Trends in Modeling, Simulation, & Gaming: Personal Observations About The Past Thirty Years And Speculation About The Next Ten

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ABSTRACT

This paper is about trends in Modeling, Simulation, and Gaming (MS&G) from my personal view. It includes observations and impressions from the early days of distributed simulation, particularly the DARPA SIMNET program, and the many programs and developments that followed. From that point of view the paper speculates about new and innovative futures that are achievable in the next 10 years.

In many regards, the development of large-scale distributed simulation was about nurturing and sustaining *operational excellence* in individuals and units. Thus it attracted many operators, scientists, and engineers that were motivated by the same goal. I believe that it was the basic nature of the technology itself that allowed so many breakthroughs and innovations: *distributed, modular, networked based simulation (of which prototyping is an inherent feature) with standard interfaces making it easy to mix and match just about anything.* And that's what people did.

The paper is in four parts: Early SIMNET activities and significant accomplishments; enabling technologies that have been converging behind the scenes; how both of these create opportunities for the future, and what that future might look like (one view, anyway); and my own lessons learned and takeaways.

The final part of the paper, the Appendix, contains a number of thoughtful, insightful observations from the many people I talked with in the preparation of this paper, their own "Lessons Learned and Other Takeaways." Their observations make for very thoughtful reading.

ABOUT THE AUTHOR

Jack Thorpe, Ph.D., (Colonel, USAF, retired) served in the Air Force as an R&D officer for 26 years. He earned his Ph.D. under a program offered by the Air Force Institute of Technology at public/private universities. Unusually, nearly half his career was spent at DARPA as a Program Manager, Office Director, and Special Assistant to the Director. He created and managed the DARPA SIMNET program and was a founding contributor to the Command Post of the Future program. He was also involved in the development of MicroTravel, Video Arcade Trainers, Desk Top Simulators, the Defense Simulation Internet, the 60% Solution methodology, Interactive History, the Electronic Sand Table, the Double Helix methodology, and SIMNET U and C2U ("U" for university). Dr. Thorpe is on the advisory board of the Army's Institute for Creative Technologies, and is the former Chair of DARPA's Information Science and Technology study group. He is still active in planning and structuring advanced research projects, lately in the area of Strategic Collaboration. Portions of this work involve applying DoD advanced technology to responding to extreme scale disasters, which involves working with California first responders.

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Alice laughed. "There's no use trying," she said "one *can't* believe impossible things."

"I daresay you haven't had much practice," said the Queen. "When I was your age, I always did it for half-an-hour a day. Why, sometimes I've believed as many as six impossible things before breakfast." (Through The Looking Glass, Lewis Carroll)

or

What It Was Like To Be A Program Manager At DARPA In The 1980s

INTRODUCTION

This paper presents personal observations about trends in Modeling, Simulation, and Gaming (MS&G). It includes impressions from the early days of distributed simulation, particularly the DARPA[1] SIMNET program, and the programs and developments that followed.

There are many historical and technical reviews of the development of distributed simulation and the efforts of standard-setting and architecture-definition groups, so I will not use space duplicating that material. A review of IITSEC archives as well as a Google search will direct the reader to these sources. You might wish to refer to the 1995 issue of the *Proceedings of the IEEE*[2] as well as issues in *Wired Magazine*[3] for overviews.

Instead I intend to share my perspectives on some of the key developments during this period and what they could mean for the future.

For the purposes of this discussion, I choose to group into one mega category all models, simulations, war games, commercial games, massively populated persistent worlds, serious games, online and console games, analytical, acquisition, and training applications, and so on. It seems to me that these all have the same underlying information technology and for the review purposes here can be addressed in the whole.

This was not the case in the 1970s and 1980s, at least in my experience. Early computers were unique, tended to be special purpose, and could be unwieldy when trying to get work done. They were underpowered by today's standards (see Duncan Miller's comments in the Appendix) and full of peculiarities that made them challenging to program. Simple computer image generators were room-sized and largely built by hand. Networking was especially difficult. The plug and play modularity of today's information technology was nonsexistent.

Further, the different types of modeling and simulation applications tended to be stovepiped. Engineering simulation existed in one domain, training simulation in another, analytic war games and studies in a third, and so forth. Today they all use the same core information technologies, and we

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[1] Defense Advanced Research Projects Agency, previously ARPA, the Advanced Research Projects Agency.
[2] Proceedings of the IEEE, Vol 83, No. 8, August 1995
[3] *"War is Virtual Hell,"* Wired Magazine, Issue 1.01, Mar/Apr 1993; "*SIMNET*," Wired Magazine, Issue 5.04, Apr 1997

know how to combine MS&G in federations. So I tend to think of them as a class.

With that as perspective, I have divided my observations into four sections:

I. The Early Days of Distributed Simulation
II. Convergence of Three Technology Trends: Networking, Instrumentation, and Command & Control
III. Future Opportunities
IV. My Lessons Learned & Takeaways

I telephoned a number of people in preparing this paper, and I am indebted for their thoughtful contributions. I could have called twice or three times as many, but just ran out of time. *You will find interesting and varied observations from many of these experts in the* <u>*Appendix*</u>*.*

At one time I estimated that there were over 300 scientists, engineers, operators, site managers, trainers, fabricators, software and hardware experts, and numerous other people working on SIMNET alone, all talented, dedicated, and hard working. It is impossible to name everyone, but I have identified some who were involved in specific parts of the story I describe below. If I left off your name, it is not because I have forgotten about your contribution.

Special recognition goes to General Paul Gorman (USA, retired) who provided extraordinarily prescient guidance early and still to this day; Colonel Neale Cosby (USA, retired) who created and led the IDA Simulation Center, an amazingly productive concentration of innovation and accomplishment; Colonel Gary Bloedorn (USA retired) who was the key subject matter expert and leader for much of this story; Colonels Jim Shiflett and Bob Reddy (both USA retired) who began this trek as Majors along with the author (Major Shiflett at Fort Knox, Major Reddy at the Pentagon, and Major Thorpe at DARPA) and went on as DARPA Program Managers and still contribute today to the preparation of soldiers for combat; Captain Dennis McBride (USN retired), aided and mentored by RADM Lee Kollmorgen, who dramatically expanded the breadth of distributed simulation with the inclusion of a wide spectrum of Navy, aviation, and behavioral simulation components; Dr. Duncan Miller who organized and led the team at BBN; Dr. Bob Jacobs who did the same at Perceptronics; Mike Cyrus, who knew there was a better and cheaper way (by 100x) to build graphics engines; and Ulf Helgesson, master designer, who touched all aspects of SIMNET with a critical, creative eye.

SECTION I
THE EARLY DAYS OF DISTRIBUTED SIMULATION

The Climate In The 1970-1980s: Substitution

Training simulators in the 1970s and 1980s were not universally popular, at least not for aircrews. One reason, a big one, was that simulators were primarily used for *substitution* tasks, tasks that could be trained either in the aircraft or in the simulator. Since a simulator hour was less costly than a flight hour, there was strong economic pressure to use the simulator. The result was often fewer flight hours for aircrews.

This substitution, however, was for *peacetime* tasks, tasks that could be performed either in the aircraft or in the simulator with similar effectiveness.

Unfortunately we did not give much attention to a number of tasks that might have to be performed in the initial hours of combat but which were rarely practiced in the aircraft for many reasons:

a. Safety (e.g., danger-close firing of real weapons; many-on-many close-in dynamic maneuvering; very low level maneuvering at night)
b. Security (e.g., not activating sensitive equipment to prevent its electronic signature from being profiled by a listener; or, not activating equipment because it jammed all the TV channels in Albuquerque; not practicing sensitive tactics in the open)
c. Scarcity of certain weapons (e.g.; cost of launching very expensive weapons for practice purposes)
d. Cost (e.g., the coordinated activities of scores of aircraft)
e. Time (e.g., time to prepare and coordinate a large-scale exercise that uses complex tactics; time to participate given all other duties)
f. Space (e.g., availability of ranges that allow massed forces to coordinate and practice, for example ingress and egress routing)

For those who began to realize that the best use of simulators might be for *non-substitution,* i.e., mastering combat skills you cannot practice in a combat vehicle in peacetime, a different appreciation of the role of the simulator started to come into focus. The value of simulation technology that allowed massed forces to practice and rehearse combat skills *without actually massing* became apparent.

To my knowledge there was no documented military requirement in any of the Services for this capability. This simulator technology did not exist in the 1970s. It was developed in the 1980s under the sponsorship of DARPA.

Rationale for SIMNET & Distributed Simulation

In the 1970s there were few simulators that were networked. One example was at the Flying Training Division of the Air Force Human Resources Laboratory, Williams Air Force Base, Arizona, where two new simulators[4] could engage in two-ship flight operations. The purpose was for training research, however, rather than actual training.

In 1978, as the notion of using simulators for *non-substitution* began to take form, I put some ideas down in a white paper[5] that proposed developing networks of simulators that would be used for combat planning, rehearsal, and execution. By happenstance I was offered the services of a graphic artist in the Pentagon, and he illustrated the key components of the proposed concept with four drawings.

Figure 1 shows the detection of an enemy aggression somewhere in the world. Real time information is relayed to a facility (here called the Tactical Development Center) where the situation would be portrayed, examined, and a response planned. The facility could be anywhere in the world.

Figure 2 shows planners assessing the situation and considering a response using a three dimensional, holographic, electronic sand table. The artist was not sure what a holographic, electronic sand table projection system would look like, so he labeled the overhead projectors "High Voltage" to convey the notion.

Figure 3 shows pilots in a four-ship of simulators rehearsing the plan. Their execution is shown on the sand table for study by the planners, who presumably would make refinements along with the

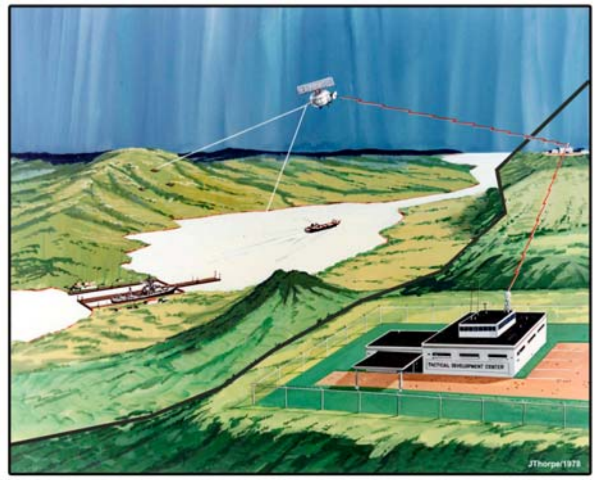

Figure 1 - Enemy aggression detected by overhead sensor

Figure 2 - Planning a response using the holographic electronic sand table

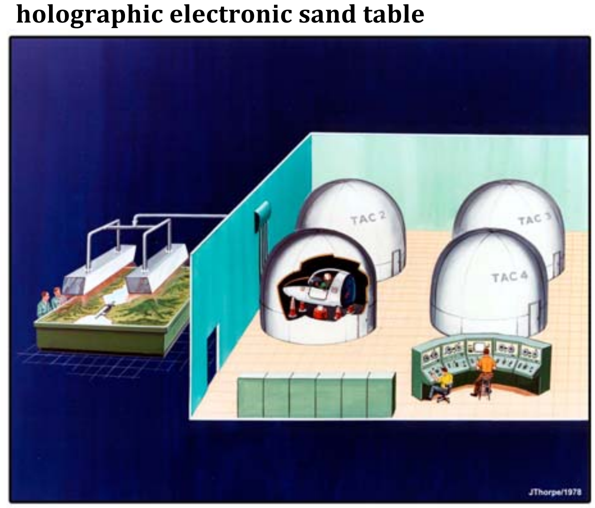

Figure 3 - Aircrews rehearse the plan and planners assess suitability

[4] The Advanced Simulator for Undergraduate Pilot Training, ASUPT, initially configured as two T-37 jet trainers.

[5] "Future Views: Aircrew Training 1980-2000," unpublished white paper, Captain Jack Thorpe, Life Sciences Directorate, Air Force Office of Scientific Research, 15 Sept 1978, available from the author.

Figure 4 - Mission execution with real time observation

pilots, and rehearse again until a plan was judged suitable.

Figure 4 shows the actual mission being executed, with the planners and battle damage assessors watching the execution in real time on the electronic sand table.

The 1978 white paper envisioned a network of simulators all within the same building: The idea of networks connecting distant military installations was not yet imagined. Nor did we understand how to connect these simulators together in the first place. The ARPAnet experiments connecting a small number of computers between different universities were underway but the results not well known. Of interest, BBN[6] was a key DARPA performer in the ARPAnet development and ultimately applied this technology to SIMNET.

While the white paper proposed an interesting concept, there was no clear idea how to make this work technically, so the idea was set aside.

Five years later, in 1983, the idea was revisited. The technical approach of mimicking the ARPAnet seemed feasible, and in April DARPA[7] initiated the SIMNET program (for SIMulator NETworking).

[6] Bolt, Beranek and Newman, Inc., Cambridge, MA
[7] In 1981 I was assigned to DARPA under Dr. Craig Fields, who contributed immeasurably to the conceptualization, organization, and execution of SIMNET.

The rationale for the program was described using Figure 5 based upon notional functions. It was argued that as the size of individuals/units involved in training moved from small (an individual combatant, a single crew) to large (an armor battalion, a joint task force, a coalition team) as shown on the x-axis, the opportunities to practice decreased given the difficulties of finding practice time and range availability. At the same time, the cost of training grew as would the cost of mission failure should the unit enter combat unprepared. You ended up with less opportunity to practice the critical collective skills that were most important and most costly if mastery was not achieved.

The conclusion was that the maximum payoff for a successful technology intervention would be in providing cost efficient training for the shaded area on the right, and this required the participation of large forces that would be networked together.

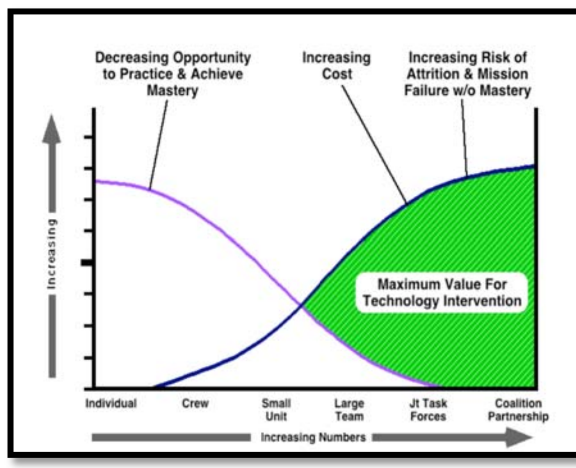

Figure 5 - Rationale for SIMNET technology intervention

Further, it was strongly held that mastery of combat skills was mastery of force-on-force, man-on-man skills: How to succeed against a hostile, sentient opponent. This mastery could only be achieved in combat (at high cost) or on an instrumented range (the Army's National Training Center, NTC, or the Navy and Air Force Air Combat Maneuvering Instrumentation ranges, ACMI, as examples). With networking technology, it might be possible to enable force-on-force engagement by networking large numbers of people together realistically in real time from their home stations.[8]

[8] General Norman Schwarzkopf, following Desert Storm, expressed how we thought about the central

In its essence this was an argument developing and nurturing the *operational excellence* *of individuals and teams, and it soon attracted other operators and technologists that were committed to this same goal. This was our motivation.*

The technical structure of the SIMNET program was informed by the lessons learned from the ARPAnet. First, to evaluate scale, we had to network a large number of simulators. How many? It was a guess, but several hundred seemed about right in order to address the challenges of sustaining a virtual world of interesting capability and military relevance.

Second, to address the coordination of networks between sites, it was determined that four sites should be constructed. Connecting two sites in real time presented one unique set of problems, connecting three sites presented another, but connecting four or more allowed us to address the generic case which, if solved, would allow scaling to very large mix and match of networks. These sites could be located adjacent to one another connected by wire, but the reality was that military units are typically home based far apart, so adding a long haul networking component to the program helped address this issue.

Third, we made assumptions about the types of entities to simulate. With the target being four sites with several hundred simulators in total, we determined that we should model Army armor vehicles grouped as battalion task forces, yielding about 90 total simulators at each of the four locations.

But being ignorant about what armor units did and what it would take to network armor simulators, we asked for help from Major General Rick Brown, the Commanding General of the U.S. Army Armor Center at Ft. Knox, and Colonel Gary Bloedorn, a recently retired armor officer and subject matter expert on training. Both men adopted the project, and bent over backwards to make it successful. Without the guidance and counsel of these two officers the project would have made no progress whatsoever.

At the time, selecting ground vehicles also seemed like a technically conservative approach, since it was reasoned that the slower moving ground vehicles would generate less update traffic on the local and long haul networks than high performance fighter aircraft maneuvering during dogfights, for example. This intuition was incorrect, it turned out, since aircraft behave in a predictable manner (e.g., they can't turn on a dime) while ground vehicles can change appearance with every bump in the road or minor rotation of a turret that needs to be reported to all other entity simulators in the area of possible visibility. Also, there are usually many more ground vehicles in potential visual range than air vehicles at any one time.

Finally, given the numbers of simulators that we would have to network in this test bed to accomplish the program's technical goals, we had to consider designing and fabricating a new class of simulator since the DoD inventory of simulators was inadequate and probably not available for test bed purposes anyway: At that time the typical full mission aircraft simulator was estimated at $20-25 million dollars each, and the Army reported that their procurement of a full mission simulator for their new M1 Abrams Battle Tank was cancelled when the estimate from industry for a single simulator was $20 million dollars. (The tank itself was costing the Army a reported $2 million dollars each.) Graphics engines (the computer image generators) for a slow moving vehicle like a tank were reported as each costing as much as $3 million dollars or more. So procuring several hundred simulators for the SIMNET test bed using current simulator technology was not feasible. We were going to have to make our own, and make them cheaply.

SIMNET Program Start

Because of the reasons above, the SIMNET program began with an intense education program for the technical teams: BBN under the leadership of Dr. Duncan "Duke" Miller, Perceptronics under the leadership of Dr. Bob Jacobs, and Delta Graphics under the leadership of Mr. Mike Cyrus. General Brown opened Fort Knox to us, and we set out to learn about armor vehicles, armor concepts of operations (CONOPS), and how collective skills were trained. We swarmed over, drove, and fired the M1

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role of the human in combat: "The analysts write about war as if it's a ballet….like it is choreographed ahead of time, and when the orchestra starts playing, everyone goes out there and plays a set piece. What I always say to those folks is, *'Yes, it's choreographed, and what happens is the orchestra starts playing and some son of a bitch climbs out of the orchestra pit with a bayonet and starts chasing you around the stage.'* And the choreography goes right out the window."
Washington Post, February 5, 1991, page A13

Abrams Battle Tank and the M2/3 Bradley Fighting Vehicle. We studied training and operational documents. And we were mentored by skilled soldiers.

But one aspect of the program had a rocky start for reasons that were not apparent at first. Several of us, coming from traditional training technology backgrounds, had a traditional training approach in mind, with structured training exercises and performance scoring that moved teams through an operational curriculum. But Colonel Bloedorn argued forcefully against this. He was for an approach that envisioned the technology creating an unconstrained virtual world where commanders could do anything they wanted: *They were the training subsystem and they would use the same performance measures and after action review techniques that they would use on the battlefield.*

The novelty of this concept, and the difficulty in articulating its essence, was a source of high frustration (and shouting!) until finally we all *got it*.

Figure 6 - Designer Ulf Helgesson (left) and subject matter expert Colonel Gary Bloedorn (right with white cup) reviewing the tank mockup

At that point the real SIMNET design effort began. The teams looked at each crew and command position to determine what was to be trained, and how, within the context of collective training. We assumed that every crewmember that would use the technology was accomplished in his particular specialty: we were dealing with experienced people, not new recruits.

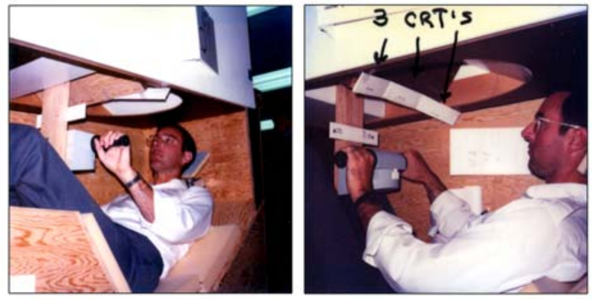

Figure 7 - Author in a plywood and foam core mockup of the tank driver's compartment four months after program start

For example, tasks that were adequately trained in other venues (e.g., in other training devices or in the armor vehicle itself) or which were not essential to collective training, could be abstracted or approximated in the SIMNET simulators. For instance, the bilge pump switch used to activate a pump to dry out the tank's engine compartment after fording a body of water was not essential for collective training, therefore was shown on the correct instrument panel in the driver's compartment as a photo of the switch, not the real switch.

This design process was called *selective fidelity.*[9] Where required by the training objectives, the simulators were fabricated with high fidelity. Where not, systems were abstracted or not implemented at all. The resulting designs were documented in *functional design specifications* prepared for the engineering and fabrication teams.

We also used a process that we would later call *The 60% Solution*, the notion that while we could take a great deal of time studying every design issue, it was considerably more efficient to be about *60%* complete and rapidly fabricate a prototype that soldiers could see and touch and tell us what needed to be improved. We would take another *60%* shot on the next prototype. This led to rapid iterations of design, many that were manifested as cheap foam core and plywood mockups, but which were good enough for soldiers to provide us valuable feedback.

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[9] Dr. Robert Jacobs, Perceptronics, coined this concept and term and guided the design team and preparation of functional specifications. Mr. Ulf Helgesson, an architect and designer, performed the majority of the design and specification of fabrication technologies and techniques for the entire SIMNET project, including families of simulators, and all facilities.

Fast, approximate, and cheap was better that slow, deliberate, and expensive.

When the program commenced in 1983 we established a cost bogie of $200,000 for these new simulators, of which half would be for a new generation of graphics engine. To illustrate, an M1 Abrams tank simulator had 4 crew positions (as in the tank): tank commander, gunner, loader, and driver. It had 9 vision blocks and sights, an audio generator and speakers, and a main computer that calculated own vehicle dynamics, subsystem performance, and communicated with other simulators on the network. It had a simulated blast door activated by a knee switch, main gun and machine gun ammunition management, gunner/ commander aiming reticle/sight, and rotating commander and loader turrets with vision blocks.

The graphics engine was created by the startup company Delta Graphics[10] led by Mike Cyrus. His team was composed of engineers and mathematicians who had been exploring different computer architectures for low cost computer image generation, including a modified z-buffer.

The functional design and performance specifications for the graphics engine were determined through a series of user interface simulations. Still and animated scenes were constructed using expensive image generators, which we rented, programmed to produce degraded images. As an example, scenes were produced at (different frame rates) x (with different resolutions) x (different levels of detail), and the resulting visual content was evaluated by military operators to see if specific tasks could be completed (e.g., identification of a target at a particular range). The final performance specifications emerged from these tests and the graphics team began to design a new machine to meet that performance.

To save costs, the simulators were designed to serve only as prototypes within the SIMNET test bed, and the design and fabrication teams built the simulators with the useful life span (goal) of five years.

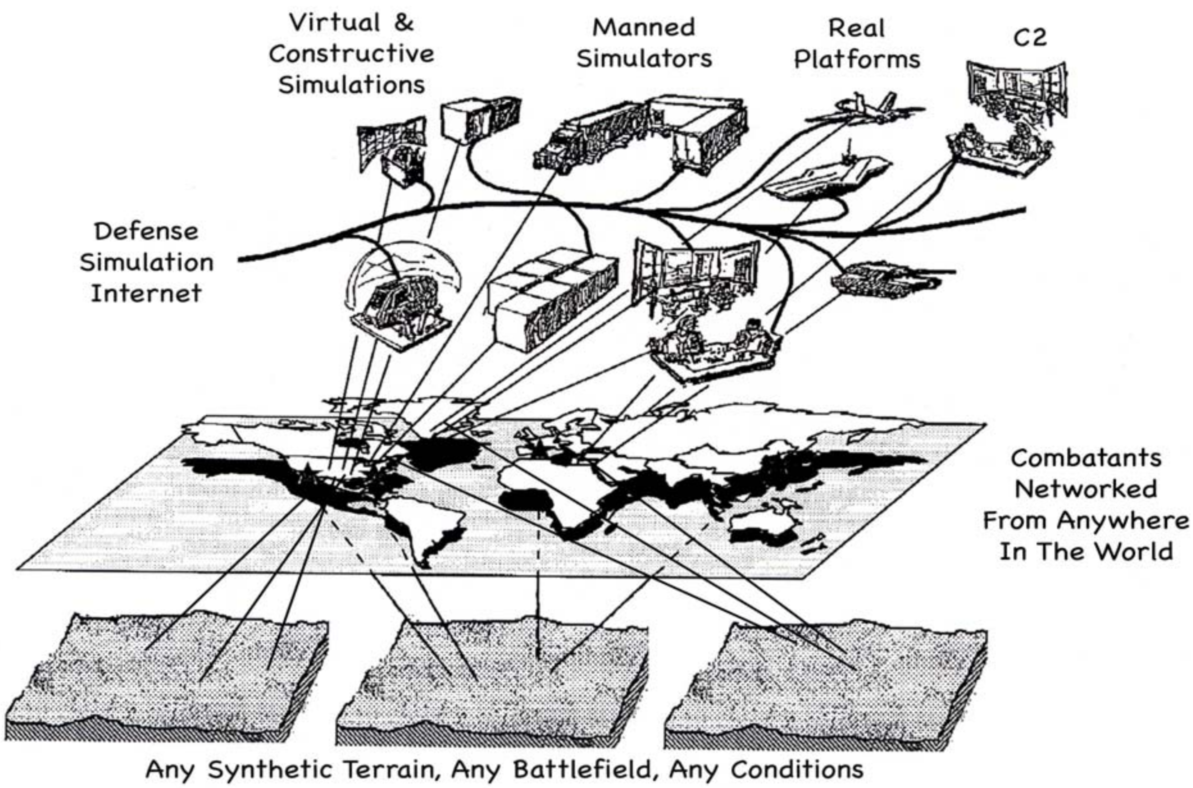

Figure 8 – Rough sketch that captured the essence of distributed simulation

[10] Delta Graphics was formed by Mike Cyrus, Drew Johnson, and Jay Beck

The program progressed in roughly these stages, with some of the many milestones shown. Other milestones from related efforts are interleaved:

- SIMNET kickoff (April 1983);
- Design and prototyping (1983-1985);
- Concept presented to the Army leadership (fall 1985);
- First two networked simulators at Fort Knox (May 1986);
- Indirect fires, command & control (via command post) and logistics added (1986)
- Installation of 60 tank and fighting vehicle simulators at Fort Knox (1986-1987);
- Beginning of development of semi-automated forces (SAF) (1987)
- Installation of a platoon of SIMNET M1 tank simulators at Grafenwoehr, Germany, to support U.S. crews in the Canadian Army Trophy (CAT-87) gunnery competition (1987)
- Creation of a second SIMNET site at Fort Benning, Georgia, and installation of fighting vehicle and tank simulators (1987-1988);
- Creation of a site at Fort Rucker, Alabama and installation of scout & attack helicopter simulators (1988-1989);
- Addition of close air support (CAS) simulators at Ft Knox (1988)
- Evaluation of the prototype Forward Area Air Defense system (FAADS) in the SIMNET-D (Development) facility (1988)
- Evaluation of the Air Defense Anti-Tank System (ADATS) at Ft Rucker (1989)
- Creation of a site at Grafenwoehr, Germany, followed by three additional German sites (1988-1989)
- Defense Science Board study "Computer Applications to Training and Wargaming" (1988)
- First DIS Workshop (Standards) (1989)
- Project ODIN (1990-1991)
- Reconstruction of the Battle of 73 Easting (1991-1992)
- Distributed Simulation Demonstration before the Senate Armed Services Committee in the Dirksen Office Building, Capitol Hill (1992)
- IITSEC Exhibitor Floor networked (1992)
- Defense Science Board Task Force On Simulation Readiness & Prototyping (1992)[11]
- SEDRIS program commences (1994)
- IEEE Proceedings, August (No. 8) on Simulation (1995)
- *Wired Magazine* describes SIMNET as the first instantiation of "cyberspace" (Issue 5.04, Apr 1997)

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[11] "Impact of Advanced Distributed Simulation on Readiness, Training and Prototyping" Chaired by Dr. Joe Braddock and General Maxwell Thurman. Membership included Gordon England, Gen Paul Gorman, Dr. Anita Jones, Donald Lathan, Larry Lynn, Dr. Duncan Miller, Dr. Ivan Sutherland, Gen Larry Welch. This is the study that asserted, "Everything is simulation except combat" and classified the whole of MS&G as Live, Constructive, and Virtual.

At program completion, we were not far off from our original cost-per-simulator target. We did not make as many simulators as planned and instead modified the original ground simulator architecture to create scout and attack helicopters, close air support fighter aircraft, and other vehicles. Some simulators were fabricated as reconfigurable building blocks to be used in the Fort Knox SIMNET-D[12] (D for Development) skunk works constructed by DARPA for the creation and evaluation of advanced concepts. At one time we had nine sites interconnected.

A note: The expected five-year life span of these simulators has been exceeded, and most are still in operation today, over 20 years later, having accumulated tens of thousands of hours of up time.

The rough sketch (Figure 8) became the clearest expression of the goal of distributed simulation: All entities (real vehicles, virtual and constructive simulations, manned simulators, command and control, anything that could be networked whether designed for that purpose or not) could be physically located anywhere in the world, connected together via networks (here the "Defense Simulation Internet"), and would be beamed onto one of several synthetic battlefields representing real places or completely notional locations.

Some Notable Events

The period 1983-1993, with which I had the greatest first hand knowledge, was marked with an explosion of innovation, excitement, and accomplishment. The SIMNET program, and the many other projects that grew out of it or spun off from related ideas, were populated with extraordinarily skilled and motivated people.

As I look back, it seems that it was the basic nature of the technology that enabled so many spinoffs: distributed, modular, networked based simulation (of which prototyping is an inherent feature) with standard interfaces making it easy to mix and match just about anything. And that's what people did.

Here is a sampling from a pool of many notable events.

[12] The SIMNET-D skunkworks eventually became the Mounted Maneuver Battle Lab

Canadian Army Trophy – 1987

The Canadian Army Trophy was a tank gunnery competition among NATO armor forces designed to encourage mastery of unit gunnery skills via friendly competition. It is no longer held in Germany.

The competition began in 1963, and up until 1987 the U.S. had never won. That year the rules prohibited competitors (platoons of 4 tanks) from practicing on the range where the competition was going to be held, though competitors could use any training or rehearsal technology they could muster. The competition involved each platoon moving down range on four parallel tracks engaging stationary and moving targets at a distance of 1,600 to 3,000 meters. Of the possible 100+ targets, only 32 would be presented, the set mixed from run-to-run. Each competing platoon ran the range only once.

We became aware of the upcoming competition as the first SIMNET M1 tank simulators were being delivered to Fort Knox.[13] The decision was made to support the competition, and a platoon of simulators (four) were shipped to Grafenwoehr, Germany along with a complete virtual model of the competition range and its targets[14] and a control and scoring workstation that would allow the platoon to select whatever set of targets they wished to engage.

The two platoons representing the U.S. were given unlimited access to the simulators and began to use them at once. They were able to efficiently use their training time, as they could complete a run on the virtual range about every 15 minutes, including detailed scoring, an after action review, and refinement of their engagement tactics before the next run. The commander could tailor target presentations to strengthen platoon weaknesses.

[13] Colonel Bloedorn was instrumental in planning & managing the SIMNET-CAT 87 support, and the SIMNET team excelled in overall support of the effort.

[14] George Lukes, then at the Army Engineer's Topographic Engineering Center, supervised the construction of the terrain databases as he had done for several other simulator applications.

Had they had access to the competition range, on the other hand, they would have only been able to schedule a few visits, and given the rigors of range safety control, they would have been lucky to have accomplished one run each hour, maybe less. So by comparison, they were able to run dozens of scored runs in simulators versus a handful on the real range if that had been an option.

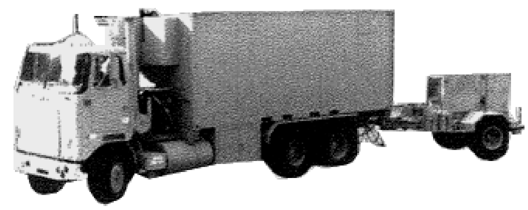
On the last engagement of the last day, 1st platoon D Company 4-8 Cavalry, U.S. Army, achieved the highest score and won the competition. They credited their use of networked simulators as a significant contribution to their victory.

Project ODIN - 1990-1991

Project ODIN was conceived as a response to a DoD challenge to make available any DARPA technology that could support the impending military action to counter Iraqi aggression and free Kuwait during Desert Storm. Under the leadership of DARPA Program Manager Commander Dennis McBride,[15] a number of the researchers and developers working on SIMNET assembled and considered options. The emerging idea was to create a *simulation center on wheels* that could be deployed into a combat zone and provide a commander with a perspective visualization of the battlefield, the same sort of visualization that had been developed as the "flying carpet" (aka, the stealth visualization system) for SIMNET. The data for the visualization would come from classified intelligence databases, for example the current position of U.S./Coalition forces, projected over the terrain database for the area.

In addition to visualizing the current conditions, "what if" simulation models would be developed and fielded that would allow a commander to see what a proposed action might look like, and to see what an enemy might do to counter it. The ability to fly around the battlefield and quickly gain insight into maneuver, for example to see what your own maneuver might look like from the perspective of the enemy commander's position, was considered revolutionary using this kind of technology.

Further, the notion that once a battle occurred it could be rapidly documented and broadcast throughout the battlefield to other commanders equipped with similar capabilities was one of the early, if not earliest, instantiations of this idea.



The ODIN system was developed and installed in a half-sized ISO shipping container mounted on a military truck with power supplied by a towed generator. It was self-contained. A commander sat at a workstation facing several large screen monitors and flying carpet controls. Four or five of his subordinate commanders could stand/sit behind him (tightly packed) as he explored options and discussed his intent.

The ODIN truck was not deployed to Desert Storm: the capability was powerful, but there was too little time to integrate the system into a command structure that was already fully consumed with its current systems. The idea of a mobile simulation and planning center on wheels was well received, however, and the ODIN truck traveled around the U.S. from post to post illustrating the concept. It also made it to the IITSEC exhibit floor.

73 Easting - 1991-1992

During the immediate days after the Gulf War, the battles fought by U.S. armor and cavalry units started to be reported. In a meeting with the Vice Chief of Staff of the Army, General Gordon Sullivan,[16] the idea originated that it might be possible to portray these battles using a sort of "reverse-simulation" methodology, i.e., recon-

[15] Commander Dennis McBride, Ph.D. (now Captain, USN retired) chose the name ODIN from the Norse God of War who carries two ravens that fly over the kingdom to gather intelligence

[16] General Sullivan had an earlier assignment as Deputy Commander of the Armor Center and was familiar with SIMNET. General Paul Gorman, USA (ret) also attended this meeting.

struct a battle as if it had been fought in simulators, where each simulator (real combat vehicle) reported its activities over a network using the correct protocol data units which would be logged as if it were a live SIMNET exercise, blue against red. Once constructed, the data logged file could be played back in the SIMNET playback environment using the flying carpet (stealth visualization) to study the battle from all angles.

The Vice Chief agreed with this idea, and arranged with the VII Corps Commander in Iraq, Lieutenant General Fred Franks, to select the candidate battle. Dr. Vic Reis, the Director of DARPA, approved the project that afternoon.

Within a number of days a data collection team led by Colonel Bloedorn was in Iraq meeting with the soldiers who had fought the battle now known as "73 Easting" (named for the battle's map grid coordinates). They interviewed a substantial number of the key combatants, toured the battlefield, recorded forensic evidence (e.g., TOW wires from U.S. firing positions to destroyed Iraqi tanks), collected the Army engineers database on each destroyed enemy vehicle including exact location, orientation, and likely means of destruction, and obtained a copy of an audio tape made by a soldier in a command vehicle that had all the command frequencies audible.

The commander of the unit was Captain H.R. McMaster, now Brigadier General H.R. McMaster.

Returning with this data, the process of reconstruction began. First, the technical staff at BBN[17] had to create a new set of tools that allowed protocol data units to be created manually and semi-manually, given that there were no simulators automatically creating this data. In parallel the technical staff at Perceptronics[18] began to disambiguate the hundreds of data elements collected in the field. As the movement and activities of a specific vehicle became clear, this information would be converted into second-by-second protocol data units for that period of time and placed in the data stream (what would normally be time-stamped and recorded by a data logger in a conventional networked simulation exercise). This was painstaking work, as each activity had to be entered at this granular level.

After six months, the reconstruction team met with the soldiers that fought 73 Easting, now back at their home station in Germany. They met at the SIMNET facility at Grafenwoehr, and used the playback system to show the soldiers the draft state of the reconstruction. As expected, the literalness of the visualization enabled a thorough critique of the accuracy of the data, and the reconstruction team collected dozens of corrections as well as substantial new information that has not been previously provided (forgotten or overlooked months earlier on the battlefield).

Unexpected, though, was the reaction of the soldiers from each unit to the activities of soldiers from the adjacent units. They were unaware of the firefights these adjacent units had been engaged in and the high level of intensity of those battles.[19] The reconstruction illuminated these activities for the first time.

The reconstruction team returned to the U.S. and continued refining and completing the data stream. After another six months (the one year mark), the key leaders of 73 Easting were brought to Washington DC to meet again with the reconstruction team. They met at the IDA Simulation Center[20] and reviewed the 30-minute main battle, and 3-hour counter attack and follow-on operation, using the SIMNET playback system in the IDA lab. At the beginning of this session there were a few dozen unresolved events or activities. As at Grafenwoehr, the vividness of the visualization and the ability to examine the battle from any visual aspect allowed the resolution of all but a handful of conflicts by day's end.

73 Easting demonstrated a new method of capturing and replaying actual battles. It took a

[17] Under the leadership of Dr. Duncan Miller

[18] Under the leadership of Dr. Bob Jacobs with the assistance of Jim McDonough

[19] The battle was fought in a blinding dust storm on a stormy, dark afternoon.

[20] Institute for Defense Analyses, Alexandria, Virginia. The Simulation Center was created and managed by Colonel Neale Cosby (USA, retired) and became a hotbed of research projects and demonstrations.

year. It prototyped a new, interactive, dynamic means of documenting history, and was the initial existence proof of the application of "capturing live combat" that has been championed by Colonel Neale Cosby.

10 Years Later: Reconstruction of the OEF Mazar-E-Sharif Operation - 2002-2003

73 Easting was an all armor battle fought on a small piece of homogeneous desert terrain with no air support or overhead imagery due to bad weather. The most intense portion lasted about 30 minutes, with minor counter attacks occurring during the following 3 hours. It was reconstructed using a single simulation environment, and took one year.

Ten years later DARPA[21] and IDA, stimulated by Colonel Cosby, undertook the second attempt of the reconstruction of a military operation in simulation: The defeat of the Taliban at Mazar-E Sharif, Afghanistan, during Operation Enduring Freedom.

This reconstruction was wholly more complicated and is described in a 2003 IITSEC paper by Richbourg, Lukes, and Page.[22] As examples, the operation lasted 25 days. It included a spectrum of operational systems from "…18th century close combat tactics [horse cavalry] with 21st century communications, synchronization, and precision munitions…" managed by U.S. special operation forces on the ground. No single simulation environment could account for all the activities and interactions, so a federation of simulations and models was assembled for this purpose. Further, attention was given to free play (what if) analyses that deviated from the reconstructed historical record.

There are a couple takeaways from this effort. First, it was 10 years between the first reconstruction and the second, and both were sponsored by DARPA. No one from the Services' history, operations research, or studies and analysis communities had picked up the methodology after 73 Easting to reconstruct additional operations. Second, the ability to federate several models, simulations, and visualization techniques has made tremendous progress, and has proven it is a feasible approach to reconstruction.

The next step: We must begin to routinely reconstruct our significant operations if we are to learn from successes and failures. There needs to be an encyclopedia of all major battles and operations in this living interactive history form.

FAADS Evaluation at Ft Knox - 1988

The SIMNET-D facility at Fort Knox was constructed adjacent to the larger SIMNET-T[23] building. The D facility had the same networking support and simulator infrastructure as the T building. Simulators in the D building could be connected to simulators in the T building (and therefore to simulators throughout the wide area simulator network) for experiment purposes.

The simulators that were designed and installed in the D building were called "stretch" simulators since they had been cut apart, expanded in the middle, and equipped with racks and other hardware support for installing test gear, such as computer workstations.[24] Their modular construction enabled rapid reconfiguration into variants of different real and proposed vehicles.

One of these vehicles was the Forward Area Air Defense System (FAADS), a system in development by the Army. DARPA was asked if a platoon of FAADS vehicle simulators could be constructed in SIMNET-D and integrated with a battalion task force of tank and fighting

[21] Ward Page was the DARPA Program Manager for this project

[22] "Learning from the First Victories of the 21st Century: Federatng Simulations for Reconstruction and Exploration." Robert Richbourg, George Lukes, & Ward Page. IITSEC 2003

[23] T for Training. This was the first SIMNET facility, and was located at Ft Knox. The SIMNET-D building (for Development) came shortly after.

[24] A number of innovative studies using SIMNET-D facilities were conducted by the Army Research Institute detachment at Fort Knox under the direction of Dr. Barbara Black.

vehicle simulators in SIMNET-T to test operational concepts given different possible configurations of the FAADS vehicle still being evaluated from a cost/ effectiveness point of view.

Major General Ben Harrison (USA retired), a key figure in Army Aviation and the leader of the Fort Rucker SIMNET integration (scout & attack helicopter simulators called AirNet), organized and led the SIMNET-FAADS exercise.

Five FAADS simulators were constructed, the fifth being the platoon commander's vehicle. The prime FAADS contractor provided the SIMNET team with the technical details of the current version of the prototype system: the chassis (based on the Bradley Fighting Vehicle), the sensors, and the missiles/guns. The data included the gunner and commander stations, and all appropriate system behaviors (e.g., procedures to acquire a target and launch a missile).

The five simulators were constructed out of the driver's compartment of Bradley simulators (complete with vision blocks). Computer work-stations with touch sensitive screens were mounted "in the back" simulating the gunner and commander stations. The layout of switches and sensor displays matched the prime contractor's specifications. Operators could activate the switches by moving a finger across the screen and "throwing" a switch: the switch would change position on the screen as if a real switch, and the proper resulting system function would occur.

A section of soldiers from the Air Defense School, en route to a field test of the prototype system at Fort Hunter Liggett, detoured to Fort Knox to practice their CONOPS in the simulators. A weeklong exercise was arranged with a BLUE battalion task force of tanks, fighting vehicles, and FAADS vehicles, opposing a RED OPFOR[25] of scout/attack helicopters, close air support fighters, and Soviet armor vehicles.

The initial session of the air defense soldiers with the FAADS simulators did not go well. The soldiers pointed out that the simulators were deficient in several important characteristics and were unusable. Upon close inspection, it was found that the simulators accurately replicated the latest version of the FAADS prototype system about to be field tested, but the soldiers had not yet received that update and had been practicing on an earlier, and now out-of-date, version. The simulators were then used for quick updating and practice.

When the force-on-force exercise commenced, another problem arose. The battalion task force commander, a Lieutenant Colonel from the Armor Center, assembled his key commanders, including the FAADS air defense platoon commander, to describe his plan of maneuver: He intended to take advantage of the superior speed and maneuverability of the M1 tank and the Bradley Fighting Vehicle in attacking his target, a ground force of T-72 Soviet tanks and personnel carriers. The FAADS platoon commander interjected, however, that because his platoon moved in pairs in bounding overwatch (leap frogging), with one pair in a fixed position providing cover to the task force while the second pair moved forward to their next fixed position, the task force would have to move much slower than the commander intended, perhaps twice as slow. This was new, disturbing information. Although the Armor Center had administratively coordinated on the specification for the FAADS, as did the other branches, the realization that the maneuver speed of an armor task force would be significantly compromised when a FAADS platoon was attached had been missed (certainly by some, anyway).

The weeklong exercise finally commenced, inclu-ding a modified maneuver plan, and in the opening encounter the BLUE maneuver force was aggressively attacked by RED fixed and rotary wing air. By the end of Day 1 the BLUE FAADS platoons successfully defended the task force and shot down a number of RED aircraft.

That evening, however, the RED force pilots met separately and modified their tactics, creating innovative means to defeat the FAADS. The next day these tactics prevailed, and several of the FAADS vehicles were destroyed as were several of the BLUE task force tanks and fighting vehicles.

Not to be outdone, the BLUE task force crews modified their maneuver and FAADS employment tactics that night, and the next day they had the upper hand. This continued throughout the week, until a state of equilibrium occurred. The FAADS crews left the exercise and Fort Knox with a portfolio of new tactics and CONOPS.

25 OPFOR: opposing force

We have seen this interplay between opponents many times, stimulated by force-on-force contests where competition is the engine that motivates innovation. This happened again in the ADATS experiments, below.

ADATS Evaluation at Ft Rucker II: Counter Target Acquisition System (CTAS) - 1990[26]

ADATS (FAADS was now called the Air Defense Anti-Tank System) faced another challenge. The vehicle's weapon system possibly required more minimum range in order to target and prosecute airborne rotary wing threats. A clever aircrew could sneak inside the weapon's employment range and have a close-in "sanctuary."

In order to counter this problem, DARPA (Dr. L.N. Durvasula) proposed that one of its laser projects might be used to augment ADATS so it would have a full range of tactical options, rendering any range to a target's optical systems a lethal one. This implied a counter to the assaulting platform's target acquisition capability (thus, the project was called Counter Target Acquisition System—CTAS).

The challenge was that each proposed DARPA laser prototype was different in ways that made it practically impossible to determine which one best suited the mission of ADATS: specifically, the weapons varied significantly in terms of laser energy output and in the environments in which it would be deployed (energy dissipation in variably dusty or moist low atmospheres, for example). This set of unknowns, coupled with the expected tactical resourcefulness of the threat aircrews to adapt, rendered the potential options experientially unbounded for the Army and for DARPA.

In order to shrink the problem to a couple of candidates, DARPA and the (U.S. and U.K.) Army conducted a series of trials at the AirNet facility at Ft. Rucker. Five CTAS prototypes were evaluated along the dimensions of concern: penetration through atmospheric obscuration, power at range, inter-employment time elapse, and other factors. The prototypes were rendered as virtual representations relative to the DARPA objective systems in terms of engineering fidelity for simulation runs. The initial tactics were derived by experienced Army officers for the ADATS platform and for the opposing air assault helicopter mission.

In brief, the ADATS mission was to secure a specific bridge against an assault spearheaded by enemy rotary wing aircraft. ADATS was deployed as a two-vehicle CTAS-enabled force; the assaulting aircraft were also represented as a two-vehicle package. All of the key vehicles were manned, though the battlespace was augmented with active SAF (semi-automated forces) in order to provide greater tactical realism.

As might be expected, with introduction of each "novel" CTAS prototype in each of the conditions described above, the new system and its envisioned tactics dominated the rotary wing threat. However, and this was the thematic key to the experiments at Ft Rucker, as the assault tactics were adapted, domination shifted from defense (ADATS) to offense (aircrews). The assault aircrews adjusted ingress altitudes, velocities, formations, etc., and as a result, changed the polarity of the outcomes.

As impressive, the equally sentient CTAS-ADATS crews subsequently adjusted defensive portfolios as well. This mutually-adaptive "tournament" of competition between the specifiable weapons physics of CTAS and its threat, and between highly adaptive employment tactics sets, generated a set of warfighting outcomes that were in no way predictable, though after-the-fact, they were very understandable. What began as a set of five laser candidates, ended as a set of two or one (depending on assumptions), with battle "scars."

The Army now had the ability to make a weapon decision for ADATS based on employment outcomes derived from a tactically realistic, virtually simulated battlefield. In other words, if the CTAS candidates were to operate on the battlefield—and thus on the simulated battlefield—as described by the engineers who championed them, the range and likely success of tactics optimized for and against the candidates became known through experience to the point that practically no one argued from a rational point of view in the face of experience.

[26] Captain Dennis McBride (USN) organized and led this project as a DARPA Program Manager with assistance from RADM Lee Kollmorgen (USN retired); This section includes his words and descriptions which I have paraphrased in places.

Thus, as Army leadership moved forward at the time with ADATS, it did so having taken the weapon candidates (their words) "to war."

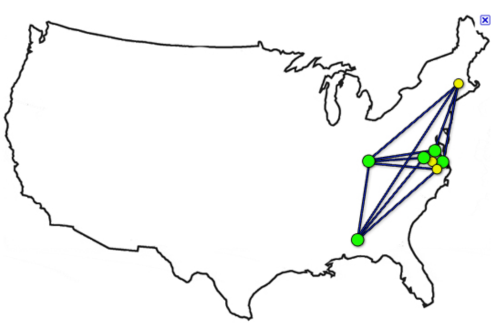
The most compelling outcome derived from this set of DARPA/Army trials was even greater than the usefulness of the laser candidates themselves. Once again we see the power of tactical agility on both sides as unforeseen until and unless combat was actually (well, in simulation at least) carried to its end points.

Battle Force In Port Training (BFIT) Proof Of Principle Demonstration, HyDy, ModSAF/BBS Integration, & BFFT[27]– 1990

Beginning in the mid-1980s the Navy connected ships in port to pier side simulators and stimulators for training. The program was called BFIT, Battle Force In Port Training. In April 1990, a proof of principle engineering demonstration was conducted to see how far the training environment could be expanded by connecting the ships to other components of a nationwide simulation network.

Figure 9 - USS Wasp in simulation and in the real world

The approach of the BFIT Proof Of Principle Demonstration was to connect old and new equipment and other assets from Navy, Marine, and Army units. The engineering task: demonstrate connectivity among things that were not designed to be connected.



Included on the network:

- Naval gunnery training system in Norfolk, VA
- USS Wasp (LHD-1) amphibious assault ship floating in the water but tied up pier side in Norfolk, VA
- Marine helicopter pilots in simulators flying from the Army Aviation Center, Ft Rucker, AL
- Marine and Army armor crews in M1 tank and M-2/3 Bradley Fighting Vehicle simulators at the SIMNET site, Ft Knox, KY
- Aegis Training Center, Dahlgren, VA
- Fleet Combat Training Center, Dam Neck, VA
- BBN, Cambridge, MA
- Stealth Observer, Institute for Defense Analyses, Alexandria, VA

The exercise was "projected" onto the terrain database of Fort Hunter Liggett on the Central California Coast and 100 miles out to sea, and was conducted over several days.

A number of innovations were demonstrated. As an example, Marines in tank simulators at Fort Knox or in helicopter simulators at Fort Rucker could designate a target and call for fire from Naval gunnery systems simulated to be offshore. The results of the incoming rounds could be

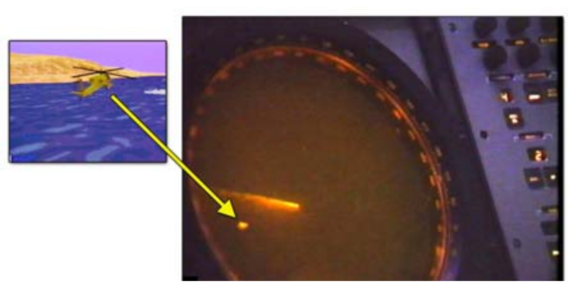


Figure 10 – An Apache helicopter (simulator at Ft Rucker) off the coast of California appears on the air surveillance radar of the USS Wasp

[27] Created and managed by Captain Dennis McBride (USN, retired) while at DARPA. Admiral Kollmorgen played a substantial role here, too.

observed by all in visual range.

Another example was the integration of shipboard air defense radar, whereas a helicopter (simulator at Fort Rucker) clearing the coastal mountains of Hunter Liggett and heading out to sea could be picked up on the radar scopes of the USS Wasp simulated to be 50 miles off the California coast but physically pier side in Norfolk VA.

As an important derivative of the BFIT experiments, DARPA and the Navy conducted a demanding series of demonstrations aimed at pushing the envelope of SIMNET-based representation of **h**igh**ly** **dy**namically maneuvering vehicles that are characteristic of actual tactical air environments. The demonstrations were termed Project HyDy.

The following high maneuverability platforms were connected simultaneously and seamlessly using SIMNET protocols:

- Simulated tactical platforms, including a pod-modified F-18 Strike Fighter at NAS LeMoore;
- Similarly configured fighters in the Point Mugu Southern California aircraft tracking range;
- The Systems Integration Test System at Mugu;
- SAF representations at the Naval Ocean Systems Center located at Point Loma, San Diego; and
- Manned Flight Simulator platforms physically located at the Naval Air Test Center, Patuxent River, Maryland.

The real time interconnection of these different platforms worked. Each platform conveyed the tactical specifics of each entity in the scenario, regardless of the platform's physical location in and beyond CONUS, and regardless of the tactical dynamics of the highly accelerated maneuvers of the fighters in any of the virtual environments. Tactical engagements were fully supported by the bandwidth and anticipated latencies of the simulation and communication network.

Another demonstration conducted by DARPA at the Naval Ocean Systems Center was the linkage between **ModSAF** and the Army's **BBS** (Brigade/Battalion Battle Simulation), the latter a constructive wargaming system designed as an aggregated model: units are plotted but not their individual vehicles. The demonstration showed that one could move a virtual "magnifying glass" over a representation of the aggregated (e.g., battalion) simulation of BBS, and observe the space in its ModSAF, disaggregated mode (squad level entities). The glass could be moved to practically any sector of the BBS simulation in near real time.

The Navy interests in determining the robustness of the SIMNET protocol network architecture were complete. Virtual, live, and constructive simulation elements were demonstrated to be inter-connectable in realistic mixtures of platform simulation types and complexity, and in highly robust networking contexts (local area, long haul, range-enabled, and so forth).

The success of the BFIT engineering demonstration helped launch the Battle Force Tactical Training (BFTT) system that has transitioned into the Navy Virtual At Sea Training program now in use by the U.S. Navy worldwide.

SAF & Behavioral Modeling

Semi-automated forces (SAF) were developed early in the SIMNET program to increase the number of entities on the SIMNET battlefield. Manned simulators were being added as they came off the fabrication line, but not nearly fast enough for operators. They wanted to engage larger and larger massed opponent forces.

As noted earlier, SIMNET was envisioned as a technology that allowed large numbers of humans to meet force-on-force and to compete driven by human intelligence and motivation. We did not believe that computer-implemented algorithms could mimic the internal workings of the brain, so the goal was to provide a playing field that connected humans and allowed them to do whatever they wanted to do, to include clumsy as well as inspired acts.

This did not solve the expressed need for larger forces, though, so work began on a means to create and control virtual vehicles (initially OPFOR tanks and personnel carriers) in SIMNET. The approach was that these unmanned vehicles were basically dumb, and therefore needed human supervisory controllers, i.e., commanders that would direct their activities. Therefore the term semi-automated.

I am not an expert on this technology, and a proper treatment would require a separate paper in itself, so I refer the reader to the IITSEC archives and other sources for a rich discussion of the progress in developing increasingly "intell-igent" entities, and allowing computers to increase their span of control over these.

However, this is what I have taken away from this work.

1) Several programs have been growing the capability of semi- and fully-automated forces since the 1980s, including SAF, ModSAF, OneSAF, JSAF, and others. Work is also reported under the technical heading of "computer generated forces" with annual technical meetings. Some efforts are purely computational, and some are deeply rooted in the cognitive sciences[28] (Also, see Mike Van Lent's & Dennis McBride's comments in the Appendix).

2) SAF (and its variants) have had to solve difficult problems. For example, in a manned simulator the synthetic environment is created and rendered, and the human determines line of sight by looking through vision devices and sees what he can see. In an automated entity, this function has to be calculated using line of sight algorithms in order to return the value of an object (could it be seen or not). Also, in a simulator (as in a real vehicle) a human operator can inspect a map and look at the terrain in selecting a route, while in SAF a series of algorithms have to be designed to do automated route planning. Further, expressing commands like a commander has required the development of a command language for computers that allow calculation of actions based upon concepts like "intent," easy for humans but tough for computers.

   The good news is that this work not only applies to SAF behaviors in MS&G, but also has application in many other disciplines, like the development of command and control systems where the employment of auto-mation is attempted. So the MS&G community has addressed and solved problems that others are just beginning to deal with.

3) Perhaps the most striking developments in SAF have come in the areas of scaling. While the initial focus was on opponent vehicles (relatively small numbers (100s) of tanks and personnel carriers, then aircraft, then dis-mounted troops), applications today require SAF to portray other types of entities: other types of vehicles, sensors, and individuals (friendly, enemy, and neutral) including cultural attributes, in large enough numbers to represent the typical "clutter" that is found in all military operations. Work reported by Davis and Lucas[29] at USC-ISI shows the progress in this area as a function of total entities that can be generated (Figure 11). The mix is diverse: some of the entities are highly realistic and responsive, and others are much less so, the idea of selective fidelity applied to entity generation. Of significant interest, this progress in scaling has been achieved with the use of DoD-owned super computers[30].

Exercise/Test	Date	# Entities
JSAF/SPP (Joshua)	2008	10,000,000
JSAF/SPP (Capability)	2006	1,400,000
JSAF/SPP (Test)	2004	1,000,000
JSAF/SPP (Urban Resolve)	2004	250,000
AO-00	2000	50,000
J9901	1999	12,000
SAF Express	1997	107,000
UE 98-1	1997	3,600

Figure 11 – Growth In Entity Generation

As systems become more instrumented, and as we become more adept at 'capturing live combat,' we can expect the sophistication and scaling of behaviorally representative entities to grow.

[28] See the SOAR site at the University of Michigan (http://sitemaker.umich.edu/soar/home) as well as SoarTech (http://www.soartech.com/)

[29] See http://www.isi.edu/~ddavis/JESPP/JESPP_Papers.html

[30] Sponsored by the J9 (Experimentation) directorate of the Joint Forces Command

Presentation to the Senate Arms Service Committee[31] – 1992

As part of testimony presented by Dr. Vic Reis, Director of Defense Research and Engineering (DDR&E) to the Senate Armed Services Committee on "The Use of Modern Simulation Technology in the Department of Defense," the IDA Simulation Center[32] coordinated the installation of a number of simulators in the main conference room of the Dirksen Office Building on 21 May 1992.

Two large, multi-screen simulators were positioned at the back of the conference room, an F-16 Falcon fighter and an AH-64 Apache attack helicopter. Two "desktop" simulators were also at the back of the room, one representing the F/A 18 Hornet and another the Pioneer Unmanned Aerial Vehicle. The fifth simulator was a mockup of the prototype NLOS (non-line of sight) vehicle being evaluated by the Army. This simulator was build out of components from the SIMNET-D laboratory.

These simulators were networked from Capitol Hill across the Potomac to IDA, and to Vienna, Virginia (a second Pioneer UAV simulator), to Fort Knox (M1 tank and M2/3 Bradley Fighting Vehicle simulators), and to Fort Rucker (scout/ attack helicopter simulators). The terrain database was Fort Hunter Liggett.

Figure 12 – CWO Robinson pilots an Apache helicopter simulator from the Dirksen Office Building

[31] The Presentation was hosted by Senator Sam Nunn, and coordinated by his assistant Dr. John Hamre. It was Dr. Hamre's idea to demonstrate simulator networking live in the Senate quarters.

The presentation included a briefing of the Battle of 73 Easting by Captain H.R. McMaster, an attack of an enemy armor column using all the platforms being simulated, and testimony by Dr. Reis and General Paul Gorman.

From General Gorman's remarks:

"These machines [simulators and computers in the conference room] function to enable human beings to understand the complexity, kinetics, and chaos of modern combat….[These machines are] a catalyst for human comprehension…..We are going to use this machinery in various ways this morning to illustrate the verity that it is men, not ships, not aircraft, not vehicles, who fight and who win wars.

Figure 13 – General Gorman addressing the Senate Arms Services Committee

If the Congress and the Armed Services are to address the future cogently, we must all rid ourselves of the notion that simulators are a cheap but not wholly satisfactory substitute for flying, steaming, or driving. And I am here to urge that we must all recognize that simulation is fundamental to readiness for war. We cannot today bring about combat readiness without some recourse to simulation.

I also want to make the point with my cathartic that we are late come to wisdom in the Armed Services. We really did not understand combat well enough to be able to know how to affect the behaviors that would enable us to fight well successfully until the very recent past, as a matter of fact, in the aftermath of the war in Southeast Asia."

[32] Under the leadership of Colonel Neale Cosby

From Dr. Reis' remarks:

"The key to acquiring that technology [to win future battles] as well as training the type of forces we need lies in the distributed, networking simulation that we have discussed and demonstrated today.

And the reason for this is simple but profound. Networked simulation is a technology that elevates and strengthens the collective problem solving abilities of human beings, people acting as teams learning and getting better. And this is true whether they are design teams, manufacturing teams, education teams, training teams, acquisition teams, or warfighting teams.

Network simulation, with modern information technology, can connect people together in an aligned, coherent, integrated enterprise. It is at the very heart of the Department's technology strategy."

The overall presentation and testimony was executed without technical problem, and the networks, simulators, and crews performed expertly. This was probably the most ambitious live presentation every attempted within U.S. Senate chambers.

SECTION II CONVERGENCE OF NETWORKING, INSTRUMENTATION, AND COMMAND & CONTROL

When looking back to the mid-1980s and early 1990s, one can argue that much of the progress described in the preceding section, and the foundation that will allow us to launch new technical developments and create new capabilities and CONOPS in the future, is the convergence of three thrusts: Networking, Instrumentation, and Command & Control.[33] This section gives examples of that convergence as preparation for discussing Future Opportunities in the next section.

[33] I recognize that other thrusts could be pulled into the argument here, as well as different ways to describe and combine them. I am less committed to the absoluteness of this particular selection of thrusts, but rather the notion that technical areas are converging and this provides us with the potential for new breakthroughs and future opportunities.

Figure 15 shows many of these interactions and byproducts. Many of the connecting lines can be thought of as double-headed arrows. As an example, network simulations and AAR techniques fed the reconstruction of 73 Easting which produced tools for creating virtual staff rides, a form of serious games, which can be a visualization technique in strategic collaboration which can enrich the next reconstruction of a real operation, and so forth. Connecting all the possible interactions could look like plate of spaghetti.

Networking

Computer networking can be traced to the ARPAnet experiments in the early 1970s. There are several comprehensive descriptions of these experiments, and a good starting point is Wikipedia, which references several.

Email became the predominant traffic on the early network, with packet switching proving a robust technical approach. Over time the ARPAnet transformed itself into the Internet, the story of which is also documented in a number of places.

SIMNET was the initial example of large-scale distributed simulation, and went online in the mid-1980s. In a way it was an Internet for simulators. By the late 1980s a wide variety of components had been added to the SIMNET network, including a warship (USS Wasp), live tactical command and control communication systems, algorithms of battle, and dozens of other components.

Gamers interested in the potential of networked gaming carefully watched this development but were hampered by the lack of computational power of home computers and their anemic graphics subsystems. The slowness and cost of available long haul networks was also an impediment. In the late 1990s that changed, and the first of the massively populated online role-playing games hit the streets. The history of this has been described in many places, too. Observers were amazed that hundreds of thousands of individuals would pay monthly subscription fees to be online, and that a large proportion of subscribers would be logged in at any time of the day or night. Some players spent (and spend) more time online each week than they did at their jobs.

Beginning in the mid-2000s, a few game developers migrated from an entertainment-only focus to a "serious games" focus, games that were intended to address serious societal problems such as first response during emergencies or resource allocation for clean up of the environment.

What is important to note about these networked environments is (1) that they connected a very large number of users in real time, (2) that their "up time" was very high and near perfect for some systems, (3) that they successfully exchanged large quantities of multi-media data, and (4) that the cost per user was very low (some subscription rates were less than $15/month). These are all desirable attributes of a military command and control system.

Instrumentation

We are currently experiencing an explosion in

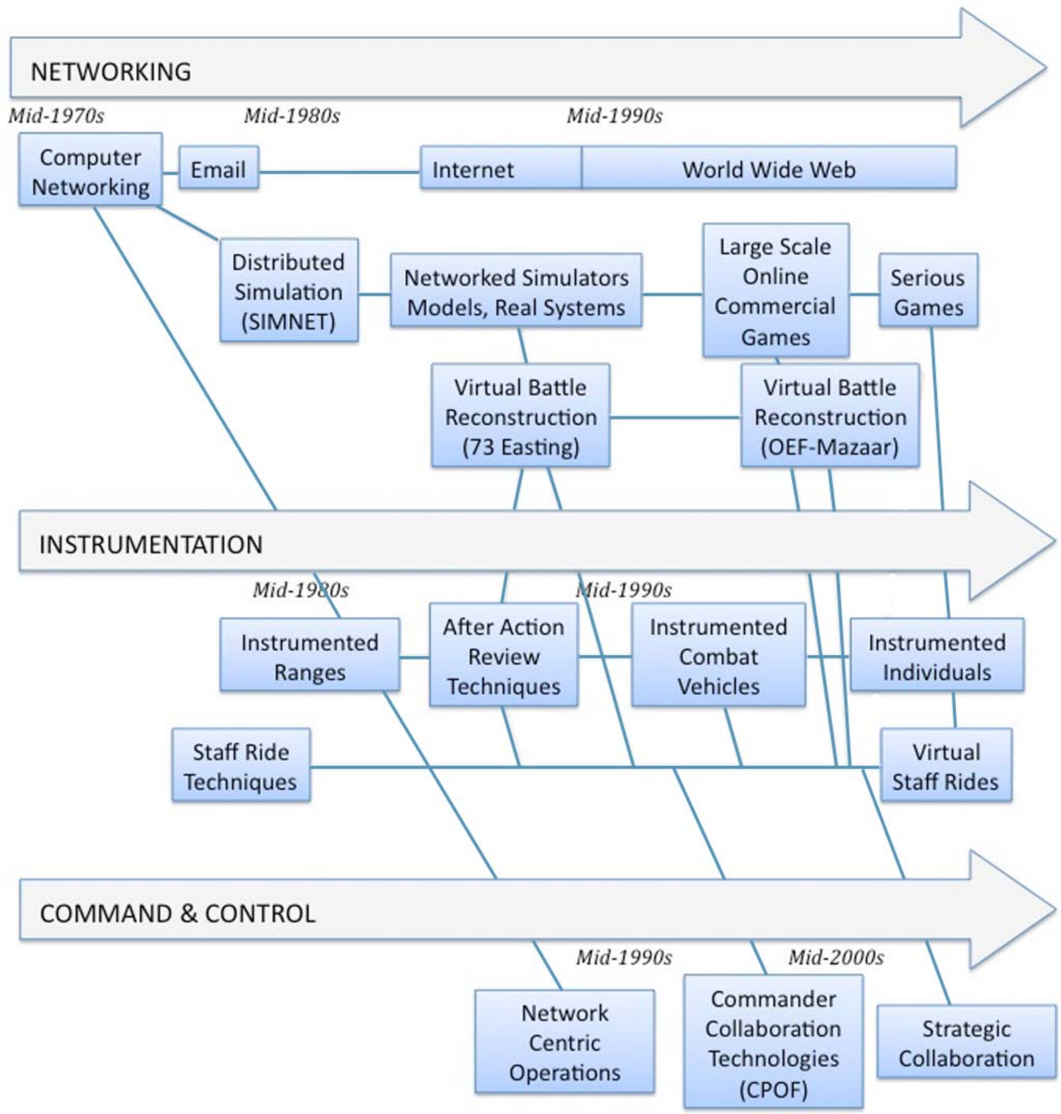


Figure 14 – A partial "influence" diagram. Most of the lines could be double arrows. Only a small number of the many examples are shown.

instrumentation, from the microelectronic sensors that are increasingly embedded by the hundreds in complex systems to the overall instrumentation architecture that allows data to be analyzed, reported, and acted upon. Professor Richard Murray[34] of Cal Tech classifies generations of systems (such as aircraft) by their level of onboard instrumentation as well as the power of new onboard computers dedicated to analyzing the instrumentation data (own system as well as external environment) and predicting performance in new situations. This new generation of instrumentation will revolutionize the performance of current systems and provide unprecedented design information for the next generation of systems.

In the early 1980s the military Services began to create instrumented ranges such as the National Training Center (Fort Irwin, California), and the air combat maneuvering ranges (Nellis AFB, Nevada and Miramar NAS, California).

The ground ranges use eye-safe lasers to score ground weapons effects. The air ranges use on-aircraft transponder-like instrumentation to calculate air-to-air weapons effects: given positions and firing commands, computers on the ground calculate weapons fly out and kill zones and determine what damage, if any, a given weapon has inflicted.

The value of this type of instrumentation is well known: It produces objective data on individual, crew, and team performance that is superior to the previous method of self-reporting (with inflation of one's own performance an occasional problem).

Along with this came new techniques for structured, objective after action reviews (AARs), critiques of performance aimed at improvement rather than censure.

A typical observation from a visitor to the NTC: "The debrief began with the visiting unit's commander and subordinates in the main conference room. An NTC Observer-Controller took the stage and simply showed five overlays: 'Here are all of the RED air defense locations; here are the ones you found; here are the ones not found; here are the ones you suppressed; and here are the ones that shot down [x] % of your air assets.' Before the OC could sit down, the commander had turned in his seat and said, 'OK, that is not satisfactory. How can we make that picture better? What can we do to fix that? Any ideas?' And the remainder of the session was a constructive discussion among the commander and his team about remedies. The availability of objective data moved the discussion from "No one could have shot us down! That data is wrong!" to "How do we improve as a team and solve this problem?""

Perhaps most importantly, capturing and analyzing objective data contributes to the professionalism of a community. *It is key for achieving operational excellence.* So it was not surprising that in the late 1980s we began to see the kinds of instrumentation initially embedded in the training ranges migrating into actual combat vehicles deployed to combat theaters. Now we are seeing this kind of technology being used to instrument individual combatants, the precursor to a fully instrumented future combatant.

In addition to instrumenting entities (vehicles and humans), we began to see the instrumenting of information and communications as with DARPA's Command Post of the Future (CPOF) program (early 2000s), below.

Command and Control

The Command and Control community, including all its offspring (e.g., C3, C4, C4I, C4ISR, and so on), began to experiment with the concept of "network centric operations" described in papers first published in the Navy in the mid-1990s. The notion was that networking infrastructures allowed an organization to flatten its hierarchy between a source of information (like a sensor) and the end user that needed that information in order to execute a task (like a shooter). It was argued that if networking improved information sharing which improved shared situational awareness, then several benefits might accrue, such as a new level of collaboration and the emergent forms of self-synchronization, problem solving, and decision-making.

As this concept was being discussed and debated within the Pentagon, DARPA launched a new program called Command Post of the Future (CPOF). Its initial technical focus was the use of smart agent technology for command decision-making. Over time, through a process that became

[34] Personal Communication

known as the Double Helix,[35] CPOF morphed into a concept that today can be characterized as streaming media versus static presentation in the understanding of battlefield events.

The static approach, from the period of Napoleon and earlier, portrayed the battlefield as a map with rectangles indicating the location of friendly and enemy forces, and various lines that indicated the separation between the two. The map was static and in error: units do not spread out on the terrain in formations of rectangles, and since the information about these positions was collected hours before the map was made, the intervening movement of the units was not shown. Experienced commanders took this into consideration when looking at a "map that was lying to me."

CPOF, instead, looked at the battlefield as dynamic, and with the real time networks of subordinates and staffs feeding the overall system at the same time, participants viewed the situation from a streaming point of view. This is not particularly easy given years of PowerPoint training, a static presentation application, but *streaming* most accurately describes how the battlefield actually behaves.

One of the key innovations in CPOF was the ability to virtually look over another person's shoulder to see what they were *thinking* even though you might be quite a distance apart. Given common training, common concepts, and common graphics representation, it is possible for one military person to look at the graphics of another and get a good idea of what was being worked on without having to engage in a conversation.

If a conversation with real time information sharing and deliberation was called for, then sharing graphics and other data in real time using shared whiteboards and other formats was enabled by this technology.

To create this level of interaction, CPOF communicated the sketching and gesturing actions of each person to others who wished to interact. This constant stream of data is a substantial part of the command and control system, particularly when augmented with digitized voice[36] and all the other data that is on the network. In the same way that data loggers capture all the network traffic of a distributed simulation, enabling precise playback and reconstruction of a simulation session, the "data logging" of the network traffic on a streaming command and control system like CPOF enables precise capture, playback, and reconstruction of that aspect of the operation.

The success of the DARPA research version of CPOF has resulted in a renewed interest in the core nature of *collaboration* with the nucleus of a community being formed around the topic of *strategic collaboration*. Its focus is on solving extremely difficult problems called "wicked problems"[37] that are part of every large, complex operational environment to include humanitarian assistance and disaster relief.

Examples of Other Convergences

After action review techniques merged with SIMNET networking technology in 1991 to enable the reconstruction of the battle of 73 Easting. Ten years later the same was accomplished with the reconstruction of the Operation Enduring Freedom defeat of the Taliban around Mazar-E-Sharif, Afghanistan. Whereas 73 Easting was homogeneous (armor vehicles) and short (30 minutes of intense battle), the OEF operation was multi-dimensional and 25 days long using a federation of several simulations and models.

Another merger was the morphing of the traditional staff ride (visit a historical battleground, walk the terrain, read accounts of the action) into the virtual staff ride using simulation and gaming techniques to reconstruct the terrain walk. The virtual visitor can achieve terrain appreciation via the powerful ability to inspect the terrain from any aspect using flying

[35] The Double Helix is a research and development process that co-evolves new technology with new technology enabled concepts of operation (CONOPS). It requires intense, regular interactions between technically savvy operators and technologists that are willing to learn about and internalize operational concepts.

[36] For example via VoIP: Voice over Internet Protocol

[37] There are a number of good overviews of this area. A six part post on wicked problems in software design/application can be found at http://www.cleverworkarounds.com under the posts "Wicked Problems and Project Management"

carpet techniques. But in addition, the virtual visitor can have the battle come to life via reconstruction of the events as in 73 Easting and Mazar-E-Sharif and immersion into these events.

An early hint of the convergence of networked MS&G with command and control occurred with the public subscription game called Kuma War[38] in the early 2000s. The game company periodically (sometimes as frequently as once a week) took newsworthy operations from the Iraqi theater, collected information about the events, constructed the simulation environment (terrain, weather, feature data, and models of the involved military equipment and personnel), occasionally talked first-hand with soldiers that had participated in the actual operation, and packaged this into an episode sent out to its subscribers who would play it using the Kuma game engine. This was a public activity, and it was reported that teenagers in Baghdad were seen playing an episode in an Internet café a week after it was published.

We now have a DoD version of that approach, the Joint Training Counter-IED Operations Integration Center (JTCOIC).[39] Information about daily operations from combat zones is screened, looking for new enemy tactics/techniques/ procedures, or lessons learned from U.S. or NATO operations (successful or unsuccessful). A selected event is sanitized of classified information, and the event is reconstructed in a gaming environment, currently Virtual Battlespace 2 (VBS2). The reconstruction can be distributed to units equipped with the VBS2 gaming software[40] who can then replay the event. In addition, using the same gaming engine, the event can be replayed and a video of the replay can be recorded, creating a machinama[41] version. This version can be distributed electronically as with a video on You Tube. A version is published that can also be viewed on a mobile device like a soldier's iPod, iPod Touch, or iPad (MP4 format).

[38] See http://www.kumawar.com/
[39] See https://www.jieddo.dod.mil/UploadedFiles/20090408_Final_JTCOIC_PressRelease.pdf
[40] The Army and Marines have reportedly procured a large number of enterprise licenses for this software.
[41] Wikipedia: Machinima is the use of real-time graphics rendering engines, mostly three-dimensional (3-D), to generate computer animation.

Where can we expect these interactions between Networking, Instrumentation, and Command and Control to progress? General Paul Gorman observed in 1987 that distributed simulation was a command and control system.[42] We did not have much instrumentation at that point, and just the start of networking. We now see many initiatives in new, low cost, ubiquitous sensors that serve as sources of instrumentation. We can expect these to be proliferated throughout future systems, providing a substantial flow of data about performance.

This will lead to a number of innovative developments where MS&G and command and control are viewed as the same. Further, lessons learned in developing advanced, large scale MS&G architectures and applications will be available to assist developers of the next generation of C4I systems in solving tough design, architecture, and implementation problems: many of these problems have already been tackled and solved by the MS&G community.

What does this suggest about the future?

SECTION III
FUTURE OPPORTUNITIES

I have made two assumptions in preparing this section:

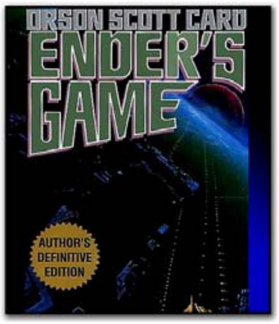
1. I assume that Networking will continue to converge with Command and Control (or one of the many variants) as well as Instrumentation, and
2. I assume that we will increasingly see that MS&G and C2 are treated as the same.[43]

Given the progress since the early SIMNET days, and the many other related developments, what can we speculate about the future? This section presents a few possibilities, some that are low hanging fruit and some that require substantial technology investment.

[42] General Paul Gorman, personal communication
[43] This is a position argued convincingly by Warren Katz of MAK Technologies and several others.

Ender Wiggin, Mazer Rackham, and the Battle School: Core Curriculum for Leader Development, Advanced Studies & Concepts, & the BattlePlex

The way I have chosen to speculate about various futures is to build on the vision of Orson Scott Card, the science fiction writer, in his series of books featuring the protagonist Ender Wiggin.[44] Using sophisticated profiling tools, Wiggin, a pre-teen/ teenager, is selected from a large population of gifted children for his potential as a battle commander. He undergoes fully immersive training and education using a wide variety of tools to develop his tactical skills in Battle School. He practices in a physical arena as well as online in gaming environments to develop his command and leadership abilities. For Card, Ender's assent to becoming a master tactician, strategist, and effective commander and leader is an all-consuming, continuous effort, without respite.



Mazer Rackham is from the generation earlier, the commander who successfully fought the preceding war. He acts as Ender's mentor.

For the remainder of this paper, I will project Ender's Battle School and Command School environments to today's challenges and opportunities, and speculate on new technology-enabled capabilities that could result.

Why Ender's Game[45] rather than some other work? Ender's development is enabled by a continued progression of *advanced MS&G*. It is a search for techniques to develop *operational excellence*. It has a strong component of *user-defined games*.[46] It has links to real world problems and *people* working on them.[47]

The Next Generation?

Launching from Ender Wiggin's Battle School, the Battle School we might envision is where the United States will grow our future leaders. It is the soup-to-nuts leader development environment made possible by advanced information technology and cognitive science. It is where we will educate and train our 21st Century leaders for all governmental enterprises.

The Battle School does not have to be a physical place. Certainly parts, perhaps the largest part, would be online. But there is something unique to having a physical component to Battle School, so I am not convinced of absolute virtuality.

Whatever the mix and match (which we would expect to change over time), Battle School is a dynamic, pervasive learning, practice, rehearsal, and execution environment that is integral to every leader, from the youngest 2nd lieutenant, sergeant or government manager to the most senior Commander, sergeant major, ambassador or agency head.

The Battle School has:

(1) A Core Curriculum For Leader Development
(2) A Graduate Curriculum For Advanced Studies and Concepts
(3) The BattlePlex as its exercise and execution arena.

All three of these are interconnected. Advanced Studies and Concepts develop tools and content for the Core Leader Development curriculum; leader skills are practiced and honed in the BattlePlex; real operations are conducted in the

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[44] Ender's Game, Speaker for the Dead, Xenocide, Children of the Mind, Ender in Exile, Ender's Shadow

[45] First brought to my attention by LtGen Jack Woodmansee

[46] As described and advocated by BGen Keith Holcomb, USMC (retired); personal communication

[47] As an example, John Schmitt, former Marine and author of USMC Publication 1, Warfighting, (see http://www.dtic.mil/doctrine/jel/service_pubs/mcdp1.pdf), is cited by Card as an influence in the construction of Ender's Game. Schmitt has also been a key contributor to DARPA's CPOF program, and has written extensively on the topics of Strategic Collaboration, Wicked Problems, and Command and Feedback (his term).

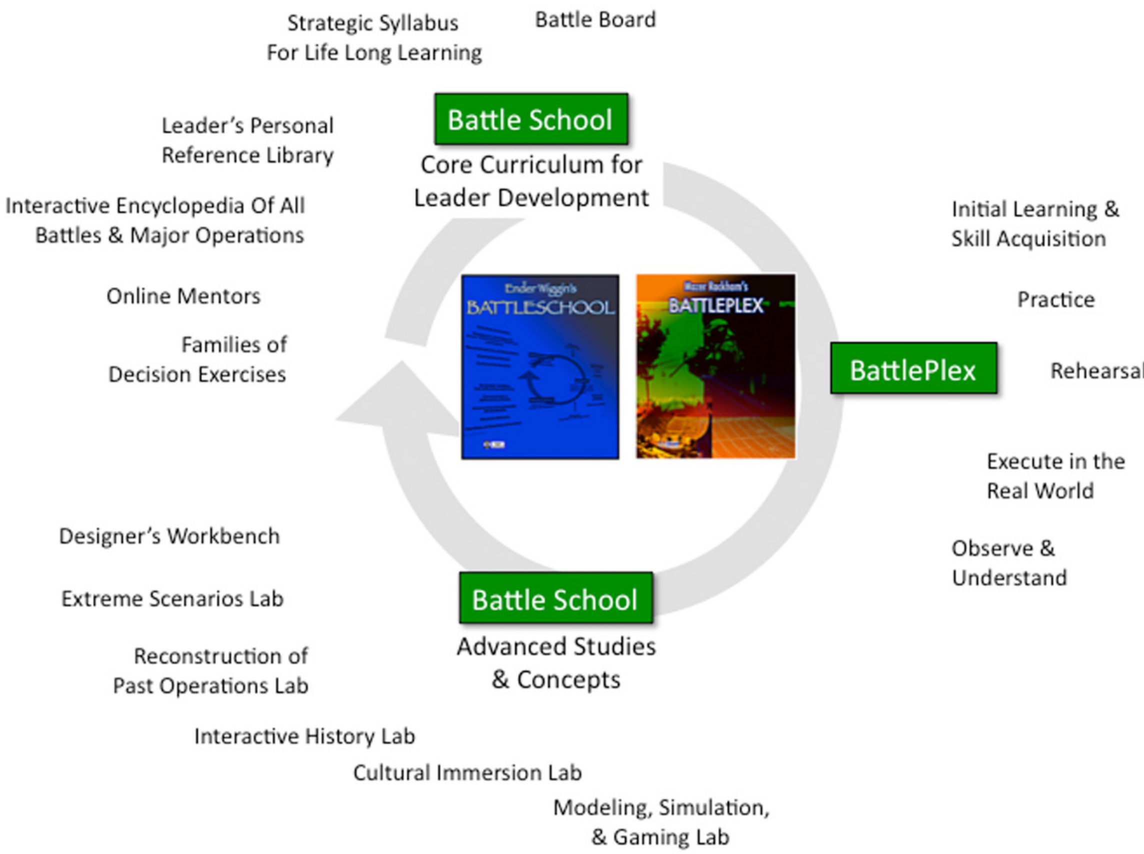
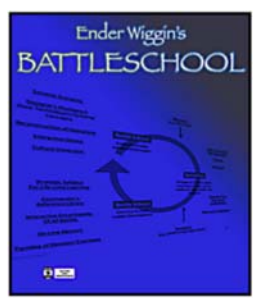


Figure 15 – Battle School and the BattlePlex components

BattlePlex, captured live, analyzed, and fed back into the Core and Advanced Studies curricula.

While designers are experimenting with new ideas in one part of the School, leaders are learning and honing new skills in another. Battle School uses advanced pedagogy for rapid learning, creativity, and stress resistant skills. Leader education and training is viewed as a life long pursuit, so leaders have access to the Battle School 24x7 throughout their careers, and their actions (successes and failures) ultimately contribute to the documented, multi-dimensional database of past, present, and future operations in the Interactive Encyclopedia of All Operations.



I. Battle School: The Core Curriculum for Leader Development

The Core Curriculum of Battle School is focused on leader development. Its goal is the maturing of leaders and leader teams (multi- dimensional, organizational, and national) for dealing with future conflicts and very large operations (e.g., humanitarian assistance/disaster relief). These are not only military leaders, but by necessity have to be leaders from all sectors of government as well as the commercial and private sectors.

This curriculum is at the heart of developing operational excellence.

The Undergraduate Curriculum has six technology components, many of which require scientific advances. All require advanced MS&G.

1. Battle Board - All leaders all are equipped with the *Battle Board*, ala Ender's Game, a tool that accompanies them throughout their careers. It is their primary but not exclusive Information Appliance.

The Battle Board is the entry portal into:

(1) The Leader's Personal Reference Library, with much of the Library resident in the appliance;
(2) Games and tactical decision exercises via the leaders gaming console and C2 dashboard (Battle Board apps);
(3) Data from instrumentation of real world situations;
(4) Powerful reference, information management, and manipulation tools including the onboard Reference Librarian, and
(5) A portal to Internet III

The Battle Board also contains the *leader's personal cognitive profile*. It knows how to sense his/her state of alertness and focus of context (what task is the leader performing and what information is needed for that task).

Figure 16 – The iPad might be the first Battle Board

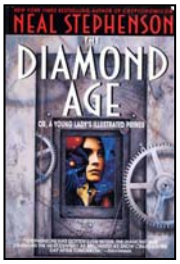
2. The Strategic Syllabus for Life Long Learning – Adaptive learning tailored to each leader.

The leader's education and training regimen is based upon a *Strategic Syllabus for Life-Long Learning* that employs ubiquitous information technology (networks, data, and computational power) to allow the leader to continuously improve and grow, 24x7, throughout his/her career. Information technologies support student work, advanced research, communication among peers, mentoring from graybeards, study of operations in 3-D interactive virtual reality, and fighting battles in the same environment against hostile, sentient foes via the BattlePlex.

Learning is moderated by an adaptive, individualized cognitive model for each leader that changes and adapts as the leader learns. It tailors training, practice, and rehearsal exercises. In combat or in very large operations, the same model tailors information and decision support systems that the leader uses as a function of the mission, the current skill level of the leader, and constraining factors such as fatigue and injury. The elements of the model are derived from empirical research on how leaders make decisions.

a) An information-driven pedagogy
b) Cognitive profiling to assess the learning capability and dynamic capacity to develop skills (ability to learn certain types of skills/tasks at certain times under a given cognitive state).
c) Adaptive Syllabus that tailors the learning environment to the cognitive receptiveness to learn, and adjusts itself as the learner progresses
d) Portfolio of Skills and Experiences that describes the leader in terms of what he/she has learned and mastered, and what experiences have been accumulated, to include performance during those experiences. This description of the leader can be used to align the leader to specific assignments later on.

3. Leader's Personal Reference Library – Patterned after Stephenson's "Young Lady's Illustrated Primer"[48]



Each leader will have access to the equivalent of the Library of Congress holdings but in a dynamic, wiki format that is easily tailored to the leader's interests and personal styles. The onboard and online "reference librarian services" provide powerful means of finding the information you need, and reasoning about it.

a) A vast reference library: 100,000s volumes, in electronic mode, portable via the Battle Board as well as online
b) Format is highly wikiized, hyperlinked, with dynamic components (e.g., animations, video, immersive environments)
c) Advanced search, retrieval, pattern matching - Advanced information search tools that allow streamlined research, annotate findings electronically that are automatically stored in personal databases, and debate conclusions with other experts electronically.
d) Advanced reasoning algorithms aid the commander in his compilation and understanding of this material. As above, he shares his observations with others studying the same material, as well as having access to observations from earlier commanders who have annotated the material and have made their observations available in a common database.
e) Advanced text processing, annotation, abstraction - Annotations can be multi-media: text, drawings, audio, video, and interactive simulations and games that illustrate the point being made, allowing the student to enter the operation and watch the results being discussed.
f) Agent-based local reference librarian (onboard the Battle Board)
g) World-wide access to a team of online reference librarians 24x7
h) Proactive Acquisition: The leader's personal reference librarian (onboard or online) automatically acquires and cross references new holdings that are relevant to the leader's interests and job, and adds these to the collection.
i) Topics: *history; military command; strategic collaboration; lessons learned from great battles and major operations; leadership; biography; politics; diplomacy; area studies; location specific information; current geospatial attributes (terrain, man made features, infrastructure); past and current cultural imperatives (to include religious, economic, political factors); other interested parties; mechanisms of influence (e.g., defeat mechanisms); and so on.*

4. Interactive Encyclopedia Of All Battles & Major Operations - Fully immersive mixed-reality environments[49] (mixes of virtual environments, augmented virtuality, augmented reality, and perhaps the real environment) recreating all past battles and major operations, and a repository of all those being executed at the present. This is like the reconstruction of 73 Easting or OEF but at a much higher level.

a) Highly detailed, accurately represented operations
b) Common language for describing/ comparing/rendering/changing events
c) Past: Operations reconstructed from the historical record, using reverse interactive simulation as a capture and verification methodology
d) Present: Capture of live combat[50]; auto-capture of after action reviews (AARs)
e) Future 1: Analytical and intelligence projections of future possibilities
f) Future 2: Extreme Scenarios (see "Extreme Scenarios Laboratory" below)
g) Leaders can observe from afar or immerse themselves into the operation (1st person viewpoint, on the ground)
h) Leaders can modify and depart from the historical record (see "Component Behaviors" in the BattlePlex)

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[48] The Diamond Age, Neal Stephenson, Bantam Books, 1995

[49] See Milgram & Kishino, "A Taxonomy of Mixed Reality Visual Displays," IEICE Transactions on Information Systems, Vol E77-D, No. 12, December 1994; http://etclab.mie.utoronto.ca/people/paul_dir/IEICE94/ieice.html

[50] As proposed by Neale Cosby

i) Battles and operations are presented and played in the BattlePlex

5. Worldwide Access to Online Mentors: Anywhere, Anytime

There will be online, continuous networking of "students" with senior mentors. This is enabled by the communications infrastructure and the ability to monitor the quality of mentoring. The techniques for structuring the mentoring are based in part on the cognitive model of the learner and how to feed this information to the mentor to help provide counsel.

a) Experienced combat or operational experts, as well as topical experts
b) Trained and monitored via a senior mentoring panel
c) Selective access to portfolio of skills and experiences to tailor mentoring
d) Ability to whiteboard and share real time experiences with the leader, as well as joining an immersive event to enrich the mentoring.

6. Families of Decision Exercises[51]

Decision exercises augment the other forms of education and training for leaders. They are designed to provoke an experiential learning event.

The leader is introduced to families of tactical decision games, most delivered electronically via the Battle Board. The results become elements in the Leader's Personal Reference Library for future use.

One can imagine five kinds of decision exercise "courses" in Battle School:

a) A "*Thematic*" course dedicated to one subject area, such as urban operations, operations other than war, homeland defense, defensive operations, counter guerrilla operations, etc. Individuals would enroll in an entire course. The objective here is to explore the use of decision exercises in support of a specific curriculum of instruction.
b) A "*Pick-Up*" course in which individuals sign up for individual decision exercises sessions based on availability of seats. The objectives here are to explore the use of the technology as a general professional-development tool (for an organization like the Marine Corps Association, for example) and to exercise the use of the web site as an administrative support tool.
c) A "*Force-on-Force*" course that pits teams of players against each other. The objective here is to refine the use of the technology in support of force-on-force exercises.
d) An "*Authoring and Facilitating*" course in which decision exercises are designed collaboratively on line and then conducted among groups. The objectives here are to exercise the authoring tool prototype and to train future decision exercises designers and leaders.
e) An "On-Site" course in which all participants are collocated, using the Battle Board prototype as the C2 device. The objective here is to explore the use of the technology in a non-distributed training environment.

II. Battle School: Advanced Studies and Concepts

Supporting the Core Curriculum are six laboratories for special research, development, design, and engineering: a part of Battle School for advanced studies and concept development at the graduate school level.

1. The Designer's Workbench Lab – This is where new technologies, systems, and CONOPS are created, prototyped, and evaluated against past, present, and future histories.

As new concepts emerge from the Workbench, leaders perfect the CONOPS in Battle School.

The Battle School subscribes to the Kozemchak[52] Axioms:

- If you can't game it, you can't build it
- If you can't game it, you can't execute it
- If you can't game it, you don't understand what just happened
- And, if you can't game it, you can't win

[51] Concepts from John Schmitt, personal communication

[52] Dr. Paul Kozemchak, Special Assistant to the Director, DARPA

So this Lab has all the components and tools to prototype and mockup just about any future system. With advanced MS&G tools, it is easy to construct these systems, technologies, operational concepts, and training and rehearsal techniques. From this laboratory promising systems can be moved to experimentation, leading to the assessment of the genuine utility of potential new capabilities.

a) Introduction of new technologies/systems/ CONOPS through prototyping and mockup
b) Played in past, present, future worlds
c) Leaders iterate on CONOPS (using the Double Helix design methodology)
d) Develop C2 techniques, integrate with the force

2. Extreme Scenarios Laboratory – A laboratory for *thinking the unthinkable* using unconventional, creative techniques. This is tied to non-traditional creative sources, like writers in the entertainment and literary fields.

a) Think & show the unthinkable
b) Generate, analyze, and present story lines
c) Seek out creative resources (not necessarily conventional)
d) Use storyboarding, plot definition, other techniques of creative talents
e) Game plausible scenarios, force-on-force, in the appropriate Battle School environments
f) Create extensive detail on the preparation & execution to communicate to senior leaders

3. Reconstruction Of Past Operations Laboratory – Development of advanced tools and skills for accurately documenting and reconstructing past battles and distributing them into the Interactive Encyclopedia Of All Battles and Major Operations.

a) Detailed reconstruction of the accurate record of all operations in a manipulatable format using techniques like reverse simulation.
b) Create and test other ways to capture past battles and operations from the historical record
c) Develop techniques for the essential autopsy of operations for learning and improvement

4. <u>Interactive History Laboratory</u> – Developing the capability to interdict the historical record, manipulate events and decisions, and create *alternative futures*.

The Interactive History Laboratory takes current battles that have been captured, reconstructs historical battles, and postulates future battles in a robust interactive form that allows everyone from students through commanders facing battle to enter the battles, watch what happened (or could happen in the future), and inject new events to study consequences. Earlier versions of this were seen in Project ODIN and Wissard.

Since all systems in the future will be instrumented and connected, all future battles and major operations will be automatically captured and stored in the Interactive Encyclopedia Of All Battles And Major Operations for future generations to study and learn from, and available in the Interactive History Laboratory to manipulate and create alternative futures of.

a) Ability to interdict the record, manipulate events
b) Requires behavioral filler (see Component Behaviors)
c) This is very hard to do, as it requires a comprehensive, implementable knowledge of human behavior across a variety of cultures

5. Cultural Immersion Laboratory – Virtual travel to all points of the world for immersion into current, past, and future histories from the cultural perspective. The mission of this laboratory is to figure out how to develop operational and actionable knowledge of other cultures.

a) Virtual travel to all points of the world
b) Immersion in current and past histories
c) Modeling then learning about other cultures, religions, societies, tribes
d) Rapid exposure to sensitivities
e) Understanding of pressure points
f) This is very hard to do

6. Modeling, Simulation, and Gaming Laboratory - This Laboratory is responsible for staying current with developments in MS&G, and sponsoring new developments in support of the Battle School.
The Battle School uses advanced gaming technology. It can be very large scale, fully distributed,

worldwide, online. It uses the latest rendering engines for maximum needed fidelity at low per station cost. Real humans as well as semi-automated and fully automated agents participate.

III. The BattlePlex

The BattlePlex is a complex of practice fields, coaching, trainers, "sports medicine," labs, media, and stadiums, where initial learning and skill acquisition is practiced, specific missions are rehearsed, real world operations are conducted via the BattlePlex, and senior leaders (especially political) can observe, learn, and understand.

The BattlePlex is the Information Meta-Infra-structure that connects all U.S. combat and governmental operational systems, and therefore is where the U.S. will fight all battles and conduct all its major operations. It is the one place where leaders and their forces go to learn, practice, rehearse, and execute.

Because future Information Age military and operational systems will have identical data representations, system specifications, and behavioral models of the real world, and they will all use the same enabling information technologies (networks, computation, data storage), there will be a seamless continuum between *real world operational systems* (aircraft, tanks, ships, C4ISR) and their *various abstractions* (simulations, models, games) as well as new combat systems (information ops).

The BattlePlex is an advanced, very large scale, highly realistic operational environment configurable to specific terrain, time period, opponent(s), and other attributes. It is blurs the artificial distinctions between virtual simulations and real world sensing, as the data representations, behaviors (systems and people), etc., are the same and are interchangeable in real time. Further, how one commands in the gaming environment is the same as in the real world, and indeed, these are the same and interchangeable. As in Ender's Game, a real world battle could easily be fought from within the gaming environment. There is no difference: The representations are the same.

The following activities take place in the BattlePlex:

a) Initial Learning & Skill Acquisition - Observe, immerse, manipulate, command
b) Practice - Refine skills with help from mentors
c) Rehearsal - Full unit rehearsal, real world conditions, data generated is automatically fed into C2 systems
d) Execute in the Real World via BattlePlex - This is where commanders and leaders conduct their operations, actions transferred to real systems
e) Observe & Understand - Platform for immersing senior leaders into the situation for understanding and decision-making.

The enabling technologies to make this happen are those discussed earlier in this paper as well as those that could be the direct products of Battle School Laboratories and it leader development curriculum. These include

a. Advanced Modeling, Simulation, and Gaming Technology
   - Online, multi-player, large scale, distributed) with the wide diversity of porting devices to enter environments
   - Simulators, workstations, Battle Boards, combat systems, C4ISR, secure Networks
b. Data about real places
   - All related phenomenologies, physical & sensor representations of terrain, features, environment
c. Component behaviors (full spectrum of the human landscape)
   - Computational proxies, semi- and fully automated, synthespians (accurately mimic behaviors of humans not present via software); online OPFOR
   - Realistic, validated threats via professionally trained, network-based forces tailored to the threat

Final Thought on Futures

For Ender, any differences between the spectrum of representations of reality are non-existent: the convergence is complete. The information and communications technology that he interfaces with blurs the distinction between the real world and its many representations, all of which he can interact with and manipulate seamlessly. It provides him the fluid command and leader environment for collaborating with his team-mates. In the end, he puts in another day in simulated battle without realizing he is actually commanding a real battle. But because technology has allowed this complete convergence, it doesn't matter. It is all the same.

It seems to me we are on Ender's path, fueled by the emergence of common information and communications technologies, including the convergence of Networking, C2, and Instrumentation, and as we look at trends in modeling, simulation, and gaming, we can trace a path that takes us into a completely different landscape of futuristic, revolutionary applications. This is one view.

SECTION IV
MY LESSONS LEARNED AND TAKEAWAYS

This section is intended to capture my own observations, lessons learned, insights, and hindsight. It is in no particular order.

Where is the book?

Bob Reddy has it right (see Appendix): We did not have a guidebook for pursing SIMNET or some of the programs that followed. We were writing it as we went along.

Scale - We knew we had to build a test bed to test the development of large-scale networking of simulators, and *large-scale* meant the test bed had to be bigger than anything like this constructed before. That forced us to rethink what a simulator was and how it could be fabricated cheaply. It also meant that to test the system we would have to have hundreds of soldiers manning all the combat stations (gunners and drivers and loaders and commanders and fire support and loggies and pilots and all the others), so they had to get real training out of it....we could not waste their time. *We had to design the full experience to have value to each individual and the team on the whole.*

Requirements - As there was *no validated military requirement* for any of this which industry might have tuned to their existing technologies (how to meet the stated need with existing products), and which the government acquisition community might have had their engineers prepare specifications for, we were out in front of industry as well as the acquisition corps. This made both very uneasy. Companies that could not adapt are no longer with us. Those that could, and dozens of new companies, were able to flourish.

Army Leadership Support - While the Army acquisition arm resisted this new technology, those in the Army senior leadership did not. General Maxwell Thurman, then Vice Chief of the Army, saw the early prototypes and the program objectives and potential, and he directed his staff to find the resources support it. So what began as a DARPA initiative with DARPA funding soon became a DARPA-Army initiative with the largest portion of funding coming from Army. This lasted throughout the course of the program. The Army senior leadership was comfortable with DARPA executing the program.

Fort Knox Support – This program was kicked off at Fort Knox because of the advocacy, vision and support of MGen Rick Brown. It continued its growth and diversification under the next Commanding General, MGen Tom Tait. Though the program caused disruption to his post as new buildings were constructed, training exercises scheduled, and a stream of visitors arrived (many requiring VIP protocol treatment), General Tait never said "no" to any of our requests, and deserves great credit for the progress the program made.

How should we do it? What is the methodology?

Austere Infrastructure - Duncan Miller observes that working with little computational power and limited network bandwidth required the technical teams to be extraordinarily clever in how they designed and implemented nearly every aspect of SIMNET. I agree. There is something to be said for being impoverished early in a program. It puts strain on the scientists and engineers, but the end result could be a much higher level of creative solutions.

Selective Fidelity - Several unique approaches became embedded in SIMNET. First, Bob Jacobs brought the concept of *selective fidelity* from earlier work. Our design analyses were driven by the training question, *"What is the collective training purpose of this xxx function/system/switch?"* Answers to that question ended up as part of *functional specifications*, i.e., specifications that were mostly about what some subsystem was *suppose to do* rather than *how* to build it. The result is sometimes counter intuitive, as Bob Reddy notes, and hard for the more literal minded to accept since some implementations can tend to be abstract. But the rigor of the approach requires a careful understanding and analysis of training goals and needs, a big plus.

Single Design Theme – A key member of the SIMNET team was our industrial designer Ulf Helgesson, who was involved from the beginning. He brought a kit bag of mockup tools to rapidly fabricate the crew workstations, the tactical command posts, and ultimately the SIMNET buildings themselves, in order to meet the functional specs. I learned the importance of having this kind of expertise on the team early.

We all think we know a little bit about design, or at least can point to something and say "Make it like that" without knowing the essence of the design principles involved. This is dangerous.

Having an overall design approach is essential, particularly for a project that so directly involves operators and users, and this has to be tuned to the target operational environment, which is not easy. I urge other program managers to take this to heart. My personal rule: *Never let your industrial designer write code, and never let your code writers do industrial design.*

60% Solution – We implemented a development approach that *valued frequent demonstrations and evaluations.* Mockups were constructed using inexpensive materials that approximated the thing being designed so that soldiers could evaluate and comment. The objective was to do this efficiently and quickly. Getting a design about 60% done and showing it to operators allowed for valuable feedback and mid-course corrections that would have taken a lot longer, and cost a lot more, had we spent more time on the design. As stated earlier, f*ast, approximate, and cheap was better that slow, deliberate, and expensive.*

Also, anything that you did that was slow, deliberate, and expensive tended to be *harder* to change once it was acknowledged as the wrong way to go.

As the simulators and networks matured, the development team scheduled a major evaluation about every 2-3 months, a demanding schedule but one that kept the operational community engaged and supportive.

IDA Simulation Center – Early in the SIMNET program IDA established the Simulation Center as a Washington, DC (Alexandria, VA) distributed simulation node near the Pentagon where evaluations and demonstrations could be conducted. During the program, and for several years after, it was the most productive single location in the U.S. for advanced development, experimentation, education, demonstration, and center of mass of creative thinking. It supported scores of significant events. A superb support staff manned the lab from early morning to late at night, with Colonel Neale Cosby at the helm.

SIMNET U – About three years into the program, with the SIMNET team having grown considerably and many new faces everywhere, we became concerned that there might be many of the newly arrived who did not fully understand the core vision of the program and its goals. So a timeout was called, and nearly all of the team from the three main contractors travelled to Fort Knox for a weeklong "refresher" which we called SIMNET-U for "university." Keynote presentations and technical talks were given, battles were fought in the SIMNET simulators, and everyone got to know each other a little better (the three teams were all located in different parts of the country). What we lost in development time we easily made up in a better-informed and tighter team.

Double Helix – Though not recognized as such in SIMNET, we were also practicing a process that later became known as the Double Helix development process in the DARPA Command Post of the Future (CPOF) program. Its premise was that applying *new* technology to an existing or *old* process invariably resulted in little or no improvement. For real improvement, the concept of operation (CONOPS) had to be improved, too, given it was now technology-enabled and had to take advantage of that. So the CONOPS and the new technology had to co-evolve as a program matured.

This requires the involvement of technology-aware operators that are willing to learn about new technical capabilities and modify their CONOPS, and CONOPS-aware technologists that are willing to modify their concepts of technology employment and think out-of-the-box. This is an iterative process that requires regular and intense interactions between the operators and the technologists, where each learns from the other and modifies the areas they are responsible for. For the programs we have tried this on so far, the result is that the team ends up at a different place than it initially started for, i.e., that serendipity and discovery result when you co-evolve technology and CONOPS.

Why "Capturing Live Combat?"

Neale Cosby (see Appendix) has been advocating the development of technology, processes, and CONOPS for routinely capturing live combat as well as operations from our training centers in a form that can be stored, transposed into the proper format, and reused for a variety of purposes, to include immediate distribution across the battlefield if new enemy tactics are encountered, insertion into simulation systems for replay and study all the way back to the schoolhouse, and use by system designers for the next generation of military systems.

Instrumentation, as discussed earlier, is becoming more pervasive, so capturing physical elements of the battlefield should become less burdensome. Streaming C2 can similarly be captured. Knowing what information to collect and what to do with it, however, requires study. 73 Easting and the OEF Mazar-e-Sharif reconstructions gave us a glimpse into some uses, but these are just the first cases.

Having objective data about operations is critical for conducting productive after action reviews and constructing the historical record. Without objective data, the evidence suggests we will take home the wrong lessons. Consequently, this is an important task for the technical community to engage in.

Bob Richbourg observes that the more immediate the reconstruction from combat data the more complete the historical record.

MS&G as a Strategic Capability as well as Strategic Vulnerability

Modeling, Simulation, and Gaming is a *strategic DoD capability*. It is based upon exhaustive and precise descriptions of all Defense activities (semantics), and brings a powerful syntax to express these. It describes static as well as dynamic processes. It can be an expression of the interplay of DoD's complex systems. MS&G can be thought of as the *representational language of all things Defense*.

It is therefore highly important that there is a strong proponent within DoD for MS&G, that it is centrally resourced, and that there is strong DoD leadership nurturing and protecting MS&G capability.

Further, there should be a business model for this strategic capability to insure that there is a robust industrial base (to include universities) developing products and infrastructure for MS&G.

Unfortunately, the main concern of many I spoke with is that while once there was strong DoD leadership and a viable business model, these have been *neglected* in recent years and are *unsatisfactorily weak* given the importance of the MS&G capability. Examples are cited in the lack of an active DoD champion and council, spotty funding, and the emergence of duplicative and redundant protocols and architectures by different DoD stovepipes.

This opens a strategic vulnerability that is further enhanced by a dysfunctional acquisition approach. Contractors are rewarded for building MS&G components from scratch rather that buying completed and tested modules off the shelf. This takes a long time and costs more. There is not strong commoditization. (see Darken, Katz, Gehorsam, others in the Appendix).

For many non-U.S. countries, contracts specify already developed and tested modules procured on a firm fixed price basis, commercial off the shelf. This is fast and economical. So any *adversary* wishing to enhance their MS&G capabilities to our detriment has a *strategic advantage*.

Virtual versus Real: A Problem In The Making?

One problem that we did not have when we started SIMNET was the ubiquitous virtual environment. Most training was in real systems, a little in virtual environments like simulators. Today we have a population of young people whose experience with some systems and environments are principally virtual. Use of handguns and automatic weapons are an example. A recruit who is an active gamer might have thousands of rounds of experience with a simulated handgun before ever firing his/her first real handgun. Differences in weight and recoil are non-trivial. Will the thousands of virtual misrepresentation have an impact? Have we commissioned the cognitive studies that will help us understand whether this is a problem or not, given that virtual environments will continue to grow?

Luck

I am uneasy when I reflect on the role that luck played in my experience. I was lucky in finding the right people to work on SIMNET who happened to be available at exactly the right time. I was lucky that others came forward that were interested in the same objectives and staunchly supported the program behind the scenes in organizations I knew nothing about. We were lucky that the technology and designs and training programs came together so quickly, though the hard work of the technical teams carried the lion's share of that weight, but they were lucky, too, as they tried untried leaps. I guess luck plays a role in all our programs, but I still shudder when I think about this.

Spinoffs

Several great accomplishments followed SIMNET and its related programs. A few: The Close Combat Tactical Trainer (Jim Shiflett); the Synthetic Theater of War (STOW) (Bob Reddy, Larry Budge, Rae Dehncke, George Lukes, Randy Garrett); BFIT, BFTT & Virtual At Sea Training (Dennis McBride , Lee Kollmorgen, Guy Purser); 73 Easting & OEF reconstructions (Bob Richbourg, George Lukes, and Neale Cosby); Command Post of the Future (Ward Page); and many more.

A Few Final Observations

- SIMNET was oriented at the whole team and provided an environment where leaders could use it for whatever they needed to do, and in a way that matched their own styles of leadership. It aimed at developing *operational excellence*.

- Simulation networks can be modular and federated providing a highly adaptable environment for intelligent and sophisticated users. Given the right tools, Soldiers, Sailors, Marines, and Airmen will innovate in ways never anticipated by developers.

- Simulation networks provide the enablers to connect people in a variety of ways, and not necessarily hierarchically. That can enable collaborative command that can enable shared perspective that can enable common ground. It nurtures emergence.

- Standards make this possible on a wholesale basis.

- But, these distributed simulation networks are subjected to the same co-opting and hijacking by enemies as with all other networks. Alertness and care is required.

- As it has turned out, SIMNET and the programs that followed have changed how we think about collective training, preparation, rehearsal, and execution. They have *changed the System* within Military and Defense institutions. This has the potential to produce the new leaders, units, and organizations needed to win in future combat and be successful in all large operations. It can be fundamental change.

APPENDIX
LESSONS LEARNED AND OTHER TAKEAWAYS FROM COLLEAGUES

This section presents lessons learned from many of the people I had a chance to talk with in the preparation of this paper. I could have talked with many more, including other key people who have made substantial contributions to this area, but I simply ran out of time. These individuals whose comments follow have had significant roles in the development and support of MS&G, and they were kind enough to offer some "takeaways" in the form of insights, observations, surprises, and advice for future community members. Not everyone I was able to talk with had a chance to submit comments.

I am certain that you will find interesting and varied observations from many of these experts in the pages that follow.

Each observation is printed here with the permission of the contributor. No one had a chance to see the paper ahead of time as it was in preparation, and these comments should not be viewed as part of a refereed publication.

The biographical tags for each person wholly understate their stature and accomplishments within the MS&G community, and are provided here only to provide a minimal context.

Contributions are presented in alphabetical order.

Some of the key themes, of many, are listed below with the names of those who discussed these in their comments. This is a very rough and incomplete index.

Larry Budge (retired Army Major General; Institute for Defense Analyses (JAWP); DARPA Program Manager for STOW; conducted several joint warfighting experiments for JFCOM J9 using JSAF)

STOW as the first of DoD's Advanced Concept Technology Demonstrations was funded with "protected" money, so though it lived in DARPA, it was not subject to the normal DARPA management constraints. The downside was that we had to "demonstrate" to the operational customer, Joint Forces Command, the capability of the emerging technology, and so had to fund the building of a large simulation system and its infrastructure that would support their ongoing experimentation needs rather than spending on developing more advanced technology, the typical DARPA mission. We ended up broader in scope but thinner in simulation technology than we would have preferred.

As an example, we were never able to fully develop the command functionality in software. We never developed, beyond an early prototype, the intelligent software "agent" that could replicate the company or battalion commander behavior in STOW.

Andy Ceranowicz (BBN; Alion; semi-automated forces; behavioral modeling)

The growth in the numbers and sophistication of semi and fully automated entities has continued. Initially a means for SIMNET to construct battlefields with more operators that could be fielded with the existing numbers of manned simulators, semi automated forces grew from being all vehicle based to vehicles, some pedestrians, and a stealth viewer ("flying carpet"). Early SAFs had, perhaps, 50 entities. The SAF's constructed by the STOW ATD were transitioned to Joint Forces Command and combined to form JSAF. In 1999, an experiment at USJFCOM was conducted utilizing JSAF to produce 10,000 entities. Besides Moore's law a key factor in this advancement was the development of a more efficient and automated class of entities representing cultural agents and aggressive use of interest management. By applying super computers, subsequent exercises were able to field over 350,000 entities.

The sophistication of the new automated agents also improved as their numbers did. Initially JSAF had two classes of agents, SOAR agents to support smart autonomous behavior and "task frame" agents which were under tight human control. Initially cultural agents were built for efficiency but their autonomous operation required them to implement more sophisticated behaviors than those provided by the "task frame" entities. A particular challenge for developing autonomous entities was the barrenness of virtual environments. Buildings were just obstacles that an entity could bump into, not functional structures that provided services and fulfilled needs. By adding the simple mechanism of codes representing building functions the creation of remarkably sophisticated behavior became easy to program.

Still the development of more sophisticated simulations is hampered by a lack of adequate domain models that computers can reason on. Model integration and behavior development can only be performed by humans. This limits the fidelity and complexity of the simulations that can be built. Semantic web technology provides a modeling media that allows the application of computer reasoning to merge models and find inconsistencies and may provide the key to still more sophisticated simulation environments in the future.

At my company (Alion Science) Rich Williams and Jeff Bittel made significant progress in creating and disseminating visual reconstructions. Simulation data captured during an exercise can be replayed using stealth visualization, and by manipulating the observers point of view (the "camera angle") one can produce videos of the exercise and export these as machinima videos. These can be exported in You Tube-like format, and as MP4s for use on popular mobile devices (iPods, iPads).

Neale Cosby (Colonel, USA retired; created the Institute For Defense Analyses Simulation Center; pivotal in SIMNET and those programs and projects that followed; provided the leadership and motivated the reconstruction of the Operation Enduring Freedom Mazar-e-sharif operation)

Here are my takeaways:

1. Simulation data should be real-time from units in combat or surrogate combat like CTCs (Combat Training Centers)
2. Simulation data should reflect not only RED forces (DCSG-A) and BLUE forces (Blue Force Tracker) but also WHITE forces (local populations)
3. Simulation research should be focused on individual combatants and small units.
4. Simulation technology should be applied to new COIN (counterinsurgency) operations, theory, and science.
5. Simulation capabilities should be "powered down" to individuals in units and individual staff members with the use of hand-help, wireless mobile systems.
6. The military should establish a goal of training three crews for every combat vehicle in the inventory -- red, white and blue crews.
7. Readiness management systems should integrate training, personnel, pay and health systems with access to every individual throughout their career.
8. We must think of Training, Operations and Planning systems as one.

In view of the two wars that we are now fighting, there are two other thoughts that I would encourage you to consider:

9. The reconstruction of 73 Easting and Mazar-e-sharif both highlighted the honest fact that the Army high command needs to pay attention to the fact that young leaders need to be practiced, practiced, practiced before they go to war because they are the deciders that will win or lose the war at the very beginning. Two young captains (McMaster and Nutsch[53]) stuck their small units in the electrical plug to start the wars. So Army leaders need to focus simulations at that level and spend less at higher levels.

10. The failure of the Army leadership to not pursue dismounted distributed leadership is a painful lesson. It is not possible to predict the

[53] Captain (now BGen) H.R. McMaster from 73 Easting, and former Captain Mark Nutsch (USA), special operations, one of the initial A teams in Afghanistan

future. When everything was focused on large-scale heavy force-on-force battles it is easy to ignore the fact that the enemy has a vote. Coming out of Vietnam, the leadership forgot about counterinsurgency operations and focused everything on heavy forces. So today we have the best collective simulation in the world for heavy forces when we <u>need</u> small team dismounted simulations for COIN. As I recall, DARPA was ready to fund research for COIN style fighting but the Infantry leadership at Fort Benning was happy with a squad leader puckster game. The hard lesson is that decision-makers need to demand full spectrum warfare solutions from the simulation community.

<u>Rudy Darken</u> (Ph.D.; Professor, Naval Postgraduate School; Former Director of the MOVES Institute)

We must change how the MS&G industry channels its energy in developing systems: there is almost no commoditization. Because of how we contract and collaborate with industry, we do not encourage new development based upon value added to a commodity but rather allow everything to be re-invented (e.g. rendering engines, networking). Moving all our existing and battle tested technologies toward commoditization allows the tremendous creative energy we have to focus on innovation and bringing new capabilities to our customers. An architecture that allowed us to procure simulations in parts, not as a whole would be an important step.

Architectures should essentially be the government's responsibility. Never outsource architecture. Architecture is the rules by which all the fast moving parts fit together. The trick is managing the architecture without stifling creativity – the same argument we often hear against standardization. We want to be able to upgrade, replace, or add parts to a simulation without excessive system integration requirements typical of modern game and simulation engines.

A goal: hyper reconfigurable, data driven, robust simulation environments. The Internet works this way, but cloud computing can't handle the real-time element of modern MS&G. We want to adapt what we've learned from the Internet to real-time systems. It's possible. We have to do it.

Another thing I am concerned about: Redefining and revolutionizing graduate education in MS&G. Do you realize that less than 1% of the Defense M&S workforce is in uniform? What rational organization would outsource to that degree? We need to seek a balanced workforce of uniformed, government civilian, and contractor expertise in all aspects of MS&G. To meet our obligation in uniformed professionals, we need to explore hybrid (e.g. mixed residence and DL) education models that make graduate education in M&S easily accessible to all the services and we need to link the educational experience of every officer to an M&S stakeholder <u>while they are in school</u>, not hope for it afterwards. The Army and Marine Corps are way ahead in this area. The Navy can and must do better. The Air Force needs to recognize that modern M&S is an emerging discipline of its own and their unique problems are best served by M&S educated professionals, not professionals from another discipline who do M&S as needed.

The educational requirements of the United States military are unique and of greater importance than ever before in the history of our nation. We need to adapt to meet the demand. This will require a model you won't find at any University.

<u>Rae Dehncke</u> (retired Army Colonel; early SIMNET user; Institute for Defense Analyses M&S Division; DARPA Program Manager, STOW; JFCOM)

My team served as the JFCOM J9 experimentation M&S lead and built the JSAF federation beginning with hundreds and evolving to millions of entities over a secure distributed network, on complex urban terrain, using Scalable Parallel Processors, with linkages to sensors and C4I hardware.

The DARPA STOW program (Synthetic Theater of War), 1995-2000, can be viewed from a technology and/or a use case point of view.

From a technology point of view we demonstrated a continual escalation in the number of entities that could be simultaneously supported on a networked federation of simulations. Eventually we employed super computers (SPPs) to achieve the large numbers. Over a period of 10 years, STOW, and its successor JSAF, produced leap-ahead advances in synthetic forces, complex synthetic environments, networking, use of SPPs, and linkage to C2 devices.

From a use case point of view, we helped pioneer the innovative use of the JSAF federation to experiment with new technology and advanced operational concepts. To support the mission of the Joint Forces Command J9 – Experimentation, we evolved the JSAF simulation to produce the required millions of behaviorally representative entities operating on complex urban terrain, and we developed a useful process of inspecting entity behavior as a means of establishing face validity (also referred to as situational verification, validation, and accreditation) for those who commissioned exercises and experiments and needed confidence that the simulated environment was grounded in believable behaviors.

The ability to federate simulations, via our RTI-S and a number of gateways, into very large, joint enterprises provided an operational option to the JSIMS program which was trying, unsuccessfully, to be all things to everyone.

We found that we could prototype quickly at the 70% level, by building simulations from incomplete requirements and then evolving the software on an almost daily basis to meet the needs of the experiment directors.

The STOW technology, later called JSAF, evolved from joint to coalition when the United Kingdom's Ministry of Defense partnered with the U.S. during the STOW ACTD. Later, coalition federations were developed during multinational experiments with Germany, and France bringing their own simulations. Other nations using JSAF include Canada and Australia.

Today JSAF remains in use in a number of allied countries, it is a part of the JFCOM sponsored Joint National Training Capability, and it is the basis for the US Navy's Continuous Training Environment. The STOW Program was selected as one of DARPA's most successful Advanced Concept Technology Demonstrations and the hundreds of members of the STOW team continue today as key members of the M&S community.

Craig Fields (Ph.D.; DARPA Director; Defense Science Board; SIMNET)

1. M&S of physical objects -- sensors, engines, platforms, etc. etc. is done commonly and well.

2. Despite a lot of effort, interoperability of the M&S done by different contractors, under different contracts, of different devices and systems, done at different times, done by different parts of DoD, is still in its infancy. While that doubtless wastes some time and money, and misses some opportunity, the problem will be solved eventually.

3. M&S of large scale IT systems, e.g. C3, is not well understood and not done well. Two problems.

It goes without saying that a model and simulation is not of value unless it conforms to reality, and ensuring that conformance -- validation -- is an absolute requirement. Models and simulations are always simplifications and abstractions, to at least some degree, of whatever is being modeled and simulated. If the simplification and abstraction is done smartly and well validation may be maintained and practical calculation of the model, of the simulation, is possible and constructive.

First problem. Large IT systems are incredibly complicated -- millions or billions of 'moving parts' all interacting. We simply don't have good intuitions regarding how to simplify and abstract without losing validity, losing conformance with real world behavior of the actual IT system being modeled and simulated. Of course the alternative is to not simplify or abstract at all, in which case the model and simulation is no less complex than the actual system --and, say, building a C3 system to model a C3 system is not reasonable.

Second problem. Many people believe that they can create a model, write a simulation, that mimics human behavior. Often in trying to model and simulate large IT systems the actions of the users are supposedly incorporated into the simulation, but it's never right and hence the simulation is never right. By "right" I mean valid, I mean conforming to actual real world behavior, past or future, of the IT system in use.

I know no solutions to all this in the foreseeable future. Of course, large IT systems will continue to be a big problem for DoD for a number of reasons in addition to these M&S issues.

4. And referring back to 3., there is still the belief, in some quarters, that human behavior can be

mimicked by software, and hence there continues to be efforts to write large-scale warfare simulations without any validation whatsoever. Oftentimes checking whether a model conforms to battles of the past is not part of the project plan at all.

5. My biggest disappointment is that the pioneering work on large scale many person gaming, wherein people mimic people and software mimics physics, ala SIMNET, remains a footnote for DoD. The opportunity lost in terms of: enhanced personnel performance; better decisions regarding what to buy with what specs and in what quantity; the evaluation of doctrine, rules of engagement, tactics and strategies in advance; and real mission rehearsal -- what a loss! I have no good idea why this has never been more fully embraced, nor what to do about it. As things are now, instead we do exercises that are oftentimes not realistic and not repeated -- saying it is too expensive to have realistic exercise and repeat them.

Randy Garrett (Ph.D., DARPA Program Manager; intelligence apps)

For the Army, we are integrating real-time, real-world intelligence and operational data with a highly accurate synthetic environment. The resulting "virtual world", is designed to provide a comprehensive analytic environment for an Army All Source analyst. The analysts use the system to understand: 1) intelligence data on enemy actions; 2) the relationship with blue force movements; 3) terrain and weather effects; and 4) sensor employment and collection management. All these information sources can be combined to provide commanders with an Intelligence Preparation of the Battlefield for traditional, hierarchically organized opponents in support of major regional conflicts; networked enemies for counterinsurgency and guerilla operations; or hybrid organizations that combine both hierarchical and networked operations. Analysts can use the system to determine optimal sensor placement for both urban and complex mountainous terrain.

Although environmental effects are a very significant factor for Intelligence (and Operations!), few systems incorporate weather, time of day, or obscurants. In contrast, this system provides sophisticated models for a wide variety of conditions. Analysts can use rainfall and terrain to look at the effects of hydrology on operations. Rainfall, terrain, and vehicle models can be used to perform mobility analyses. Weather, terrain, and sensor models can be used to assess the effectiveness of proposed intelligence gathering operations and optimize collection plans. Telemetry data provides "pervasive awareness" of collection assets, showing platform positions, ground tracks, and sensor footprints. In addition, the simulation capability can be used to perform "what if" analysis of potential collection plans.

"Intel overlays" for any information that has geospatial content can be shown in 2D and 3D. Analysts can see where the Intel event occurred, against the complete context of terrain, weather, blue forces, and other Intel reports. Clicking on the overlay takes the user to the full report.
Collaboration is an inherent feature of the system. Users can interact with the environment, the information, and each other in a manner that is naturally intuitive. Users can view the same or different locations, as needed, from any point in time or space. The system allows users to create private or shareable "geo-stickies" to annotate locations and events. The distributed architecture provides thousands of simultaneous users, located anywhere in the world, with real-time access to terabytes of information.

Robert Gehorsam (Game developer and game company executive; invited speaker at DoD Highlands Forum; member of DARPA advisory groups)

The adoption of modern gaming technology by the Defense acquisition community has been slower and less imaginative than I'd hoped for. This technology – and the culture around it -- is fast moving, dynamic, flexible, which is the opposite of the acquisition bureaucracy. From the perspective of someone in the private sector, there has been little sign of either urgency or motivation to change the current technological and business approaches, even when they are acknowledged to be ineffective.

There are also hidden gotchas. For example, take security policy. There are, not surprisingly, complex and stringent requirements for authorizing software to run on various hardware and network platforms. Products that emerge from R&D might face two to three years and cost several million dollars to be "certified." The small companies that often create these technologies cannot bear that cost.

However, there is some promise. Some simple products – highly focused game applications – have resonated with their intended users. But they are really just trainers, and the promise of online games and virtual worlds is several orders of magnitude beyond that. TRADOC is also embracing simple virtual worlds for both e-learning and collaboration. As large-scale virtual worlds show the community how to integrate real-world terrain, external data feeds from sensors and other sources, and empower collaboration among distributed groups, some user communities are starting to take initial steps. An encouraging effort being kicked-off at the National Defense University should be closely followed, as they hope to create an infrastructure for DoD and other agencies to provide "worlds on demand" for any user and any purpose.

General Paul Gorman (USA, retired; CINC South; innovator)

I see at least two major innovations underway that involve the MS&G community. The first is in the area of virtual staff rides. Historians seem to be opposed to the substitution of walking the ground of actual battles for technology. If you can get to it, the actual battleground has a lot to offer. But most people cannot get to it. So technology can port them there, and, in an improvement over walking, it can provide unique perspectives that enhance terrain appreciation. Further, simulation technology can immerse the learner into the battle and allow him to appreciate decisions made under stress.

The second innovation parallels the break-throughs made in distributed simulation, and can even be thought of as part of the same wave of progress. It is the transformation from hierarchal command and control from World War II and Viet Nam to streaming, collaborative command as represented by the Command Post of the Future (CPOF) development. CPOF allows commanders and staffs at all levels to create shared perceptions of the battlefield, nurturing common ground. Because it shares information across a network, capturing the traffic captures the command information in total, and allows for replay and manipulation, just as logging data on a distributed simulation network allows capture of the session and replay and manipulation, too.

A project at the Army's TRADOC, in partnership with the Joint Improvised Explosive Device Defeat Organization (JIEDDO), has pursued the convergence of C2 with MS&G by dissecting streaming data from battlefields overseas, networked to U.S. facilities in real time, picking out teachable incidents (for example new insurgent techniques), and inserting them into a game environment for illumination, presentation and electronic distribution. The organization that does this daily is the Joint Training Counter-IED Operations Integration Center (JTCOIC) and their motto could be "From the battlefield to the classroom in 24 hours." I think this is a significant innovation in leader development, battlefield analysis, and collaborative command.

Jim Hollenbach (retired Navy captain; DMSO Director 1994-98; Simulation Strategies, Inc.)

M&S is now, and will increasingly be, critically important for DoD. The use of distributed simulation has taken root, as evidenced by the increasing scope and jointness of distributed simulation events. Model-based engineering is an emerging, powerful improvement to acquisition. M&S is becoming ubiquitous, but it is far from being optimally cost-effective.

Technical challenges remain (e.g., data engineering, modeling discipline, human behavior representation), but the biggest problems impeding the advancement of M&S are a dearth of DoD leadership and an ineffective DoD business model. There is no current master plan. Standards are not being enforced; the distributed simulation architecture situation has devolved into anarchy. A significant portion of M&S Coordination Office resources are being wasted on unrealistic, inappropriate, or narrowly-useful projects. There is little appreciation of the need for central funding to sustain the key capabilities that enable a cost-effective M&S business ecosystem. The greatest benefits from reusing M&S resources accrue at the Department level, but rather than align the cost burden with the benefits received, the M&S Steering Committee unrealistically expects someone else, usually end-users, to pay to sustain the key cross-cutting standards and services it wants them to use.

Bob Jacobs (Ph.D., Perceptronics, Illusion Engineering, Hughes Aircraft; human factors; behavior & design)

Selective fidelity was clearly appropriate for this program, but it cut against an operational community that had been lobbied by manufacturers to believe that only "full fidelity" simulators could deliver desired training results. But "full fidelity" itself is an illusive concept, as few could objectively define its attributes. In the end it really was code for what the manufacturers had available to sell.

On the other hand, the operational community, i.e., the users of our technologies, when they understood what we were trying to do, let us take risks. They knew something significant was on the horizon and supported our efforts to make it happen. We were trusted.

The methodology of immersing our scientists, engineers, and designers in the problem space paid off in spades. All our key people visited Fort Knox, learned about armor vehicles and the tactics of employment, and many drove and fired the Abrams M-1 tank and Bradley Fighting Vehicle. A couple of years into the program, with many new faces on the program, we called a time out and brought everyone to Fort Knox (a hundred people or more) for what we called "SIMNET U" for University, an opportunity to hear from the original team regarding goals and methodology, meet, talk, and eat with soldiers, and fight force-on-force battles in the simulators.

We chose a development regimen that scheduled many demonstrations and tests. It was rare if more than a couple of months would go by before we had something new to share with our operator sponsors. This was an excellent way to get regular, no-nonsense feedback, essential for making adjustments.

We tried to anticipate future technology developments, and assumed that better tools and capabilities were on the way. So we did not allow ourselves to get wired into a specific solution. We tried to avoid being risk adverse to the extent we could.

When we started SIMNET the threat was Soviet armor warfare, so the focus was on vehicles and their systems. This was aligned with the technology, as it was easier to simulate vehicles and harder to simulate dismounted individual infantry as well as peoples from different cultures and different languages. Now the threat has changed, and it is this second class of simulations that is the challenge. Progress is being made in this area, but it is very tough: we have to capture and model how people act, and embed that into models that can be executed by machines.

From our current state of the art, I see several opportunities for the future. I think that we will continue to see the merger of a class of devices for (1) skill enhancement, (2) performance improvement, (3) outcome calculus, and (4) decisive engagement (options management). Also, I think we will see techniques for situational understanding that will compare my behavior with an optimal, and guide improvements.

I think we will also see improvements in mixed initiative technology to advance the sophistication of our user interfaces. Further, training intelligent algorithms for social environments, religious beliefs, and social interactions will become more prevalent than they are today.

Finally, all of this happened because of an uncommon highly synergistic collaboration of a bunch of really bright people – from the government, from the military, and from the contractors. In this group, we viewed ourselves primarily as members of the SIMNET TEAM, and only secondarily as representatives of our respective organizational interests. We worked together to solve important and challenging problems, and when issues divided us, they were issues of technology rather than issues of proprietary interests. The credit for this goes to the program leadership and our guiding visionaries who reminded us that our primary goal was to save soldiers lives by better preparing them to travel into harm's way. It was easy to prioritize this ahead of any monetary compensation.

Dr. Anita Jones (Professor of Computer Science, University of Virginia; former Director, Defense Research & Engineering; member, Defense Science Board)

The DoD leadership should assert proponency for interoperability of defense models and simulations. It is too important for the Department not to be proactive on this issue.

That leadership could come from OSD, motivated by a more cost-effective test and evaluation or acquisition requirement that systems must interoperate with relatively little preparation time. That leadership could also come from a service that justifies benefit for that service alone, with joint and NATO coalition interoperability being an additional benefit. Or it could come from an information provider, such as NGA, in whose interest it is to have the largest number of users of common products at the lowest cost.

The Internet has few built in tools for security, enabling cyber attacks with lack of attribution. This is a serious shortcoming, and as distributed simulation is network-dependent, it needs to be a concern for the modeling and simulation community too.

One of the great achievements of the past 15 years of simulation development has been the "serious games" that engage the imagination of the player and teach not just skills (e.g. hydraulic system control, piloting) but facilitate understanding of social phenomena, psychological behavior, and cultural behavior. These serious games need to be advanced further; they represent a training advantage that the U.S. now holds.

Warren Katz (MIT; SIMNET; BBN; MAK Technologies; architectures; simulation modules as commodities)

Our goal should be to continue to push MS&G further into a true commercial market. Since the 1990s, the modeling and simulation community has transitioned from everything being custom built to commercial off the shelf (COTS): Just about every simulation module you might ever need is available today from some vendor somewhere, and most of the time several competing choices are available. There is no (non-profit motivated) reason to construct things from scratch. For the MS&G market, this was made possible by standards such as DIS, HLA, OpenFlight, CIGI, SCORM, etc., enabling vendors to create interchangeable, interoperable components and sell them competitively at a fixed price.

In spite of this, there is tremendous incentive within the U.S. defense market to create from scratch: The cost plus fixed fee government contracting approach makes it more profitable to spend labor on reinvention, reconstruction, and repetition. Given that we have excessive budgets, a contractor base, and acquisition work force that are motivated and indoctrinated to do the work this way, this approach is self-perpetuating.

Overseas the story is different. Without excessive budgets, customers demand firm fixed price delivery of systems. As the COTS modules already exist, they can service prime contractors needs more quickly and economically than in-house re-invention. Sophisticated integrators working under Firm Fixed Price contracts are rewarded with higher profits for reducing cost, as does a competitive market in all other walks of life.

But this problem is not just a time/money issue. The cost-reimbursable business model creates a tactical and strategic disadvantage on the battlefield. Our enemies can construct and use state-of-the-art commercial technologies against us faster and more efficiently than we can plod through a classic acquisition program. They can operate inside our OODA loop (from Boyd's "observe, orient, decide, act"). Consequently this is not just a budgetary issue or speed to market issue. This is a genuine operational threat issue.

In my view, the same commercial transition is happening in the C4I community and market (command, control, communications, computers, intelligence). Because M&S and C4I systems are merging, we are seeing modules from M&S being employed by C4I developers, such as 2D and 3D visualizations; real time communications architectures; geospatial databases, etc. Therefore, there is an opportunity for the M&S community to assist in the transformation of the C4I community to a leaner, more efficient, state-of-the-art, commercial-based market.

Dan Kaufman (DARPA Office Director; commercial gaming; gamer; Real World)

The government desperately needs to get away from proprietary systems.

We need common libraries and standards to empower the end user.

End users should be able to assemble and run complex simulations using good tools and without training.

Training needs to go to the user not the user the training – commanders are less and less willing to send their troops to a training place, they want to train them where they are.

We no longer have days for training but need to provide training in the few scattered moments of downtime – which reinforces the point above. This also means we need software developed in a manner that the support organization is minimized not maximized.

End users need to directly influence what they need – the government requirements process is too cumbersome and no longer accurately reflects what the users need.
We need accountability – how many products purchased for how much money are being actively used etc.

We need to migrate towards heterogeneous platforms and systems – PCs are losing ground and we need to get ahead of that curve.

We need to open the aperture so we get iPhone numbers of application developers as opposed to the relatively small number we get today – this will take significant acquisition reform but is critical.

Paul Kozemchak (DARPA Special Assistant to the Director; simulation and gaming devotee; intelligence and advanced technology)

I am discouraged that the tools that have been created over the last 25 years by the modeling, simulation, and gaming communities are not more aggressively used, daily, in all aspects of the Defense enterprise. Perhaps one reason is that it requires hard thinking, and hard thinking is hard.

I absolutely subscribe to the notion that

- If you can't game it, you can't build it
- If you can't game it, you can't execute it
- If you can't game it, you don't understand what just happened
- In short, if you can't game it, you can't win it.

Gaming is essential to Fighting the Past, Fighting the Present, and Fighting the Future. What can be more important to Defense than that?

George Lukes (Research Staff of the Institute for Defense Analyses; DARPA Program Manager; Army Topographic Engineering Center; terrain databases for distributed simulation; principal involved in reconstruction of the battles around Mazar-E-Sharif, Afghanistan, OEF).

The Synthetic Theater of War (STOW) made major breakthroughs in synthetic environments with integrated TINS incorporating feature data such as cut-and-fill roads, dynamic terrain, dynamic environmental effects and dynamic sea state driven by four-dimensional meteorological and oceanographic data from operational sources. A large demonstration of these features was conducted in November 1997 in a Coalition Joint Task Force exercise led by the Atlantic Command and the United Kingdom. Subsequently, these capabilities were adopted by the Joint Forces Command for Joint Experiment (JFCOM/J9) and are used operationally by the Navy for Fleet Synthetic Training.

There has been a complementary demand for simpler terrain databases that can be generated in real-time from properly formatted terrain, feature, model and image data such as the Common Database (CDB). Not unlike Google Earth and Microsoft's Virtual Earth, ready access to shared simplified environments provides powerful capabilities for collaboration and flight simulation. Accurate representation of weather and dynamic effects, however, remains a challenge.

Today, the National Geospatial-Intelligence Agency is providing far cleaner and more timely terrain, feature and image data sets in support of on-going operations. These digital products, used to provide topographic and image maps to the field, are also valuable for analytical applications and simulation. There is new emphasis on both contemporary worldwide feature data at topographic map scales and high-resolution three-dimensional urban feature data. Critical applications include route planning and intervisibility/line-of-sight calculations. In addition, ease of use continues to improve with new tools exploiting available computational power.

Dick Lindheim (R.L. Leaders; USC Institute for Creative Technology; Paramount Studios; role of story in training; entertainment; train travel)

MS&G is at a decision point, as when information technology moved from mainframes to PCs. We are moving from generic training to specific, real world dimensions, mission rehearsal, capturing the complexities of the real situation fed by real world data. All key aspects of the real situation can be expressed. This is roaring ahead and driven by the entertainment industry.

We can look at technological progression in the movie industry. Before the 1950s cameras were big, there were single light sources (arc lights), and film was slow, resulting in sound stages as the production venue. In the 1950s we saw the advent of new film, lightweight cameras, and halogen lights, giving us the ability to film on location. Unfortunately this required hundreds of support people.

Now we are back in the studio with new technology and a smart stage, and the ability to construct a virtual world of whatever you want, the recent movie Avatar being a good example.
The military is stuck with legacy MS&G systems that have no ability to move into this world. Visually, for instance, the computer image generators are from the 1990s, all obsolete. There is no way to move them onto/into the "smart stage."

Some military leaders "get it" and try to innovate but run into a wall.

The entertainment industry is now separating "game engines" from "visualization engines." Traditional game engines tend to be too limiting to the work they are doing. As a result, the entertainment industry people have created visualization engines as the solution. They can integrate with traditional game engines, but go quite a bit beyond in capability. And these visualization engines are developing rapidly, improving in capability and speed.

Farid Mamaghani (SIMNET; STOW; CCTT; SEDRIS; FCS; Systems engineering and program management; Environmental models, data, and standards)

The efforts in the defense community to express and represent environmental data unambiguously, and to share and reuse the data efficiently, continue to make progress. The needs in the modeling and simulation (M&S) community, particularly motivated by distributed, inter-operable simulations (a large number of components networked together needing the same data) have been a significant driver in the development and progression of these efforts. But the problem is not unique to M&S, or to defense. We find that other communities need this disambiguated data too, especially the command and control community (both within and outside defense).

While progress in this area, and similarities in what is needed across communities, is notable on a technical level, there seems to be a lack of focused leadership and coherent strategy for tackling these problems across the board and under a uniform approach at the Defense level. There are incremental and often significant improvements, to be sure, but no single champion for this important area has taken the lead to articulate a vision for the future across all communities and rallied the communities to move out smartly. This invariably has resulted in the unintended establishment of stovepipes and the continued impediments to interoperability. We have failed to inspire the current generation of leaders to take this role.

The command and control community appears to be facing similar technical and interoperability challenges that hindered the networked M&S community more than 20 years ago early in its development. Perhaps other communities, including command and control, that are increasingly required to network systems, components, and applications together, can benefit from the lessons learned in M&S.

Dennis McBride (Ph.D., Captain, USN retired; Aviation Psychologist; President Emeritus Potomac Institute; DARPA Program Manager; ODIN, WISSARD, HyDy, BFIT, others)

The use of protocol data units (PDUs) in SIMNET to maximize the amount of information shared while minimizing network clogging was a substantial breakthrough.

The progress from 1983 to 1993 can be categorized as growth in the number of components that could be networked (scale), growth in the size of the semi and fully automated forces that could be portrayed, enrichment of the behaviors possible with semi and automated forces through work with the scientific community, especially SOAR, growth in the diversity of the components that could be networked (e.g., addition of real weapon systems; constructive simulations), and growth from single Service to joint to coalition.

For me, there was also a more specific theme: Determining if and how we could use Navy networks and communication systems to support large scale distributed simulation, particularly the mix of real and virtual systems the Navy wanted to have interoperate. This could be put under the title "BFIT/BFTT."

BFIT was the Battle Force In-Port Training program, pier side delivery of training. Its extension was the Battle Force Tactical Training. Both were/are programs of record, the first one fostered the second in terms of Navy, and largely DARPA technology.

This is what I was aiming for rather than random experiments with virtual/live/constructive simulations. The experiments such as HyDy, WISSARD, and even ADATS were aimed at solving the SIMINET networking idea extended to Navy communication contexts (bandwidth, embedded training, etc.), training environments (ultimately, VAST = Virtual At-Sea Training), and tactical development environments (e.g., ModSAF is now de facto at Naval Warfare Development Command; TACAIR; and was key during the LeatherNet Project[54] at the Marine Corps Base at 29 Palms

The mix of virtual and live (real weapon systems), in the context of the Battle Force In Port Training (BFIT) program which transitioned into the Battle Force Tactical Training system, ultimoately revolutionized Navy readiness preparations to deploy via the Virtual At Sea Training program

I would be remiss if I did not mention that this effort brought me into contact with Allen Newell, the distinguished scientist and author of Unified Theories of Cognition. Dr. Newell helped us frame our approach to behavioral modeling in simulation and contributed substantially to our understanding of the complexities of the problem and the solution.

Jim McDonough (retired Marine officer; Perceptronics; Illusion Engineering; E Team; system developer and subject matter expert)

From my years of being an end user first and a developer second, I learned a big lesson: "Never ask an end user what he wants. Always ask him what his problem is."

You can't wait for "Requirements [with a capital R]," as the "requirements driven process" has not produced any significant breakthroughs. A "problems-to-be-solved" approach to the application of technology is needed.

Both of these observations reflect the fact that the operational community is captive of its experience and expertise; it will seek incremental improvements and miss the opportunity for breakthrough solutions, absent an on-going, problem-solving partnership with the technology community.

Duncan Miller (Sc.D., Mechanical Engineering, MIT; BBN; MIT Lincoln Laboratory; SIMNET; DIS; Simulation Interoperability Standards Organization (SISO)).

When SIMNET began, the first commercial microprocessor chip sets were just becoming widely available. They were ridiculously underpowered by today's standards, and while we could connect simulators within a building using Ethernet, our "long haul" networks were built up using 256 kbit/sec lines between sites.

The resource limitations we coped with turned out to be a benefit. The software engineering team I assembled at BBN was forced to be extraordinarily creative in developing very efficient protocols to achieve the best possible performance using the available resources. Later on, the efficiency of the protocols we developed allowed us to scale up to larger simulations far more easily than if we had not had to worry about capacity limitations to begin with. As a result, I've been told that though most of the components have been upgraded multiple times, the basic simulation structure we first put in place at Fort Knox and Fort Rucker is still in operation today.

[54] For additional information on Leathernet, see: see http://www.stormingmedia.us/48/4859/A485913.html & http://www.ai.sri.com/~lesaf/brochure.html

As in many so areas of life, newer members of the modeling and simulation community often don't appreciate the history behind the capabilities they now take for granted. These simulation components originated in a culture that understood the critical importance of simulation interoperability and reuse, building on a base of common standards that needed, and still need, to be continuously maintained and improved. The Distributed Interactive Simulation (DIS) standards (IEEE 1278) grew directly out of the original SIMNET protocols, and the High Level Architecture (HLA) standards (IEEE 1516) were a further extension and generalization of these. Today, the Simulation Interoperability Standards Organization (SISO) is a non-profit organization that continues to develop and support these and other standards. Although much of the DoD's modeling and simulation infrastructure depends on these standards, it is difficult to convince either the Pentagon leadership or government and industry program managers to invest in sending their people to participate in the continuing process of standards development and support at SISO's Simulation Interoperability Workshops (SIWs). From the standpoint of many program managers, they can purchase what they need to solve their immediate problems off the shelf, so why worry about consistency and commonality for future programs?

A somewhat different situation exists regarding the representation of terrain and the natural environment. In this domain, there is a genuine effort to achieve multiple uses for database representations, largely because of the substantial effort required to develop and validate detailed and realistic databases (i.e, those that represent real-word places and conditions). This effort is not yet as standards-based as it should be, but the sponsors of database development and the practitioners who develop them seem to have a real appreciation of the need for consistency and commonality, because developing realistic new databases from scratch is still a very time-consuming and expensive process.

The gaming community is very sophisticated and continues to make significant strides, but is fundamentally uninterested in standardization. There appears to be little financial incentive for cooperation among game developers. Years ago, DoD was the 800-pound gorilla, and DoD's requirements tended to drive the technology that was being developed. DoD sponsored the conferences and did the heavy lifting. Today, however, game developers do not much care what DoD does. DoD (and NASA, and other agencies) represent an insignificant fraction of the markets they serve.

But DoD still has some unique requirements and capabilities: the need to connect simulations with real systems, vehicles, and individuals, worldwide, and to involve large numbers of skilled operators, with real command and control infrastructure, in order to conduct exercises, mission rehearsals, and tests. This need to connect with real equipment, systems, and organizations, is one that few game developers deal with.

The development of the High Level Architecture supported DoD's needs by providing XML-like data constructs that can easily be modified to develop new simulations. HLA has become the new baseline on which new DoD simulations are built. But HLA carries some baggage, as well. Its development was driven in part to accommodate interactions with the large constructive simulations developed during the Cold War era. These simulations typically focused on massed armor battles, while today's combat challenges are more concerned with irregular warfare, political insurgencies, dealing with failed states, and national reconstruction. As an initiative for interoperability and reuse, HLA experienced resistance by those who saw it primarily as a compulsory standard for all DoD simulation development. This is unfortunate, because simulation interoperability – the ability to create new simulations quickly by reusing and adapting existing modules – is so critically important to DoD's needs to understand, plan, train, and rehearse new capabilities and contingencies. Flexible standards will always be a critical means for doing so quickly and cost-effectively.

Ward Page (former DARPA PM; Command Post of the Future project; Navy R&D in San Diego; science fiction buff)

I see two major trends in technology development for the military (primarily the Army and Marine Corps) – one in the way tools are developed for operational use and the second in the future of training.

In the operational community, the tools that are the most successful (i.e., the most used) are those that can be adapted quickly to changes in the operational environment (enemy and population behaviors). We do this now primarily by attaching an army of developers to deployed units that can make code changes in a matter of hours or days vice the traditional six-month (minimum) turnaround between releases. CPOF, TIGR, and Palantir are good examples of this model. An alternative approach is emerging as well - Apps (as defined by the iGang). They have bite-sized utility but they take virtually no training to use. With apps users can design their tool set very easily and tune system capability to their current operational environment. The main advantage of apps is that they greatly reduce the time needed for adaptation – the user adapts the system to changes in the environment by their selection and sequencing of apps. With sufficient numbers of apps the user becomes the developer. Efficiency drops but utility increases through this adaptability.

Technology for training will have to change for the same reason – it can't keep up with the rapid pace of changes in the real world. It just takes to long to develop the behavioral models and scenarios needed to train troops. The technology solution for training needs to change in similar ways as technology for operations. We need to take the army of trainers, coders, and scenario generators out of the loop to be able to tune training for current operational environments. This means being able to develop new scenarios within hours or days. This will require either automated generation of behavioral models from real data, clever approaches to re-using real world data to present behaviors to the trainee, or powerful but simple authoring tools for commanders to rapidly build training environments.

Guy Purser (retired Naval officer; fighter pilot; BFIT; STOW; C2 and MS&G convergence; Navy Continuous Training Environment; Virtual At Sea Training; Secutor Systems)

Navy Modeling and Simulation in training and experimentation today is wholly based upon the developmental efforts of the DARPA STOW programs and the technologies developed in those programs. First applied at the Navy Warfare Development Command for purposes of experimentation, the STOW technologies were matured in order to create operational level of detail scenarios that contained tactical level detail in order to effectively stimulate combat and command and control systems. Maturation of the STWO technologies was required and complex interfaces to existing and future command and control systems were developed. The simulation effort, while expensive to deploy, was by far the best warfighting M&S environments witnessed by senior level Commanders (Fleet Commanders) and decisions makers. To keep funding costs in check, we began exploring the "art" of applying business practices to the development and application of simulation. Timing could not have been better. At the same time, the costs of fuel for aircraft and ships began to skyrocket and a more affordable approach to training was required in the Navy to replace the significant expense of sending ships to sea in order to meet deployable readiness standards.

The approach taken by the NWDC M&S team for the Navy was to analyze the costs of large scale distributed exercises and determine where costs, over a 15 to 20 year application, could be cut or reduced. The first and most significant cost we went after was the enormous investment of what we referred to as the DARPA experimental approach to exercises; a series of events to configure and ensure the simulation, network, and interfaces between C4I and simulation were functional. To accomplish this, we took the configuration management approach where the investment was made once per simulation and network configuration versions vice per exercise. By using the same configuration event after event, the test and preparation time was reduced by over 90%. As a result, the Navy was the first to publish a document, some 600 pages plus establishing the architecture and standards under which Navy training would be supported. The standard configuration approach also paid dividends in future and ever increasing focus on Information Assurance (IA) standards. Today, the Navy Continuous Training Environment Network of global simulations is the poster child in the Navy for IA.

The second cost we tackled was in system integration. The simulation system focus on simulation was thrown away and the focus was on an enterprise system that included the networks, the simulation, the C4I and the C4I interfaces, the exercise control systems (white cell and control) and the voice and data support systems as a single system of systems. All configuration management and development efforts were done in an open forum process that included the engineers representing each and every discipline. Under this approach, the network was designed from the beginning to support all of the traffic required for an exercise and in a manner where appropriate attributes such as quality of service could be enabled to support the overall unified communications structure.

Third we went at the cost of operating and supporting a global network of simulation and its transport. The communications network was modeled after the tele-communications model of 24/7 support with minimal manning. The standards and the integration also played into this cost reduction area. Today, the Navy operates this network that spans the globe from Japan through Hawaii and all Navy ports and air stations on the east and west coasts of CONUS and connects to Australia, the UK, Canada, Germany, France, and Italy consisting of well over 80 nodes (with several other countries scheduled to come on line.) The network is operated from a central location in Norfolk, Virginia and operated by a force of only 8 personnel. To date, the Navy has not lost a single minute of training time as a result of a network outage. The network is a well-integrated, centrally configured network of modern day tele-communications technology.

With time, each and every cost center was examined and costs cut. C4I interfaces were replaced with a single, common interface framework. True "best practices" have been established. With the publishing of a single integrated architectural and standards document, program offices for aircraft, submarine, and shipboard simulations can build from the start to an integrated solution.

Today the Navy operates and maintains the largest simulation enterprise in the DoD on a 24/7 basis. No scheduling is required to make use of the infrastructure in order to conduct a unit level (single ship) to three carrier strike group exercise. The cost of operations and support is a fraction of what other services and JFCOM pay to support similar efforts on a non- 24/7, event by event basis. The Navy NCTE is the realization of distributed simulation in today's world.

Bob Reddy (Infantryman; retired Army officer; DARPA program manager; SIMNET; trainer; outdoorsman)

There was no precedent or reference book available, so the SIMNET program incrementally "Wrote the Book" on how to do it as we went along. It was high risk to deliver a useable capability while also creating the initial prototype, testing it, and then developing and proving it to soldiers and units. It was the first implementation of distributed interactive virtual simulation.

SIMNET forever changed how training takes place.

Selective fidelity was introduced but it is still not fully understood and can be opposed.

The SIMNET climate was collaborative and innovation and highly valued. The people were very dedicated and this sometimes led to dysfunction via narrow focus as some became very sure of their point of view.

Early demonstrations of technologies in development sometimes backfired as the technology could be very immature and give some people excuses to "doubt" the approach.

To demonstrate that SIMNET Core technology could scale, we designed in STOW-E (Synthetic Theater of War-Europe) in support of a European Reforger, proving the core technology and architecture. The full STOW program followed as one of DoD's Advanced Concepts Technology Demonstrations (ACTDs). This ACTD was judged one of the top 10 ACTD's. This event was not possible without SIMNET.

One of the concepts evaluated at this time was creating a virtual Southwest USA range, integrating all the maneuver ranges in California, Nevada, and the Pacific Ocean off California. While a good idea, each range had its own specific objectives, and an operationally relevant integration was never achieved.

Recently, the Army fielded One SAF – an entity based model – One SAF has its roots in Mod SAF which has its roots in SIMNET SAF 4.3.3. See, it started with SIMNET!

There is so much more to say but it is beginning to sound like bragging.

Bob Richbourg (Ph.D., retired Army officer; Research Staff, Institute for Defense Analysis; previously Professor at West Point; principal involved in reconstruction of the battles around Mazar-E-Sharif, Afghanistan, OEF)

There are several growth areas in MS&G: medical simulations (virtual patients), gaming systems (like America's Army), and cultural modeling.

But there are some challenges, too: for the MS&G architectures (e.g., HLA and DIS) there are no business or management models for DoD. There is a lack of leadership at the DoD level, and thus we have seen the emergence of different approaches without the needed interoperability.

We have seen interoperability at the syntax level (i.e., passing of bits, basic information technology) but not at the more critical semantic level (what do things mean?). This is less of a problem if there are people at each end of a communication, as humans are good at disambiguation. But this is very hard for artificially intelligent agents.

The hardest challenge remains behavioral modeling. We still need "semi-automated" forces, those with direct human control, as we have not solved the fully automated problem.

Some additional observations:

1. Sometimes, you can do a whole lot with a partial solution (selective fidelity, the "better is often the enemy of the good").
2. Goals should be built around a long-range vision
3. Experience is usually the best teacher, but virtual experience can be as good as physical experience if designed correctly (CAT-87 training & its successful outcome).
4. Historical analyses make good learning vehicles; immersive history (for those who made it) allows the capture of more complete history (for those who will study it). (For example, the review process by troops of the 2d ACR during the reconstruction of 73 Easting).
5. The more immediate the reconstruction, the more complete the historical picture.
6. Technology is rarely perfect, but it can be perfectly applied

Jim Shiflett (retired Army Armor Officer; Close Combat Tactical Trainer Program Manager; DARPA Program Manager; SAIC)

The first big idea that drove our development of distributed simulation was that the dynamic nature of warfighting has to have humans involved. Warfare is intrinsically interactive and adaptive. Those that survive adapt and adjust how they conduct operations.

The next big idea was that the "system" was the network. Prior to SIMNET, simulation systems tended to be stand alone applications that ran on a single computer or computers tightly coupled with proprietary network interfaces. There was a constant pursuit of the newest, most capable computer. SIMNET changed the paradigm by allowing humans to interact with computers that were tied together over a general purpose network that used the emerging Internet protocols and commercially available networks to the maximum extent possible.

I believed that the most important technological aspect of the SIMNET program was not the current SIMNET product instantiation of manned modules or the IG system – it was the simple (though we thought complex at the time) SIMNET standards. Products come and go over time and it became quite clear that the commercial computer and graphics technology was expanding at an accelerating pace. What used to be the purview of Defense R&D would be eclipsed by the commercial industry. Look at gaming in the 80's (ATARI and Pong) compared to the 1st person shooter games of today.

Transitioning the SIMNET protocols to the broader Modeling and Simulation community was one of the enduring contributions of the DARPA SIMNET program. A concerted effort was made to find a method to standardize the SIMNET protocols into an open and publically available process. The upcoming solicitation for the Close Combat Tactical Trainer (CCTT) program provided the vehicle, and the work of numerous dedicated people paved the way for the transfer of SIMNET technology from DARPA to the Army. Simulation Interoperability Standards Organization (SISO) and their semiannual workshops along with the IEEE became the venues for opening the SIMNET work to all in a public forum. This allowed the SIMNET standards to move forward and become the IEEE 1278 standards that we have today.

Sometimes we fail to see what is most important and enduring. One of my observations is that we need to "Standardize on Standards – not on

Products". Products come and go, but products adhere to standards. SIMNET standards were well defined and relatively simple. This is not the case for command and control systems, which have many standards, but few have common standards. One can argue that without standards, a technical community cannot advance.

<u>Mike Van Lent</u> (Ph.D.; SOAR Technology; USC Institute for Creative Technology; artificial intelligence)

My experience is deepest in the areas of immersive or game-based training applications for military audiences and the application of artificial intelligence to make these immersive training applications more realistic and/or more effective. After doing this for about 15 years (and producing about 15 applications with varying levels of success) I've learned a few lessons and perspective that I think are worth sharing. While modeling and simulation has a wide range of applications, my experience is mostly with using M&S for training which biases my lessons learned.

Games and game technology have fairly recently emerged as a new area of focus within the military M&S community. While the details differ significantly, at a sufficient level of abstraction games are really just specialized forms of simulations. From my perspective, most of the interest and successes in the application of games and game technology to the military come of three factors:

1. Games have emphasized the value of immersion in capturing the attention of the audience and getting them engaged in the experience. Before the introduction of games there was a great deal of emphasis on realism and validation (both of which are very important) in the M&S community but relatively less emphasis on immersion and actively engaging the audience. This is very much a matter of degrees. Immersion hasn't been absent from the military MS& community (e.g., flight simulators) and realism hasn't been absent from games (e.g., some military themed first person shooter games). Commercial games have caused the community to reexamine the value of immersion relative to other factors. Interestingly, there hasn't been sufficient investigation of the impact of immersion on training effectiveness (that I'm aware of). We don't know enough yet about how being immersed effects training.
2. Game technology represents a new suite of M&S tools that are the product of a completely separate industry. The military M&S community has been developing M&S tools/technologies for decades and many of those technologies are very mature and very well suited to the roles in which they are used. Game technology comes from the commercial game industry and has been developed for a completely different set of goals (i.e., immersion over realism) with different constraints (i.e., shipping a game every 18 months). Much of the recent work in games for the military has been focused on understanding how these new technologies can be applied to the military space.

3. Games (at least single player games) are generally intended to be used with no supporting staff. Players learn how to play games without a human teacher and often without reading the manual. Players can have entertaining experiences playing against the AI (artificial intelligence) built into the game. In contrast, most military simulations rely on instructors, operators, and other forms of supporting staff. This suggests that incorporating more game-like approaches might result in military M&S applications that require less (or no) support staff which could save money and enable distance learning. Personally, I don't believe games provide any magic bullets in this regard. Military M&S systems strive to achieve different (and more challenging) goals than commercial games. The issue is not simply the need for more intuitive M&S interfaces but the fundamentally different objectives. I think achieving these objectives requires human involvement or advanced technologies (beyond the current state of the art in either community) such as intelligent tutoring systems.

With these lessons learned as context, what are some of the future challenges that the M&S community (which I think includes those building game-based applications).

<u>Population Modeling</u>: One of the principles of counterinsurgency is that the center of gravity of a

COIN operation is the support of the local population. The latest doctrine declares that success in COIN hinges on the degree to which the local population supports their government. Thus, effective simulation of COIN operations requires a realistic, culturally specific and reactive model of the population in the area of operation. Who does the population politically support? What are their needs and motivations? How do they think about you, and what are triggers that will drive them to an action? What action? There has been extensive work on "computer generated forces" or models of individuals in kinetic operations including both BLUEFOR and OPFOR. More recently, there's been work on modeling individuals from other cultures to teach cultural awareness and cross cultural social interaction. Modeling populations, including the factions, tribes and organizations within the population and the key individuals who lead or influence the population, is a critical next step to enable effective simulation-based training of the full spectrum of operations.

Dynamic Tailoring of Simulated Experiences: One of the key advantages that good instructors and simulation operators provide (and a reason they are so necessary) is the ability to actively monitor and adjust the training experience in response to the needs of the audience. Good instructors are constantly updating their model of what the students know and don't know and using that model to decide what experiences and challenges will be most valuable. Good operators work closely with the instructors to manipulate the training experience to steer the student towards these valuable training experiences and to adjust the level of challenge to the student's abilities. As discussed above, games do not provide any special solution to this challenge. However, a combination of emerging technologies including student assessment, student modeling, intelligent tutoring and automated experience direction have the potential to help fill this gap in the future for situations where human instructors and operators are not available.

Brian Williams (Research staff, Institute for Defense Analyses; gamer)

From a business perspective:

I still have a sense that the industry, especially the industrial establishment that supports DoD, views the world through a conflict induced supplemental surge funding lens and does not entertain the fact that SIGNIFICANT funding redistributions are necessary and unavoidable. The question might be what does training and learning, MS&G look like in a reduced conflict world. Five years from now when we are reducing our footprint in the world's conflicts and the surge funding has diminished what will the investment dollars be spent on? With what ROI and what purpose? Remember in that world MS&G will be competing for the same few dollars. A "re-sizing," call it rightsizing needs to occur and it will be at someone's expense.

There is still an arrogance about DoD that thinks that the Best game developers want to work with DoD while in fact DoD needs the best Game developers to work with DoD more than the developers need them.

It would be interesting to conduct a lessons learned for two alternative game development by looking at the investment and ROI of contrasting the approaches to the funding and game development of VBS2 and Total immersion.

The reason we are still wrestling with some of the same old questions of interoperability is that we are hesitant to face up to the issue of value creation and value extraction, who invests and who benefits.

Don't build a model when information from other sources will do.

It is about the flow of ideas not the inventory. Bring tech that encourages not discourages idea flow.

Future games:

Where does the whole of government play? Now maybe it is time to look again at a federation, a quilt of different interrelated games that let the all the elements of national power play…not just COIN but diplomacy, reconstruction and stabilization.
The art of story of storytelling in participatory media is advancing. Like early film Gaming is turning from to more subtly of storytelling. It used to be that MS&G used to be about practicing without the risk of loss, maybe we should add loss, and lessons where moral and ethical decisions need to be explored. For example, if we could have these issues in a training scenario then the

teams and their young leaders could rehearse ways in which to reduce early contributors to PTSD. I can't put this into a simple one liner but certainly could talk to it.

When will games truly make it into the systems that we use? While Neale argues for more training out at the tip of the spear I might suggest that we need a different type of command, planning and management game. Managing the "Strategic corporal" is significantly different then commanding in the old days.