Mass Destruction, and START II). This division has the 1700-loaner billet.

The Projection Forces Division works with mobility issues and "owns" JWARS.

This division analyzes policies and

programs that support the United States' ability to protect combat forces overseas, such as mobility, rapid deployment forces, and sealift. The Surface Warfare billet is responsible for sealift and the mobility model MIDAS.

The Tactical Air Forces Division works with all issues concerning tactical & support aircraft. The Naval Aviator billet analyzes primarily Navy Air and aircraft carrier issues.

Naval Forces Division is my division and we are responsible for all battleforce floating assets (carriers, combatants, subs, amphibious ships, etc.), maritime patrol aircraft, and sea-based helicopters. The 1050-loaner (any warfare specialty) billet is responsible for Naval-related campaign analysis, force trade-off studies, Combat Logistic Forces/Support Ships, and Maritime Patrol Aircraft/LAMPS helicopters. The Submarine Warfare billet is responsible for analyzing all submarine-, carrier-, and Undersea Warfare-related issues. Finally, the Surface Warfare billet is responsible for all surface combatant-, forward presence- and crisis response-related issues.

One of the main reasons why I wanted this particular billet in PA&E was the significant amount of analyses that were done by my predecessor compared to the amount of analyses I had previously conducted in N81. Initially, I had the same duties in Naval Forces Division as I had in N81 (monitoring requirements and acquisition process for surface ship-related programs, maintaining the Navy's long range force structure for ships and conducting force presence analyses). But since reporting to PA&E, I have also developed a crisis response model for aircraft carriers and conducted the Navy force structure analyses for the Quadrennial Defense Review (i.e., the forward presence & crisis response analysis for carriers, Amphibious Ready Groups, combatants, and submarines).

How the Operations Research Master's Degree Prepared Me

Now that some typical OR-payback tours in the DC area have been described, specifically mine in N81 and in PA&E, I want to discuss how well I believe our Master's Degree prepared me for these two jobs. I will discuss my thoughts on

(See DC TOURS, p. 12)

DC TOURS

(continued from p. 12)

my refresher courses, each major OR-sequence, my electives, and some thoughts from other OR-analysts I work with.

For my refresher, the calculus & statistics courses were great to get me back in the frame of mind for studying, while the TI-59 and logic courses were a waste of time.

Because of a recent change in the curriculum, the NPS OR students are taking a course on the use of spreadsheets during their refresher. This is great change because most of the models I've worked with the past three years have been spreadsheet models. In general, Microsoft Office (Excel, PowerPoint & Word) is a must.

I believe I have used the principles learned in the Probability & Statistics Sequence the most among all the six OR core sequences, specifically, the statistics and data analysis portions (i.e., mean, average, variance, confidence intervals, and regression). I have not used anything learned in the probability distribution portion. The next most common use of principles learned while at NPS has been from the simulation sequence. I have been involved with the development of simulation models, the use of models, and the data analysis of the results of models. For the Warfare Modeling Sequence, I have only observed or assessed the data analysis of the results from various campaign models. In the Computing Sequence (I had FORTRAN), I observed some of the development of two FORTRAN-based models in my turnover for PA&E, but I was not an active participant in the development of those models. I have not used, nor seen anyone use, Visual Basic and/or Java. Also, I have not used any of the principles learned in the Optimization and Stochastic Models Sequences, but I know other NPS OR graduates who have used them.

There are additional courses I took while at NPS where I have used the principles learned from these classes, but these courses are outside the six major OR-sequences. I believe two of the courses are still required (Search Theory and Test & Evaluation), while the other three were electives of mine. I used the principles learned from my Search Theory course while reviewing the analyses conducted for a surface combatant force level study and the principles learned from the Reliability

and Test & Evaluation courses while conducting program assessments in N81. Additionally, I have used the general principles learned from the other two electives (Decision Theory and Design of Experiments) in all of my tours since NPS.

A point to note is that just because I haven't used the principles taught in some of the OR-sequences, doesn't mean that other OR-payback tours don't use them either. For instance: linear programming (optimization sequence) was used by the Joint Staff for their Submarine Forces of the Future Study and by PA&E during the Deep Attack Weapons Mix Study (DAWMS); stochastic models (stochastic models sequence) are starting to be used during the second phase of JWARS; campaign models (warfare modeling sequence) are being used extensively by all staffs (Navy, Joint & OSD); and several FORTRAN programs (computing sequence) were written by my predecessor while assigned to PA&E.

The bottom line → overall, I believe the OR curriculum taught at the Naval Postgraduate School provides us a sound background for any OR-payback tour we are assigned. I even find myself frequently using the principles learned to solve problems at home. And, just because I haven't used the principles taught in all the sequences, doesn't mean they should be treated with little regard; other OR-payback tours do use them.

Staying Involved in the OR Community

Finally, I'd like to give you my recommendation of how to stay involved with the community. While at NPS, my classmates and I all joined the Operations Research Society of America and then all dropped out shortly after graduation. Since reporting to the Pentagon, I have joined Military Operations Research Society (MORS) and have been thoroughly involved. In the 3 1/2 years since joining, I've been the Co-Chair and Chair for the Littoral Warfare & Regional Sea Control Working Group, the Chair for the Naval Warfare Composite Group, a member of the MORS Reengineering Committee, a MORS Board Director, and I am currently the Assistant Program Chair for the 66th MORS Symposium. I have also presented a paper in the Littoral Warfare WG (my QDR force structure analysis) and I am present-

ing a tutorial this year on how to conduct a successful working group.

While attending the past three annual MORS Symposia as an attendee, a worker, and a presenter, I have not only expanded my tool bag, but I have also had the opportunity to meet OR analysts from all of the services, the private sector, academe, and other government agencies. These rewarding experiences have allowed me to grow and mature as an Operations Research Analyst and keep up with key OR-related issues. As a result of my experiences, my recommendation is to become actively involved with the Military Operations Research Society. With 32 different Working Groups and seven different Composite Groups, there is something of interest for everyone.

Washington, DC is a great place for Navy OR Analysts and their families

I feel that since reporting for duty at the Pentagon almost four years ago, I have grown as an Operations Research Analyst because of the types and amount of analyses conducted in both my OR-payback tours and the experiences gained from being an active member of the Military Operations Research Society. An additional benefit gained while stationed here in the Washington, DC area was the stability that was achieved for my family: my son will graduate from the high school he started at four years ago and my daughter will attend just one middle school and one high school! After avoiding the DC area for so many years, I now find myself highly recommending it, both professionally and personally. If you're a Naval Operations Research Analyst and you haven't had a tour in the DC area: *try it, you might like it!* I do! ☺

Lab Tours at the Naval Postgraduate School

The following labs will be open for tours during the 66th MORSS. The dates and times follow. You may sign up for these tours during registration at the Symposium.

War Lab: Three tours per day with eight people per tour. 1215-1230, 1230-1245 and 1245-1300

Global Command and Control System: One tour per day with twenty people per tour. 1215-1245.

Complexity of Decisions and the Challenges Ahead



Dr. Oliver
Hedgepeth,
GRCI

Introduction

In Part I we discussed how operations research (OR), development of combat models and simulations (M&S) and methods of analyzing the complexity of the simulated battlefield have undergone a paradigm shift over the last 30 years. And, that the M&S community is embarking on a new paradigm of M&S analytical development called JWARS. Part II touches on how it is felt that JWARS will be the first of a new paradigm of analytic models that can better address the complex warfight issues of the OR and M&S community.

Complexity of Decisions

The JWARS intelligence fusion process is based on five basic principles. That is, it must represent military doctrine; second, the fusion process must be open to changes in technical approaches to deductions; the battle will be closed form; causality of deductions must be transparent; and, finally the deduced perception must not be influenced by actual battle truth. These are then the constraints on the complexity of the decision making process based on perception algorithms that form the heart of JWARS.

The complexity of algorithms of a fusion process is no less complex as the computer programming logic. These algorithms can be any combinations of artificial intelligence techniques to statistical processes to tables and rules. However, due to the causality constraint on JWARS and similar new generation models and simulations, the algorithmic methods must be used within variable limits that do not cause unexplainable conditions. This does mean that rare or chaotic events could occur — as long as their dependent factors are explainable.

In the JWARS prototype, the perception is reported to be only for one level of decision making, at the Joint Task Force (JTF) headquarters. The future production versions of JWARS will have to address multiple layers of decisions, as in a real combat

organization. How staff decisions are made or perceived and passed to other staff organizations for actions will involve more complex conditions than with the prototype. This process will involve more complex algorithmic features, more variables, and more assumptions about conditions affecting those variables. However, in becoming more complex, JWARS may break new ground in balancing complexity with transparency. Some of these complexity factors for the next version must consider increased impacts with the terrain, weather as well as an increase in sensor input. Conflict resolution of conflicting data will become more important.

The technique of fusion used by JWARS is similar to that used by **Richard T. Antony**, *Principles of Data Fusion Automation*. There are several related levels of complexity for data fusion. Level one is the front line of information gathering, the sensors. This is where JWARS sensors detect objects and refinement of the target attributes (such as velocity or location) occurs. The remaining levels are designed to resolve conflicts or deficiencies in the sensor input.

A complexity factor is the multiple, heterogeneous sensor configuration. Combine with this sensor data, the a priori knowledge base about the threat state space, and the fusion process is complete, but far from simple. The fusion process ends in some indication of a threats characteristics or potential or possible impact within the battlespace, depicted in a situation map or SITMAP. This SITMAP is an iterative cyclic process of planning, deciding and acting on a perceived battlespace truth. The JWARS SITMAP has information on the threats equipment numbers and types, electro-optical signatures, electronics signatures, movement, direction, etc.

In the current prototype of JWARS the arithmetic complexity is limited to use of Kalman filters to associate new and old data entering the SITMAP. This simple process is how new entries are added to the SITMAP. A Pearson product moment coefficient of correlation is used to test the strength of any association between SITMAP entries and the threat order of battle. Finally, the fusion process compares the information within the SITMAP to the possible COA of the threat, for final

conclusion of possible threat activity.

Since JWARS has completed its prototype phase, it is now entering the next production phase. This is where the paradigm shift of balancing transparency with causality will pioneer new M&S structures. One of the first complexity increasing factors will be taking the fusion process to different levels of command. This is where conflict resolution will occur as independent sensor information is gathered, and independent conclusions are made. Testing of conditions to ensure near real life decisions are made under these new and different conditions has yet to be complete. This will require new and more complex mathematical techniques, and the continuing tests for arithmetic stability.

Another complexity factor is the degree of user input to JWARS to fill the a priori knowledge base compared to what is needed to interact with the sensor produced information. Understanding this part of the user-sensor data input interface will help support not only real-life analysis, but the shift in the analysis paradigm for the next century.

The Challenges Ahead

The next few years of JWARS production will challenge the OR community, the M&S philosophy of design, and the level of analysis. Some of the technical challenges are:

- The levels of fusion or perception, where different fusion products will be linked at different command and control points.
- Fully understanding the assumptions behind the current simple mathematical concepts as they become more complex, with multiple dependencies.
- Balancing transparency with controlled complexity of the fusion process.
- Identifying those key elements needed for this fusion-centered model, knowing that not all elements of real life can be modeled.
- Expanding more variables used by the Kalman filter.
- Increasing the fusion process from many more sensor sources without affecting run time.

(See DECISIONS, p. 16)

DENNIS BAER

(continued from p. 7)

ence relevant to others around them. Training the "younger" analyst is very important, if we intend to keep the Operations Research field a viable community in the 21st century. Here are some thoughts on how we as a team can accomplish this theme.

Meeting operations is the "livelihood" of our Society. We must keep the topics relevant to current issues and applicable to a majority of our membership. A continued review of the meeting process and products must be conducted to ensure we are best serving our Sponsors and membership. We must actively ensure that the leaders of our organizations allow our "younger" analysts to observe and participate in these Mini-Symposia and special times are allowed in the program for tutorials and training.

MORS is indeed a professional Society and as meeting operations is the "livelihood" of our Society, professional affairs is the "cornerstone" of our Society. The education process should be integrated into the Symposium and Mini-Symposium process. A training track should be developed for our yearly Symposium, so those "younger" analysts have the option of attending both the working groups and educational sessions. The Heritage Committee (to include our Fellows) can also play an important part in mentoring our "younger" analyst.

While accomplishing both our professional and meeting operations objectives, MORS must maintain continued fiscal reality in our decision making process. We will continue to provide a quality product to our six Sponsors and membership, while keeping our meeting fees affordable.

The Executive Vice President is the "quarterback" of our team. I am confident he and the remainder of the MORS staff will maintain their proactive role in guiding and looking into the future of our Society. The MORS Society greatly appreciates their contributions on a day-to-day basis and I feel most comfortable leading this professional Society knowing I have their utmost faith and support.

This will truly be another great year for MORS. Along with the gratification of developing our "younger" analysts, we will continue to enhance the quality and usefulness of classified and unclassified Military Operations Research. A volunteer society must both work and have fun. The new and old executive council and committee chairs

must be prepared to work prior to the 66th MORSS. We must have a strong turnover and "hit the deck running," while having time to enjoy the 66th and be able to meet the people we are truly representing as Board of Directors. I'll provide specific details of this turnover during my allotted time for the candidate's speech. Thanks again for this great opportunity to represent MORS as "your" President! ☼

DICK

(continued from p. 7)

sional Affairs we have seen the publication of the third edition of *Military Modeling for Decision Making*, the planned reprint of the **Morse** and **Kimball** classic *Methods of Operations Research* and the continuation of our Education Colloquiums. But it does not end here, as events and goals for 1998-1999 are already well into the planning stage. This is akin to Planning, Programming, and Budgeting System (PPBS) where we have been in the execution phase while concurrently planning and programming for the future, and at each subsequent Symposium, we set aside the time to build the next Program Objectives Memorandum (POM). Moreover, I think our strategic planning has been reinforced by the new process of selecting a President Elect to lead that effort for the coming year, and execute it the following year when that individual takes on the role of leading the Society.

The Theme for 1998-1999

As we press forward into the next year and then into the next century, one of our greatest challenges will be how to keep abreast with technology that is changing at such a staggering pace. Technology changes are cutting across every facet of analysis, from the modeling tools we use, to the processors we run them on, to the ability to collaborate with other analysts in real time, and even in the distributed learning technologies which will allow us to better educate more future analysts as well as helping the rest of us keep current in our trade. I envy the young analyst just entering the field, a field whose future has never been brighter. The ability to keep pace with technology and use it to our advantage will result in the effect of producing a better analytical product which in turn will necessarily increase the demand for analysis. That is

our profit margin!

Each area mentioned above has seen, and continues to see, a technology explosion. Tools such as Office 97 and the associated Excel and Access applications put a tremendous amount of modeling power right on every analyst's desktop. The new object-oriented languages, such as C++ and Java lend themselves to allow composable/decomposable distributed modeling and simulation, and are allowing us to build our major tools of the future, such as JWARS and JSIMS. In the area of processing power and peripherals, the next generation can be thought of in less than a year. In the past year we have seen the introduction of the Pentium II processor, the writeable CD, and the Digital Video Disc (DVD). Just around the corner, around the turn of the century, are quantum leaps, with 1GHZ processors synchronized with similar leaps in hard drive capacity and bandwidth, with cable companies scrambling to catch up to replace coaxial cables with fiber optic networks. These technology changes will have a big impact on how we work, who we work with, and even where we work, as well as, who sees and uses the results of our labor. Thus, the theme used for the 64th MORSS with a slightly different connotation here, **PACING TECHNOLOGY FOR THE ANALYST**, is so important as we forge ahead.

Responsiveness to Our Sponsors

We need to pace technology to allow us to improve both the quality and the timeliness of our products to our Sponsors. Our meetings should be designed with inherent learning methodologies so that we can measure both what was learned as well as what needs to be learned next. Rather than spending our energy trying to recollect and compose what happened in the last meeting, we need to exploit technology so that we emerge from a special meeting with about 90 or 95 percent of the product already done, so that we can then spend our time refining what is good into what is outstanding, and then turn that back to our Sponsors before our efforts become stale.

Pacing Technology for the Society

One of the most important challenges for our leadership is to keep our broad membership base informed, active and enthusiastic. Since our organization is based entirely on

(See **DICK**, p. 15)

DICK

(continued from p. 14)

volunteers, it is this base which we must depend upon to continue to produce the high quality of material to feed our Symposium Working Groups, to attend and contribute to our Workshops and Symposia, to write relevant and analytical provoking material for our publications and to generate the source from which our leadership arises, to our CG/WG Co-Chairs, our Board of Directors, our Past-Presidents, and to our Fellows. Pacing technology will allow us to keep a vibrant membership base by facilitating the distribution of information and helping to generate an earlier interest in the activities of the Society. Technology is allowing us to better communicate and exchange our ideas than ever before, through the use of electronic media aids such as mailing lists and discussion groups. It has significant impact on the planning of meetings, such as allowing faster turn around of TORs and facilitating the coordination of planning committees. In short, technology allows us to reach out to our membership base and energize it in a way not heretofore possible. Of course, as we all become more informed and more aware, it will only demand more of our time, since we will not be able to resist getting involved!

The Way Ahead to 1998-99

In looking ahead to next year's program, the technology theme fits well beginning this summer with the 66th MORSS which is rallying around the tune of *Preparing for Military Operations Research in the 21st Century*. Following on the footsteps of the 66th MORSS in August 98 will be Phase II of Simulation Technology 2007 which seems tailor made as the first Special Meeting to kick off the 1998-1999 program theme of *Pacing Technology for the Analyst*. Information technology will continue to be in the forefront in the C4ISR Special Meeting in the fall and the Advanced Distributed Simulation (ADS) Special Meeting planned in the spring of 1999. In planning the next Education Colloquium, I would envision that MORS collaborate with service activities in the training and education communities to make this a distributed learning colloquium, to leverage ongoing training technology efforts to conduct Advanced Distributed Learning (ADL) tutorials or even establish an online OA course for cred-

it. ADL, I believe, is the key to realizing our continuing education needs such as expressed by **E. B. Vandiver** at the sixth Junior/Senior Analyst Special Session held as a part of the 1995 MORS Symposium when he asserted that every analyst should have taken a 3 credit hour class within the last five years.

Challenges For the Future

In summary, most futurists agree on the premise that the information technology explosion will result in significant societal changes over the next few decades. With the enormity of information at the fingertips of future decision makers, the demand for timely, relevant quality analysis will only be driven to greater extents. Our challenge as a profession will be to meet that demand, to keep pace with technology as technology paces us. MORS must, and will, provide the leadership to meet that challenge.

Biography

CAPT Lawrence L. (Lee) Dick, MORS Secretary, received a Master of Science degree in Operations Research at the Naval Postgraduate School in 1982. He is an Acquisition Professional and a graduate of the Advanced Program Management Course at the Defense Systems Management College at Ft Belvoir, VA.

Lee is currently the Director of the Acquisition Division/Office of Training Technology for the Director of Naval Training on the staff of the Chief of Naval Operations. His assignments have included analyst, Nuclear Force Division, J8 Joint Staff; Head Program Appraisal/Force Structure and Assessment Branch OP-815/N815 on the staff of the Chief of Naval Operation; and Program Manager Modeling, Simulation and Warfare Analysis (PMW 131) Space and Naval Warfare Systems Command. Before accepting his selection as an Acquisition Professional, Lee also served in a long surface warfare career at sea culminating in command of USS Stephen W. Groves (FFG-29) in 1989-91.

Lee was elected as a MORS Director in 1995. He has participated in numerous Special Meetings, including the keynote address at SIMDATAM 95 and as Working Group Chair for the MORS JROC Workshop in addition to giving Symposia presentations. He has served as the Electronic Media Committee chairman and Secretary and in that capacity established the MORS

website and use of mailing lists to facilitate communications within the MORS infrastructure. ☉

SHELDON

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Science texts traditionally pose the steps to the scientific method as: 1) observe and define the problem; 2) form a hypothesis; 3) test the hypothesis; 4) record and analyze data; and, 5) form a conclusion. Operations Research texts present a modified version of the scientific method, that typically include the following steps: 1) define the problem; 2) construct a model; 3) validate the model; 4) solve the model; and, 5) implement the final results. Military OR combines operational expertise and scientific skills to provide practical solutions to real-world problems.

The Role of MORS Today

According to our Organization Manual, "The purpose of MORS is to enhance the quality and effectiveness of classified and unclassified Military Operations Research. To accomplish this purpose, the Society will provide media for professional exchange and peer criticism among students, theoreticians, practitioners and users of Military Operations Research." At the heart of our Society are meetings and Symposia, superbly managed by the professional staff at the MORS office. It is through these exchanges that we draw Military OR expertise from across the Services, industry, and academia to increase the community's collective skills at solving formidable military problems.

Defining the problem is the critical starting point of the scientific method. As Morse and Kimball pointed out from their World War II experience, "It often occurs that the major contribution of the operations research worker is to decide what is the real problem." A clear definition of the problem statement can often point directly to an answer. According to Lieutenant General **Glenn Kent** (USAF-Ret.), "...the job of the analyst is to provide illumination and visibility — to expose the problem." As General Kent often says, "If you stare at a problem, often you see the answer staring back at you." Here again is proof of MORS' value — bringing together scientists and
(See **SHELDON**, p. 16)

SHELDON

(continued from p. 16)

military operators to clarify the problem and point the way to a practical solution.

The scientific method emphasizes three aspects of modeling: 1) construction; 2) validation, and; 3) solution. MORS addresses these critical issues both in our annual Symposia and in special focus workshops, such as those involving Verification, Validation, and Accreditation (VV&A) and SIMTECH. Another example of the value MORS brings to the community is our continuing emphasis on improving not only the tools we use but the capability of the tool-users themselves — *the analysts*. Experienced Military OR analysts realize that just doing good analysis is not enough to get the results implemented — effective presentation is essential. Our annual MORS Symposia are built around working groups where analysts present their results and receive immediate, constructive feedback. This opportunity for peer review provides an excellent professional growth experience for Military OR analysts.

Another valuable contribution of our organization is the bridging we make possible between professional communities. MORS cooperates with the Military Applications Society (MAS), the military arm of the Institute for Operations Research and the Management Sciences (INFORMS), to publish *PHALANX* and the *MOR* journal. The unique role MORS plays in this collaborative environment involves the capability to hold classified Military OR meetings.

Direction for the Future

The strategic direction MORS will take must posture Military OR analysts to maintain relevance into the next millennia. We are setting the stage for this future by capitalizing on our past. MORS preserves the rich heritage of Military OR by republishing classic Military OR literature and through an oral history project to capture the experience of Military OR pioneers. Today, MORS is a dynamic Society that adapts in form and function to meet its challenges. Looking to the future, we must continue to evolve to meet Sponsors' needs. MORS' Workshops, Mini-Symposia and the Education Colloquium need to be responsive to define tomorrow's problems and envision insightful solutions. This goal is attainable if we continue to build the future on the two pillars of our field — teamwork and scientific method.

Biography

Bob Sheldon received a BS in Mechanical Engineering and an MS in Industrial Engineering both from the University of Minnesota and a Doctor of Philosophy in Operations Research from Cornell University.

Bob retired from the Air Force as a Lieutenant Colonel. His career included a tour as an aircraft mechanic (prior enlistment), Civil Engineering, and teaching Math and Operations Research at the Air Force Academy prior to becoming Chief Analyst at the Air Force Studies and Analyses Agency.

Currently a senior scientist at Systems Simulation Solutions, Inc. (S3I), Bob supports the Joint Strike Fighter Program Office's campaign analysis and varied Air Force air campaign analysis studies.

He has attended and presented briefings at numerous MORS Symposia and special meetings. Bob served as working group chair and on synthesis panels at various Symposia and Special Meetings. He is now MORS Vice President for Professional Affairs. ☼

MORS PRESIDENT

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We are a Society of volunteers. Our members can make contributions in many ways in addition to serving on the Board of Directors or supporting special meetings. For example, **Jim Bexfield**, FS, drafted an addition to our MORS organization manual that will provide guidance to us in the future for evaluating joint meetings. Also, LTC **Jack Marriott**, Army Sponsor's Representative, has scoped out opportunities and procedures for fellowships that our "best and brightest" may be able to use. This would address a need to grow future leaders for top level managers of analysis organizations. Another example is the effort that **Priscilla Glasow**, AD, led to carefully determine the need for a MORS sponsored international Symposium in 1998 or 1999. Planning for this event has now stopped. We are thankful for these examples of continued commitment to MORS. The point is that there are ample opportunities for volunteers to contribute to their professional society. Just volunteer!

I stated in my President's Platform article last June, it was a very special privilege

to be asked to be a candidate for President of your Military Operations Research Society. This special feeling continued to be enhanced throughout the year as I represented you as your President. I thank you for this wonderful opportunity and for long term support and dedication to our enduring, annual theme, to *keep Military Operations Research Relevant*. ☼

DECISIONS

(continued from p. 13)

Summary

The language of building combat models and simulations has taken a significant turn over the last decade, and most recently with the advent of a new series of models, such as JWARS. Understanding the nature of observing JWARS development and the nature of its complexity has become a basic assumption in building and using these new models. Using an information-centric versus attrition-centric paradigm, will create a new generation of model builders and impact decision makers in ways different than the past 30 years.

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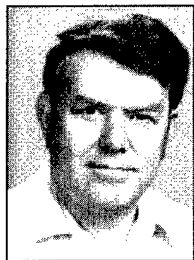
Prosser, LTC Terry W. and Dr. Charles R. Leake, "The Representation of Intelligence Fusion in the Joint Warfare System (JWARS) Analytic Model — Prototype Application," Proceedings of the Third International Symposium of Command, Control, Research and Technology, NDU, June 1997.

Acknowledgments. Thanks to **Terry Prosser** for discussions and insights of the fusion process and complexity of JWARS. ☼

"OR gives the capability
to envision the future
and make it happen."

General Max Thurman
12 October 1988

On Razors and Sabers: Occam's Razor and Other Instruments for Shaving Extraneous Assumptions and Complexities from Models



Dr. Robert L. Helmbold
Combat Analysis
Department Editor

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.

What is a model? And by what measures is one model "better" or more preferable than another? These are subtle issues that have dogged military operations research since its beginning. They are ever present, skulking like hungry sharks and giant squid just below the surface, even when not immediately and obviously matters of urgent concern. These stealthy beasts can surface suddenly and steal success from sailors on their seas. What should we seamen take to see us safely to the shores across such dangerous waters?

To help us keep our bearings, let's first equip our ship with Chernoff's Compass (**Herman Chernoff** and **Lincoln E. Moses**, *Elementary Decision Theory*, Wiley Publications, New York, 1959, p228), "We shall regard a *model* as a *useful convenient simplified representation of the essentially important aspect of a real object or situation*." (Emphasis in the original.) So a model should *represent the essentially important aspect of a real object or situation*. It should do this in a *useful* way. It should be *convenient*. And it should be *simple*. A model so complex that it's nearly as hard to understand as what it models can't be very convenient or useful. So let's see what arms are stocked in the arsenal of simplicity.

That arsenal is well-supplied with trusty weapons old and new. Despite its age, we would do well to bring aboard Buddha's Broadaxe (**Gautama Buddha**, circa 500

BC), "Some form their Dharma arbitrarily and fabricate it artificially; they advance complex speculations and imagine that good results are attainable only by the acceptance of their theories; yet the truth is but one; there are not different truths in the world."

We should also stock our ship with **Socrates'** Saber (as reported in **Plato's Theaetetus**, 360 BC), Socrates: "Too much, Theaetetus, too much; the nobility and liberality of your nature make you give many and diverse things, when I am asking for one simple thing."

Let's also add Aristotle's Archery (**Aristotle**, *Politics*, circa 350 BC), "But ... governments differ in kind, as will be evident to any one who considers the matter according to the method which has hitherto guided us. As in other departments of science, so in politics, the compound should always be resolved into the simple elements or least parts of the whole. We must therefore look at the elements of which the state is composed, in order that we may see in what the different kinds of rule differ from one another, and whether any scientific result can be attained about each one of them."

We certainly cannot do without what is probably the best known, most frequently quoted, and most often employed weapon in the battle against needless, unnecessary and unwise complexity, which is Occam's Razor (**William of Occam**—alternatively spelled Ockham, *Quodlibeta Septem*, circa 1320 AD), "*essentia non sunt multiplicanda praeter necessitatem*." The Latin phrase can be variously translated as "entities are not to be multiplied beyond necessity," or as "a plurality must not be asserted without necessity." A less literal but more modern expression that captures Occam's thought is "the best theories use the fewest and simplest hypotheses required by the facts." This, together with Occam's other sharp arguments, resulted in his denunciation by the Pope, arrest, excommunication, and exile. So we must be careful lest we hurt ourselves on these dangerous weapons!

From the rack we can also requisition many modern weapons, such as Richardson's Rapier (**Lewis Fry Richardson**, *Statistics of Deadly Quarrels*, Boxwood Press, Pacific Grove, 1960, p xliv), "Formulae are not to be complicated without good evidence." Wielded by a master, the Rapier in Richardson's hands rapidly cut away complexities and carved to the core of a host of thorny issues in the analysis of data on wars. Richardson is also famous for his dimensionless "Richardson number" in the theory of turbulent flow, and for many important contributions to physics, meteorology, and numerical analysis. For his scientific accomplishments, he was elected a Fellow of the Royal Society.

Perhaps we could put on Parkinson's Poniard (**C. Northcote Parkinson**, Parkinson's Third Law, circa 1960), "Expansion means complexity, and complexity decay. Or: *the more complex, the sooner dead*." Parkinson's famous and better-known First and Second Laws are (1) "Work expands so as to fill the time available for its completion," and (2) "Expenditure rises to meet income." Despite their gaudily-decorated sheaths, these weapons have very sharp barbs.

We might have somewhere in the hold **Helmbold's** Hatchet (circa 1970), "The burden of proof is on the party claiming that such-and-such a factor must be introduced to explain the data. On the one hand, the claimant must show that the data *are not* compatible with the simpler theory in which the new factor is left out. And, on the other hand, he must show that they *are* compatible with the more complicated theory that arises when the new factor is introduced."

We could also carry the acute Koopman's Cutlass (**Bernard O. Koopman**, "An Operational Critique of Detection Laws," *Operations Research*, vol 27 (1979), number 1 (Jan-Feb), pp115-133), "Complications in models are not to be
(See COMBAT ANALYSIS, p. 29)

Planning Your Time at the Symposium

RADM **Pierce Johnson**, Program Chair

Dr. **Yupo Chan**, Tutorials Coordinator

Eleanor Schroeder & Dr. Ernest Montagne, Poster Session Coordinators

Ted Smyth, Plenary/Special Sessions Coordinator

Jim Duff, Prize Paper Coordinator

Dr. **Roy Rice**, Working Group/Composite Group Coordinator

The 66th MORSS will be held at the Naval Postgraduate School, Monterey, CA, on 23-24-25 June 1998.

It is being hosted jointly by the Naval Postgraduate School, Naval Support Activity, Monterey Bay, and TRADOC Analysis Command, Monterey. We would like to thank members of all these activities for their outstanding support.

Now that you've made plans to attend the 66th MORSS, you're wondering what is on the agenda besides the Working Group and Composite Group sessions. To assist you, here is an overview of the tutorials being offered, some specifics on the poster sessions, and more details about the special sessions.

Tutorials

Three different types of tutorials will be offered at the 66th MORSS: Monday afternoon tutorials, normal lunch-hour tutorials, and lunch-hour "series" tutorials. For those of you arriving early, Dr. **Sam Savage** will offer a 4-hour tutorial on Operations Research in Spreadsheets. Dr. Savage teaches courses in Analytical Modeling in Spreadsheets in the Department of Engineering, Economics Systems & Operations Research at Stanford University. There will be an additional \$50 registration fee to attend this tutorial. Also offered on Monday afternoon is "Genetic Algorithm and Evolutionary Programming," by LTC **Jack Marin** of West Point. See details on the next page.

During the normal 1200-1330 lunch-hour timeslot, three different tutorials will be offered. **Tom Little** of the Navy's Sea-based Weapons and Advanced Tactics School will present a discussion on Littoral Undersea Warfare/Battle Space Realism for Simulators, **Mark Bowden** from the Philadelphia Inquirer newspaper will pre-

sent his on-line series on "Lessons from Mogadishu: SOF and OOTW," and CDR **Kirk Michealson** will provide training on "How to Conduct a Successful Working Group."

Something new for the 66th MORSS, TWO "series" tutorials will be offered this year (instead of ONE offered last year). These are two separate one-hour presentations that build on the previous session, and are also scheduled during the 1215-1315 timeslot on Tuesday, Wednesday and Thursday. Dr. **Greg Parnell** of the Virginia Commonwealth University will present discussions on "Marketing Operations Research" and Drs. **Joseph Tatman**, **Den-nis Buede** and **Terry Bresnick** will present "An Introduction to Bayesian Networks."

Poster Sessions

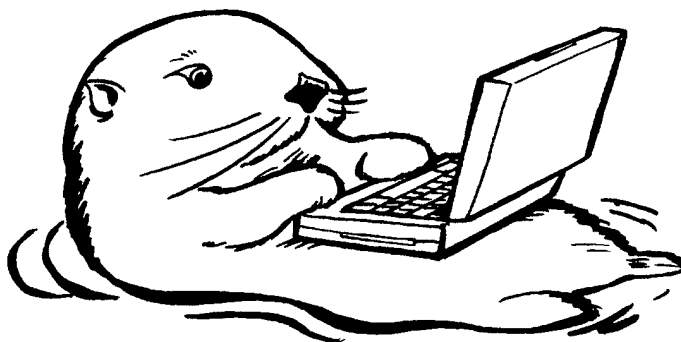
The Poster Session returns once more providing MORSS presenters one of the best ways for reaching the broader audience. Presentations that use special visual

aids (videos, computers, etc.), short presentations best depicted with color charts, and works in progress are especially appropriate for the Poster Session. The Sessions are currently scheduled to be held during the mixer on Tuesday, 23 June 1998 from 1715 to 1900 and during the lunch break on Wednesday, 24 June 24 1998 between 1200 and 1330.

Special Sessions

The Special Session scheduled for Tuesday, 23 June will focus on the subject of "Leadership in an Information Dominant Battle." The purpose of this Special Session is to provide the warfighter leader insight to the OR community on the leadership challenges caused by information tools on the battlefield. Invited participants include LTG **Paul J. Kern**, USA (formally the CG, 4th Mechanized Infantry Division during the Army's Force 21 Warfighting Experiments at Fort Hood, TX); RADM R. Nutwell, USN (Deputy Director, Space

66th MORSS



23-24-25 June 1998

Naval Postgraduate School

66th MORS SYMPOSIUM

Information Warfare Command & Control, Navy Staff (N6B)); CDR **Terry Pierce** (author of "We Gotta Have a War-Fightin' Revival," US Naval Institute Proceedings); LTC(P) **Douglas MacGregor** (author of "Initiative in Battle: Past and Future," US Marine Corps Gazette); LTC **Jeffrey Lesser** (author of "Battle Command Vision for Success," Military Review); and brigade & task force commanders during the Army Force 21 exercises.

The Prize Paper Session will also be held during Tuesday's special session. Each year MORS offers two prizes for outstanding papers; the Rist prize for papers submitted in response to an announcement and call for papers and the Barchi prize for papers selected as best papers from the MORSS working group, composite group, and special session during the previous Symposium. **Howard Whitley** is the co-chairman for the 1998 Rist prize and is coordinating the evaluation of six papers. Col "**Crash**" **Konwin** is co-chairman for the 1998 Barchi prize and coordinating the evaluation of 22 papers. Winners will be honored at the 66th MORSS and their papers will be presented Tuesday from 1530-1700.

The Wednesday, 24 June Special Session will focus on the issue of "Validation Methodologies." It is anticipated that several case studies will be presented and discussed by a select number of panelists. Invited Panelists include: Dr. **Dale Pace** (The Johns Hopkins University/Applied Physics Lab); CAPT **Robert Eberth**, USNR (Navy Staff, N85); Ms. **Michelle Kilikauskas** (Naval Air Warfare Center, China Lake, CA); and Maj **Suzanne Beers**, USAF (AFOTEC).

Also during Wednesday's special session, the popular Junior-Senior Analyst session will be held. As a departure from earlier years, this session will be divided into sections arranged by service. At the beginning of the meeting, the senior analysts will give overviews of their experiences and topics of importance in the practice of Military OR. For the main portion of the meeting, the junior & senior analysts will engage in a no-holds-barred discussion stimulated by questions and answers. If you are inter-

(See **PLANS**, p. 20)

66th MORSS Junior/Senior Analyst Special Session Wednesday, 24 June, 1530 – 1700

Questions/concerns: Please call **Howard Whitley**, 301-295-4611, whit-ley@caa.army.mil, **Lana E. McGlynn**, 703-601-0012, mcglyla@dcsopsp3.army.mil or **Gene Visco**, 301-598-8048, visco03@ibm.net

SIGN UP NOW! This is an invitation to participate in the 8th annual MORSS Junior/Senior Analyst Special Session, Wednesday, 24 June, 1530 – 1700. As a departure from earlier years, this session will be divided into sections arranged by service. At the beginning of the meeting, the senior analysts will give overviews of their experiences and topics of importance in the practice of Military OR. For the main portion of the meeting, the junior & senior analysts will engage in a no-holds-barred discussion stimulated by questions and answers. **If you are interested in attending this session, you must pre-register by completing the form below and faxing it to the MORS office at 703-751-8171.** Invited senior analysts include:

Session 1:

Mr. **Jim Johnson** (OSD/PA&E - Deputy Director for Theater Assessments & Planning)

Dr. **Jerome Bracken** (Army & Defense Consultant, Adjunct Professor, Yale University)

Session 2:

LTG **David K. Heebner** (Assistant Vice Chief of Staff, Headquarters, Department of the Army)

Dr. **Seth Bonder** (President, Vector Research, Incorporated)

Session 3:

LTG **David L. Vesely** (Assistant Vice Chief of Staff, Headquarters, Department of the Air Force)

Ms. **Natalie Crawford** (RAND, Vice President & Director, Project Air Force)

Session 4:

VADM **Pat Tracey** (Director of Naval Training, Office of the CNO)

Dr. **Susan Marquis** (Associate Director, Assessment Division, Office of the CNO)

Session 5:

MajGen **Patrick G. Howard** (Deputy, MCCDC)

Dr. **AL Brandstein** (Director, Studies & Analysis, MCCDC)

Name (PRINT) _____

Phone: _____

Email: _____

Session choice:

☐ Session 1 ☐ Session 2 ☐ Session 3 ☐ Session 4 ☐ Session 5

FAX to (703) 751-8171

66th MORSS Monday Tutorials

Monday, 22 June, 1300-1700

NPS, Glasgow Hall

Ready Fire Aim – Operations Research in Spreadsheet

Dr. Sam L. Savage, Dept of Engineering Economic Systems
& Operations Research, Stanford University

Traditional field artillery is set up, aimed at a large stationary target, and finally fired. To hit small moving targets, tracer-firing, automatic weaponry was developed, which is fired first and then aimed.

A parallel holds between large traditional application of operations research and small analytical models on personal computers. This tutorial covers interactive

applications of simulation, forecasting, decision analysis and optimization in the spreadsheet environment.

Detailed topics to be covered include: Modeling in Spreadsheets; Forecasting; Simulation; Markov Chains; Decision Trees; Linear Programming; Integer Programming; Nonlinear Programming; Stochastic Optimization.

Genetic Algorithms: Application and Theory

LTC John A. Marin, USMA

Genetic algorithms are a class of probabilistic algorithms that simulate nature's process of natural selection in which an evaluation function is used to determine which members of the population are "good" or "bad". Genetic algorithms are simple to understand, easy to code, robust, and appear to work on a large class of interesting problems for which no reasonably fast algorithms exist. For example, genetic algorithms have been applied to scheduling, routing, transportation, optimal control, and variable reduction problems. Genetic algorithms are domain independent, and are naturally massively parallel. Also, genetic algorithms generally explore more of the solution space than other heuristic search methods because genetic algorithms maintain and manipulate a population of possible solutions rather than altering one solution at a time. This tutorial will address the

standard implementation procedures of genetic algorithms, such as: genetically representing potential solutions, genetic operators that alter the composition of children during reproduction, and assigning values for various parameters that a genetic algorithm employs. Additionally, this tutorial will address asexual reproduction techniques sometimes referred to as evolutionary programs. Several common problem types, such as the travelling salesperson problem and nonlinear transportation problem, will be used to illustrate how the solution methodologies work. Applications addressing genetic algorithms in military command and control and simulation will be presented. Advanced topics including hybrid systems involving genetic algorithms used in variable reduction, data mining, and neural network topology selection, will also be presented.

PLANS

(continued from p. 19)

ested in attending this session, you must pre-register with the MORS Office. Invited senior analysts include:

OSD — Mr. James L. Johnson (OSD/PA&E) & Dr. Jerome Bracken (Army Consultant)

Army — LtGen David K. Heebner (Army AVCOS) & Dr. Seth Bonder (President Vector Res, Inc)

Air Force — LtGen David L. Vesely (Air Force AVCOS) & Ms. Natalie Crawford (VP Rand)

Navy — VADM Pat Tracey (NETC Pensacola) & Dr. Susan Marquis (Navy Staff, N81)

USMC — MajGen Patrick G. Howard, Deputy, MCCDC & Dr. Alfred G. Brandstein (MCCDC)

The Thursday, 25 June Special Session will focus on a Navy 3 Star panel discussion on the subject of "Preparing Today's Operations Research Analysts for the Next Century." Invited panelists include Vice Admirals Lautenbacher, Redd, Cebrowski, Oliver, and Tracey. All of these invited officers have either an Operations Research background and/or considerable experience and knowledge of the contributions provided by the operations analysis community in support of both operational and program requirements.

Getting Involved in a Symposium

Now that you have an idea of what's planned during the 66th MORSS, you decide that you're interested in becoming involved for the 67th MORSS, but you don't know where or how to volunteer. The Measure of Effectiveness (MOE) that defines the degree of success of each MORS Symposia (at the Strategic level) is directly correlated to the success of individual Working Groups (at the Tactical level). Several Working Groups (WG) at the MORS Symposia are recognized as having built a tradition of success in terms of high attendance (loyalty) and quality. This achievement has been the result of a succession of chairpersons who operated with two goals in mind: hard work and creativity. Therefore, a good place to start volunteering in the MORS organization is as a co-chair of the Working Group that interests you the most.

Name (PRINT) _____

Phone: _____

Email: _____

Tutorial choice: ☐ Ready Aim Fire – Operations Research in Spreadsheet

☐ Genetic Algorithms: Application and Theory

Cost: \$50.00

Payment Method: ☐ Check ☐ Cash ☐ American Express ☐ Visa ☐ MasterCard

Print Name as it appears on card: _____

Credit Card No: _____ Exp. Date _____

Signature: _____ Billing Zip Code: _____

As a co-chair, you would be supportive to your chair, assist them in the administration & organization of the working group, and help them solicit papers for the next Symposium. After a year or two as co-chair, you could volunteer for more responsibility by moving up and taking over as the working group chair or the advisor. The majority of individuals in a position of leadership in MORS today started out as a Working Group Chair. Getting involved in the Society is a great opportunity for many of our younger MORSians to become more than just an attendee. If you like the experience of being the backbone of MORS, please consider volunteering for more responsibility and other positions. You could volunteer to help on some of the MORS committees, work on a Mini-Symposium or Workshop, or be a Composite Group chair or advisor. Every day is a great day to be in MORS!

How do you volunteer as a co-chair? During the Symposium, contact the chair of the working group you want to get involved with, the current Working Group/Composite Group Coordinator (Dr. **Roy Rice**), or the 66th MORSS Assistant Program Chair (CDR Kirk Michealson) and complete a co-chair nomination form. These completed forms will be turned into the MORS Office to be provided to the next WG/CG Coordinator. The 67th WG/CG Coordinator and their WG/CG committee will select the key personnel (chairs, co-chairs, and advisors) in July & August. All personnel selected to participate as members of the backbone of MORSS (WG & CG key personnel) will be notified by early September. If you're interested in learning about the duties and responsibilities of a Composite Group or Working Group chair before you volunteer, you can attend the *How to be a Successful Working Group Chair* tutorial Tuesday or Wednesday from 1215-1315.

The 66th MORSS Program Staff hopes you are as excited about attending the Symposium, as we are. The entire staff has made every effort to make this Symposium "The Best Ever!" It doesn't hurt that the setting is at the historic Naval Postgraduate School on the beautiful Monterey Peninsula. If you have any questions about the Symposium, please contact the MORS office at (703) 751-7290 or CDR Kirk Michealson at (703) 697-0064. We can't wait to see you in Monterey for the 66th MORSS from 23-25 June 1998! ☺

The Fifteenth International Symposium on Military Operations Research (15 ISMOR) "Is a Revolution in Analysis Required?"

To be held at: The Royal Military College of Science
Shrivenham, Swindon, Wiltshire, UK

1st - 4th September 1998

ANNOUNCEMENT AND CALL FOR PAPERS

Last year there was no specific theme for ISMOR. Instead, a broad approach was encouraged, seeking papers on recent advances in military operations research across the board, but specifying a number of topics on which papers would be especially welcome.

This year the Symposium will have a theme. There has been a revolution in military affairs following a shift in the emphasis of defense policy from great power conflict to alliance involvement in operations other than war (OOTW). The issue is whether there needs to be a complementary revolution in analytical affairs. Perhaps this has already occurred in some respects; perhaps it needs to go further with the adaptation of the softer methods more common in civil OR or the development of new approaches.

Nevertheless, although this is the theme of the Symposium, papers discussing recent advances in military operations research across the board or case studies will also be welcome.

The Symposium will assemble in time for welcoming drinks at 1800 hours on Monday, 31 August. However, since this is a Public Holiday in the UK, some delegates may wish to delay their arrival until the Tuesday morning and the Symposium will not therefore formally begin until 1000 on Tuesday, 1 September. Departure will be after

luncheon on Friday, 4 September 1998.

All activities will take place on the campus of the Royal Military College of Science. Accommodations will be in one of the Halls of Residence. There will be an inclusive charge of not more than 330 pounds to cover the cost of administration, meals, accommodations, the Symposium dinner, entertainment, and other incidentals on the five days.

If you wish to participate please contact Mrs. **P.A. Follows**, ISMOR Administrative Director, Highmoor Cottage, Lower Haddon, Station Road, Bampton, Oxon. OX18 2AT, Tel. 44-1993-851880, Fax 44-1993-851956.

Requests for applications and inquiries from within the USA can be made to Mr. **Eugene Visco**, FS, 3752 Capulet Terrace, Silver Spring, Maryland 20906, Tel: 301-598-8048, Fax 301-438-0395 or Email: visco03@ibm.net.

ISMOR is officially backed by the MOD, sponsorship being exercised on behalf of the Chief Scientist by the Deputy Chief Scientist (Scrutiny and Audit). The event is also supported by the Commandant RMCS. We are grateful also for continued help and advice from the US Deputy Under Secretary of the Army (Operations Research).

Unit Cost Escalation: Implications for Policy

Philip Pugh, HVR Consulting Services, Ltd, United Kingdom

Introduction

The attention of operational analysts is focused generally upon the next step — be it better use of existing equipment or, else, the specification of whatever is to succeed that. This paper takes a longer view. It highlights the phenomenon of unit cost escalation which, working persistently decade by decade, comes to influence profoundly procurement programmes and, through these, the size, composition and effectiveness of armed forces.

It is argued that the progress of unit cost escalation has now reached a stage at which — for even the largest nations — it presents acute problems for solution by defence planners. If Operational Analysis (OA) is to assist in the resolution of these then it is urgently necessary to advance the methodology of OA both as regards better solutions for some old problems and in tackling problems of a new kind.

Definition

As used here, the term “unit cost escalation” refers to the persistent tendency for new equipment to cost more unit-for-unit than that which it replaces (even after due allowances have been made for inflation, changing production quantities and the like). It is manifest as exponential growth of Unit Production Cost (UPC) with In-Service Date (ISD) such as is shown in Fig. 1 for strike aircraft over the period from 1940 to the present.

Chronicity and Ubiquity

Unit cost escalation is neither a new nor a rare phenomenon. On the contrary, chronicity and ubiquity are its hallmarks.

Historical research has found unit cost escalation, at rates much as now, in the costs of oared warships of the Hellenistic era, of warhorses of Norman times and of castles of the Plantagenet period. As for the present era, over at least the last half century UPC has approximately doubled every decade for all of the multifarious types of weapon system listed in Fig. 2.

Hence, while the remainder of this paper employs naval examples by way of illustration, the same theme can be

expounded equally well via the histories of land or air forces.

Unit cost escalation defies even major geopolitical and technical changes. As Fig. 3 illustrates, the rate of unit cost escalation remains sensibly constant through peace and war and is unaffected by technical advances even as major as the change from gun to aircraft as armament of capital ships. When threats recede procurement may lapse (as during the “battleship holiday” following the Washington Naval

Arms Limitation Treaty); but when threats return and construction resumes it is at unit costs which continue the former trend as if nothing had happened in the interim.

Cause and Consequence

The chronicity and ubiquity of unit cost escalation arise from it being intrinsic to military competition.

Cost relates to performance. Spending more will, *ceteris paribus*, obtain equipment of higher performance. But, effec-

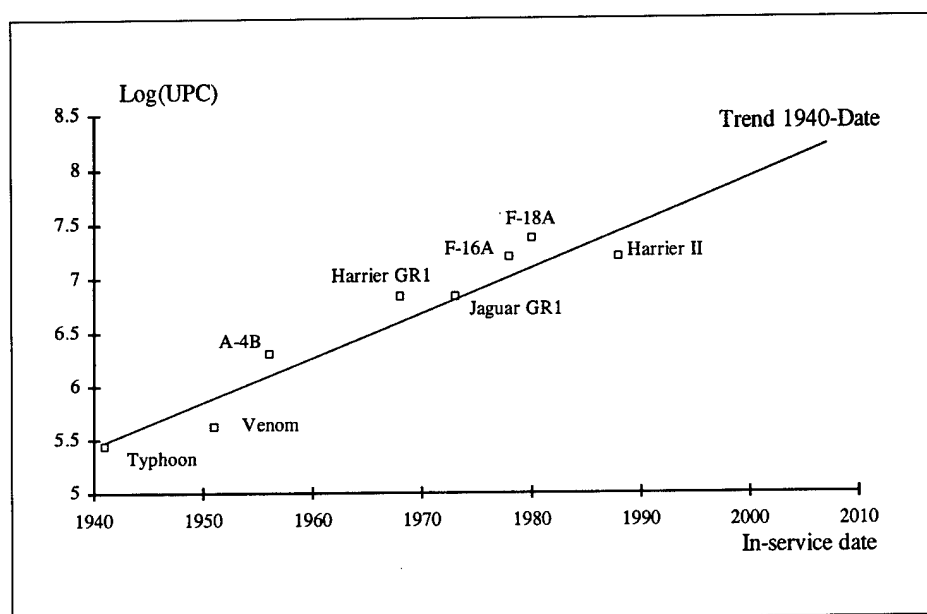


Figure 1: Unit costs of Strike Aircraft (Upc in £ at 1995 prices)

Over at least the last half century, UPC has approximately doubled each decade for:

Sea Warfare

Battleships
Battle/heavy cruisers
Fleet aircraft carriers
Light cruisers
Escort carriers
Submarines
Destroyers
Frigates
Corvettes
Fast patrol boats
Mine warfare vessels
ASW helicopters
ASW aircraft

Land Warfare

Anti-tank GW
Area air defence GW
Main battle tanks
S.P. artillery
Attack helicopters
Transport helicopters
Tactical air transport
Strategic air transport

Air Warfare

Strategic bombers
Interdictor aircraft
Strike aircraft
Fighter aircraft
Medium range AA GW
Stand-off weapons

Figure 2: Unit cost escalation is now virtually ubiquitous

tiveness flows not from performance per se but from performance advantage over a rival. To procure equipment of higher performance and, so, enhance one's own security is inevitably to diminish the rival's security by reducing the effectiveness of his forces vis a vis one's own. One's security and his insecurity (and vice versa) are but two sides of the same coin.

Thereby, as Fig. 4 demonstrates, there is set up a positive feedback loop leading to continual exponential growth in unit costs.

The effect of this unit cost escalation is to diminish continually the effective purchasing power of defence budgets. By way of example, Figs. 5a & 5b show the variation over the period 1972-95 of the UK defence and equipment budgets with these expressed in alternative economic terms. Fig. 5a provides the conventional presentation of (more-or-less) level spending in terms of "constant (UK, 1996) purchasing power" (i.e. the additional quantity of retail goods which taxpayers might have bought in the High Street had they not been taxed for their defence). In contrast Fig. 5b demonstrates the rapid fall of budgets in terms of their ability to buy the latest and best of contemporary military equipment.

Thereby arises the paradox that taxpayers perceive themselves to be paying much as before while defence planners experience increasing pressure of costs upon budgets.

Smaller and Older Fleets

As unit costs rise so lesser quantities can be procured generation on generation — as demonstrated, for example, by Fig. 6 showing the decline of UK warship production decade by decade save following the exceptional, immediately post-war, period of 1946-55.

Since new matériel arrives at a diminishing rate, the active fleet must either decrease in size or grow older (or both).

This process is illustrated in Fig. 7 which plots the histories of the number of "power projection" ships (battleships, cruisers, aircraft carriers, assault ships and monitors) in service with the Royal Navy and of the average age of that fleet. At times the fleet was briefly rejuvenated with the retirement of its oldest members, in other periods numbers declined and average age remained steady and in others numbers were steady while the fleet grew

(See UNIT COST, p. 24)

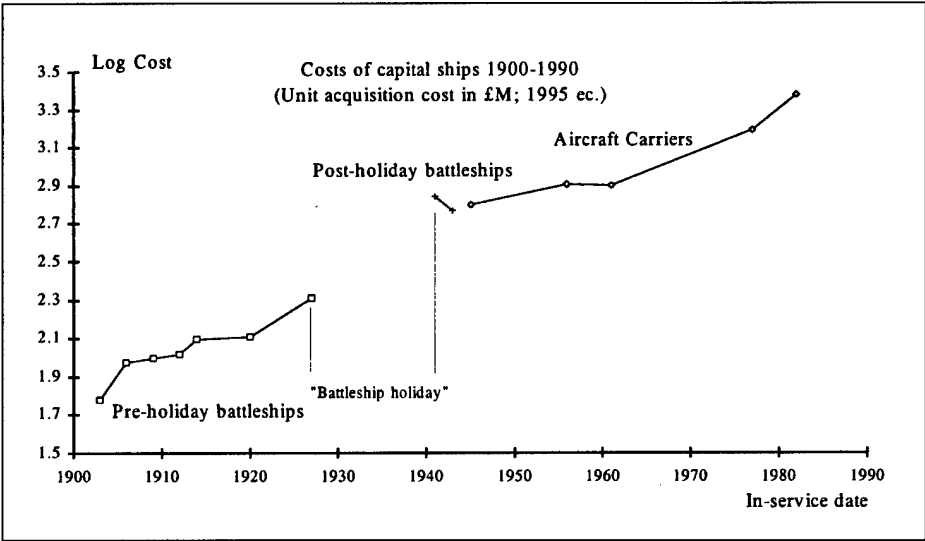


Figure 3: The Continuity of Unit Cost Escalation

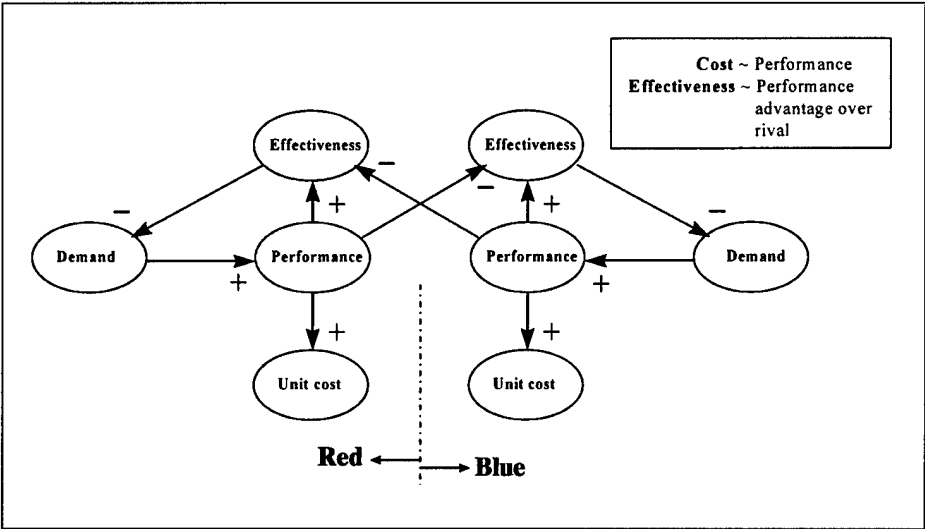


Figure 4: The chronicity and ubiquity of unit cost escalation arise from it being intrinsic to military competition

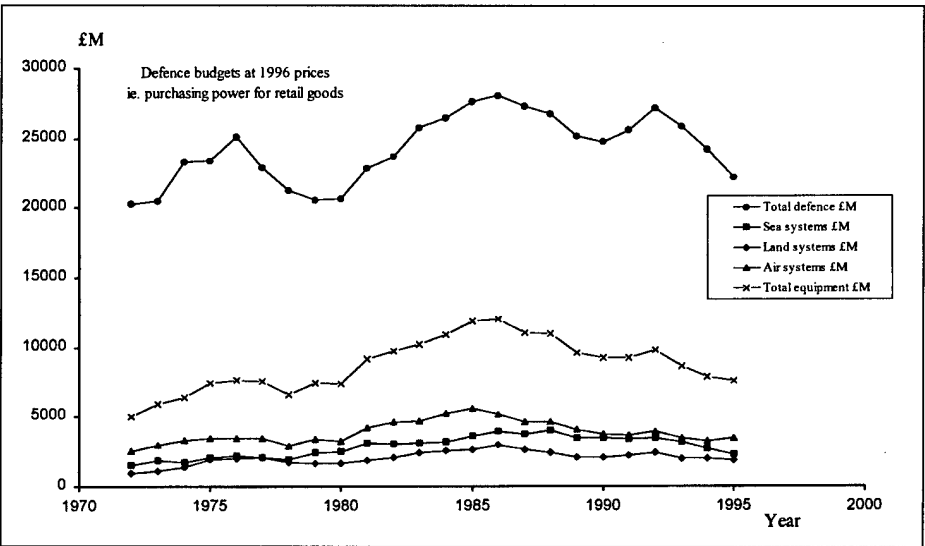


Figure 5a: Retail purchasing power of UK defence and equipment budgets

UNIT COST

(continued from p. 23)

older. However, overall long-term trends were firmly towards marked reductions in size and increases in average age.

A similar analysis of the USN carrier fleet exhibits differences in detail but the same trends predominate (see Fig. 8).

More Eggs, Fewer Baskets

Since age cannot be allowed to increase indefinitely, forces have to adapt, over the longer term, to much reduced numbers of units. Just how far that process has gone already is illustrated in Fig. 9 for the two fleets just examined.

As each major warship represents now 10% or 20% of its kind within a navy then, allowing for ships in refit or transit, if a force is to be deployed into distant waters some third or half of its power may well be embodied within a single hull. The success of a major operation can, therefore, turn upon the loss or preservation of that single vessel. One lucky hit could transform the balance of naval power within a region and/or doom an expedition to failure.

Managing Change

Nevertheless, as has been shown, if the impotence of obsolescence is to be avoided then, over the long term, continued reductions in numerical strength are inevitable.

This is not the unalloyed bad news that it might appear. After all, friend and foe suffer alike in that both experience unit cost escalation and, hence, both must undergo continual change. Advantage lies, therefore, with whomever manages change best.

But, to manage change requires foresight and forecasts are rarely correct.

Examples of erroneous forecasts are legion and it is to be emphasised that that shown in Fig. 10 was chosen only for it being to hand. In common with many others which might have been cited in its stead, this exemplifies how expectations are continually disappointed — largely through the effects of unit cost escalation.

Breaking the Mould?

A major reason why plans are so often in error is that future escalation in unit costs is obscured by chronic under-estimating of the costs of equipment yet to be developed. Recent research suggests that,

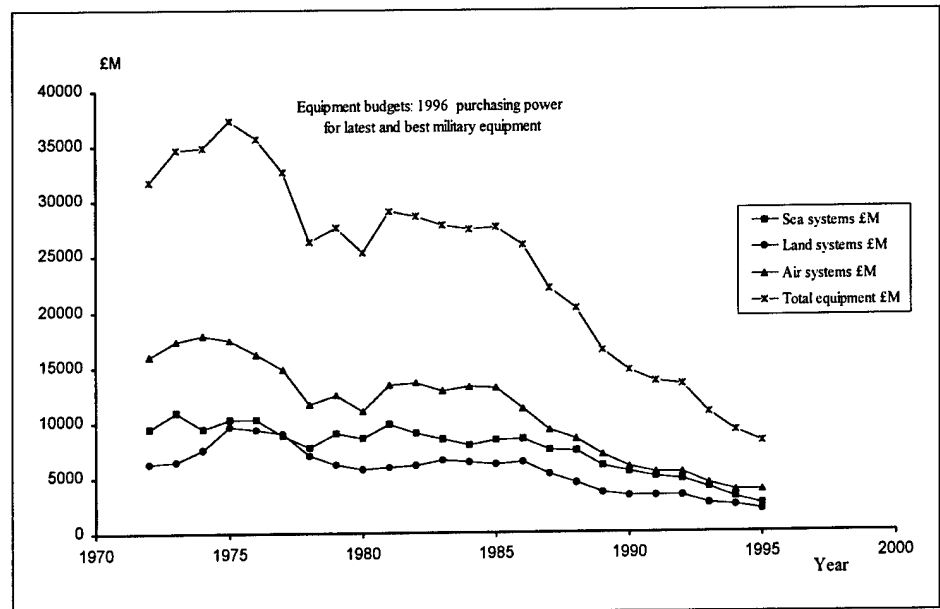


Figure 5b: Purchasing power of UK defence and equipment budgets in terms of units of the contemporary latest and best military equipment

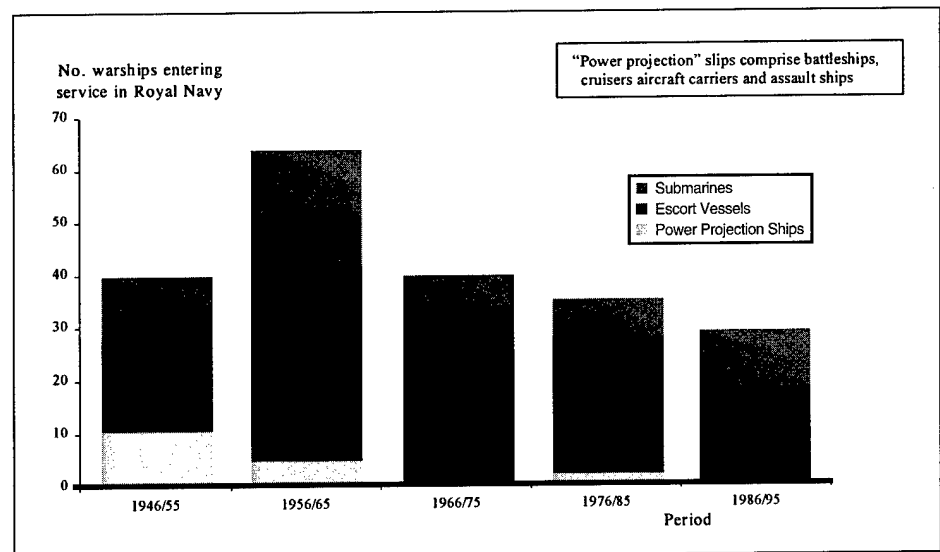


Figure 6. Rates of UK warship construction 1946 to 1995

at the start of major defence projects, errors in cost estimates have a probability distribution much as shown in Fig. 11. There is a high probability of eventual (outturn actual) costs exceeding estimates made early in the life of a project and significant probabilities of actual costs being several times those then estimated.

Under-estimating future costs can lead to the (erroneous) belief that "the mould has been broken" and that technological and/or management fixes have been found for previous problems of cost escalation. Such hopes are raised often and disappointed invariably.

Better Cost-Estimating

Yet, cost-estimates need not be so much in error — even very early in a project. The accuracy of early cost-estimates is much improved by the use of newly-emerging "performance-based" techniques of "concept costing."

Whereas traditional methods relate cost to design details subject to doubt until much development work is complete, these new methods relate costs to performance requirements — known with some certainty from the earliest stages. The new methods benefit, therefore, from building their early estimates upon firmer foundations.

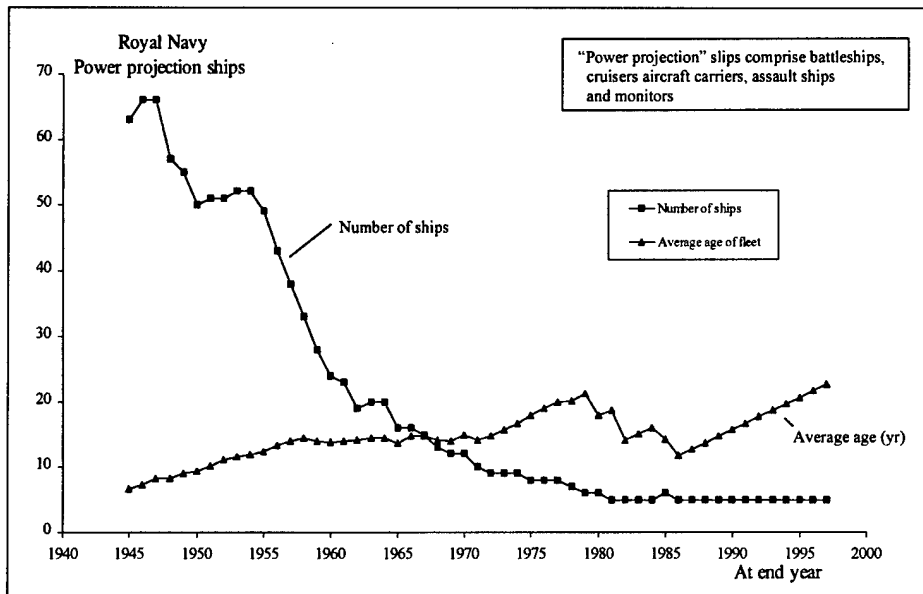


Figure 7: Numbers and age of UK "power projection" warships

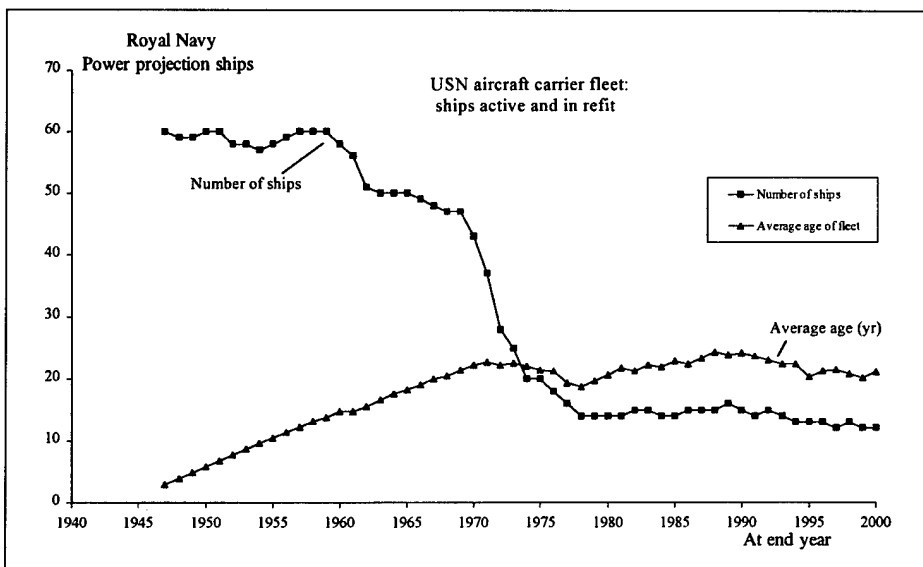


Figure 8: Numerical strength and average age of USN carrier fleet

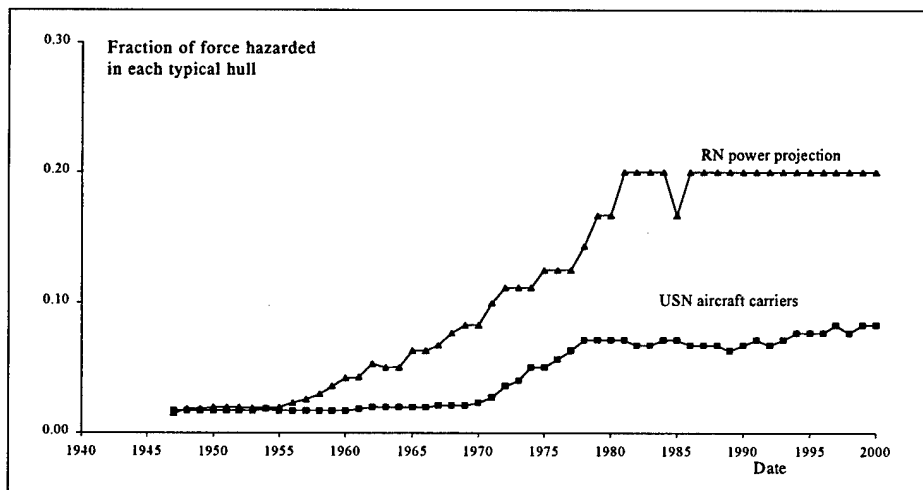


Figure 9. Fraction of force hazarded in a single typical hull

Thereby, as Fig. 12 shows, they can use only information available at the start of a project to generate immediately forecasts towards which the outputs of traditional methods incline only as work proceeds.

The problems presented by chronic under-estimation of costs are, hence, soluble via newly emerging techniques.

Conclusions

Significant conclusions flow from this study of unit cost escalation and its implications. They may be summarised conveniently, as below, under two heads according as to whether they concern simply technical matters for the operational analyst or, else, they raise wider policy issues towards whose resolution new approaches may be required within OA.

Technical

Over the long term, the pressure exerted upon budgets by escalating unit costs becomes the primary determinant of force sizes and structures. It follows that:

1. One-for-one replacement of old equipment by new is an implausible assumption in OA studies
2. Quality versus quantity trade-offs and comparisons at constant (total) cost should be of the essence in studies to define requirements for new equipment.

Moreover, if plans are to be realistic then accurate cost estimates have to be available from the very earliest stages of projects. That requires widespread adoption of the newly emerging means of "concept costing" shown already to be practicable and effective.

Policy

The geopolitical future appears to be one in which Operations Other Than War (OOTW) are likely and general war a remote contingency. However, the latter cannot be ruled out entirely since although its probability is small its consequences, should it come to pass, would be huge. There is, therefore, a problem of reconciling the manpower-intensive demands of most OOTW with the further decline in numbers (of men as well as equipment) that is inevitable if forces are to continue to be equipped with the "latest and best" —

(See UNIT COST, p. 26)

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(continued from p. 25)

as is essential if they are to remain effective in war. Hence, it would seem necessary for operational analysts to study how one might formulate measures of effectiveness which comprehend both probable but elective and also improbable but vital contingencies.

Increasingly, major units involved in operations will be few in number but very valuable individually. There is a need, therefore, to address issues arising from the risks and constraints associated with exposure of such units to hazard. In addition to increased uncertainty as to outcome, there are questions of how to represent both perception and reality within the calculus of risks on either side within, say, wargames.

The Way Ahead

Unit cost escalation will pose increasingly difficult problems in the formulation of defence policy. If operational analysts are to contribute as they should to the resolution of these then there is particular need for:

1. Improvements in the accuracy of cost estimates such as could be effected via widespread adoption of newly emerging means of "concept costing" shown already to be practicable and effective.
2. The devising of methodology for handling operational issues arising from the exposure to hazard of major units that are few in number but very valuable individually and the construction of measures of effectiveness which comprehend both probable but elective and improbable but vital contingencies.

Acknowledgements

Much of the material upon which this paper is based was developed during the course of work commissioned by DSc (Land) and/or DOA/HL of the UK Ministry of Defence. Other material is taken from the results of HVR-CSL company funded work. The support of these authorities is gratefully acknowledged. Interpretation and conclusions remain, however, the responsibility of the author alone. ☼

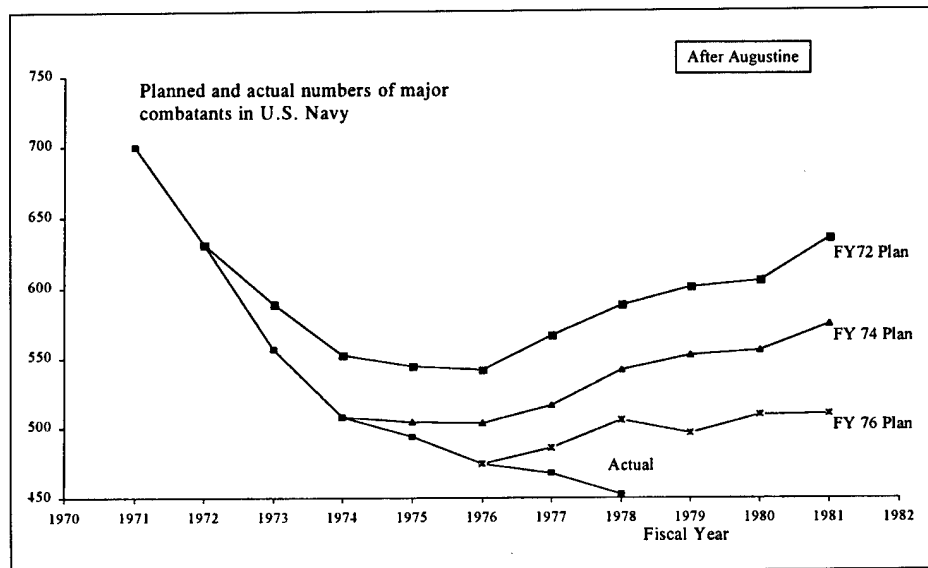


Figure 10: Plans and reality – U.S. Navy in the 1970s

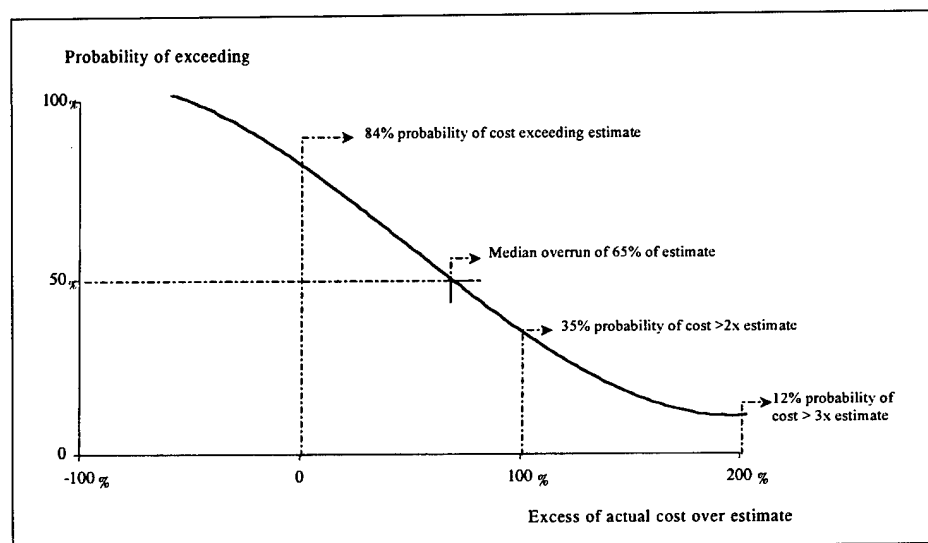


Figure 11: Accuracy of cost estimates made by current methods at the start of major projects

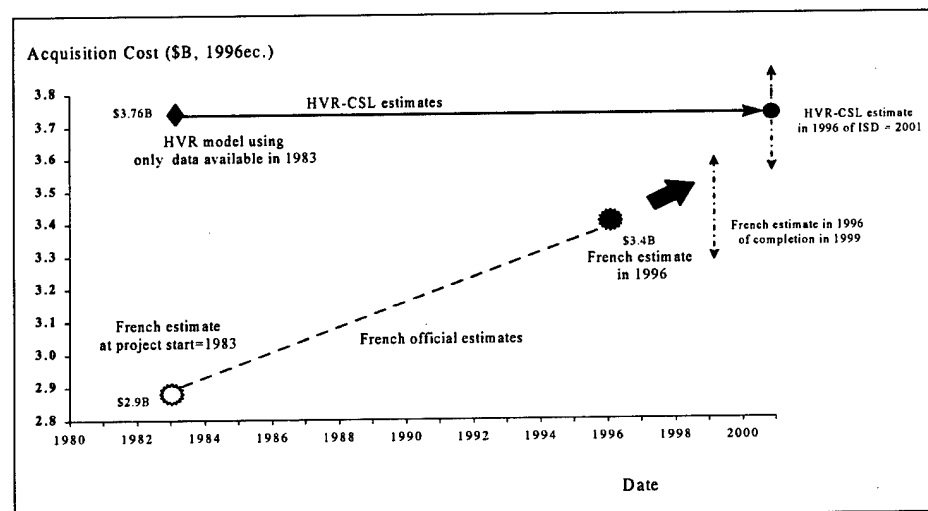
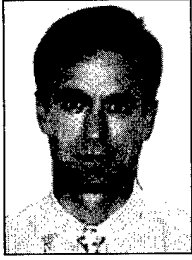


Figure 12:

Biomedical Modeling and Simulation: A Review of Basic Concepts



Dr. Matthew
Reardon, SAIC

Introduction

The importance of modeling and simulation to our nation's repertoire of capabilities is such that they have become critical core technologies. Stand-alone and embedded modeling

and simulation-based applications have become ubiquitous and essential components of modern systems and methods. They are used as tools for education and training, planning and decision making, forecasting and predicting, design and virtual prototyping, process visualization, concept exploration and verification, analysis and discovery, and identification of domain-specific knowledge gaps.¹ The model development process itself often results in improved understanding of complex processes that are obfuscated by uncertainty and complexities such as multivariate feedback dynamics and/or various types of nonlinearities.²

The progress of biomedical modeling and simulation has paralleled similar efforts in other fields. Biomedical models and simulations have become a preferred method of concisely describing and illustrating the dynamics and interaction among subsystems in complex biological systems. Modeling viewpoints range from the biomolecular to organ-system to higher level aggregate models that predict group responses. The latter, in particular, are resulting in useful predictive biomedical decision aids that logically and consistently evaluate more variables simultaneously than an unassisted leader or medical advisor. Biomedical models are finding other practical applications. Some are incorporated into biomedical devices where they function, for example, as components of model-based feedback control mechanisms.

Biomedical modelers typically rely on toolboxes of complementary representations and methods. Models and algorithms may be descriptive, graphical, analog (e.g., mechanical or electronic), biological (e.g. animal or cell culture models), or digital (involving use of computers and software).

Alternatively, biomedical models may be formulated using mathematical constructs, logic symbology, software algorithms and code, or a combination of these.

Mathematical models are particularly useful because they are concise and often can be solved exactly or approximated to close tolerances using iterative numerical algorithms. Of course mathematic and logic constructs provide modelers with the advantage of reliable frameworks of proven rules for manipulating and evaluating predictive equations and algorithms. Such analytic frameworks can be used to verify whether inferences regarding biomedical processes are logically possible or used to formally derive results and insights that were not otherwise apparent.

Strategies for Formulating Biomedical Models

There is a spectrum of biomedical model development methods.³ At one end of the spectrum are parametric models derived using formal analytical techniques applied to a base of well established biophysical principals

and corresponding formulas. This approach results in mechanistic models that take advantage of concisely formulated a priori mathematical knowledge about interrelated processes. At the other end of the spectrum are essentially nonparametric models wherein few or no a priori assumptions are, or can be, made regarding the theoretically correct forms for a system's governing equations or structure. This is exemplified by the relatively primitive, but practical, trial-and-error curve fitting approach to model development. Correlational models and data lookup tables with implied linear interpolation between data points are other examples of nonparametric modeling methods. Because a priori knowledge about the theory underlying a modeled process is usually not complete, models are often of mixed type. However, in all cases experimental data is required for parameter identification and validation.

The body tissue compartment is a common abstraction used in the formulation of biomedical and pharmacological models.⁴ It involves important simplifying assumptions. In compartment models, body segments (e.g., the digits in models for pre-

dicting maximum cold exposure times) are neatly partitioned into stereotypical (e.g., concentric cylinders) geometric volumes having isotropic tissue and biophysical properties. A typical compartment structure depicted graphically has a central blood compartment, a solid cylindrical core compartment representing viscera, intrathoracic, and cranial tissues surrounded by successive concentric hollow cylinders representing muscle, fat, vascular skin, and nonvascular skin. Because of assumption of tissue isotropism and effectively instantaneous intracompartamental energy equilibration, each compartment can be represented as a single point having the temperature and biophysical properties of all other points in the compartment.

As cases in point, heat and cold strain models for predicting tissue compartment temperature profiles inherently assume that all points within any body tissue compartment always change simultaneously by identical amounts.⁵ This results in models that support transcompartmental but not intracompartamental temperature gradients thereby implying that heat flows infinitely fast within compartment boundaries. This would be an untenable assumption if it were not for the extensive and fairly uniform plexus of blood vessels that traverses most tissues. This allows rapid convective heat transfer between compartments thereby supporting the tendency for temperature equalization within tissue compartments. The compartment model, therefore, encapsulates an abstraction of the details of convective blood flow. For most practical applications this simplification results in sufficient accuracy and resolution.

Greater predictive accuracy and spatial resolution can theoretically be obtained with distributed-parameter models, however, their solutions are often more difficult to derive.⁶ This class of mathematical model also uses compartments but the biophysical properties of tissue within each compartment are specified with greater resolution as functions of specific location. Likewise values for predicted variables are functions of exact intracompartamental location and time. For example, distributed parameter models determine time dependent heat conduction from point to point

(See **CONCEPTS**, p. 28)

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within each compartment. Rather than just one temperature per compartment there are as many separate temperatures as the spatial resolution of the solution method permits.

As advantageous as that might be, this type of model is not as commonly used as the lower resolution lumped parameter type because it is much more difficult to identify the functions or specific values describing spatially varying tissue properties and initial conditions. Also, a distributed parameter model is generally more difficult, expensive, and time consuming to validate, if it can be done at all. This is because validation requires that initial and boundary conditions for the predicted variables be obtained for points throughout the objects being modeled. For many variables, the technology may not exist to make this possible. Additionally, even if a distributed parameter model can be validated in carefully controlled experimental settings, it may be impractical, during operational use, to fully and accurately determine or specify the functional form for the initializing conditions.

Developing models directly from analysis of experimental data constitutes an empirical or "black box" approach. For this model building method, best-fit criteria and multiple regression techniques are typically used for selecting among candidate families of equations. The selected forms, however, may have no, or only fortuitous, relationships to the underlying physical processes; their only merit being that they best fit the data according to predefined criteria.

The black box method results in equations that can be trusted to reliably predict responses for only a limited range of the independent variables. For example, data from a study evaluating a process known to have asymptotic logistic response curves may be seemingly well modeled, along limited intervals of the independent variables, by linear or polynomial functions. However, extrapolating significantly beyond the range of the independent variable used in the studies from which the parameters were defined would soon result in large errors as the response predicted by the polynomial functions and actual asymptotic data increasingly diverged.

Assumption and Biomedical Models

Assumptions are an inescapable aspect of modeling. Some were discussed in the previous section. Users of model-based analysis and decision tools should understand their operationally important explicit and implicit assumptions and determine to what extent failure to fully comply with them might affect the model's prediction accuracy.

Numerous legitimate assumptions are frequently invoked during model derivation and development. They may be necessary in order to simplify very complex processes, to comply with a specific modeling paradigm (e.g., lumped parameter representation), to make solutions tractable, or to span knowledge gaps that would otherwise prevent model completion. Assumptions are often most necessary during the development of aggregate or high-level models where many effects are consolidated into relatively few parameters or coefficients.

Assumptions may also be needed to account for the effects of uncertainty and seemingly random variations in the modeled processes. Such assumptions typically aggregate multiple separately described effects into a single term or coefficient. Additionally, although equations in a complex model may be individually stable and well behaved, one must validate the assumption that an algorithm of interconnected equations is also stable and well behaved within the variable space over which each equation individually was determined to be valid.

Validation of Biomedical Models

It is generally recognized that model-based products for operational use must be adequately validated. The military mandates a formal model verification, validation, and accreditation process for operational model-based products. Validation is a process that demonstrates the extent to which statistically significant differences occur between measured and model-based predicted outcomes.

Unfortunately, validation of biomedical models is a difficult and time- and resource-intensive process. This is largely because validation of models and simulation algorithms can only be performed piecemeal for isolated points or small areas or volumes in a hyperdimensional space defined by the realistic range of the inde-

pendent variables.

Since any particular validation study expands the envelope for a validated region by only a limited amount, extensive validation of a model is typically very costly, resource intensive, and extends out over many years or even decades. Verification and validation of model-based algorithms should be a recurrent process since they become partially or completely obsolete as additional data becomes available over time.

Conclusions

Biomedical modeling and simulation products have many potential and practical advantages. For example, high risk scenarios and alternative decision strategies can be explored which are too dangerous, expensive, numerous, or time consuming to physically evaluate. There are, however, potential pitfalls in the use of models and simulations.

Model and simulation fidelity is almost always limited to some extent. This itself circumscribes validity and generalizability of results. Likewise, insufficient fidelity can adversely impact transfer of training from model-based simulations to corresponding real situations. Transfer of training may be incomplete and low fidelity model-based simulations or decision aids can potentially contribute to negative training transfer.

Models can also be plagued by technical problems that are not readily apparent to the casual user or evaluator. The structure and logic of a model may be technically correct but biased due to coefficients obtained from data wherein test subjects or study conditions were not representative of the more general conditions for which the model is typically used. Biomedical models also usually include simplifying assumptions. Therefore, model-based results, or predictions, will only be accurate insofar as the assumptions used in developing the model apply to the specific situation under consideration.

Another common problem in the use of biomedical models and simulation tools is failure to adequately integrate them into organizational practices, doctrine, and guidance. This results from neglecting to establish and implement a high-level, comprehensive, systems-oriented, life-cycle plan for model development, installation,

(See **CONCEPTS**, p. 29)

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and support. Model development is often a lengthy, complex, and resource intensive process. Therefore, the development of model-based products should routinely use project management and control methods such as configuration management, risk identification and mitigation processes, and provide for life-cycle product support.

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Biography

Dr. Matthew Reardon is a principal Investigator and staff occupational medicine physician at SAIC. He earned his medical degree from the University of South Florida, an MPH from Boston University, and engineering degrees from the University of Florida, University of Central Florida, and Northeastern University. He previously was a research scientist at the Army's Aeromedical and Environmental Medicine research labs. He has numerous publications in environmental medicine and human factors modeling. ☼

COMBAT ANALYSIS

(continued from p. 17)

multiplied beyond the necessity of practical application and insight." This clearly has been crafted from the same bright, hard and durable steel as Occam's Razor.

That these weapons, when properly wielded, can win through is illustrated by Jones's Javelin (**Reginald V. Jones**, *The Wizard War: British Scientific Intelligence, 1939-1945*, Coward, McCann & Geohegan, Inc., New York, 1978, pp371-372), "What I had done, after congratulating myself on spotting a clue that nobody else had seen, was to employ the principle known as Occam's Razor: *essentia non sunt multiplicanda praeter necessitatem* (hypotheses are not to be complicated without necessity). For if you start allowing more complicated hypotheses than are essential to explain the facts, you can launch yourself into a realm of fantasy where your consequent actions will become misdirected. As one of my academic colleagues once put it to his pupil: 'If I tell you that the explanation of why I never see a tiger when I open the door is that there really is a tiger outside but that the tiger is frightened of me, so that every time it hears me opening the door it runs away and hides behind a corner, you would say that I was mad—or, at least, a little peculiar!' Time after time when I used Occam's Razor in Intelligence it gave me the right answer when others were indulging in flights of fancy leading towards panic." This piece expresses Jones' experiences as Director of Scientific Intelligence for the British Air Staff during World War II. On 27 October 1993, the US Central Intelligence Agency presented the first two R. V. Jones Intelligence Awards, engraved with his likeness, for crucial contributions to the Allied war effort. One went to Jones and the other went to the brave World War II spy heroine, **Jeannie de Clarens** (codename AMNIARIX).

We also want to bring aboard the Army's Artillery (US Army Field Manual FM 100-1, August 1986, pp17-18), [The ninth principle of war is] "**Simplicity**. Prepare clear, uncomplicated plans and clear, concise orders to ensure thorough understanding. ... Again, simplicity can serve as the measure against which the courses of action can be compared." (Emphasis in the original.)

Throughout the treatment of data, another weapon we should take is Tukey's Tor-

pedo (**John W. Tukey**, "Sunset Salvo," *The American Statistician*, vol 40 (1986), number 1 (Feb), pp72-76), which gives the following advice from a world-famous statistician.

1. The data may not contain the answer. The combination of some data and an aching desire for an answer does not ensure that a reasonable answer can be extracted from a given body of data.
2. The data may not even contain an appearance of an answer, although we should look for appearances and then report them with adequate caution.
3. We must expect often to purvey appearances clearly labeled as such, rather than answers.
4. We ought usually to take our standard statistical ... [to be understood as] confirmatory) task as assessing the minimum uncertainty to be assigned to the results found.
5. We can and should help our subject-matter-skilled clients with the assessment of systematic and other nonsampling errors to make the indicated uncertainty still larger; but we cannot often pretend to do the entire job ourselves.
6. Exploration, as purely a matter of seeking appearances, may need considerable aid from calculations, often rough, of minimum uncertainty. In the simplest cases, such rough calculations are built into our intuition. In more complicated ones, we must support our intuition with the results of numerical calculations."

To keep our weapons well-honed, we should also ship Shaw's Sharpener (**George Bernard Shaw**, 1856-1950): "Science is always simple and always profound. It is only the half-truths that are dangerous."

There are, of course, dangers in oversimplification. To prevent the weight of all these separate simplifications from swamping our ship, I suppose we could jettison everything else and equip ourselves exclusively with Einstein's Excalibur (Albert Einstein, 1879-1955), "Everything should be made as simple as possible—but no simpler!" Since Einstein excels all as the exemplar of expertise in the effective employment of the simplest, keenest, and most efficient hypotheses, he well deserves to have the last word. ☼

QUADRENNIAL DEFENSE

(continued from p. 1)

The Challenge. To determine force structure and force posture to meet the challenge of an uncertain security environment is, in many ways, far more demanding than any comparable determination conducted during the Cold War. In those earlier days, a single overwhelming threat determined the requirements our forces had to meet. The QDR Report noted that "while the prospect of a horrific, global war has receded, new threats and dangers — harder to define and more difficult to track — have gathered on the horizon."

The QDR went on to note that rather than facing a single monolithic enemy, our forces today face a full spectrum of possible threats. At the same time, while forces and defense budgets have decreased by a third or more in the last decade, the tempo of peacetime operations has reached an all-time high. This high peacetime activity level is rapidly becoming the major determinant of current day-to-day troop operation.

Much of what happens on a daily basis is designed to "shape the strategic environment to advance US interests." Our forces support many political and economic requirements driven by our national security policy. At the same time, we must "maintain the capability to respond to the full spectrum of threats." Not only that, we must also "prepare now for the threats and dangers of tomorrow and beyond." Thus the QDR defined a "shape-respond-prepare strategy," stating that "underlying this strategy is the inescapable reality that as a global power with global interests to protect, the United States must continue to remain engaged with the world, diplomatically, economically, and militarily."

To meet the demands of shaping, responding, and preparing requires a very careful balancing, especially in an era of constrained budgets. When our forces are engaged in "shaping," they are often foregoing training that might be needed to be able to "respond" to a spectrum of threats. Also, choosing forces and a readiness posture that emphasizes "responding," may detract from modernizing forces, tactics, and concepts to "prepare" for the threats that will emerge some fifteen or twenty years out.

QDR-97 approached this balancing question by examining "three alternative

paths that differed in where they accepted risks and emphasized investment over the near term, mid term, and long term." One path focused "more on current dangers and opportunities." Another path focused "more on future dangers and opportunities." QDR-97 chose a third path which "strikes a balance between the present and the future, recognizing that our interests and responsibilities in the world do not permit us to choose between the two."

Lessons from the Quadrennial Defense Review

As indicated above, I believe there are a few ingredients necessary for good analysis. First in importance are quality individuals — decision makers, warfighters, and analysts — and their interaction. Also very important is the availability of accurate, relevant data and adequate tools to scrutinize that data. These tools range from recognized methodologies based on the scientific method; to simple models; to large, complex, computer simulations.

Good analysts. As the QDR showed again, analysts play an important role in designing requirements for new and improved models. Good analysts also frequently have to apply existing models that are far from perfect. They are practiced in 'working around' limitations of the models now in hand, often displaying remarkable creativity, even as they long for the improved models still under development.

Since many deficiencies in the TACWAR model related to "inadequate attention" to air power, good airpower operators and analysts played an essential role in developing viable "work arounds." In this context, it is useful to recall some words attributed to the Air Force's first Chief of Staff, General **Carl Spaatz**, some fifty years ago. He commented "that soldiers and sailors spoke solemnly about the years of experience that went into training a surface commander, thus making it impossible for outsiders to understand their arcane calling." This is true for airmen as well, whether operators or analysts. Good analysts and experts from *each* of our military services are not only useful, they contribute the specialized knowledge needed to supplement models used in joint analyses.

We must remember that joint analyses of joint operations will be a large part of future Quadrennial Defense Reviews. Joint

operations involve joint doctrine, which is based on the understanding and appropriate integration of doctrines of the services. In fact, evaluating and integrating new ideas, concepts, and systems, as continuing parts of the planning and programming process, will involve much analysis.

To be effective in evaluating and integrating these new ideas, it is helpful to work closely with the other Services. This can be difficult, but analysis can help, since good analysis is an aid to effective communication. In other words, intuition may lead me in the right direction, but if I need to explain it to someone else, an analytic explanation can show why the intuitive result works.

The value of analysis is apparent both in deepening the understanding of a valid intuition, as well as in the derived value of analysis as a communication aid. When analysis is conducted in a joint climate with high stakes, communication can take longer than it should, and there can be much discouragement along the way. However, the pursuit of understanding has high rewards that justify and demand the effort.

Improved Tools. QDR-97 noted that its force assessment had "highlighted the need for better analytical models that will allow us to accurately and rapidly conduct force requirements analysis While professional judgment will always be required to use and interpret the models, we need better tools to conduct the analytical assessments of warfighting risk."

The Panel was more pointed in its comments. Having observed that models and gaming were used extensively in QDR-97, it complained that "the models used, such as TACWAR, were developed originally for analysis of the NATO-Warsaw Pact Central Front scenario. Ten years ago they were believed to have significant shortcomings, even for that use."

To compensate for the limitations of these models, there were many "work arounds" or supplements. One of these — gaming — lacks the reproducibility and speed of constructive computerized models, but has the advantages of flexibility and involvement of human players. For example, the Joint Staff Dynamic Commitments war game seminars effectively highlighted the stresses imposed on our forces by Small Scale Contingencies, and Military Operations Other Than War. They did not, however, fully examine the impact of

these non-traditional operations on the military's ability to conduct major theater warfare, nor did they look beyond "today's forces against historically-based vignettes as opposed to preparing for likely future challenges."

Analyses of Military Operations Other Than War and weapon systems based on advanced technology will be among the important data requirements of the future. Analytic experience has suggested other areas as well. Sources to tap for data should include tests, exercises, technology demonstrations, training centers, battle labs, actual applications of distributed interactive simulation, and intelligence agencies.

Further, the information dimension of warfare in many cases lacks even a basic understanding of the underlying causal relationships. There are many models of radar detection, tracking, countermeasures, and counter-countermeasures because those subjects have been studied since World War II. Sophisticated "information warfare" attacks on financial markets and other information-based systems, however, have acquired interest only with relatively recent advances in computer and communications technology. The knowledge needed for modeling such warfare will come in time through analysis of specific "information operation" scenarios, gradual learning, and development of appropriate strategy and tactics. But modeling the overall "information dimension of warfare" will take a great deal of hard thinking and experimentation over a protracted time period.

The National Defense Panel worried that legacy models such as TACWAR would become even less relevant with the "continued introduction of sophisticated systems such as airborne surveillance platforms, nonlethals, stealthy platforms, standoff weapons, and modern day information systems." The Panel also expressed concern about the "likely challenges of urban warfare, weapons of mass destruction, and non-state entities such as organized crime." Finally, the Panel urged that the characteristics of the emerging conflict environment such as "operations with no clear front lines, space, and the information dimension of warfare" be captured in the simulations and models that are currently being developed. It added that "to be of maximum utility, they must also reflect the key elements that give the US significant asymmetric advantage, such as high quality personnel, flexible leader-

ship, realistic and intense training, information operations, stealth, counter-stealth, and precision munitions."

The Panel suggested close to twenty items similar to those listed above as candidates for better tools, with some issues being much more challenging than others. For example, the specific effects of standoff weapons and precision munitions can be modeled much more easily now than in the past, given the wealth of data available today from test or intelligence sources. On the other hand, measuring how these systems will be delivered in the complex combat environments of the future requires more work.

These general lessons, while by no means new, are profound in their implications for QDR-01. It takes time to develop models and simulations, to acquire basic knowledge needed for model development,

"Faced with an uncertain security environment and, at best, limited growth in the defense budget, senior decision makers need the very best analytic support available to ensure that budget dollars are spent wisely."

to assemble data bases, to train analysts to establish rapport with decision makers and warfighters, and to accomplish appropriate studies of likely advanced technologies and concepts of operations. However, with good analysts, and a commitment to improving and developing the models needed for future warfare, we will be better prepared for the next round of defense reviews.

Summary

QDR-97 yielded valuable lessons, and underlined old lessons, in the use of models in analysis and the use of analysis in decision-making. Both activities involved joint analysis and participation of the services. In fact, the most satisfying efforts were those that involved extensive multi-Service participation. For the best use of analysis,

these efforts demonstrate the importance of good interactions among staff members, as well as across staff relationships. Effectiveness and efficiency demanded especially good coordination.

There must also be good inter-model relationships that allow Air Force-specific tools to benefit from related tools of the other Services. For models such as TACWAR to represent air power better, Air Force and Joint Staff analysts must be available to take advantage of insights provided by other models. Though far less sweeping than the Panel's suggested model improvements, even this level of collaborative effort would be a major step forward.

While use of selected legacy models continues, there must also be development of other models that incorporate emerging conflict environments and elements of the United States' "significant asymmetric advantage." With or without these new models, however, the analytic community must start collecting useful data, thinking through the implications of these new environments, and exploring innovative styles of warfare, new systems, and operational concepts. New and better models will then emerge.

I support the National Defense Panel's call for model improvement, since I believe we can and must do better in the area of analytic tools. I also recognize that tools are based on knowledge and have provided examples of areas where we don't yet have the knowledge necessary to create useful tools. In these cases, and many others, the analytical community needs to work with the rest of the defense establishment to build the appropriate knowledge base so we can eventually meet the Panel's challenge. Our basic need is to provide stronger support for present and new areas of analysis, with the accompanying improvement in data bases, models, and simulations. Faced with an uncertain security environment and, at best, limited growth in the defense budget, senior decision makers need the very best analytic support available to ensure that budget dollars are spent wisely. Using analysis properly will help build on the most recent QDR and enable future QDRs to continue the process of shaping America's military to best meet the nation's long range security objectives. By doing this, we will answer the challenge and continue to shape a military best suited to meet America's security needs in the 21st century. ☉

MORS AWARDS

1997 Individual Payne Award and the Background of the Payne Awards

Eugene Visco, FS

Continuing the tradition established when he took the post of Deputy Under Secretary of the Army (Operations Research) in 1981, **Walter W. Hollis**, FS and Army Sponsor of MORS, presented the **Dr. Wilbur B. Payne** Awards for Excellence in Analysis at the 36th Army Operations Research Symposium, 12 November 1997, Fort Lee, Virginia. Mr. Hollis created the awards, originally named the Department of the Army Systems Analysis Awards, to acknowledge the best analysis conducted by Army personnel (uniformed and civilian) during a preceding year. Nominations are solicited by Mr. Hollis from throughout the Army. Candidate papers are reviewed by a panel of senior analysts. Through the years, the majority of the members of the panels have been Army analysts themselves; often senior analysts from other services as well as analysts from elsewhere in the government have participated on panels. In 1990 the Secretary of the Army, following a recommendation made by Mr. Hollis, approved changing the name of the award to the **Dr. Wilbur B. Payne Memorial Award for Excellence in Analysis**. Dr. Payne, elected to Fellowship in the Society in 1990, was the founder of and the first to hold the Office of the Deputy Under Secretary of the Army (Operations Research). He was a distinguished Army operations analyst, with a long career of quality, careful and objective analysis starting in the mid 1950s. After Dr. Payne's untimely death, Mr. Hollis, in suggesting the name change for the award, said to the Secretary of the Army: "During his career [Dr. Payne] played a major role in developing what the Army Analysis community is today. Because of his extensive contributions to the Army, renaming this award in his honor would be a particularly appropriate means of memorializing his accomplishments. An award so named would specially recognize the recipients for the effort and dedication that typify what Dr. Payne represented." Wilbur Payne often participated in reviews of candidate papers



Mr. Walter Hollis, FS, presenting the Individual Payne Award to MAJ Patrick DuBois as E.B. Vandiver, FS, looks on.

for the Army's Systems Analysis Awards and contributed significantly to the criteria now used to judge papers for the award presented in his name.

The Payne Award is given in two forms each year: one to acknowledge the best group analysis done during the previous 12 months by Army analysts and one to acknowledge the best individual analysis during the same period.

The winner of the Payne Award for Excellence in Analysis, 1997, individual category was **MAJ Patrick J. DuBois**, Ph.D., US Army Concepts Analysis Agency, for his paper: *Statistical Analysis for Land Disposal Restriction - Utah Group*, published as CAA-SR-97-2, August 1997. The citation accompanying the award, consisting of a handsome plaque and certificate signed by the Secretary of the Army, reads:

In 1995, the State of Utah began development of treatment requirement standards, to prepare for dealing with waste products before disposal of land on which toxic chemicals are stored and where demilitarization takes place.

The US Army Chemical and Biological Defense Command was designated to help the State of Utah in that development. The Command established the Land Disposal Restriction-Utah Group to provide assistance to the State; the Group was comprised of the US Army Center for Health Promotion and Preventive Medicine and the US Army Concepts Analysis Agency.

By 1996, the State of Utah and the Army had developed health risk-based land disposal requirements which identified maximum concentrations of hazardous materials that were stringent enough to protect human health and the environment. Both organizations used a deterministic approach. However, each used different assumptions when selecting input values for the parameters in the computations and thus arrived at dramatically different results. Considerable negotiation between the State and the Army failed to resolve the differences. The State recommended a stochastic approach be developed to incorporate the variability of the values (distributions

rather than point estimates). The Concepts Analysis Agency was charged with developing an appropriate method. MAJ DuBois was given the assignment by the Director.

MAJ DuBois, recognizing the need for speedy action on this critical health matter, quickly developed an approach derived from the Environmental Protection Agency's Risk Assessment Guidance. The method established by MAJ DuBois includes identification of exposure scenarios, identification of the exposure model, research to determine input parameters based on the exposure scenarios, a Monte Carlo simulation to incorporate the uncertainties relating to the input parameter values, analysis of the output distributions, and selection of output distribution percentiles based on risk.

When he applied the stochastic approach, MAJ DuBois found that the earlier deterministic results produced overly conservative land disposal restrictions. The results from the stochastic approach, judged more realistic by the State and the Army, mean that the State of Utah can relax the more stringent land disposal restrictions while maintaining human health and environmental standards. In addition to adequately protecting the public and wildlife, considerable cost savings result. The method is transferable to all locations with stockpiled chemical agents.

By completing the analytic effort in a timely fashion and solving a major health and financial problem related to future land use, MAJ Patrick J. DuBois has made an important contribution to the Army and the nation and is recognized for that contribution as the recipient of the 1997 Dr. Wilbur B. Payne Memorial Award for Excellence in Analysis, Individual Category.

The winner of the Payne Award for Excellence in Analysis, 1997, group category was the OPTEC Task Force XXI Advanced Warfighting Experiment Team, for the paper *Task Force XXI Advanced Warfighting Experiment Live Experiment Assessment Report*, published as US Army Operational Test and Evaluation Command, 1997-AW-ACTI-1817A, August 1997. Information about their award can be found in the March issue of *PHALANX*. ★

CAA Moving to Fort Belvoir

Kevin S. Tomich, US Army Concepts Analysis Agency (CAA)



Laying the foundation for the future. (L-R) MAJ Hand, Mr. Sigal, Mr. Vandiver, Mr. Hollis

A formal groundbreaking ceremony was held on 3 November 1997 at the site of the US Army Concepts Analysis Agency's future home — Dr. Wilbur B. Payne Hall, Fort Belvoir, Virginia. Many words were spoken and shovels of earth turned to celebrate this momentous occasion in, coincidentally, the 25th year of CAA's existence. Chief among the forty or so attendees were the speakers: Mr. Walter W. Hollis (Deputy Under Secretary of the Army (Operations Research) [DUSA-(OR)]), Mr. E. B. Vandiver III (Director, US Army Concepts Analysis Agency) and Major J. T. Hand (Deputy District Engineer for Civil Works, US Army Corps of Engineers, Baltimore District. Also attending were Colonel Michael A. Leeper (Garrison Commander, Ft. Belvoir) and Mr. Jerry Sigal of Sigal Incorporated, the general contractor for this project.

The new structure will memorialize the late Dr. Wilbur B. Payne, the first Deputy Under Secretary of the Army for Operations Research (1968 - 1975) and subsequently Director, TRADOC Systems Analysis Agency. Besides being the first DUSA (OR), for all intents and purposes Dr. Payne was the founding father of the Operations Research analysis community as it is constituted in the US Army today. The selection of his name to honor the new CAA building was quite deserving in view of his great contributions to analysis in the US Army, and fitting since he was largely responsible for the creation of CAA.

The genesis of this move from leased space in Bethesda, Maryland was the 1995 Base Realignment and Closure Commission recommendation to the President that CAA be relocated to Fort Belvoir, Virginia. The structure, to be located at the intersection of Goethals and Franklin Roads, is scheduled to be occupied in late March of 1999. To CAA's knowledge, this will be the first new structure within the Army that was expressly designed for an analysis activity, and therefore should be looked upon with some pride.

The dedication of Dr. Wilbur B. Payne Hall will be in the late spring of 1999. Targeted attendees will include a well represented assemblage from within the US Army, other military services, and the OR community at large. Taken altogether this should comprise a broad cross section of the *PHALANX* readership. We look forward to seeing you at this ceremony. ★



1998 RIST PRIZE CALL FOR PAPERS

MORS offers two prizes for best papers—the *Barchi Prize* and the *Rist Prize*. The *Rist Prize* will be awarded to the best paper in military operations research submitted in response to this **Call for Papers**. The *Barchi Prize* will be awarded to the best paper from the entire 66th Symposium, including Working Groups, Composite Groups, and General Sessions.

David Rist Prize: Papers submitted in response to this call will be eligible for consideration for the *Rist Prize*. The committee will select the prize-winning paper from those submitted and award the prize at the 67th MORSS. If selected, the author(s) will be invited to present the paper at the 67th MORSS and to prepare it for publication in the MORS Journal, *Military Operations Research*. The cash prize is \$1000. To be considered, the paper must be mailed to the MORS office and postmarked no later than **September 30th, 1998**. Please send the original, six copies and the disk.

Richard H. Barchi Prize: Author(s) of those papers selected as the best paper from their respective Working Group or Composite Group, and those of the General Sessions at the 66th MORSS will be invited to submit the paper for consideration for the *Barchi Prize*. The committee will select the prize-winning paper from among those presented and submitted. The prize will be presented at the 67th MORSS. The cash prize is \$1000. To be considered, the paper must be mailed to the MORS office and postmarked no later than **25 November 1998**. Please send the original, four copies and a disk.

PRIZE CRITERIA

The criteria for selection for both prizes are valuable guidelines for presentation and/or submission of any MORS paper. To be eligible for either award, a paper must, at a minimum:

- Be original and a self-contained contribution to systems analysis or operations research;
- Demonstrate an application of analysis or methodology, either actual or prospective;
- Prove recognizable new insight into the problem or its solution; and
- Not previously been awarded either the *Rist Prize* or the *Barchi Prize* (the same paper may compete for but cannot win both prizes).

Eligible papers are judged according to the following criteria:

Professional Quality

- Problem definition
- Citation of related work
- Description of approach
- Statement of assumptions
- Explanation of methodology
- Analysis of data and sources
- Sensitivity of analyses (where appropriate)
- Logical development of analysis and conclusions
- Summary of presentation and results

Contribution to Military Operations Research

- Importance of problem
- Contribution to insight or solution of the problem
- Power or generality of the result
- Originality and innovation



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THE LAST WORD

Edward D. Napier, FS, Executive Secretary of MORS from 1977-1984, died of a heart ailment on 2 April 1998. He died at his home in Falls Church, Virginia, where he had lived for the past 35 years.

Ed was a retired Navy Captain and decorated combat veteran of two wars. During World War II, he served aboard the battleship New Mexico in the Pacific, and participated in the invasions of the Marshall, Gilbert, Mariana, and Philippine Islands, as well as the battle for Okinawa. During the Korean War, he commanded the fleet minesweeper Ruddy, off Korea.

After World War II and Korea, his assignments included a tour as engineer officer aboard the carrier Essex and command of a destroyer and Polaris missile test ship. Washington assignments included tours as chief of the systems analysis division in the Organization of the Joint Chiefs of Staff. His last post, before retiring from active duty in 1973, was as senior staff scientist in Institute of Management Science at The George Washington University.

Ed, a native of Pennsylvania, was a 1943 graduate of the US Naval Academy at



CAPT Edward D. Napier, FS

Annapolis and received a master's degree in operations research from the Naval Postgraduate School in 1958.

His decorations included the Legion of Merit and Navy Commendation Medal.

In 1970, Ed was elected to the board of the Military Operations Research Society. He retired from the board in 1975 as its First Vice President. In 1977, he succeeded

Vance Wanner to the position of Executive Secretary. He retired in 1984 when he decided it was time to travel and enjoy life with his wife, **Kay**. He was elected a Fellow of the Society (FS) in 1990.

Ed was very interested in his roots. He began a vigorous study of his family genealogy after his retirement, and he was a founder and director of the Clan of Napier in North America. He was a descendent of mathematician **John Napier**.

Ed was interred in the Columbarium at the Naval Academy on 8 April at a service attended by his family, all dressed in Napier Clan tartan, many friends and Naval Academy Classmates. **Dick Wiles, Jerry Kotchka** and **Natalie Addison** attended the service, which was a tribute to a dedicated family man, friend and Naval officer. Jerry presented Kay and each of the grandchildren with a MORS coin in appreciation for Ed's service to the Society.

Survivors include his wife of 45 years, Catherine (Kay), of Falls Church; three sons, **Jim**, of Damascus, **Joe**, of Tempe, AZ, and **David**, of Alexandria; a daughter, **Chris Woodard** of Leesburg; and 10 grandchildren. ☺