THEATERS OF WAR:

THE MILITARY-ENTERTAINMENT COMPLEX

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War games are simulations combining game, experiment and performance. The U.S. Department of Defense (DoD) has been the primary proponent of war game design since the 1950s. Yet, commercial game designers produced many of the ideas shaping the design of military simulations, both before and after the advent of computer-based games. By the 1980s, the seeds of a deeper collaboration among military, commercial designers, the entertainment industry, and academic researchers in the development of high-end computer simulations for military training had been planted. They built "distributed interactive simulations" (DIS) such as SIMNET that created virtual theaters of war by linking participants interacting with distributed software or hardware simulators in real time. The simulators themselves presented synthetic environments—virtual worlds—by utilizing advances in computer graphics and virtual reality research. With the rapid development of DIS technology during the 1990s, content and compelling story development became increasingly important. The necessity of realistic scenarios and backstory in military simulations led designers to build databases of historical, geographic and physical data, reconsider the role of synthetic agents in their simulations and consult with game design and entertainment talents for the latest word on narrative and performance. Even when this has not been the intention of their designers and sponsors, military simulations have been deeply embedded in commercial forms of entertainment, for example, by providing content and technology deployed in computer and video games.

Building on a brief overview of the history of war games, we will sketch the history of military simulations leading to SIMNET in the late 1980s and projects building on this work through the mid-1990s. Changes in government procurement policies, we argue, led the military to spin off many of its key technologies for simulation and training. Their adoption and further development by the game entertainment industry has resulted in the improvement of tools for designing war games. It has also fueled the growth of the video

game industry, which by several measures has reached the level of film and television in its importance as an entertainment medium.[1] During the Cold War it was customary to critique the military-industrial complex as an economic parasite separated from, but living off the free enterprise system. We conclude that the new military-entertainment complex of the 1990s has become a partner of the entertainment industry while transforming itself into the training ground for what we might consider the post-human warfare of the future.

Strategy & Tactics: Traditions of War Gaming

The U.S. Department of Defense defines a war game as "a simulation, by whatever means, of a military operation involving two or more opposing forces, using rules, data, and procedures designed to depict an actual or assumed real life situation."[2] This notion of the war game as a simulation, as an imitation of combat by other means, preceded the use of computer-based models for encoding rules, data, and procedures. War games have taken many forms ranging from large-scale field exercises to abstract strategy games played with maps, counters or miniatures. Because they can be set in reconstructed historical events or imagined scenarios, strategists and military planners use them to rehearse or test strategy, operations and tactics. They accomplish this goal by staging a performance involving people, systems, and technology.

The war college tradition of modern war games began with von Reisswitz's *Kriegsspiel* in the early 19th century.[3] As it developed through many variants over the course of the 19th century, the *Kriegsspiel* established conventions of war gaming, such as identifying the opponents as red and blue, the use of maps and umpires, and fundamental rules for movement and combat resolution. Used as early as the 1820s for officer training in the Prussian military, it was imported to the United States in the early 1880s for training purposes by Major W. R. Livermore of the U.S. Army Corps of Engineers, author of *The American Kriegsspiel.*[4] The founding of the Naval War College in 1884 stimulated naval war gaming in the United States, which emphasized tactical elements such as fleet maneuvers and ship-to-ship engagements.

The circulation and revision of the *Kriegsspiel* among the war colleges of Europe and North America encouraged debates about the game's design. For example, authors of various

versions disagreed about whether rigidly applied rules and tables or the less restricted judgment of referees relying on their own martial experience should govern the game. The so-called *Kriegsspiel libre* introduced by von Meckel and Vernois in the 1870s emphasized the latter. Vernois argued that when the *Kriegsspiel* fell short of its potential value in training officers, the reason was usually "purely on the technical side of leading the game," specifically the difficulty officers experienced with "the rules, the application of dice, and the loss tables." He insisted that the value of such an exercise depended on the capacities of the umpire and the "degree of his military training," rather than rules.[5] Further refinements were added to the several national variants of the *Kriegsspiel*; Livermore, for example, added "fog of war" rules to the American version that reduced each side's knowledge of the other's activities. Yet, the authors of these changes continued to wrestle fundamentally with oppositions such as codified rules versus subjective experience, rigidity versus flexibility, and realism versus playability.

This war college tradition focused on strategic and operational levels of battle, meaning that these simulations explored the decisions that officers would need to make. The best-known tactical and even individual combat (or "skirmish") games were created outside the military establishment as the work of hobbyists. Board games and miniatures were particularly popular. Fred Jane's *Naval War Game* (1912) and H.G. Wells' *Little Wars* (1913) established these modes of playing war games as entertainment.[6] By the 1970s, however, sophisticated war game designs had been created in the commercial sector, beginning with the founding of The Avalon Hill Game Company by Charles S. Roberts in 1958. Roberts' *Tactics* (1952), *Tactics II* (1958) and subsequent Avalon Hill titles established conventions of the modern war game: the Combat Results Table (CRT), the map grid divided into hexagons to regulate movement, the use of printed cardboard counters to represent military units and display their capabilities in numerical form, etc. Just as important, these games shifted the mechanics of game design from abstract strategy or, alternatively, chance to an emphasis on historical realism defined by systems of rules and data, that is, to simulation.

Charles S. Roberts.   Source: The Charles S. Roberts Awards, URL:
http://members.aol.com/TheCharlies/CSRawards.htm.

While Avalon Hill introduced the modern conception of historical war games as simulations, further refinement and popularization of this genre was the work of Simulations Publications Inc. (SPI), led by James F. Dunnigan and a group of game designers that included Redmond Simonsen, Al Nofi, and others. While a student at Columbia University, Dunnigan designed his first game, *Jutland,* for Avalon Hill in 1966.   In 1969, he became the publisher of *Strategy & Tactics* magazine, which had been founded two years earlier. The early issues were analysis of data and rules in existing games, but before long *S&T* published game modules, add-on modules and eventually complete, original games in every issue. Just before taking over the magazine, Dunnigan had founded SPI, which took over publication of *Strategy & Tactics* as well as publishing boxed war games. SPI became the leading publisher of commercial war games, usually called "historical simulations," and disseminated information on military systems and history in the magazine.

In 1976, SPI published *Firefight,* a game that simulated Soviet and U.S. small unit tactics and the first important title in a series of games that examined the "future history" of potential NATO-Warsaw Pact conflict. *Strategy & Tactics* offered an analysis of the military situations simulated in *Firefight,* together with an additional game of contemporary warfare, *Revolt in the East: Warsaw Pact Rebellion in the 1970s,"* designed by Dunnigan and Simonsen.[7] The *Firefight* game system had been conceived and designed for the U.S. Army Infantry School before its release as a commercial game; it probably represented the first collaboration between Dunnigan and then Lt. Col. Ray Macedonia of the U.S. Army. Macedonia was determined to invigorate military war gaming by injecting the design advances, research standards, and modeling of SPI's historical simulations into a revived War College system. The rise of

seminar-like political-military gaming since the 1950s in the Office of the Joint Chiefs of Staff and an "increased civilianization of military affairs" appears to have "cast a long shadow over all gaming techniques" and led to the "virtual castration of wargaming" in the 1960s and early 1970s.[8] Macedonia re-introduced war gaming for staff officer training at the Army War College at Carlisle, Pennsylvania and had asked Dunnigan to consult with him in 1976 as part of the work that led to *Firefight*.

"SPI: The Greatest Selection of Conflict Simulations," Advertising flyer, 1978.

Dunnigan and Macedonia forged the military's first concerted efforts to tap the potential of computer-based war gaming.[9]   In 1977, the Office of Naval Research sponsored "Theater-Level Gaming and Analysis Workshop for Force Planning," a meeting of game designers and defense analysts that included Dunnigan and Andrew W. Marshall, director of Net Assessment for the Department of Defense. Dunnigan recalls the meeting as kicking off a new breed of war games in the U.S. military:

"The rumblings within the professional wargaming community [were] one of the causes of the 1977 Leesburg conference. This was the first gathering of all the major forces in military wargaming. Two others were held, one in 1985 and another in 1991. I was invited to all three, but the first invitation

was a clear sign that things were changing as I was clearly an outsider. It was obvious that the winds of change were blowing strong when Andrew Marshall, a senior official of OSD (Office of the Secretary of Defense) and one of the key sources of funding for professional wargames, got up in front of the assembled multitude and stated bluntly: 'You people have never given me anything I can use.'
When my turn came to speak, I pointed out that what was needed was a wargame the commander could sit down with and operate himself. Having the ultimate user of wargame results actually operate the wargame would save a lot of time, get much better results and eliminate a lot of confusion. It would also enable the commander to experiment with options that he might be reluctant to try through his staff (because the idea, or the results, might prove embarrassing). This last point is important, as the sociology of senior command makes it difficult for a commander to appear ignorant of anything or capable of doing something stupid, especially in front of subordinates."[10]

Marshall was clearly looking for new impulses in war gaming, and after meeting again with Dunnigan, he let a contract to SPI for the development of a new global strategy game, which when completed under Mark Herman in 1980 became the Strategic Analysis Simulation (SAS), a computer-assisted simulation that allowed officers to explore the consequences of their decisions along the lines Dunnigan had outlined at the 1977 conference. Herman had participated in "R&D sessions" at SPI since the mid-1970s, led Victory Games, a game publisher, and later became a professional military analyst. When appropriate data made available from the Falklands War in 1982, results from SAS' Tactical Analysis Module could be validated as being consistent with the outcome.[11]   By the late 1970s, the Army was pushing for more use of computer technology in war games generally, and it turned outside its ranks for fresh ideas.   At the behest of the Army Chief of Staff, Edward C. Meyer, Macedonia took on the task of producing a new architecture for computer-based games. He assigned the project to Fred McClintic, who had previously programmed conversions of several SPI boardgames for use in the War College. The resulting "McClintic Theater Model" (MTM), another conversion of one of Dunnigan's older manual designs, was applied to simulation games sponsored by Army Chief of Staff by November 1980 and became the basis for a series of computer-based theater and operational simulations during the 1980s. Further refinement of MTM by a group at the Jet Propulsion Laboratory and Rolands & Associates Corporation led to the Joint Theater Level Simulation (JTLS) developed in the mid 1980s and in use through the 1990s, thus linking some two decades of commercial and military-sponsored war game design.[12]

The Army led in pushing for more detailed simulations in the early 1980s, but other services joined in over the course of the decade. These efforts included the National Training Center (founded in 1980) and its training facilities, as well as the upgrading of Navy war gaming with the development after 1979 of the Naval War Game System (NWGS), written by Computer Sciences Corporation for the Naval War College and replaced by the Enhanced Naval Wargame System (ENWGS) in 1985. In 1982, the National Defense University also created a war gaming center. During the 1980s, the increasing expense of traditional (live) exercises focused attention on the resource efficiency of simulations.[13] The potential savings was one factor that expanded the scope of game designs in this period, particularly in the linking together of different levels of simulation, such as individual tanks and higher-level unit commands or operational and theater levels of command. This trend was an important factor in the construction of SIMNET and the sophisticated theater-level simulations of the 1990s based in part on MTM.
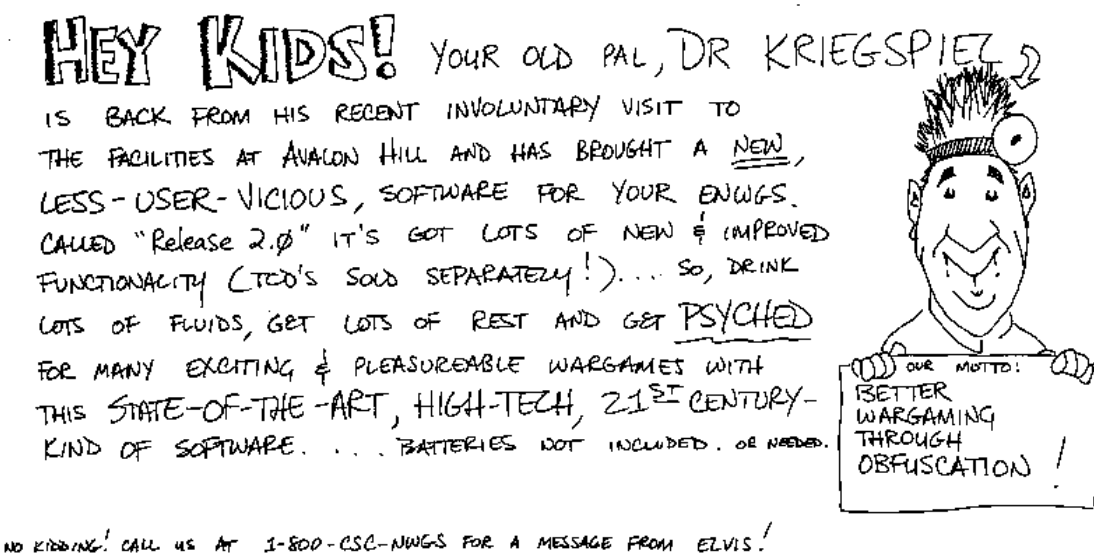
Bill Cooper (?), "Doctor Kriegspiel #3" This cartoon by one of the testers from the ENWGS project refers to release 2.0 (1987), which was designed for Intel 80286/80386 microprocessor-based workstations. Source: Robert Matern, Multics Humor at ENWGS, URL: http://www.multicians.org/enwgs-humor.html.

The value of using computer-based war games as predictive models for combat was demonstrated convincingly before the Gulf War in the summer of 1990. General Norman Schwartzkopf and his staff prepared at the U.S. Central Military Command in Florida for a

potential conflict in this region by playing scenarios of the war game *Operation Internal Look*
designed by Gary Ware. Ware had compiled enormous amounts of data – cartographic and
military – on Kuwait and Iraq, and immediately after the invasion of Kuwait, the war gamers
shifted Internal Look to running variations of the now "real" scenario. They focused on a
group of possibilities revolving around the variant: "What if Saddam keeps on coming right
away?" It took computers about 15 minutes to run each iteration of the forecasted thirty-day
war. As a prediction, Operation Internal Look got good marks. Despite some shifts in the
initial balance of forces, the 30-day simulated air and ground campaign was pretty close to
the real sequence, although the percentage of air and ground action was slightly different.
The ground battle pretty much unfolded as forecasted. Lessons learned from Internal Look
shaped the defensive plan for Desert Shield, and drove home the power of computer
simulation in preparing for war.[14]

The impact of the simulation on future planning and training exercises was discussed by
General H. Norman Schwarzkopf in his memoirs, *It Doesn't Take a Hero* (Bantam, 1992).
Recalling the uncanny similarities between Internal Look and the real thing, Schwarzkopf
wrote: "We played Internal Look in late July 1990, setting up a mock headquarters complete
with computers and communication gear at Eglin Air Force Base in the Florida panhandle.
As the exercise got under way, the movements of Iraq's real-world ground and air forces
eerily paralleled the imaginary scenario of the game....As the war game began, the message
center also passed along routine intelligence bulletins about the real Middle East. Those
concerning Iraq were so similar to the game dispatches that the message center ended up
having to stamp the fictional reports with a prominent disclaimer: 'Exercise Only.' "

Distributed Networks: SIMNET
The biggest boost to military war gaming came from the construction of the DARPA-
funded SIMNET, the military's distributed SIMulator NETworking project. Simulators
developed prior to the 1980s were stand-alone systems designed for specific task-training
purposes, such as docking a space capsule or landing on the deck of an aircraft carrier. Such
systems were quite expensive, for example, more than $30-$35 million for an advanced pilot
simulator system in the late 1970s, and $18 million for a tank simulator at a time when an
advanced individual aircraft was priced around $18 million and a tank considerably less.

High-end simulators cost twice as much as the systems they were intended to simulate. Jack A. Thorpe was brought into DARPA to address this situation based on a proposal he had floated in September 1978. Thorpe's idea was that aircraft simulators should be used to *augment* aircraft. They should be used to teach air-combat skills that pilots could not learn in peacetime flying, but that could be practiced with simulators. Thorpe proposed the construction of large-scale, battle-engagement simulation technology as a 25-year development goal.[15] Concerned about costs for such a system he actively pursued technology developed outside the DoD, including computer and video games.[16] In 1982 Thorpe hired a team to develop a network of tank simulators for collective training. The team that eventually guided SIMNET development consisted of retired Army Colonel Gary W. Bloedorn, Ulf Helgesson, an industrial designer, and a team of designers from Perceptronics of Woodland Hills, California, led by Robert S. Jacobs. Perceptronics had pioneered the first overlay of computer graphics on a display of images generated by a (analog) videodisc as part of a tank gunnery project in 1979.

The SIMNET project was approved by DARPA in late 1982 and began early in the spring of 1983 with three essential component contracts. Perceptronics was to develop the training requirements and conceptual designs for the vehicle simulator hardware and system integration; BBN Laboratories Inc, of Boston, which had been the principal ARPANET developer, was to develop the networking and graphics technology; and the Science Applications International Corporation (SAIC) of La Jolla, California was to conduct studies of field training experiences at instrumented training ranges at the National Training Center in Fort Irwin, California.

Several of the most innovative aspects of SIMNET derived from Thorpe's insistence on affordability during the development of its components. Prior to the late 1980s simulators were typically designed to emulate the vehicles they represented as closely as engineering technology and the available funds permitted. The usual design goal was to reach the highest possible level of physical fidelity—to design "an airplane on a stick." The SIMNET design goal was different and was reminiscent of the "design for effect" approach that had been adopted by board wargame designers earlier. It called for learning first what functions were needed to meet the training objectives, and only then specifying the needs for simulator

hardware. *Selective functional fidelity,* rather than full physical fidelity, was SIMNET's design goal, and as a result, many hardware items not regarded as relevant to combat operations were not included or were designated only by drawings or photographs in the simulator. Furthermore, the design did not concentrate on the armored vehicle per se. Rather, the vehicle simulator was viewed as a tool for the training of crews as a military unit. The major interest was in *collective,* not *individual,* training. The design goal was to make the crews and units, not the devices, the center of the simulations.[17] This approach made possible the design of a relatively low-cost device.[18]

An early crisis threatened to undo the project, however. The visual-display and networking architecture being developed by BBN would not support the SIMNET system concept within the limits of the low-cost constraints. Analyses and expert judgments, from both within and outside of DARPA, indicated that the planned use of available off-the-shelf visual-display technology would not support the required scene complexity within the cost, computer, and communications constraints set by the SIMNET goals. However a proposal from Boeing allowed Thorpe to take advantage of the new generation of DARPA-funded microprocessor advances in VLSI and RISC for development of a new low-cost microprocessor-based computer image generating technology for visual displays. The technology proposed by Mike Cyrus of Boeing met the scene complexity ("moving models") requirements at acceptably low dollar and computational costs. Also, it permitted use of a simpler, less costly networking architecture. The proposed technology would use microprocessors in each tank simulator to compute the visual scene for that tank's own "virtual world," including the needed representations of other armored vehicles, both "friendly" and "enemy." The network would not have to carry all the information in the visual scenes (or potential visual scenes) of all simulators. Rather, the network transmission could be limited to a relatively small package of calibration and "status change" information.[19]

With these architecture and design elements in place SIMNET was constructed of local and long-haul nets of interactive simulators for maneuvering armored vehicle combat elements (MI tanks and M2/3 fighting vehicles), combat-support elements (including artillery effects and close air support with both rotary and fixed-wing aircraft), and all the necessary

command-and-control, administrative and logistics elements for both "friendly" and "enemy" forces. A distributed-net architecture was used, with no central computer exercising executive control or major computations, but rather with essentially similar (and all necessary) computation power resident in each vehicle simulator or center-nodal representation.[20]

The terrains for the battle engagements were simulations of actual places, 50 kilometers by 50 kilometers initially, but eventually expandable by an order of magnitude in depth and width. Battles were to be fought in real time, with each simulated element—vehicle, command post, administrative and logistics center, etc.-being operated by its assigned crew members. Scoring would be recorded on combat events such as movements, firings, hits, and outcomes, but actions during the simulated battle engagements would be completely under the control of the personnel who were fighting the battle. Training would occur as a function of the intrinsic feedback and lessons learned from the relevant battle-engagement experiences. Development would proceed in steps, first to demonstrate platoon-level networking, then on to company and battalion levels, and later perhaps on to even higher levels.

Each simulator was developed as a self-contained stand-alone unit, with its own graphics and sound systems, host microprocessor, terrain data base, cockpit with task-training-justified controls and displays only, and network plug-in capability (Figure 2). Thus, each simulator generated the complete battle-engagement environment necessary for the combat mission training of its crew. For example, each tank crew member could see a part of the virtual world created by the graphics generator using the terrain data base and information arriving via the net regarding the movements and status of other simulated vehicles and battle effects. The precise part of the virtual world was defined by the crew member's line of sight—forward for the tank driver, or from any of three viewing ports in a rotatable turret for the tank commander.

The visual display depended primarily on the graphics generator resident in each simulator. This computer image generation (CIG) system differed in several important characteristics from earlier CIG systems. First, it was microprocessor-based (vs. large mainframe or

multiple minicomputer based), and therefore relatively low in cost (less than $100,000 per simulator visual-display subsystem, vs. more than $1 million per visual channel; typical flight simulators have at least five visual channels). Secondly, it was *high in environmental* complexity with many moving models and special effects, but *low in display* complexity with relatively few pixels, small viewing ports, and a relatively slow update rate of 15 frames per second (vs. the opposite with earlier CIG systems and the technology being developed to improve and replace them). The development of the essentially unique graphics generator for SIMNET was a principal factor in permitting the system to meet the low-cost-per-unit constraint of the plan.
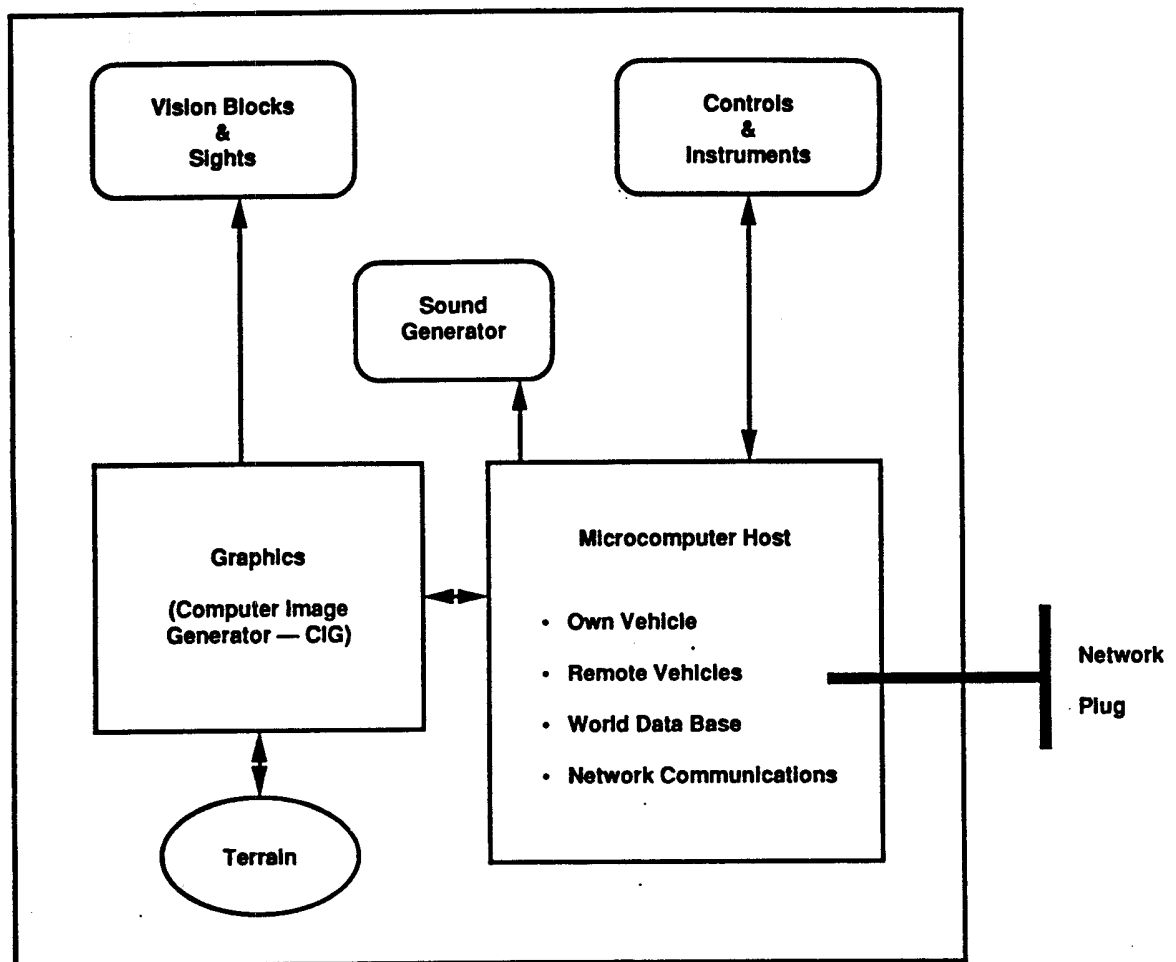
Figure 2. Architecture of a Single M1 (Abrams Tank) Simulator in SIMNET (From J.A. Thorpe, "The New Technology of Large Scale Simulator Networking: Implications for Mastering the Art of Warfighting," in *Proceedings of the 9th Interservice/Industry Training Systems Conference, Nov. 30-Dec. 2, 1987,* American Defense Preparedness Association, 1987, p. 495.)

The architecture of the microprocessor-based graphics generator permitted anyone or any simulator so equipped to connect to the net. This, combined with the distributed computing architecture of the net, provided an extremely powerful and robust system. New or additional elements can be included simply by "plugging into" the network. Once connected to the net, simulators transmit and receive data "packets" from other simulators or nodes (such as stations for combat-support or logistics elements), and compute their visual scenes and other cues (such as special effects produced by the sound system). Because the data packets need to convey only a relatively small amount of information (position coordinates, orientation, and unique events or changes in status), the communications load on the net and the increase in load with the addition of another simulator are both quite modest. Also, where updating information is slow in coming from another simulator, its state can be inferred, computed, and displayed. Then, when a new update is received, the actual-state data are used in the next frame, and any serious discontinuity is masked by the receiving simulator's automatic activation of a transition-smoothing algorithm. Should a simulator fail, the rest of the network continues without its contribution. Thus, network degradations were soft and graceful.

The prototypes and early experiments with SIMNET elements were carried out between 1987-89, and the system was made operational in January 1990. The Army bought the first several hundred units for the Close Combat Tactical Trainer CCTT system, an application of the SIMNET concept, the first purchase of a system that would eventually contain several thousand units at a total cost of $850 million.[21]

The Battle of 73 Easting

The value of the SIMNET as a training system for preparing units for battle became apparent almost immediately during the Gulf War. Hailed as the most significant victory of the war, the Battle of 73 Easting took place on February 26, 1991, just three days into the ground war, between the U.S. 2d Armored Cavalry Regiment and a much larger Iraqi armed force (armed elements of the 50th Brigade of the Iraqi 12th Armored Division). The battle was named for the location at which it occurred: 73 Easting is the north-south grid line on military maps of the Iraqi Desert. The battle lasted from about 3:30 PM until dusk fell at

5:15 PM, and took place in a swirling sandstorm. The U.S. 2d Calvary consisted of M1A1Abrams battle tanks and M3 Bradley fighting vehicles. During the action the cavalry troops destroyed 50 T-72/T-62 battle tanks, more than 35 other armored fighting vehicles, and 45 trucks. More than 600 Iraqi soldiers of the 12th Armored Division and Tawakalna Republican Guard Armored Division were killed or wounded and at least that many more were captured. Immediately after the battle, General Franks, the VII Corps commander, claimed the action of the 2d Cavalry a classic of the cavalry mission to find, fix, and fight the enemy.

It was immediately appreciated that 73 Easting had potential as a simulation for network training on the military SIMNET.[22] The 2d Armored Cavalry had trained intensely before the battle in places ranging from gunnery shoots at Fort Knox, Kentucky, to unit engagements at the National Training Center in California and at Gräfenwohr, Germany. In addition to this field training, the crews of the mechanized vehicles had spent hundreds of hours in training on the SIMNET in the period preceding the battle. A few days after the battle it was decided to capitalize on the SIMNET experience and technologies to record the Battle of 73 Easting for use as a vehicle for networked training in the future. Most of the same team led by Jack Thorpe that had built the SIMNET was assembled once again for the 73 Easting simulation, including Thorpe himself, the Institute for Defense Analyses Simulation Center (IDA) under the leadership of Lieutenant Neale Cosby, BBN as prime technical contractor, Gary Bloedorn (by this time retired) as field documentation leader, and Col. Michael Krause as advisor on military history. Additional expertise was furnished by the Army's Engineer Topographical Laboratories.

Early military simulations incorporated very rote behaviors. They did not capture "soft" characteristics well. An effort to go beyond this was taken by the IDA in their effort to construct a computer-generated "magic carpet" simulation-recreation of the Battle of 73 Easting, based on in-depth debriefings of 150 survivors of a key battle that had taken place during the Gulf War.[23] The goal of the project was to get timeline-based experiences of how individuals felt, thought and reacted to the dynamic unfolding of the events—their fears and emotions as well as actions—and render the events as a fully three-dimensional simulated reality which any future cadet could enter and relive. Going a step beyond the traditional

"staff ride"—a face-to-face post-battle tutorial at the site itself in which a commander leads his staff in a verbal recreation of the skirmish—this tour of a battle site was a simulacrum of the war itself. Work on data gathering for the simulation began one month after the battle had taken place. The data assembled by the team included battle site surveys and interviews with participants. Documentation included action logs, oral and written interviews, recordings from radio nets, and soldiers' own tape recordings made during the battle. In addition, overhead photography made before and after the battle was obtained. On the battle site itself, trained observers marked friendly and enemy positions including tank and other vehicle hulks that littered the terrain. Troopers from the 2d Cavalry accompanied the DARPA team members to reconstruct the action moment-by-moment, vehicle-by-vehicle. The IDA brought the soldiers who had actually taken part and had them sketch out the battle. They walked over the battlefield amidst the twisted wreckage of Iraqi tanks, recalling the action as best they could. A few soldiers supplied diaries to reconstruct their actions. Some were even able to consult personal tape recordings taken during the chaos. Tracks in the sand gave the simulators precise traces of movement. A black box in each tank, programmed to track three satellites, confirmed its exact position on the ground to eight digits. Every missile shot left a thin wire trail which lay undisturbed in the sand. Headquarters had a tape recording of radio-voice communications from the field. Sequenced overhead photos from satellite cameras gave the big view. A digital map of the terrain was captured by lasers and radar.[24]

With this data a team at the IDA Simulation Center spent nine months constructing a simulation of the battle. A few months into the project, they had the actual desert troops, then stationed in Germany, review a preliminary version of the recreation. The simulacra were sufficiently fleshed out that the soldiers could sit in tank simulators and enter the virtual battle. They reported corrections of the simulated event to the technicians, who modified the model. Nine months after the confrontation the recreated Battle of 73 Easting was demo-ed for high-ranking military in a facility with panoramic views on three 50-inch TV screens at the resolution of a very good video game.

The Battle of 73 Easting was viewed as confirmation of Jack Thorpe's original vision for the SIMNET of using networked simulation technology to use history to prepare for the future.

It set the standard of a future genre of training simulations. The simulation provided a link with history, but at the same time a dynamic interactive training vehicle for the future. As a computer simulation with programmable variables, the scenario could be replayed with different endings. Indeed the next step after creating this detailed, accurate historical simulation was to couple it with a war game simulation engine, called Project Odin that had been developed in preparation for Desert Storm by the Neale Cosby and the staff of the IDA. The idea behind Project Odin was to create a simulated electronic environment housed in moving-van sized truck with generator-trailer. Odin was intended for use in the field. It would allow the intelligence officer, the operations officer and the commander to see the battlefield in three dimensions and enable them interactively to zoom to any location to see the arrangement of forces. The knowledgebase for the system was provided by up-to-date intelligence information arriving from the field. By being able to zoom to the different perspectives of the opponent it would be possible to infer the counterpart's intent, and more easily gain mastery of the battlefield. As Neale Cosby explained, the idea was to create a mobile electronic battlefield with semi-automated forces, whose behavior closely emulates that of the enemy.[25] Odin was not designed to destroy targets, but to assist in visualizing the battle about to be entered, or ideally, even going on. SIMNET technology was at the core of Odin. As described above for SIMNET simulation units, Odin combined a digital terrain database of any part of the world; intelligence feeds of friendly and enemy orders of battle (through another DARPA program called Fulcrum); an order of battle generator; a map display with a two dimensional as well as an out-the-window three dimensional display called the "flying carpet"; and a war gaming engine with semi-automated forces using AI components.

The "flying carpet" was the most innovative aspect of the SIMNET machine. It allowed zooming to any part of the battlefield as well as forward or backward jumping in time, from any perspective. Commanders could cruise a computer-generated battlefield that showed the deployment and operations of both allied and enemy orders of battle in two-dimensional and three-dimensional views. The simulated battlefield could be visually displayed from any viewpoint, air or ground, or the overall situation at any moment could be seen on a digitized map. Another important feature of the system was that in 3D mode a popup "billboard" display feature was present which permitted a commander to click on an aggregate of

battalions of armor, for instance, and get a selective representation of different classes of weapons, a useful feature for rapidly inspecting the force layout on the battlefield without all the clutter.

Once the 73 Easting project was completed the IDA project Odin provided a perfect platform for an interactive, predictive simulation. With the simulation database plugged into Odin, it was possible not only to rerun the historical simulation, but change the equipment used by the enemy to test out tactics for other scenarios. For example, it was hypothesized that a major factor that favored the 2d Cavalry in the battle was they had use infrared vision systems to navigate in the sandstorm whereas the Iraqis had only optical sights on their equipment. By adding that feature to the Iraqi equipment it was possible to see how the outcome of the battle would have been affected. In addition multiple Odin simulators could be hooked up to the network all running the 73 Easting database. Soldiers in the simulators and commanders at workstations could break into the simulation and add new tactics. With improvements in processors and graphics cards became available it was imagined that the size of the simulation units could be reduced and actually embedded into M1 tank units, attack helicopters, or F-16s themselves as real soldiers train for an impending mission right up to the hour of the engagement.

From DARPA to Your Local Area Network: Fashioning the Military-Entertainment Complex

Contrary to initial expectations, the military-industrial complex did not fade away with the end of the Cold War. It has simply reorganized itself. The major defense contractors receive more funding today than they ever have. According to William Hartung, as a result of a rash of military-industry mergers encouraged and subsidized by the Clinton administration, the "Big Three" weapons makers—Lockheed Martin, Boeing, and Raytheon—now receive among themselves over $30 billion per year in Pentagon contracts. This represents more than one out of every four dollars that the Defense Department expends on everything from rifles to rockets.[26] While defense spending has not diminished, and seems destined not to in the foreseeable future, a radical shift has occurred in the relationship between defense contracting and the commercial sector. In the early years of the Cold War, when Eisenhower

first called attention to the phenomenon of the military-industrial complex, attempts were made to keep relations between defense contractors and commercial firms either rigidly separate or delicately balanced in a complicated dance. During the late 1980s and early 1990s following the collapse of the Soviet Union and the debates surrounding large government research projects such as the Superconducting Super Collider, policy discussions focused on reorienting defense research spending so that research not only served national defense but also that it ultimately benefited the commercial sector. The new military-entertainment complex is one of the effects of this shift.

With the end of the Cold War, a stronger emphasis was placed during the 1990s on running a fiscally efficient military built on the practices of sound business and of making military procurement practices interface seamlessly with commercial industrial manufacturing processes. With pressure to reduce military spending applied by the Federal Acquisitions Streamlining Act of 1994, the Department of Defense remodeled policies and procedures on procurement (through DOD Directives 5000.1 and 5000.2) that had been in place for over 25 years. Among the policies the new directives established was a move away from the historically based DOD reliance on contracting with segments of the US technology and industrial base dedicated to DOD requirements, moving instead by statutory preference toward the acquisition of commercial items, components, processes and practices. In the new mandated hierarchy of procurement acquisition, commercially available alternatives are to be considered first, while choice of a service-unique development program has the lowest priority in the hierarchy. DOD components were directed to acquire systems, subsystems, equipment, supplies and services in accordance with the statutory requirements for competition set out in directive 10 USC 2304. Organizational changes were required to implement these changes. Adapting technology development and acquisition to the fast-paced high technology sector of the US economy meant adopting simplified flexible management processes found in commercial industry, including the institutionalization of Integrated Product Teams, treating cost as an independent variable, and implementing a paperless procurement system of electronic commerce by the year 2000. Program managers were informed that this mandated change meant that military planners would work more closely with industrial partners in team fashion sharing information on designs and

specifications. In effect these changes, introduced by Secretary of Defense William Perry, have transformed military contracting units into business organizations.

The military SIMNET and the entire field of computer simulation and training was an immediate beneficiary of these economic trends and shift in policy. Given the enormous expense of military aircraft and other armed systems, and given both the cost and political difficulties in arranging large scale training maneuvers, an effective campaign could be mounted in the name of cost-effectiveness in support of military investment in simulation technology. The DOD has been the major source of long-term funding for high-end computer graphics, visualization technologies, and network infrastructure throughout their now more than 30-year history. The perceived importance of simulation to the outcome in the Gulf War provided stimulus for increasing DARPA-supported research and development efforts around SIMNET. STRICOM, the Army's Simulation Training and Instrumentation Command was founded in order to manage and direct the simulation effort. Directive 5000.1 on defense procurement acquisition mandated that models and simulations be required of all proposed systems, and that "representations of proposed systems (virtual prototypes) shall be embedded in realistic, synthetic environments to support the various phases of the acquisition process, from requirements determination and initial concept exploration to the manufacturing and testing of new systems, and related training."[27] The total 1998 budget for programs for modeling and simulation exceeded $2.5 billion.[28] These were not large sums compared to expenditures in other domains of research and by no means matched the computer industry's own R&D investment in graphics at the time, but channeled through the new DOD procurement system intent upon seamless integration into the civilian high-tech industrial sector, these funding programs played an important role in accelerating the development and dissemination of modeling and simulation technologies.

Large DOD Development Programs in Modeling and Simulation

Project Name	Description	Estimated Program Cost ($millions)
Close Combat Tactical Trainer	Networked simulation system for training army mechanized infantry and armor units. It is composed of various simulators that replicate combat vehicles, tactical vehicles, and weapons systems interacting in real time with each other and semiautonomous opposing forces.	$ 846
Battle Force Tactical Training	Tactical training system for maintaining and assessing fleet combat proficiency in all warfare areas, including joint operations. It will train at both the single-platform and battle group levels.	165
Warfighter's Simulation 2000	Next-generation battle simulation for training Army commanders and battle staffs at the battalion through theater levels. It has a computer-assisted exercise system that links virtual, live, and constructed environments.	172
Joint Tactical Combat Training System	Joint effort by the Navy and Air Force to create a virtual simulation at the battle group level in which combat participants will interact with live and simulated targets that are detected and displayed by platform sensors.	270

Synthetic Theater of War (STOW) Advanced Concept Technology Demonstration	STOW is a program to construct synthetic environments for numerous defense functions. Its primary objective is to integrate virtual simulation (troops in simulators fighting on a synthetic battlefield), constructive simulation (war games), and live maneuvers to provide a training environment for various levels of exercise. The demonstration program will construct a prototype system to allow the U.S. Atlantic Command to quickly create, execute, and assess realistic joint training exercises.	442
Joint Simulation System (core)	A set of common core representations to allow simulation of actions and interactions of platforms, weapons, sensors, units, command, control, communications, computers, and intelligence systems, etc., within a designated area of operations, as influenced by environment, system capability, and human and organizational behavior.	154
Distributed Interactive Simulation	A virtual environment within which humans may interact through simulation at multiple sites that are networked using compliant architecture, modeling, protocols, standards, and databases.	500
TOTAL		**$2,549**

SOURCE: U.S. Department of Defense, Office of the Inspector General. 1997. *Requirements Planning for Development, Test, Evaluation, and Impact on Readiness of Training Simulators and Devices*, a draft proposed audit report, Project No. 5AB-0070.00, January 10, Appendix D.

The emergence of the military-entertainment complex has been a direct outgrowth of the new emphasis on simulation and the reorganization of procurement. STRICOM typifies the new-styled military organization resulting from the mandate to leverage non-military industry resources for the development of military programs. This phase of the story points to the impact of the procurement reforms in creating a mutually beneficial synergy between the military and the entertainment industries. In the newly streamlined, flexibly managed military of the 90s, STRICOM is the DOD's executive agent in charge of developing the Advanced Distributed Simulation Technology Program behind much of the military's simulator training efforts. STRICOM has an interesting web presence. On one side of STRICOM's spinning weblogo is a figure in what might be either a space suit or a cleanroom suit worn by a chip worker. In the background are objects that could be tanks or chips on a board. The figure holds what could be a laser gun. Just when the viewer begins to wonder, "Is this a video game?", the reverse side of the spinning logo dispels that illusion. The figure there holds a lightning bolt as a weapon, but is otherwise a traditional helmet-clad soldier. The rim of the logo reads, "All But War Is Simulation."

In its capacity as manager of the military simulation training effort STRICOM arranged a partnership of the San Diego-based Science Applications International Corporation (SAIC) and Lockheed Martin to develop hardware, software, and simulation systems for, among other things, networking simulations in live simulation environments such as SIMNET. Given the new imperative to build on products supplied by commercial industry, one key to success in this program of "integrated product development" is the development of standards for distributed interactive simulations (DIS standards) and the high-level software architecture (HLA) that sets specifications, interfaces and standards for a wide range of simulations.[33] The adoption of these standards across the board by industry and by the American National Standards Institute prepares the ground for assimilating networked videogaming and more robust military simulations.

The STRICOM mode of operating has conditioned the historical evolution of the Post-Cold War effort to create a seamless environment in which research work carried out for the high-end military projects can be integrated with systems in the commercial sector. By 1993, GE

Aerospace had been exploring commercial applications of real-time 3D graphics technology, including work with Sega for its arcade graphics hardware, when it was acquired by Martin Marietta, another leader in the field of visual simulation.[34] Martin Marietta not only advocated expansion of the relationship with Sega, but also encouraged further research and analysis to look at other commercial markets, such as personal computers and graphics workstations. In 1995, Martin Marietta merged with Lockheed Corporation to form Lockheed Martin, and shortly thereafter launched Real 3D, located in Orlando, Florida, home of STRICOM and other simulation laboratories.[35] The startup focused solely on developing and producing 3D graphics products for commercial markets. A strategic alliance was formed in November 1996 between Real3D and Chips and Technologies, Inc. of San Jose, CA to distribute Real 3D®'s R3D/100 two-chip graphics accelerator to professionals who use 3D graphics acceleration on Windows® NT machines.[36] Finally, in December 1997, Lockheed Martin established Real 3D, Inc. as an independent company and Intel announced it had purchased a 20 percent stake in the firm. The technology offered by Real 3D drew upon more than three decades of work in real-time 3D graphics going back to the Apollo Visual Docking Simulator, experience in a variety of projects related to construction of real-time distributed simulations, and considerable intellectual property, consisting of more than 40 key patents on 3-D graphics hardware and software. In turn the company sought to profit from its role as a supplier of commercial videogame technologies developed by companies like Sega to the research community developing military training simulators.

Examination of the work and careers of individuals who have participated in both the military simulation community and the entertainment industry suggests paths through which the dissemination of research ideas across these seemingly different fields takes place. Consider the example of Dr. Robert S. Jacobs, currently director and president of Illusion, Incorporated. His education includes a B.S.E. in systems engineering from the University of California, Los Angeles, an M.S. in management science from the University of Southern California, and a Ph.D. in engineering psychology from the University of Illinois, Urbana-Champaign. Having headed up the design team at Perceptronics that worked on the original design of SIMNET, he has been a technical contributor to the majority of later, related training programs. At Illusion Jacobs has directed the definition, development, and

manufacturing of advanced technology training and simulation products including analytical studies, hardware design, software development and courseware production.

As we have seen, SIMNET has been an incubator for the ideas and technology behind many current-generation video games. WizBang! Software Productions, Inc., which created the 3D environments for *Hyperblade* and Microsoft *Baseball,* is a 3D computer games company founded in 1994. The founders and staff have accumulated years of experience in military simulation, artificial intelligence, traditional gaming, music composition and theater production, as well as game development.[38] Company founder Stuart Rosen's computer game development experience began at Atari, where he became a program manager and oversaw the *Pac-Man* conversion for home computers and video consoles. Rosen also contributed to the design team for one of the first movie-to-computer game spin-offs: Stephen Spielberg's *E.T: The Extra-Terrestrial.* Rosen left Atari to manage the Image Generation Department at Singer-Link Flight Simulation, one of the early companies in the flight simulator business, which built such systems as the Apollo Docking Station and the DC8 flight simulator used in airlines around the world, and many others. For Singer-Link Rosen developed virtual reality databases and advanced modeling tools for pilot training simulators. Rosen then moved to Bolt Beranek & Newman Advanced Simulation, where he led the design, development and integration of networked interactive simulation systems for U.S., British and Japanese forces. This included extensive work on the SIMNET project.[39]

Andrew Johnston, WizBang!'s other founder and president, was also a key contributor to SIMNET. Along with M. Cyrus from Boeing Johnston was the co-founder, vice president and director of engineering of Delta Graphics (later acquired by Bolt Beranek & Newman), and he directed the software development effort for the SIMNET computer-image generating system (CIG), the CAD modeling system for the CIG database, and commercial computer animation software. Prior to that, while at Boeing Aerospace in Seattle, Johnston managed a group of 45 engineers involved in research and development in advanced computer-image generation; he was a key architect of a real-time 3D computer-image generation system under contract with DARPA. This system was the basis of the Boeing B1-B Weapons System Trainer, a large scale computer-image generation system.[40]

The career of Real3D senior software engineer Steven Woodcock provides another career trajectory within the military-entertainment complex. Woodcock was lead software engineer for Gameware Development at Lockheed-Martin Real3D since January 1995. He began his career in the development of game simulations for Martin Marietta. From October 1989 to January 1992, he was senior software engineer and from then until 1995 lead software and technical engineer for Martin Marietta Information Group, National Test Bed. By then, he was responsible for all weapons code development, testing, integration, and documentation for ARGUS, the Advanced Real-time Gaming Universal Simulation.[41] ARGUS was a distributed, interactive command and control simulation focusing on Ballistic Missile Defense (BMD) and Theater Missile Defense (TMD) that ran initially on a TCP/IP network consisting of a Cray-2 supercomputer and more than 50 Silicon Graphics workstations. As noted above, Martin Marietta had contracted with Sega to build the Model 2 arcade platform. Woodcock contributed to that effort. From 1995 until 1997 Woodcock moved from military network simulations to the interactive game industry as lead programmer overseeing all aspects of game development on the Sega-produced *Behind Enemy Lines.* This arcade game featuring a true 3D environment and extensive use of artificial intelligence. Woodcock has noted that his previous experience at Martin Marietta on the NTB and ARGUS from 1989-95 in distributed applications, real-time simulations, and artificial intelligence proved invaluable in designing real-time, 3D, multi-player environments for games such as *Behind Enemy Lines.* During the same period, he worked with Dreamality Technologies in the Intel-initiated Open Arcade Architecture Forum to design the location-based entertainment (LBE) simulator *DreamGlider.* For that project Woodcock adapted the military's Distributed Interactive Simulation (DIS) protocols to support large-scale, many-machine, network connectivity. In 1996 he was also AI and game engine developer for a Sony PlayStation project named *Thundering Death.* On this project Woodcock implemented the first goal-based AI on the PlayStation using neural networks to provide an ever-learning opponent. Such techniques are now stock-in-trade of every videogame.

Welcome to America's Army: Computer War Games and the Game Industry

If the career of Steven Woodcock illustrates the ways in which ideas, technologies, and personnel have flowed from military simulation efforts to the entertainment industries,

DOOM II and *FALCON 4.0*, produced by Id Software and one of Spectrum Holobyte, respectively, demonstrate that the impact of commercial games on military war gaming did not end with SPI. If anything, these games provide glimpses into how the exchange has intensified, with increasing impact of the game industry on military simulation leading to the release in July 2002 of the Army's own commercial war game, *America's Army.* As we shall see, the commercial sector has more than held its share in the flow of technology within the military-entertainment complex.

DOOM was released in December 1993. Its changed the direction of almost every aspect of personal computer-based gaming, from graphics and networking technology to styles of play, notions of authorship, and public scrutiny of game content. The authors of DOOM were a group of programmers led by John Romero and John Carmack, who had started as designers of games distributed with *Softdisk* magazine. Based on the success of games such as the *Commander Keen* series, they formed id Software in February 1991. From the beginning, id focused on the development of superior graphics technology. Carmack had demonstrated that personal computers could produce smoothly scrolling graphics to rival video consoles by writing a version for the PC of Nintendo's *Super Mario Bros. 3.* At id, Carmack turned his attention to 3-dimensional graphics, writing the graphics engine for id's *Wolfenstein 3-D,* an action game published by Apogee. It depicted the action as the player's character would see it, setting the stage for DOOM as the next evolution of this game genre, the "first-person shooter." DOOM added numerous technical and design improvements: a superior graphics engine, fast peer-to-peer networking for multiplayer gaming, a modular design that let authors outside id create new levels, and a new mode of competitive play devised by Romero called "death match." DOOM was a phenomenal success, immediately establishing competitive multiplayer gaming as a leading genre of PC games.

The Ultimate DOOM: Thy Flesh Consumed (id Software, 1995): Source:
http://www.idsoftware.com/games/doom/doom-ultimate/.

The shift in culture of the military with regard to simulation design and the new
procurement policies led from SIMNET to *DOOM.* Marine Corps Commandant Gen.
Charles C. Krulak's directive 1500.55 issued in 1996 aimed at implementing improvements in
what he termed "Military Thinking and Decision Making Exercises." In his comments on
the planning guidance Gen. Krulak wrote: "It is my intent that we reach the stage where
Marines come to work and spend part of each day talking about warfighting: learning to
think, making decisions, and being exposed to tactical and operational issues." He identified
an important way to exercise these skills:

> The use of technological innovations, such as personal computer (PC)-based
> wargames, provide great potential for Marines to develop decision making skills,
> particularly when live training time and opportunities are limited. Policy contained
> herein authorizes Marines to use Government computers for approved PC-based
> wargames.[42]

General Krulak directed the Marine Combat Development Command to assume
responsibility for the development, exploitation, and approval of PC-based wargames. In
addition, they were to maintain the *PC-based Wargames Catalog* on the Internet[43]. With this
incentive a group of Marine simulation experts from the Marine Corps Modeling and
Simulation Management Office in the training and education division at Quantico, Virginia
tracked down a shareware copy of the commercial game *DOOM* produced by Id Software,
Inc. and began experimenting with it. This led to the adaptation of the game as a fire team

simulation, with some of the input for the Marine version coming from Internet *DOOM* gamers employing shareware software tools.[44] Using the shareware tools, the Marines then rewrote the code for the commercial game *DOOM II*. Instead of employing fantasy weapons to face down monster-like characters in a labyrinthine castle, real-world images were scanned into the game's graphics engine along with images of weapons such as the M16(a1) rifle, M-249 squad automatic weapon, and M-67 fragmentation grenades. In place of the monster characters, 3D scans were done of GI-Joe action characters. The game was also modified from its original version to include fighting holes, bunkers, tactical wire, "the fog of war," and friendly fire. *MARINE DOOM* trainees used Marine-issue assault rifles to shoot it out with enemy combat troops in a variety of terrain and building configurations. In addition to training fire teams in various combat scenarios, the simulation can also be configured for a specific mission immediately prior to engagement. For example, Marines tasked with rescuing a group of Americans held hostage in an overseas embassy could rehearse in a virtual building constructed from the actual floor plans of the structure. Users needed only to purchase version 1.9 of the commercial game and add the Marine rewrite code to run the new tactical simulation. The Quantico-based software could not run without the original commercial package, so no licensing violations occurred. Indeed, any personal computer owner with *DOOM II* can download the code for *MARINE DOOM* from the Modeling and Simulation Management Office's web page. You too can become a military assault commando.

The success of the *DOOM II* simulation rewrite led the Marines to look ahead to the next step in commercial war gaming. Discussions with MÄK (pronounced "mock") Technologies (Cambridge, MA), a commercial game manufacturer specializing in network simulation tools for distributed interactive simulations, led to the design of a tactical operations game built to Marine specifications. According to the contract the Marine Corps would help develop the software code and in turn would receive a site license to train on this game, while MÄK would sell it commercially as an official Marine Corps tactical training game. This from-the-ground-up development would eliminate all of the nuances of the other adapted games that are not particular to Marine combat.

MÄK was founded in 1990 by two MIT engineering graduates, Warren Katz and John Morrison. After graduating from MIT both were original members of Bolt Beranek & Newman's SIMNET project team from 1987 to 1990, which developed low-cost, networkable 3D simulators for the Department of Defense. MÄK's corporate goal is to provide cutting-edge research and development services to the Department of Defense in the areas of distributed interactive simulation (DIS) and networked virtual reality (VR) systems and to convert the results of this research into commercial products for the entertainment and industrial markets. MÄK's first commercial product, the VR-Link™ developer's toolkit, is the most widely used commercial DIS interface in the world. It is an application programmer's toolkit that makes possible networking of distributed simulations and VR systems. The toolkit complies with the Defense Department's DIS protocol, enabling multiple participants to interact in real time via low-bandwidth network connections. VR-Link is designed for easy integration with existing and new simulations, VR systems, and games. Thanks to such products, MÄK was ranked 36th in the 1997 New England Technology Fast 50 and 380th in the 1997 National Technology Fast 500 based on revenue growth between 1992 and 1996.

In addition to its work in the defense community, the company's software has been licensed for use by several entertainment firms, such as Total Entertainment Network and Zombie Virtual Reality Entertainment, to serve as the launching pad for real-time, 3D, multi-user video games. One such game, Spearhead, a multi-user tank simulation game released in mid-1998, was written by MÄK and published by Interactive Magic. Spearhead can be played over the Internet and incorporates networking technology similar to that used in military simulations.

MÄK's products use technologies called Distributed Interactive Simulation (DIS) and High Level Architecture (HLA). Both technologies efficiently connect thousands of 3D simulations together on a computer network. Replacing the DIS standard for net-based simulations, HLA has been designated as the new standard technical architecture for all DoD simulations. All simulations were required to be HLA-compatible by the end of 1999. The transition to HLA was part of a DoD-wide effort to establish a common technical framework to facilitate the interoperability of all types of models and simulations, as well as

to facilitate the reuse of modeling and simulation components. This framework includes HLA, which represents the highest priority effort within the DoD modeling and simulation community. MÄK has leveraged its technology for both the military and commercial markets by taking advantage of the nearly $500 million a year spent by the US government on optimizing the speed and capabilities of DIS and HLA. State-of-the-art military DIS systems are now capable of running over 10,000 simulations simultaneously, networked together across far-ranging geographies. As low-cost commercial data services (bi-directional cable TV, ADSL, etc.) became more widely available to consumers, industry analysts projected the market for on-line, 3D, multi-user simulations to reach $2 billion in the year 2000. The networking capabilities of distributed simulation technology developed by MÄK and other government suppliers enables entertainment providers to create platforms for 3D worlds supporting up to 100,000 participants simultaneously. Katz described his vision provocatively in a chapter for the book *Digital Illusion: Entertaining the Future with High Technology*. The chapter is titled "Networked Synthetic Environments: From DARPA to Your Virtual Neighborhood."[45] In the near future MÄK co-founders Katz and Johnson are betting that Internet-based populations the size of a mid-sized U.S. city will be able to stroll through an electronic shopping mall, explore and colonize a virtual universe, or race for prizes in cyberspace's largest 3D road rally.

The contract awarded by the US Marine Corps to MÄK in 1997 served this vision of a vastly shared virtual reality, what might be termed "massively multiplayer" games for the military; it closed the gap between military simulation technology and the technology available to players of games like *Ultima Online* (1997) and *Everquest* (1998). The contract was for *MEU 2000*, a computer-based tactical decision-making game for US Marines which was also be released simultaneously as a commercial computer game. This contract was eventually rewritten to support a new edition of *Spearhead II* developed in cooperation with the U.S. Marine Corps in order to ensure that a high level of realism would be incorporated into the simulation. The special operations unit commander in this multiplayer game will see a battle engagement from a 3-D tactical view, enabling him to select units, issue orders, and monitor the progress of his forces. Each player will be able to assume a position in the command hierarchy of either US or opposing forces. Additionally, players of platform-level simulations will be able to assume their appropriate positions in the command hierarchy. MÄK will use

the same game engine in both its military and civilian versions. The military version will add more accurate details about tactics and weapons, while the civilian game will be less demanding. But both versions will allow multiple players to compete against each other over a local-area network or the Internet.

While a number of military simulations and commercial airline flight simulators have been adapted to the commercial game market, **FALCON 4.0** was the first commercial flight simulation video game to be adapted to military training. **FALCON 4.0** is a network-based game which supports either single player or multiplayer modes. Multiplayer mode supports dogfights with up to four squadrons of four F-16s each. The game's whopping 600-page manual suggests the seriousness of play involved and indicates why the military finds it attractive for its own training purposes. As producer Gilman Louie explains, the **FALCON 4.0** is a detailed simulation re-creating the feel of being an F-16 pilot operating over a modern battlefield. The simulation has a highly accurate flight model and avionics suite that incorporates flight parameters conforming to real-world specifications. **FALCON 4.0** accurately re-creates such effects as deep stall (to escape, the player must use the real-world procedure of flipping the Manual Pitch Override switch and "rocking" the aircraft out—the standard game trick of simply lighting the afterburners won't restore normal flight in this simulation). Weapon modeling is equally realistic and, except for omitting a few classified details, provides an amazingly accurate representation of weapons deployment. The simulation is so detailed, in fact, that reviewers of the game report consulting a real-world "Dash 1" manual for the F-16 when playing the game. The realism of **FALCON 4.0** is further enhanced by graphics generated from actual aerial photographs and map data from the Korean peninsula. In its current version, the game plays best on a computer with a processor of 400 MHZ or higher.

The extreme realism in this video game led Peter Bonanni, graduate of the F-16 Fighter Weapons School and pilot instructor of the Virginia Air National Guard, to work with Spectrum HoloByte Inc. to modify the **FALCON 4.0** flight simulator game for military training. According to Bonanni, **FALCON 4.0** mimics the look and feel of real military aircraft and allows users to play against computer-generated forces or, in a networked fashion, against other pilots, which facilitates team-training opportunities. Another reason for

Bonanni's enthusiasm is the virtual world around the player. Although the product features scripted Tactical Engagement missions as well as an Instant Action mode for newcomers, the heart and soul of the product is the dynamic campaign mode, where the player assumes the role of a pilot in an F-16 squadron during a conflict on the Korean peninsula. The campaign engine runs an entire war, assigning missions to units throughout the theater. A list (displayed either by priority to the war effort or by launch time) shows the missions available to the player's squadron. The player can fly any of these missions, with the freedom to choose air-to-air or air-to-ground sorties. Unlike games with pre-scripted outcomes the campaign engine allows story lines, missions, and outcomes to be dynamically generated. Each play of the game influences the next. If a player is first assigned a mission to destroy a bridge but fails, the next mission may be to provide support to friendly tanks engaged by an enemy that just crossed the bridge.

Networked video games such as **FALCON** *4.0* are emblematic of the calculated emergence of a military-entertainment complex but also of the fusion of the digital and the real happening around us. It is hardly surprising that Bonanni not only helps adapt the video game to military training needs but also writes a regular column for the www.falcon4.com website on tactics and has designed several of the 31 pre-built training missions included with the game. He is co-author of two best-selling books on **FALCON** *4.0*, one with colleague James Reiner, also an F-16 instructor pilot and graduate of the F-16 Fighter Weapons School, and like Bonanni a consultant on the game. Beginning with some basics on the game and the various gameplay options, **FALCON** *4.0: Prima's Official Strategy Guide* gives readers a guide to instant action missions, multiplayer dogfights, and full-fledged campaigns. The book is a serious no-nonsense manual, devoting separate chapters to laser-guided bombs and even the AGM-65 Maverick missile. Bonanni's second book, **FALCON** *4.0 Checklist,* is scheduled to appear soon and is already high on the Amazon.com sales list before it has even hit the bookstores. Recalling that *Ender's Game* has been taught in flight schools, would-be Falcon pilots will probably want to add a copy to their Amazon.com shopping cart for inspirational reading.

The two-way flow of people and technology we have described provides mutual benefit to the military simulation effort and the video game industry. For example, the military has tracked the development of "first-person shooter" games from id Software's release of its

code and level editor for *DOOM,* used for the first tactical shooter designed for military training, to the adoption of the *Unreal* game engine used in *America's Army.* At the same time, the game industry has benefited from people like Woodcock, Katz and Morrison skilled in networking and artificial intelligence, who have added a whole new dimension to commercial games. But following the initial spurt of innovation contributed by the new companies spun off from former defense contractors, the subsequent development has been heavily weighted in terms of contributions from the game industry. Interestingly, this trend in game design closely parallels computer graphics technology. In the graphics market, Silicon Graphics, which had specialized in high-end simulations, learned from its collaboration with Nintendo to adapt development cycles to the game industry's demand for new and improved products on the shelf every December. A group of young SGI engineers decided to spin off a new company, Nvidia to create graphics chips specifically targeted at the computer game industry's demand for realism in graphics, while allowing for rapid and smooth upgrades from version to version. The result has been a new generation of graphics-intensive games. Military technology, which once trickled down to civilian use, now usually lags behind what is available in games, rides and movie special effects. As STRICOM Chief Scientist and Acting Technical Director Dr. Michael Macedonia, the son of Ray Macedonia, wrote in a recent article in *Computer*:

> As Siggraph—the computer-graphics community's showcase—has demonstrated over the past several years, the demands of digital film development are making way for computer games' even more demanding real-time simulation requirements. As a mass market, games now drive the development of graphics and processor hardware. Intel and AMD have added specialized multimedia and graphics instructions to their line of processors in their battle to counter companies such as Nvidia, whose computer graphics chips continue breaking new performance boundaries.[46]

The Institute for Creative Technology

Until the last two or three years these crossovers from military simulations and the entertainment industries have been unplanned and opportunistic. In December of 1996 the National Academy of Sciences, acting on the initiative of Professor Michael Zyda, a computer scientist specializing in artificial intelligence at the Naval Postgraduate School in

Monterey, California, hosted a workshop on modeling and simulation aimed at exploring mutual ground for organized cooperation between the entertainment industries and defense.[47] The report and follow-up proposal by Michael Zyda stimulated the Army in August 1999 to give $45 million to the University of Southern California over the next five years to create a research center to develop advanced military simulations. The research center has enlisted film studios and video game designers in the effort, with the promise that any technological advances can also be applied to make more compelling video games and theme park rides. The idea for the new center, called the Institute for Creative Technologies, reflects the fact that although Hollywood and the Pentagon may differ markedly in culture, they now overlap in technology. In opening the new Institute for Creative Technology Secretary of the Army Louis Caldera said, "We could never hope to get the expertise of a Steven Spielberg or some of the other film industry people working just on Army projects." But the new institute, Caldera said, will be "a win-win for everyone."

While putting more polygons on the screen for less cost is certainly one of the military's objectives at the Institute for Creative Technologies and in similar alliances, other dimensions of simulated worlds are equally important for their agenda. Military simulations have been extremely good at modeling hardware components of military systems. Flight and tank simulators are excellent tools for learning and practicing the use of complex, expensive equipment. However, movies, theme park rides, and increasingly even video games are driven by stories with plot, feeling, tension, and emotion. To train for real world military engagements is not just to train on how to use the equipment but how to cope with the implementation of strategy in an environment with uncertainties, surprises, and participants with actual fears. As Marine Corps Commandant Gen. Charles C. Krulak's directive on "Military Thinking and Decision Making Exercises" emphasized, decisions made in war must frequently be made under physical and emotional duress. The directive stated that the PC-based wargame exercises in peacetime should replicate some of the same conditions: "Imaginative combinations of physical and mental activities provide Marines the opportunity to make decisions under conditions of physical stress and fatigue, thereby more closely approximating combat."[48]

How might the interest in pursuing this line of development in new settings like the Institute for Creative Technology (ICT) proceed? The directions of research previously pursued by the Institute's principal staff give us an indication. Prior to the launch the focus of work by several key members of the ICT was on constructing semi-automated forces and multiple distributed agents for virtual environments, such as training programs. Others in the ICT work on building models of emotion for use in synthetic training environments. The work of professors Jonathan Gratch and Jeff Rickel are prototypical. Prior to the formation of the ICT these researchers had been working on the construction of intelligent agent technology for incorporation into state-of-the-art military simulation systems. More interested in modeling training behaviors, they have not been particularly interested in developing "believable agents" for video games or film. The goal of one of their projects is to develop command and control agents that can model the capabilities of a human military commander, where commander agents must plan, monitor their execution, and replan when necessary.

At the opening ceremonies of the ICT, Richard Lindheim the executive director outlined several projects the institute would be pursuing. Among those he described was a construction of what he referred to as "the holodeck." The idea, Lindheim explained, is to leverage new media technologies of virtual reality to link immersive virtual environments with interactive synthetic agents, so-called synthesbians, that are elements of simulation- and game-based learning exercises. Some examples of the programs that have been underway at the ICT are the Mission Rehearsal Exercise, the Advanced Leadership Training Simulation, and the ICT Games Project.

One of the scenarios completed in the Mission Rehearsal Exercise creates a training situation to help train soldiers heading for combat, peacekeeping and humanitarian missions. In the interactive scene you are an American soldier in Boznia-Herzegovnia whose Humvee has accidentally struck a civilian vehicle and injured a young child. A soldier stands, awaiting orders on whether to continue with the mission or call for Medivac assistance. "Sir, we should secure the assembly area," he says—a platoon already in position is expecting your arrival as backup. Along the cobbled streets, a crowd has gathered. A TV crew is now on the scene. A helicopter circles overhead. Tension mounts. The five-minute scenario is projected

onto a 150-degree movie screen, complete with 10.2-channel audio that creates floor-shaking sound effects. To enhance the sense of reality, smells including burned charcoal can be pumped into the room. Participants can gesture and touch objects and elicit responses in the simulator. The machine also uses voice recognition technology and different languages to allow participants to converse with the characters they encounter. The designers of this simulation, led by Jonathan Gratch, have spent considerable time trying to make this artificial intelligence respond in unpredictable ways so the experience is slightly different each time the system is used. Other simulations are being constructed to train soldiers for circumstances too dangerous for real-life training—for example, a chemical spill. The goal of constructing "the holodeck" is to create the type of technology that allows teams of soldiers to be embedded in any environment. By 2008, ICT hopes to take the experience off the movie screen and compress it into a helmet, which users can wear to experience virtual reality anytime, anywhere.

Conclusion:

On Independence Day, 2002, the traditional summer blockbuster date in the entertainment industry, the US military released its new videogame, *America's Army: Operations*. Designed by the Modeling, Simulation, and Virtual Environments Institute (MOVES) of the Naval Postgraduate School in Monterey, California, the game, intended as a recruiting device, is distributed free on the internet. Produced with brilliant graphics and the most advanced commercial game engine available (the *Unreal* game engine) at a cost of around $8 million, the game is a first-person multiplayer combat simulation that requires players to complete several preliminary stages of combat training in an environment mirroring one of the military's own main training grounds—cyber bootcamp. On the first day of its release the military added additional servers to handle the traffic, a reported whopping 500,000 downloads of the game. The site continued to average 1.2 million hits per second through late August 2002. *Gamespot*, a leading review, not only gave the game a 9.8 rating out of a possible 10, but also regarded the business model behind the new game as itself deserving an award.

As the military's new blockbuster videogame illustrates, the military-industrial complex, contrary to initial expectations, did not fade away with the end of the Cold War. It has

simply reorganized itself. In fact, it is more efficiently organized than ever before. Indeed, a cynic might argue that whereas the military-industrial complex was more or less visible and identifiable during the Cold War, today it is invisibly everywhere, permeating our daily lives. The military-industrial complex has become the military-entertainment complex. The entertainment industry is both a major source of innovative ideas and technology, and the training ground for what might be called post-human warfare.

The rise of the military-entertainment complex is not without a certain irony. Military-supported games, it turns out, are considerably less violent than their competitors. *America's Army: Operations*, for instance, renders only a puff of blood when a player is hit. *Real War*, another game commissioned by the military from Rival Interactive and simultaneously released as a commercial product, is rated "Teen" because of its lack of gore. Although Rival Interactive's president James Omer defends the game as a strategy challenge, not an actual simulator, several online game reviews have criticized this game and other military-funded game projects for not being realistic enough. Calling the movements in *Real War* jerky and cartoonish, *Gamespot* gave the game a "3" out of "10".

What scores a "10" in the game community? Games like Rock Star Games' *Grand Theft Auto*, a role-playing game in which the player, betrayed and left for dead, curries favor with mob bosses and crooked cops while avoiding a lethal street gang, or Max Payne, where a fugitive undercover cop framed for murder is hunted by the mob. To date, the ICT has not followed the game industry strategy of opening its game editor and level design software to the mod developer community, but if their intent is truly to leverage the commercial market for military interests in the new era of cyberwarfare, that step cannot be far behind. Indeed, it may not even be necessary: the Unreal game engine used by the MOVES Institute for *America's Army* has spawned a very large mod community of its own, visible, for instance, on the PlanetUnreal.com website. One group currently recruiting there is developing a mod based on the Unreal engine called *Terrorism: Fight for Freedom*, expected to be completed in early 2003., the architects of this multi-player web-based game--a distributed multi-national group-- describe their project in an update from August 11, 2002, as "a modern-day, small-scale warfare Total Conversion for Unreal Tournament 2003. The mod is based upon wars that are currently occurring in the world."

The military is using newly-minted best practices of game design and business models to compete in the arena for young highly-trained cyberwarriors. In a post 9-11 world where distributed collaboration in a military context has come to signify "terrorist cells," the potential mods based on the Unreal engine conjure up an all too frightening potential *reality*. No doubt somewhere, either in the game industry itself or among the worldwide community of mod builders, a group is currently developing a cyberterrorist game based on attacking the computer infrastructure of a country, disabling its power grid, infiltrating its financial networks, and hacking into mainstream news media such as the *New York Times* to confuse the public about what's going on. Will this be a market in which the U.S. military can choose (or afford) not to compete?
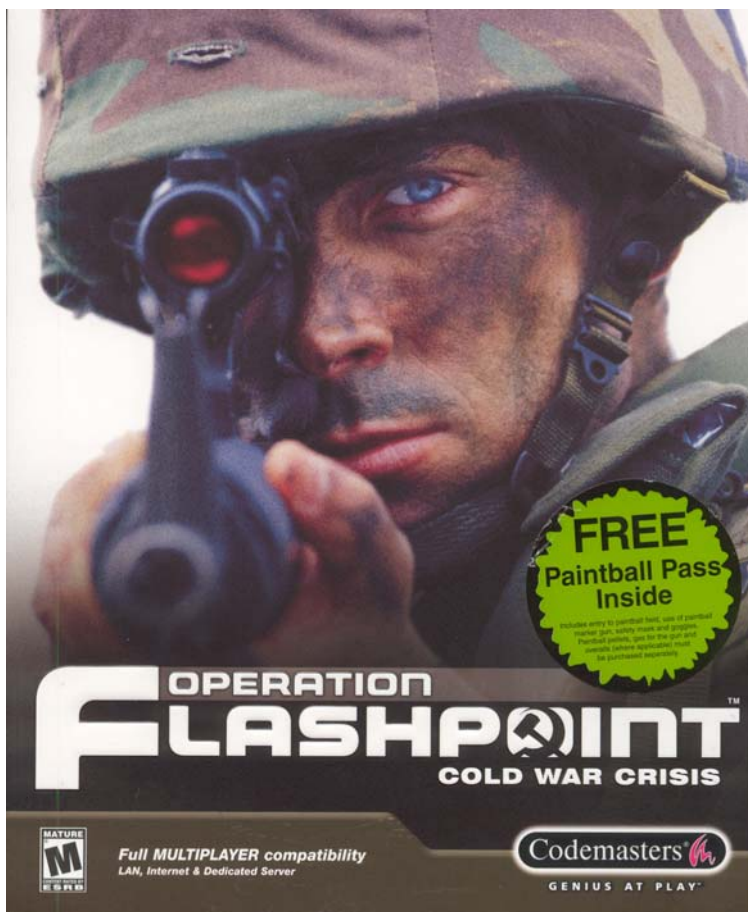
Operation Flashpoint (Bohemia Interactive and Codemasters, 2001).

Endnotes

[1] Two of the statistics cited frequently as evidence of the growth of videogames as a popular medium are annual revenues and "eyeball time." Sales of computer and video games in the United States alone, including hardware and accessories, exceeded $10 billion in 2001; box-office receipts in the U.S. movie industry, by comparison were about $8.35 billion, itself a record total. Global sales of hardware and software are expected to exceed $30 billion in 2002. The publishers of *Half-Life: Counterstrike,* the most popular multiplayer game, reported some 3.4 billion player-minutes per month in mid-2002, exceeding estimates based on viewership ratings for time devoted to even the highest-rated U.S. television shows. Another measure: With roughly 1.5 billion movie admissions per annum, less than 15% of the U.S. population attends movies every week (down from 46% after World War II); by comparison, statistics gathered by Peter D. Hart Research and cited by the Interactive Digital Software Association suggest that 60 percent of the American population played "interactive games on a regular basis" in the year 2000. Khanh T. L. Tran, "U.S. Videogame Industry Posts Record Sales," *Wall Street Journal* (Feb. 7, 2002); Valve L.L.C., "Valve Unveils Steam At 2002 Game Developer's Conference," (Press Release, March 21, 2002); Sharon Waxman, "Hollywood's Great Escapism; 2001 Box Office Receipts Set a Record," *The Washington Post* (Jan. 4, 2002); Anne Valdespino, "The Big Screen Keeps Pulling Us In," *Los Angeles Times* (July 1, 2002); Interactive Digital Software Association, *Essential Facts about the Computer and Video Game Industry* (Washington,D.C.: IDSA, 2000): 5, also available a

[2] Joint Chiefs of Staff (JCS) *Publication 1, Department of Defense Dictionary of Military and Associated Terms* (Washington, D.C.: G.P.O., 1987): 393.

[3] Georg Heinrich Leopold von Reiswitz, Freiherr v.Kaderzin und Grabowska, *Anleitung zur Darstellung militairischer Manöver mit dem Apparat des Kriegs-Spieles* (Berlin: Trowitzsch, 1824). The *Anleitung* has been translated into English as: *Kriegsspiel : Instructions for the Representation of Military Manoeuvres with the Kriegsspiel Apparatus,* trans. Bill Leeson]. 2nd ed. Hemel Hempstead : Bill Leeson, 1989.

[4] William Roscoe Livermore, *The American Kriegsspiel: A Game for Practicing the Art of War upon a Topographical Map* (Boston : Houghton, Mifflin, 1882).

[5] "Vorwort," in: Julius von Verdy du Vernois, *Beitrag zum Kriegsspiel* (Berlin: Ernst Siegfried Mittler & Sohn, 1876),

[6] Herbert George Wells, *Little wars; a Game for Boys from Twelve Years of age to one Hundred and Fifty and for That More Intelligent Sort of Girls Who Like Boys' Games and Books.* (London, F. Palmer [1913]); Fred T. Jane, *How to Play the "Naval War Game": With a Complete Set of the Latest Rules, Full Instructions, and Some Examples of "Wars" That Have Actually been Played* (London: S. Low, Marston & Co., [1912])

[7] Stephen B. Patrick, "Firefight: U.S. and Soviet Small Unit Tactics," and James F. Dunnigan and Redmond Simonsen, "Simulation. Revolt in the East: Warsaw Pact Rebellion in the 1970s." *Strategy & Tactics* 56 (May-June 1976).

[8] Peter P. Perla, *The Art of Wargaming: A Guide for Professionals and Hobbyists* (Annapolis: Naval Inst. Press, 1990): 108-114.

[9] Perla, *Art of Wargaming*: 147-50. Also, Thomas B. Allen, *War Games: The Secret World of the Creators, Players, and Policy Makers Rehearsing World War III Today* (New York: McGraw Hill, 1987).

[10] James F. Dunnigan, "Wargames at War: Wargaming and the Professional Warriors," Chapter 9 of *The Complete Wargames Handbook,* updated web edition of 3d edition published in 2001. Available at: http://www.hyw.com/Books/WargamesHandbook/9-3-wpw.htm.

[11] Perla, *The Art of Wargames*: 241.

[12] James F. Dunnigan, "Genealogy of Computer Wargame Technology," from *The Complete Wargames Handbook*. Available at: http://www.hyw.com/Books/WargamesHandbook/6-3-gene.htm. On the link from MTM to JTLS, see Ellen F. Roland; Patrick A. Sandoz; Edward P. Kelleher, Jr.; and Ronald J. Roland, "The History of Joint Theater Level Simulation," Rolands & Associations Corporation website, available at: http://www.rolands.com/Pdf/JTLS_History.pdf. Also: Ronald J. Roland; Ellen F. Roland; and Edward P. Kelleher, Jr., "Approaches and Aspects of Implementing a Computer Wargame Simulation: A Historical Perspective." White Paper, Rolands & Associates Corporation, Jan. 1989, available at: http://www.rolands.com/Pdf/treatise.pdf.

[13] Arguments for the cost effectiveness of simulation had also been the foundation for hardware flight simulators. Link, which had provided trainers to the Navy and Army since the early 1930s, cited budget savings, as well as efficiency and safety, in the proposal to the Air Force that led to development of the first jet simulator, the C-11, in 1949. The argument was based on data from the 1930s and later experiments, summarized in: R. E. Flexman; S. N. Roscoe; A. C. Willliams; and B. H. Williges, *Studies in Pilot Training: The Anatomy of Transfer* (Urbana: Univ. of Illinois at Urbana-Champaign, College of Engineering, 1972). For a summary of the 1949 proposal, see *Virtual Reality and Technologies for Combat Simulation* (Washington D.C.: Office of Technology Assessment, Congress of the United States, 1994): 7-9.

[14] SEE HENRY's NOTE IN THE TEXT.

[15] J.A. Thorpe, "Future Views: Aircrew Training 1980-2000," unpublished concept paper at the Air Force Office of Scientific Research, 15 September 1978, discussed in Richard H. Van Atta, Sidney Reed, and Seymour J. Deitchman. *DARPA Technical Accomplishments: An Historical Overview of Selected DARPA Projects, 3 Volumes,* Institute for Defense Analysis, IDA Paper P-2429, 1991: Vol. 2, chapter 16, p. 10. Harris, M., "Entertainment Driven Collaboration," Computer Graphics, 28,2, May 1994, pp. 93-96 argues that SIMNET was inspired by the Atari game Battlezone.

[16] Ibid., note 50. Chapter 16, p 10.

[17] The training concept was to provide a means of cueing individual behavior, with the armored vehicle being part of the cueing. When individuals and crews reacted, they would provide additional cues to which others would react. Thus, the technology was to play a subservient role in the battle-engagement simulations, making no decisions for the crews, but rather simply and faithfully reproducing battlefield cues.

[18] Van Atta, Chapter 16, p. 13.

[19] Once the decision to remove BBN from the graphics portion of the project Cyrus then left Boeing and formed an independent company, Delta Graphics, in order to devote his full energies to developing the graphics technology for SIMNET. The initial contractor, BBN, continued with responsibility for the network technology, but with the needed change in architecture, i.e., with use of microprocessor-based graphics generators.

[20] See J.A. Thorpe, "The New Technology of Large Scale Simulator Networking: Implications for Mastering the Art of Warfighting," in *Proceedings of the 9th Interservice Industry Training Systems Conference, November 30-December 2, 1987,* American Defense Preparedness Association, 1987,492-501.

[21] R.J. Lunsford, Jr., *US Army Training Systems Forecast, FY 1990-1994*, Project Manager for Training Devices (US Army Materiel Command), Orlando, Florida, October 1989, p. 14. Cited in Van Atta, Chapter 16, p. 31.

[22] F. Clifton Berry, Jr., "Re-creating History: The Battle of 73 Easting," *National Defense*, Nov. 1991.

[23] Ibid. Also see the discussion of the Battle of 73 Easting in Bruce Sterling, "War Is Virtual Hell," *Wired Magazine*, Vol 1, No. 1, January 1993, online at: http://www.wired.com/wired/archive/1.01/virthell.html?topic=&topic_set= see especially pp. 6-7 of the online article.

24 Berry, "Re-creating History." Also discussed in Kevin Kelly, "God Games: Memorex Warfare" from *Out of Control*, (New York; Addison Wesley, 1994): http://panushka.absolutvodka.com/kelly/ch13-e.html

25 Personal communication.

26 William D. Hartung, "Military Monopoly," *The Nation*, January 13/20, 1997.

27 DoD Directive 5000.1, March 15, 1996, Section D: Policy, Para 2: Acquiring Quality Products, item (f): Modeling and Simulation.

28 U.S. Department of Defense, Office of the Inspector General. 1997. *Requirements Planning for Development, Test, Evaluation, and Impact on Readiness of Training Simulators and Devices*, sited by Committee on Modeling and Simulation, *Modeling and Simulation: Linking Entertainment and Defense*. Washington, D.C.: National Academy Press, 1997, Table 1.1, p. 17.
http://www.nap.edu/readingroom/books/modeling/table1.1.html
http://www.nap.edu/readingroom/books/modeling/ (main url)

29 In 1999 video games alone grossed $6Billion. According to a recent survey by *Entertainment Weekly* of entertainment preferences in American households 35% listed reading books as their favorite entertainment. In second place was playing video games at 30%, while watching a video ranked 17%.

30 According to responses in interviews I have done for a project on the development of computers in medicine and frequently mentioned in articles for the popular press.

31 Real3D went out of business in October, 1999. The numerous patents held by the company were bought by Intel and many of the people went back to contracting for Lockheed Martin. See WAVE Report, Issue 9099, 10/20//99.
http://www.wave-report.com/1999%20Wave%20issues/wave9099.html#anchor27942

32 See the discussion by Jeffrey Potter of Real 3D *in Modeling and Simulation: Linking Entertainment and Defense*, pp. 164-165.

33 For the program description see: http://www.stricom.army.mil/STRICOM/PM-ADS/ADSTII/

34 TIM, CAN YOU CITE YOUR EALIER PAPER HERE? YOU COVERED REAL3D THERE.

35 The National Center for Simulation was founded in Orlando in 1994 and includes a group for "Entertainment and Simulation."

36 The R3D/100 chipset directly interfaces with Microsoft® compliant APIs (application programming interfaces), such as OpenGLª.

37 See the press release on the Open Arcade Architecture forum:
http://www.intel.com/pressroom/archive/releases/CN71497B.htm
Also see the speech by Andy Grove at the June 20, 1997 Atlanta Entertainment Expo, "The PC Is Where the Fun Is," http://www.intel.com/pressroom/archive/speeches/asg62097.htm

38 See "Company" at: http://www.wizbang.com/

39 Ibid.

40 Ibid.

41 For Steven Woodcock's bio see: http://www.cris.com/~swoodcoc/stevegameresume.html Also see Steven

Woodcock Interview on the future of AI technology and the impact of multi-player network-capable games in *Wall Street Journal Interactive Edition* (May 19, 1997). Also see Donna Coco, "Creating Intelligent Creatures: Game Developers are Turning to AI to Give Their Characters Personalities and to Distinguish Their Titles from the Pack," *Computer Graphics World*, July 1997, Vol. 20, No. 7, pp. 22-28.
http://www.cgw.com/cgw/Archives/1997/07/07story1.html

[42] General Charles C. Krulak, Marine Corps Order 1500.55, "Military Thinking and Decision Making Exercises," online at http://www.tediv.usmc.mil/dlb/milthink/

[43] For the PC-Wargames Catalog, see: http://www.tediv.usmc.mil/dlb/milthink/catalog/title.html

[44] For an interesting discussion of Marine Doom, see Rob Riddell, "Doom Goes to War: The Marines are Looking for a Few Good Games," in *Wired Magazine*, Vol 5, No. 4, April 1997. Online at:
http://www.wired.com/wired/archive/5.04/ff_doom.html?topic=&topic_set=

[45] The book is published by Addison-Wesley. For more information, visit http://www.aw.com/cseng/.

[46] Michael Macedonia, "Why Digital Entertainment Drives the Need for Speed," *Computer*, Vol 33, no. 3, 2000:
http://www.computer.org/computer/co2000/r3toc.htm

[47] Cited in Note 38 above: Committee on Modeling and Simulation, *Modeling and Simulation: Linking Entertainment and Defense*. Washington, D.C.: National Academy Press, 1997.
http://www.nap.edu/readingroom/books/modeling/ (main url)

[48] Loc. Cit. Note 49 above.