Army Simulations: Moving Toward Efficient Collective Training Sims

A Monograph
by

Major Brian K. Gates
United States Army

School of Advanced Military Studies
United States Army Command and General Staff College
Fort Leavenworth, Kansas
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Major Brian K. Gates

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Approved by:

_____ Monograph Director
William J. Gregor, Ph.D.

_____ Director, School of Advanced Military Studies
COL James K. Greer, MMAS

_____ Director, Graduate Degree Program
Philip J. Brookes, Ph.D.

Abstract

ARMY SIMULATIONS: MOVING TOWARD EFFICIENT COLLECTIVE TRAINING SIMS by Maj Brian K. Gates, U.S. Army, 50 pages.

The U.S. Army spends millions of dollars to develop and implement simulations for training. Simulations allow the Army to train commanders and staffs in a wide range of tasks. Simulations have evolved into complex software and hardware programs designed to allow the Army to conduct collective training using wide area networks to increase the scope of training events. The Army has placed great emphasis on simulations as part of efforts to reduce training costs. These collective training tools have become vastly more complex and greater in scope,

This monograph asks whether or not the simulations currently being run to conduct collective training and those that are planned for the future can be more efficient. Current simulations are not as interoperable and portable as they can be. Portability and interoperability are important in allowing simulations to be accessed from a variety of locations and computers. Simulations do not employ like technologies; they are not developed with specific training objectives in mind; and they are not subject to a single unifying set of standards. The Army can save both in personnel costs and transportation by increasing access to simulations.

There are several reasons that simulations are not as efficient as they can be. The Army is not applying a unifying, specific set of technology standards to the models and simulations community that is compatible with the rest of the Army's architecture. Additionally, the simulations are being built to meet very general goals and objectives. The lack of specific goals enables programs to seek greater, and perhaps unneeded, fidelity in simulations and the latest technology. This technology is not compatible with the rest of the Army's architecture.

The monograph concludes that the collective training simulations can be made more portable and interoperable. The Army should provide greater standardization to the M&S community. Additionally, The Army should identify specific training objectives that simulation systems can be measured against. Finally, The Army should determine to what degree simulation activities should be executable from outside the M&S architecture. These steps would represent an even greater effort to maximize the Army's current technology and maximize the portability of simulation.

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INTRODUCTION AND BACKGROUND

The U.S. Army continues to develop and formalize the use of computer-based simulations for training. These simulations are used to train soldiers, leaders and staffs from the tactical level through Corps level. The scope of these simulations has grown, linking corps-level simulations with both joint and lower-level tactical simulations. To enable more complex simulations training efforts, the Army has become reliant on networking computers to run simulations. Evolving from simple electronic simulators for tank gunnery, the Army's Simulation Network (SimNet) has fueled many advancements in distributed networking.

Originally most simulations used networks to link dumb terminals to a central computer that performed the modeling and control functions. . Gradually, the Army developed simulators that could determine likely engagement results and portray the battlefield by performing modeling and calculations functions, thereby allowing a common picture to be sent to individual tank crews across a network[1]. Over the same period, collective training systems, beginning with the first field training exercise (FTX) driven by a simulation, have continued to become more complex. In the past, the U.S. Army bought expensive, powerful mainframe computers and mid-range servers to run these collective training simulations. Advancements in networking technologies and continual increases in the power of individual processors have decreased reliance on mainframe computers for most simulations. Many simulations now rely on smaller, powerful servers and desktop computers running simulations across a network. Developers of WARSIM, the Army's next generation corps-level simulation, is looking into the viability of cluster technology, linking servers across networks into a powerful super-computer able to perform the modeling and calculations. Currently, however, WARSIM anticipates using

[1] U.S. Congress, Office of Technology Assessment, *Distributed Interactive Simulation of Combat*, OTA-BP-ISS-151 (Washington, DC: U.S. Government Printing Office, September 1995)., pages 2-4.

predominantly dual processor PCs linked across networks to perform most functions. Two current Army simulations programs, JANUS and the Corps Battle Simulation (CBS), do not need supercomputing power to operate. The next version of CBS will run as a personal computer-based system, while the next version of JANUS is being developed to run on computers that are expected to be fielded with WARSIM[2]. All of the current and planned systems will operate across local and wide area networks.

The Department of Defense (DOD) has been a leader in developing networking technologies. The Department of Defense funded the development and implementation of the Advanced Research Projects Agency Network (ARPANET), the precursor to the Internet, as an experimental project to support research, development, and testing of network technologies. While most computers in the early 1980's were connected by standard telephone wire and communicated at 14.4 bits per second, today data transmission rates of 135 Megabits per second (Mbps) are possible. With widespread use of personal computers in businesses and homes, private companies have taken the lead in developing PC technology allowing the Army to procure and use more powerful PCs at less cost. The hardware controlling and routing information along networks has also vastly improved, allowing up to 100Mbps. There have been a succession of advances in the rate at which information can be exchanged across networks. These advances have allowed the Army to develop wide area network applications aimed at delivering simulation capabilities to the Army's simulation centers.

The simulation centers are using several different simulations to conduct collective and individual training. Beginning as efforts to train specific groups or echelons of Army personnel, these simulations have evolved as separate efforts. Only recently have serious efforts begun to link these simulations to take advantage of the capabilities of each most efficiently. The technology available today, powerful PCs and high-speed networks, can allow the Army to link

[2] Ray Hanes, Bob Ramsey,Janus Systems Analyst, Interview by author, 1 November 2001 notes taken, Janus office, National Simulation Center, Fort Leavenworth, Kansas.

multiple simulations across networks. Although there have been considerable improvements in the Army's M&S technology, the Army is not achieving the efficiencies possible given the technology available. The Army could decrease the personnel costs associated with training; decrease the cost of hardware executing simulations; and maximize use of the capabilities each of the simulations provide in training.

The simulations that are in use within the Army were not designed to take advantage of current network capabilities. Portability and interoperability between simulations were not program goals at the inception of simulations in use today. Therefore, current simulations cannot be ported to most personal computers and they cannot efficiently be linked together. Additionally, current computer capabilities, both in networking and computing power, were not anticipated, and no comprehensive standard was applied throughout the Army. Some of these weaknesses, portability problems and lack of technology standards, continue to recur within programs being developed for future Army training. Though portability and interoperability have become a major goal of these programs, some changes are required.

To understand the required changes in M&S programs and management, it was necessary to evaluate current and planned simulation programs to determine if the Army is making its simulations programs as portable and widely available as possible. Making simulations portable to as many computers throughout the Army's architecture can provide maximum flexibility in reducing the personnel costs associated with conducting training simulations. There are several aspects of the Army's simulations that were evaluated to determine whether the simulations programs are as portable as possible. The focus of this paper is on collective training simulations not on stand-alone simulators of advanced systems, weapons, etc. If the technology, training objectives and standards being used today and those being considered for the future are examined several questions can be answered. First, can the Army's simulation programs run on the PCs that are already sitting on desks throughout the Army performing administration, command and control, and multimedia functions? Second, is the Army modeling and simulation effort

positioning itself to take full advantage of the vastly increased capabilities in networking, Internet communications, and the capabilities of off the shelf computers that are in use throughout the Army?

To evaluate the portability and interoperability of the Army's simulations, it is important to understand the whole of the Army's simulation management structure, program and plans. The management structure affects how standards and technology are promulgated and applied. Evaluating the Army's simulation programs and plans for the future identified the degree to which these programs are portable to non-simulation computers and interoperable with other simulations. The documents also reveal the Army's vision for simulations, to include training goals and methods and wheter program managers are implementing changes that will allow the Army to maximize distributed computing to implement training. Additionally, understanding the standards being applied to software development and program management is important. A comparison of the hardware requirements needed to run simulations and the standards required for desktop computers allows a reasonable judgment as to what actions the Army should take to insure it can take full advantage of the infrastructure and computers available to conduct distributed, networked training. The Army's training goals and objectives are important as they should drive the requirements and complexity of simulations, which in turn drive the technology and software solutions required to implement simulations for training. Evaluating information gathered on the Army's simulation management structure, programs, plans, technology and training requirements yields recommendations for changes to the Army's M&S efforts.

Study Limitations

Much of the information gathered in conducting information concerning the Army simulations program is available through the Internet. The Army Simulations program is defined in a set of regulations and published plans. Most of the documentation is recent, less than three years old and provides a fairly current view of Army programs and vision for the future. It is probably true that program managers and developers do not comply with every element of the Army's guidance. Yet, it is safe to assume that organizations follow published guidance and understand the direction that the Army has set for using simulations in future training. The degree to which published guidance is not followed cannot be measured. The impact on the portability and interoperability of simulations is impossible to gage without conducting independent testing of the simulations, network and computers.

Networks and computers were not independently tested. Specific information regarding the computing requirements for active simulation programs was obtained through representatives of those programs: WARSIM, JANUS and CBS, and from information published on web pages by those organizations. The accuracy of this information is depends upon those individuals being diligent and forthright in keeping their websites current. Additionally, WARSIM information is consistently changing. WARSIM is a program under development and there may be significant changes between current plans and the end product. WARSIM's implementation has already been delayed by more than three years. Corps Battle Simulation (CBS) is also being updated; the newest version is not completed and may undergo further revision before being fielded. The engineers working on CBS provided the latest information available. The current Army organization and standards were drawn from Army regulations and documents published by The Army Model and Simulation Office.

U.S. ARMY SIMULATIONS PROGRAM AND DEVELOPMENT

The Army M&S Organization and management

It is not possible to understand the standards being applied to the Army's simulation effort, without first examining the Army's model and simulation management guidelines and structure. The U.S. Army has established guidelines for the overall management control for the development of models and simulations (M&S); Army Regulation 5-11 (AR 5-11) "prescribes policy and guidance and assigns responsibilities for the management of Army" M&S. AR 5-11 establishes three primarily organizations to accomplish necessary management functions: The Army Model and Simulation General Officer Steering Committee (M&S GOSC); Army Model and Simulation Executive Council (AMSEC); and The Army Model and Simulation Office (AMSO), Requirements Integration Working Group (RIWG). Figure one depicts the key organizations within the M&S management scheme.[3] Additionally, AR 5-11 recognizes three domains within Army M&S: Training, Exercises and Military Operations; Advance Concepts and Requirements; and Research, Development and Acquisition. The Army Model and Simulation General Officer Steering Committee (AMS GOSC) and the Army Model and Simulation Executive Council (AMSEC) provide the strategic-General Officer leadership and executive

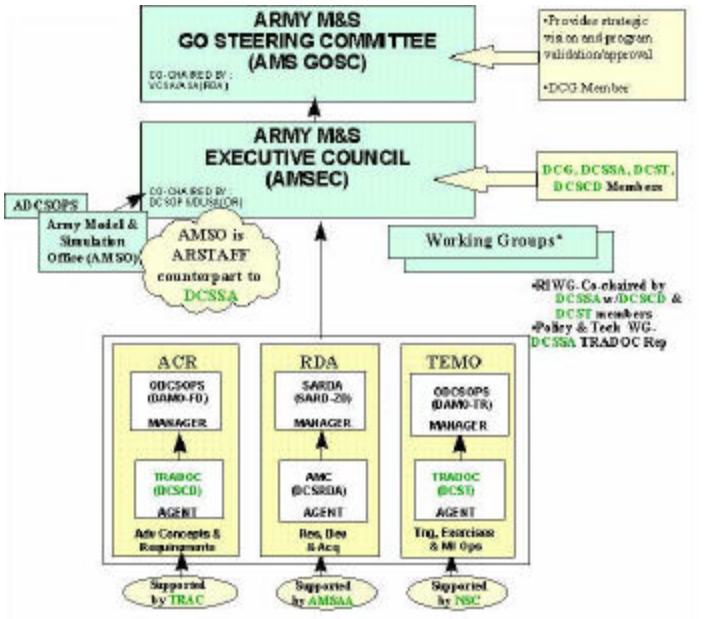

Figure 1: ARMY M&S Management

[3] Figure taken from Headquarter Department of The Army, TRADOC Pamphlet 25-73, Fort

committee guidance for all Army Modeling and Simulation issues. The Requirements Integration Working Group reviews and integrates requirements across domains and works to "eliminate duplication."[4] The Army Model and Simulation Office (AMSO) is the central management agency for all Army modeling and simulation programs. As such, AMSO's "mission is to provide the vision, strategy, oversight, and management" of modeling and simulations. AMSO Develops policy, establishes standards, prioritizes and integrates requirements and investments and directs research and technology in modeling and simulations for the Army. Ultimately, these organizations dictate policy guidance, to include standards, training goals and methods, and technology approaches for U.S. Army M&S training efforts.

AMSO publishes the Army Model and Simulation Master Plan As part of the effort to "provide world-class M&S (modeling and Simulations) that meet the needs of the Total Force."[5] This plan provides the vision, management structure, process, and strategy for Army M&S development. Within the introduction of master plan, AMSO states that "the strategic intent is to depend upon decentralized execution guided by centralized oversight" to achieve objective modeling and simulation programs. The Army has recognized three domains of related activities within M&S to ease management, integrate requirements, and prioritize programs within Program Evaluation Groups. The first of these domains is Advanced Concepts and Requirements (ACR). ACR provides the "strategic direction," and developes requirements, concepts, and force planning. Second is Research, Development, and Acquisition (RDA). The focus of RDA is fairly self-explanatory. The final domain is Training, Exercises, and Military Operations (TEMO). TEMO's activities center around training--from individual to collective training events, tactical to operational. The Domain Agents for the ACR and TEMO domains come from TRADOC, while the RDA domain agent position is filled by a general officer in Army Materiel Command. The

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Monroe VA, 13 December 2000, page 112.

[4] AR 5-11

[5] Headquarters Department of the Office of the Deputy Chief of Staff for Operations and Plans and Office of the Deputy Under Secretary of the Army Operations Research. "The Army Model and

domain agents and managers execute the management tasks that develop and maintain M&S for the Army. Separating the proponency for ACR, TEMO and RDA may work against developing fully portable simulations. Separating of responsibility for domains probably restrictss efforts to apply standards to technology. AMSO must oversee the coordination between ACR, TEMO and RDA or requirements envisioned by ACR and TEMO may not be fully coordinated with RDA.

To provide expertise and facilitate M&S program management, AMSO has broken the M&S life cycle management into six components: management tools, requirements, investments, standards and Technology, M&S infrastructure, and Education. AMSO has identified strategic objectives for each of the components. The objectives include sufficient requirements, necessary investment, a comprehensive standards and efficient M&S infrastructure.[6] As the strategic-level management agency for Army M&S, the objectives for each of the components are broad in nature. They are conceptual and subjective rather than precise and measurable. To provide further direction, the Master Plan identifies sub objectives for each strategic objective. The objectives and sub-objectives of the requirements, investment and standards and technology components are of specific interest because the objectives of these components provide the direction and enable the metrics upon which M&S program requirements and standards rely. Without effective measurable objectives, it is difficult to identify specific requirements and standards that can be applied across M&S programs.

The Master Plan sets the development of "requirements that are sufficient to support the full range of mission needs across the operational and business spectrum" as a sub objective and identifies the "number of programs looking beyond 2003 and 2010, as one metric by which to determine whether objectives are being achieved.[7] At the same time, under the investment component, the plan identifies the objective to develop "Funded programs that efficiently deliver M&S capabilities necessary to meet the most critical needs of the force." This objective is further

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Simulation Master Plan." Army Model and Simulation Office. October. 1997.

divided into two sub-objectives: fully funded programs that are necessary to meet most critical needs of the force, and M&S investments that are balanced across the domains and support efficient program leveraging." The metrics established to evaluate investment objectives include the relationship between plan and POM results, increases and decreases in M&S accounts due to Program Decision Memorandums and Program Budget Decisions, and the number of fully funded programs. The sub-objectives are also subjective and conceptual, leaving the domain managers to identify what is critical to the Army and what is sufficient to meet the full range of operational needs. The metrics established appear to be aimed as much at gaining funding as they are at meeting the needs of the service. Metrics oriented toward funding may be appropriate given that appropriations are at issue at the Department of the Army level.

The Standards and Technology component defines its objective as "a comprehensive set of standards that facilitates efficient development and use of M&S capabilities." The sub objectives include establishing a comprehensive set of DoD-compliant standards for Army simulations and supporting data, for modeling and cultural environments, for modeling Army operations and physical phenomenology, for modeling cognitive processes, and for ensuring the credibility of Army M&S. The actions required to establish standards for Army simulations and data include development of standards for architecture, data, functional description of the battlespace, object management, semi-automated forces, and visualization. The Master Plan contains the definitions of the Standards Categories and the associated requirements. The architecture standards developments requirements include:

- Develop, demonstrate, and promote common components, standards, protocols, interfaces, processes and methodologies.
- Transition current standardization efforts and all new standard development efforts to be in compliance with emerging joint technical architecture and specifically the DoD M&S High Level Architecture.

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[6] IBID, iv
[7] Ibid, page 4-8.

- Develop an awareness of evolving architectures, including, but not limited to Virtual Reality Machine Language (VRML) and the Dismounted Warrior Network.[8]

Within the master plan, there are no specific hardware requirements. The master plan simply identifies the need for standardization to promote common components, standards, etc. Because there are no specific standards for hardware at the strategic level program managers are likely to select technology solutions for their particular simulation that is incompatible with simulations developed elsewhere.

The strategic guidance within which managers strive to meet the Army objectives states specifically that project "managers must ensure that only the minimum amount of resources are used to accomplish their mission[9]" and that domain managers and leaders must look for better ways to deliver modeling and simulation programs to the Army. Additionally, managers are to plan to reuse M&S developments from across Army programs and from other services and DoD programs. Throughout the guidance, there is a focus on Force XXI, building programs for tomorrow, rather than building M&S programs for today. This guidance identifies the need for managers to recognize the requirements of joint operations and provides near-term, mid-term and "far-term" guidance. This guidance prioritizes future simulations by placing the Army's main effort on capabilities to meet the needs of Force XXI. Legacy systems (those programs that exist today, but are not envisioned within future M&S programs) will not be enhanced. The hardware and capabilities associated with conducting collective training using simulations will remain fairly static until the next generation of simulations is implemented.

[8] Ibid, page B-1-1.
[9] Ibid.

Current Army M&S Training Systems

The Army trains using a wide range of simulations. These simulations vary from tank simulators to the Corps Battle Simulation (CBS). The programs have been largely developed separately over the past two decades, being used for fairly narrow training purposes. Because these simulations have developed separately, they are incompatible in many respects, using dissimilar databases, networking architecture, programming languages, and models. As network and computer capabilities have continued to grow, efforts have increased to link these separate simulations. Though the Army has not specifically identified the degree of complexity needed to conduct collective training, there is a continual press to gain greater realism and participation in simulation training events. As this effort has continued, the simulations the Army is using for training have become more and more complex, increasing the challenge to make the individual programs interoperable; the more complex the program, architecture and databases, the more difficult it is to link to other simulations. The Army has begun to take a more systemic view of simulations and is moving to replace some of these simulations with more capable, more complex, and more networked simulations.

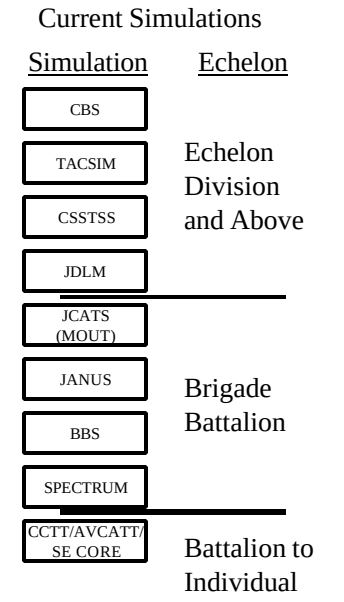

Figure 2: Current Simulations

The simulations currently being used have limited interoperability. They have been designed to provide training for specific echelons. Simulations designed to provide training at brigade and below are not interoperable with simulations that were designed to train higher echelons. As seen in figure one, the simulations can generally be grouped by those that are used for training commanders and staffs at the division level and higher, those that are used for

training at battalion and brigade level, and those that are used for individual training through collective training to the battalion level. The complexity of the simulation models tends to become greater and greater as the number of elements, or objects, that the program attempts to simulate increases. Consequently if a corps-level simulation and a battalion-level simulation both attempt to simulate everything down to the platoon or individual weapon system, the corps-level simulation would encompass perhaps 100 times the number of objects. The interactions of the increased number of objects within the simulation magnifies the number of computer operations, database interactions, and data transmissions required to perform necessary modeling, However, an individual tank simulation can be extremely complex as it attempts to portray lifelike terrain environments to the tank crew in real-time while simulating all of the actions that the tank crew must take to acquire and destroy simulated enemy vehicles. As part of attempts to seek greater realism, leaders have attempted to link individual tank simulators to create virtual platoons which are ultimately linked into companys and higher-level simulations. Linking simulators allows a company or battalion commander to take advantage of crew-levle training time to add realism and participation in collective training; thus, improving the quality of collective training while training crews and individuals. The drive to provide very realistic individual system simulators and model individual systems in collective training simulations increases the computing and communications capabilities needed. Program managers have developed the Army's current set of simulations to meet differing, though increasingly more demanding, technological needs. CBS and CCTT were begun and implemented to satisfy very different training needs, and the technology used to meet those requirements reflects the programs' differences.

The highest echelon Army training simulations currently provide training at the Joint and Corps-level. The Corps Battle Simulation (CBS) simulates land combat, to include army aviation and airlift/airdrop operations. The simulation models the battlefield operating systems, engineer, logistics, NBC, air defense, and artillery; additionally it simulates special operations and infiltration actions. CBS is capable of operating through workstations distributed worldwide using

a wide area network of dedicated processors that link "Ethernet based Local Area Networks (LANS)[10]." The simulation runs on a combination of hardware; a single CPU, the PC Game Events Executive processor (PC-GEEP) and several MicroVAX computers that are linked to workstations acting primarily as graphics display controllers[11]. The PC-GEEPs currently run on a machine with dual Pentium III one GHz processors, having 30 Gigabyte hard disks and 1 Gigabyte of RAM. The workstations that are currently being used as graphics control workstations are Pentium III 800 MHz equivalent computers. CBS is currently not portable to non-CBS PCs and is not interoperable with most existing M&S programs. The CBS simulation has been classified as one of the legacy systems in the Army M&S architecture and is scheduled to be retired after WARSIM is fielded. CBS does interact with the TACSIM intelligence simulation.

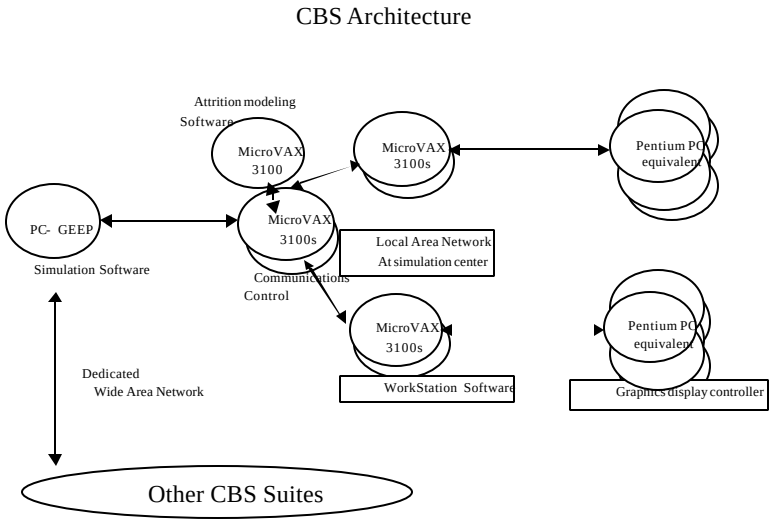

Figure 3: CBS Architecture

TACSIM provides intelligence collection and dissemination to the simulated environment by replicating friendly and enemy combat systems and friendly intelligence assets. TACSIM requires four separate computer systems to receive messages from CBS because of the differing message formats and simulations. TACSIM messages are sent to real world intelligence processing and dissemination systems such as ASAS through a communication support

[10] National Simulation Center. "Information Paper. Subject: Corps Battle Simulation CBS." Internet, http://www-leav.army.mil/nsc/famsim/cbs/info_pap.doc accessed 16 November 2001..

processor. In effect, TACSIM operates as a single system in coordination with CBS to provide intelligence training and inputs. No additional simulations hardware is needed at the user level to provide input to the system. TACSIM maintains coordination with the CBS model by maintaining a duplicate database and by receiving continual database updates from CBS. The intelligence module within WARSIM will replace TACSIM, a legacy system[12].

Another Corps-level simulation system is the Combat Service Support Training Simulation System, CSSTSS. This system is used to train mission essential tasks to combat service support units. CSSTSS is used to train battalion and larger organizations of Corps Support Commands (COSCOM), Theater Army Area Commands (TRANSCOM), and Transportation Commands (TRANSCOM). The CSSTSS simulation can be run with preplanned events, or it can be linked to a CBS simulation exercise by inputting exercise start point information into the CSSTSS database. CSSTSS "produces Standard Army Management Information Systems (STAMIS) and other information reports." These reports are sent from the CSSTSS systems to the training unit's organic equipment. Subordinate role players;, for example, battalions of a support group, provide role players working at CSSTSS workstations. The role players represent core support functions: ammunition, supply, transportation, maintenance, petroleum, and personnel. An individual soldier with expertise as a logistician is required to be a role player for each of these functions[13]. The central computer running the CSSTSS simulation is an IBM-based mainframe computer. This system transmits and receives exercise data from CBS-fielded Vax computers which, in turn, control the CBS workstations acting as graphics control units. CSSTSS' central computer can also use the Internet through TCP/IP to send and receive reports to PCs using software to emulate Vax terminals[14]. The CSSTSS program uses computers that are

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[11] Sargent, David. telephonic interview by author. 23 Jan 2002..

[12] "Introduction to TACSIM." Internet. http://www-leav.army.mil/nsc/famsim/tacsim/intro.doc accessed 15 December 2001.

[13] "Combat Service Support Training Simulation System (CSSTSS)," 7 March 2000, Internet, http;//www-leav.army.mil/nsc/facsim/csstss/index.htm accessed 21 November 2001

[14] Larry Flynn, Supervisory Logistics Management Specialist, telephonic interview 24 Jan 2002.

limited to the simulation world and requires at minimum emulation of a VAX terminal for interaction. The program is not as portable or interoperable with other programs as it could be, requiring many functions to be duplicated in other programs.

The Joint Deployment Logistics Model (JDLM) is another logistics simulation. JDLM provides deployment training in an Army, Joint or combined environment. This program was developed when the Chief of Staff of the Army tasked the Battle Command Training Program to include deployment training in division warfighter exercises. The model simulates air, ground and sea movements of personnel and equipment. The simulation is a "PC-based (Pentium II) system." JDLM is a logistics training simulation; the capabilities provided by JDLM will be included in WARSIM.

The Joint Conflict and Tactical Simulation (JCATS) is an object-oriented simulation that can simulate joint task force through tactical combat. JCATS models include urban terrain, subterranean, and marine environments. JCATS allows very detailed simulation, focusing on entity level operations, within these environments making it suitable for tactical simulation training. The JCATS UNIX-based software can run on personal computer laptops and has the ability to communicate with "real world C4I systems (GCCS), Linux based PC platforms" and other systems[15].

JANUS is a simulation that provides training from the platoon to brigade level. The JANUS simulation that the Army uses evolved from a nuclear simulation program. The Army version, JANUS 7.1 operates on a single personal computer with up to 24 workstation computers providing user interface and inputs. Users at the workstations "fight" the battle, making decisions and moving units according to their plans and changes in the situation and in response to other, opposing and friendly, players moves[16]. Currently individuals must be trained at JANUS

[15] "JCATS Joint Conflict & Tactical Simulation", 12 December 2001, Internet, http://www.jwfc.acom.mil/genpublic/jw500/jcats/ accessed 15 December 2001.

[16] National Simulation Center, JANUS Information Paper, 10 April 2001, Internet www.leavenworth.army.mil/nsc accessed 10 November 2001.

terminals in appropriately equipped simulation centers. It operates as a stand-alone system, relying solely on inputs from the training audience at the terminal. The computer simulates all actions that are not input by the training audience. JANUS can track up to 3,000 individual elements moving across a 200 square kilometer area. JANUS' operating computer is a Pentium IV, 900 MHz PC with 128 Megabytes of RAM (may be upgraded to 512 Megabytes) and a 15-gigabyte hard drive; the workstations are 150 MHz equivalent systems[17]. These systems communicate across dedicated local area networks. The Army plans to replace the JANUS system with OneSaF, the Army's next generation brigade and below simulation hardware.

The Brigade/Battalion Battle Simulation (BBS) supports command and staff training at the brigade and battalion level. It models air and ground combat, including transportation, resupply, medical, and maintenance support functions. BBS operates across either a Local Area or a Wide Area Network. The simulation models two levels below the target training level; for a brigade-level training event, the simulation models down to the company level. The headquarters being trained interact with the simulation by providing inputs to and receiving reports from workstation operators. BBS is an entity-level simulation that models down to the individual soldier. The primary means of training the target headquarters is through the AAR process, supported by collecting and displaying near real time data to evaluate performance. The standard BBS suite operates across a network that incorporates "six Micro Vax's and 11 workstations," however up to 42 workstations and an additional AAR station can be added[18]. The BBS training functions are to be included in WARSIM.[19]

SPECTRUM is a model specifically designed for the complex environment that military operations other than war (MOOTW) present. This program models "the political, economic, and

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[17] Ray Hanes, Bob Ramsey,Janus Systems Analyst, Interview by author, 1 November 2001 notes taken, Janus office, National Simulation Center, Fort Leavenworth, Kansas.

[18] "BBS Information Paper," 17 May 2001, Internet, http://www-leav.army.mil/nsc/famsim/bbs/infopaper.htm accessed 20 January 2002.

[19] TEMO Investment Plan

socio-cultural environment into which military forces can deploy and conduct MOOTW[20]" and provides training through scripted events triggered through friendly force actions. Spectrum can provide training from the tactical through strategic levels; however the program is oriented toward training an individual staff or group. Within the documentation and description of the program, there is no indication that program developers envision using SPECTRUM in conjunction with other simulations. The currently established hardware requirements set the minimum standards for a workstation as a Pentium 155 MHz equivalent with 64 Megabytes of RAM and at least a 500 Megabyte hard drive. The system operates across a network running WindowsNT. There are several scenarios available to provide training to brigade-sized staffs.[21] There is no evidence that SPECTRUM is included in TEMO's long-range plans for the Army. MOOTW aspects will be added to future simulations and SPECTRUM will probably be discontinued.

The Close Combat Tactical Trainer (CCTT) and Aviation Combined Arms Tactical Trainer (AVCATT) are individual systems trainers that can be linked together. The CCTT, has recently, however, added capabilities, to support training staffs at the brigade level and below. These simulators replicate the environment and command and control of combat systems, such as the M1 tank and M2A2 Bradley Fighting Vehicle. Force XXI Battle Command Brigade and Below (FBCB2) has been installed into the manned simulation modules and simulated forces of CCTT, using "real tactical FBCB2 hardware and software." Individual weapons systems modules are linked together over a local area network. Additionally, the program will be linked to the Army Battle Command Systems (ABCS) enabling training and evaluation at the battalion task force level, as simulation modules are linked to live ABCS in the field. According to the TEMO

[20] Quoted from the "Modeling and Simulation Websites for the Signaleer," Internet, http://team-signal.net/html/links39.htm#JSIMS accessed 20 December 2001.

[21] "This is Spectrum," SPECTRUM the National Simulation Center, Internet,: http://www.leavenworth.army.mil/nsc/famsim/spectrum/intro.htm#5 accessed 15 November 2001.

investment plan, CCTT functions will be included as part of the Army's ongoing M&S efforts.[22] AVCATT, used to train aviation units on collective tasks, are a group of "interactive, networked" aviation simulators. AVCATT also will be continued and integrated into future programs as part of combined arms training.

From the individual training system, a CCTT module, to CBS, these systems represent the current state of Army M&S efforts. They currently do not represent a seamless architecture of simulations that would allow concurrent, real-time, training using the same simulation model within an exercise. Each has been developed to enable collective training at specific Army echelons, evolving as more capabilities have been requested and as computer and communications capabilities have increased. Although, CBS, JANUS, and CCTT simulations have fielded specialized hardware, other simulations, such as SPECTRUM and JCATS, are primarily software efforts. The next version of JANUS has also become primarily a software-only project that awaits fielding of hardware associated with WARSIM.

The set of simulations currently being used by the Army have several weaknesses that reduce efficiency in conducting training. They rely heavily on technology that was specifically developed for individual programs, which limits portability to other computer systems that have been procured and placed in simulation centers. Additionally, The programs have very general training goals associated with them. The broad training goals preventing a full examination of the detail and complexity required for each simulation. The simulations are not interoperable and their capabilities cannot be shared. Programs have duplicated many software functions and routines to perform modeling functions. Had the Army begun with central standards and goals, duplication would not have been necessary. There are major efforts ongoing to replace most of these systems with a less disjointed more capable set of training simulations.

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[22] "Close Combat Tactical Trainer." 10 April, 2000. Internet. http://www.stricom.army.mil/STRICOM/PM-CATT/CCTT/IOP/icd_web_1.html accessed 10 November, 2001.

The Army's Future Simulations

In line with the Army's vision to " 'move more electrons and less troops'" in training,[23], there is a much greater focus on developing and fielding systems that are interoperable. The Army is funding fewer simulation programs, but future systems are intended to incorporate the capabilities provided by the many simulations now being used. New programs pull current capabilities together under fewer separate programs. In 1986, Wilber Payne asked the question whether or not the number of models representing land combat operations functions was warranted. He concluded that the many separate simulations programs represented serious management problems and were resource-intensive. However, he believed it was necessary to divide the modeling operations into separate programs to permit the work to be completed in parallel.[24], The Army has since decided that fewer simulation programs, incorporating existing functionality will be most effective in the future. Though there are some "digital Interim Tools" such as interim CBS, BBS, and the Digital Battle Staff Trainer (DBST), they represent the transition between current and future capabilities. The focus here is on future simulation efforts and not on the transitional programs. Only three major programs, WARSIM, CCTT/CATT, and ONE SAF are in Training and Doctrine Command's (TRADOC) long-range Training and Exercises investment plan. TRADOC envisions

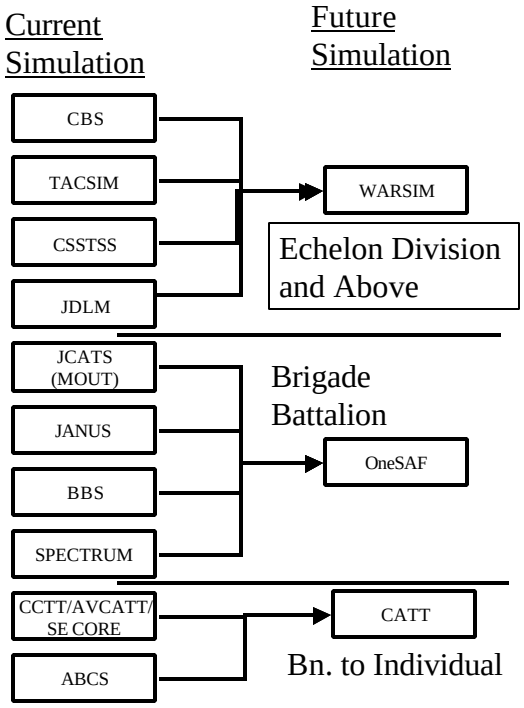

Figure 4: Transition to Future Simulations

[23] "Joint Simulation System" Internet, http://www.jsims.mil/about.htmlaccessed 20 October 2001.
[24] William Payne, Ground Battle Models edited by Wayne P Hughes Jr, in *Military Modeling*,

relying on virtual training environments to train battalion and brigade staffs because, in comparison with live fire exercises, simulations cost is less than training conducted in the field.[25] In general, simulations require workstation operators from two echelons below and one above the targeted training unit to input orders and reports. The emphasis on training cost appears to add increased focus toward building simulations that at once can be used to train participants from the platoon level through the Corps. Additionally there appears to be an increased emphasis on taking advantage of the communications networks already in existence to conduct training over large Wide Area Networks. In this vein, the Army is attempting to meet the requirements of the Department of Defense High Level Architecture (HLA).

HLA, established in 1996, is "a general purpose architecture for simulation reuse and interoperability.[26] HLA is in effect the technical architecture specifications that allow individual simulation(s) to participate within the same exercise--the rules that govern the interactions between simulations. Defining these rules has been an important step in combining separately evolving programs into a family of simulations that can be combined into an operational-level simulation, if desired. The combination of an established set of standards allowing interoperability together with an increased emphasis on using WAN technology should greatly influence the software and hardware solutions to the Army's simulations requirements.

The hardware solutions needed are, in part, driven by the complexity of the models and simulations. The drive toward more complex simulations includes a desire to effectively represent terrain effects realistically. Terrain has a significant impact on attrition by complicating the target acquisition and engagement by blocking or restricting line-of-sight (LOS).[27] The desire to model

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(Military Operations Research Society, Alexander, VA Aug 1986), page 157.

[25] "TEMO Domain Management Plan," 14 March 2000, Intenet http://www.amso.army.mil/structure/domains/temo/plan/ accessed 16 February 1999.

[26] Defense Model and Simulation Office "High Level Architecture," Internet, http://www.dmso.mil/index.php?page=64/edu_trng/regional/core_mat/ accessed 10 January 2002

[27] James G Tayler, "An Introduction to Lanchester-Type Models of Warfare," in *Proceedings of the Workshop on Modeling and Simulation of Land Combat*, by Dr L. G. Callahan Jr. (School of Industrial and Systems Engineering, Georgia Tech Printing and Photographic Office, April 1985). page 56

terrain effects on engagements, and ever-increasing fidelity of terrain data, has increased the requirements to store, transfer, present, and analyze the data. Additionally, the M&S community is being driven to determine terrain effects on more than just engagements. The combat support and combat service support functions are also affected by terrain. These communities seek greater validity in modeling terrain effects, and simply representing elevation effects on the plausibility of direct fire engagements is not enough. There is significant desire to more realistically represent complex terrain, urban areas, vegetation, and weather effects. These requirements drive the M&S community toward using cutting edge technology with the processing capabilities (both mathematically and graphically), data storage and communications to handle requirements.

The Program Manager of WARSIM faces the problem of needing the latest technology to meet Army desires for realism. Lockheed Martin, under the program management of U.S. Army Simulation, Training and Instrumentation Command (STRICOM) in Orlando, Florida, is developing WARSIM to replace many of the collective training simulations. WARSIM, as planned, incorporates the functionality of the division and higher echelon training systems: CBS, CSSTSS, TACSIM, and JDLM. WARSIM is the Army's "contribution to the Joint Simulation System (JSIMS)." It will provide the land component functions to joint simulations, allowing land component command functions of battalion through Joint Task Force (JTF), to be executed by Army Forces (ARFOR) or Army Service Component Command (ASCC) headquarters. In addition, WARSIM is being developed to include the ability to simulate "up to ten separate doctrine sets and multiple sides or factions." That capability will allow the simulation to support coalition-based training scenarios using combined forces. To insure the quality of training without joint partners, the program must model the capabilities and effects of other services. Only then will the simulated battlefield provide doctrinally correct training of Army units in a joint force.

The Mission Needs statement for the Family of Simulations that include WARSIM outlines general capabilities. WARSIM will closely replicate the "lethality, stress and complex interactions of the battlefield." Command posts participating in WARSIM-driven exercises will operate out of their tactical operation centers (TOCs) using their wartime equipment and procedures. The program will allow for interaction with "stand-alone, linked-distributed, multi-corps or theater-wide joint warfare simulation systems." The simulation will provide for the "rapid and accurate development of training evaluation feedback to facilitate the AAR process. " Additionally it will allow for reserve and National Guard units to train at home, and use the modern telecommunications structure. While there is no list of specific training objectives that WARSIM must meet, it is designed to support "the collective training of battalion through theater-level commanders and their staffs."[28] Within the requirement to train staffs, the project envisions training staff officers in the functional areas of personnel, intelligence, operations, plans, logistics/combat service support, fire support, tactical air, air defense, airspace management, aviation, engineer, NBC, civil/public affairs, communications-electronics, law enforcement/security, and legal affairs. According to the Mission Needs statement, all of the systems must also meet the following constraints:

- be able to interact with field training units, simulators, other services simulations and multiple databases in a seamless fashion
- be designed in accordance with DOD's and the Army's state-of-the-art standards for the DIS program.
- Able to use Defense Mapping Agency data
- use DIS-compliant high-speed telecommunications traffic.
- comply with the appropriate classification requirements
- able to be operated by a small number of support personnel.
- able to interact with any new system in a doctrinally correct fashion using its assigned multimedia command and control system equipment.
- AAR system must be able to be operated by a single operator/analyst.
- operated in a conventional training environment; does not need to be hardened, but must be survivable and transportable in the field

[28] Capabilities for WARSIM taken from "Warfighters Simulation 2002 Operational Concept Document," (Lockheed Martin Corporation Information Systems, Orlando, Fl), Internet, http://www-leav.army.mil/nsc/warsim/ord/ops.htm#_Toc424372376 accessed 20 November 2001

- have the telecommunications capability to interface with training units that are on the move over large areas. [29]

These constraints have serious implications for WARSIM developers. The simulation is being developed to interact with a unit's ABCS equipment in the field. WARSIM interacts with a unit's C^4I equipment through simulations support modules (SSMs) at or near the field training location. As shown in figure 4, controllers and support personnel will man positions within mobile SSMs in order to allow WARSIM to interact with the units' ABCS systems and to provide the inputs to the simulation. The training unit must provide unit controller/role players who use the workstations to control and role-play the training unit's "surrounding (higher, adjacent, subordinate, supported, and supporting) friendly units."[30] The major simulations modeling functions are being designed to run on computers that will be fielded at regional training centers. Soldiers supporting WARSIM-driven training will have to operate computers at simulation centers

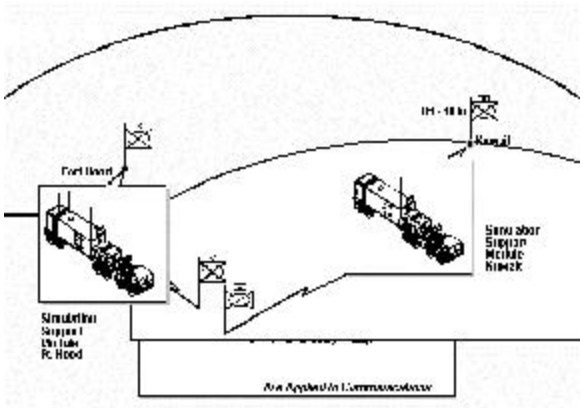

Figure 5: WARSIM SSM

The computer hardware that is currently being tested to run WARSIM is fairly powerful. Specifically, the major modeling software is being run on Sunfire 3800 servers; each of these servers can have up to eight 750MHz or 900MHz processors. The servers are connected to workstation servers, having dual 1 GHz processors, 1 Gigabyte of RAM and four 36 GB hard

[29] "Training Device Mission Need Statement for Command and Control"; Internet, http://www-leav.army.mil/nsc/warsim/mns.htm, accessed 10 November 2001.

[30] "Warfighters Simulation 2002 Operational Concept Document," (Lockheed Martin Corporation Information Systems, Orlando, Fl), Internet, http://www-leav.army.mil/nsc/warsim/ord/ops.htm#_Toc424372376 accessed 20 November 2001.

drives. Up to 18 control workstations can be connected to each workstation server. The individual controlling workstations have dual 933MHz processors, with one GB of RAM and 96GB of hard drive storage[31]. Each of the computers that WARSIM is using has dual processors; the average desktop computer does not meet this requirement. WARSIM, using multi-processor CPU's throughout the hardware architecture may impact on other program's attempts to decrease the overall hardware requirements of the Army's M&S programs.

OneSAF, the simulation that is replacing Spectrum, Janus, BBS, CCTT-SAF, and JCATS (MOUT functionality only), is a software only effort[32]. As is true of thecurrent simulations at echelons above brigade, Janus, Spectrum, and BBS are not fully interoperable and do not meet the HLA technical specifications. OneSAF will meet all applicable DoD, military and Institute of Electrical and Electronics Engineers (IEEE), standards for software development and testing. The objective program will not simply mold current simulations together, but will be an entirely new architecture that is HLA-compliant. As with WARSIM, OneSAF must be able to use data with multiple levels of security from unclassified though SCI. Additionally, OneSAF will provide a "synthetic natural environment (SNE) that is scalable, editable, and interoperable with constructive, virtual and live training[33]." OneSAF will provide the simulations training functions for Army organizations at brigade level and below. Being designed for use in unit training exercises and in the classroom, OneSAF will offer a "a simple 'generic' training environment as well as a real-world mission-specific rehearsal." The simulation can be used in the full spectrum of military operations environments from conventional warfare to stability and support contingencies. When OneSAF is linked with WARSIM and the manned simulators of CATT and AVCATT, the simulations will provide a synthetic training environment that spans from the

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[31] Doug Anderson STRICOM Chief Engineer Constructive Simulations and Rick Copeland, Lockheed WARSIM Chief Engineer, Interview by author, 18 January 2002 notes taken, STRICOM WARSIM office, Orlando, Florida.

[32] "OneSAF information paper" Internet, http://www-leav.army.mil/nsc/nextgen/onesaf/13feb01.doc accessed 21 November 2001.

[33] Ibid.

individual soldier in a tank through corps level. Similar to WARSIM, OneSAF will interact with the units' C4I systems (ATCCS & FBCB2), allowing better use of C4I systems in training. OneSAF also has data collection, analysis and AAR graphics and tables specifically designed to aid in the AAR and training process.

OneSAF will operate on existing hardware provided by the unit or simulation center. The initial two-year training course, planned for fiscal years 2005 and 2006 (FY05 and 06) will be for both "simulation support contractors, and for unit personnel (military or civilian) at sites without a BSC.[34]" The fielding of OneSAF, when complete, will primarily be software loading. Fielding will include a two-week train-the-trainer program at using simulations centers or at the National Simulation Center (NSC), followed by a "first-use" exercise[35]. The simulation is being designed to run the primary modeling software on a workstation server. It may, however, operate in a split-mode with some functions running on workstations while others remain on the server[36]. The OneSAF software could run on workstation servers being developed and fielded as part of WARSIM or may be run on hardware already in existence at the simulations centers. It is being designed to run on commercially available PCs[37]. The graphic requirements of the personal computers running the OneSAF software are not readily apparent. OneSAF development documents suggest a significant increase in graphics-processing requirements, as they attempt to add three-dimensional aspects to terrain modeling and attempt to increase the fidelity of weather effects on systems throughout the battlefield. Though the hardware OneSAF requires will likely be fielded by WARSIM, without exact specifications for data processing, storage and graphics, it is difficult to evaluate the portability of OneSAF to computers not fielded within WARSIM.

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[34] "OneSAF information paper" Internet, http://www-leav.army.mil/nsc/nextgen/onesaf/13feb01.doc accessed 21 November 2001.

[35] Ibid.

[36] Doug Anderson STRICOM Chief Engineer Constructive Simulations and Rick Copeland, Lockheed WARSIM Chief Engineer, Interview by author, 18 January 2002 notes taken, STRICOM WARSIM office, Orlando, Florida.

[37] "OneSAF Operational Requirements Document," 27 Feb, 2001, Internet, http://www.onesaf.org/OneSAF_ORD_v1.1(FinalXXYYZZ).doc accessed 15 November 2001.

The Army's plan is to make OneSAF interoperable with networked simulations and individual simulators. The Combined Arms Tactical Trainer (CATT) family of simulation systems is being developed to provide training at the platform (individual tank, helicopter, etc.) through battalion task force level. The system's computers create a simulated battlefield, which when viewed by soldiers who are using the system, creates the illusion of moving and fighting over actual terrain while operating or riding in the actual vehicles and employing the mounted weapons systems.[38]. The plan calls for manned simulators for armor, mechanized infantry, dismounted infantry, air defense, and aviation that are interoperable over a network. The simulation system provides interactive networking of combat vehicles and C3 and support stations that represent the combat systems, weapons and headquarters for battalions, companies and platoons and their support elements[39]. To achieve interoperability of these simulators, the systems must have a common infrastructure that includes common exercise control and common data handling and storage elements. The Close Combat Tactical Trainer (CCTT) System is being used as a baseline for specifying the capabilities of other systems within the CATT family.

The CCTT program manager has identified three elements needed to achieve interoperability: a consistent exercise control method; consistent communications mechanism to exchange object and event data (including methods of data transmission, protocol and content); and a common synthetic environment including the simulated terrain (in a 50km x 75km rectangle), atmosphere, and ocean, entities and objects.[40] These tactical simulators must replicate not only the internal environment of the weapons systems/vehicles, but also the view of the terrain upon which they move, the characteristics of the weapons, weather effects and the movement of other manned simulators and simulated systems on the same simulated battlefield.

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[38] STRICOM "Training Device Requirement (TDR) for the Close Combat Tactical Trainer (CCTT)" 11 July 2000, Internet, http://www.stricom.army.mil/STRICOM/PM-CATT/CCTT/FILES/cctt_tdr_20000611.pdf accessed 10 November, 2001

[39] Ibid.

[40] "Close Combat Tactical Trainer", 10 April, 2000, Internet,

The simulators must provide Item System Resolution, the ability for individual weapons systems to engage other systems from their physical location on the simulated battlefield.[41] The simulators are networked together with computers that allow for input and control of the additional forces that replicate the equipment, platoons, and companies that are not represented by the limited number of manned simulators. The CCTT program envisions fielding platoon and company sized sets of networked simulators. Computers will simulate the additional platoons or companies to make battalion task forces or, the simulation centers will be augmented with mobile CCTT simulators. Computer workstations that control the Computer Generated Forces (CGF), support units, and headquarters elements are networked together into one simulation to allow for collective training that incorporates the manned training modules. The CCTT program, as envisioned could allow company and battalion commanders to train crews, staffs, and leaders. The program could be most efficient if individuals could participate in exercises from unit locations, allowing leaders and staffs to participate in simulation training without ever leaving unit locations. Battalion commanders could then take advantage of a platoon or company exercise to conduct training without the cost of moving personnel and equipment.

Together the CCTT, OneSAF, and WARSIM programs represent the Army's focus in developing a seamless set of collective training simulations. While each of these programs is focused on a distinct level of operations, it is apparent that much greater emphasis has been placed on the interoperability of these simulations. The degree to which the programs will be interoperable will likely depend on the quality of and enforcement of development standards. Additionally, the degree to which the Army will be able to move more digits and less troops will depend on how widely the Army's modeling and simulation standards are applied.

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http://www.stricom.army.mil/STRICOM/PM-CATT/CCTT/IOP/icd_web_1.html accessed 10 November, 2001.

[41] Ralph A. Toms, Lauri Dobbs, and Jeffrey Pimper. *High Resolution Combat Simulations to Support Training for Close Combat Light Operations*, (Lawrence Livermore National Laboratory, June 1990). page 4.

Standards and Specifications, the Army & the M&S Effort

Standards are important in system development, software, and hardware to make a complex systems design effort successful. data structure, data storage requirements, and data transfer are important elements needing standardization. As with any set of standards, the more general they are the more interpretation and variation that is possible. Alternatively, overly specific standards can have the effect of restricting developers from applying the latest technological and software solutions. Exploring the standards being applied to the Army's simulation efforts yields an understanding of how effective these programs will be in both achieving interoperability and in achieving the greatest flexibility.

The Defense Information Systems Agency (DISA) is the DoD agency responsible for identifying and promulgating information technology and software standards. One of the key documents in this effort is the DoD Joint Technical Architecture List of Mandated and Emerging Standards. This list includes a wide range of standards being applied to achieve interoperability across DoD information technology systems and networks. The document addresses standards for information processing, transfer, modeling, human-computer interfaces, security, C4ISR, combat support and weapon systems as well as standards for modeling and simulations. The list recognizes the Army's Modeling and Simulations Master Plan and the High Level Architecture. The document states that the "efficient and effective use of models and simulations across DoD and supporting industries requires a common technical framework for M&S to facilitate interoperability and reuse. This common technical framework is: "A high-level architecture (HLA) to which simulations must conform."[42] Further the standards listed are established to cover the specific aspects of simulation programs "necessary to foster interoperability and reuse, but

[42] Department of Defense. "Joint Technical Architecture List of Mandated and Emerging Standards," (2 April 2001) Internet, http://www-jta.itsi.disa.mil/jta/jtav4_dnld.html. accessed 12 December, 2001.

avoid overly constraining implementation details.[43]" Army Regulation 25-1, Army Information Management, supports the JTA standards, and provides that the Army will follow data and architecture standards published within the JTA[44]. The JTA recognizes that M&S efforts may have unique processing requirements beyond those that can be covered by the JTA. This recognition allows simulation programs managers to apply more advanced technology than the rest of the Army is required to have and may preempt efforts to run simulation applications on less specialized computers. Simulations may require greater processing speeds and communications than those needed for the Global Command and Control System and Defense Messaging System, the basis for many JTA standards. Allowing separate standards to be applied within the overall DoD architecture may have a serious limiting effect on the Army's ability to maximize use of simulations by limiting the number of computers, and perhaps, networks that the simulations will be able to utilize. The JTA allows the modeling and simulation community latitude in their efforts in following DoD-wide standards by recognizing these special standardization requirements. An appreciation of the JTA standards documentation leads to the conclusion that the M&S community becomes the agent for insuring that simulation efforts can maximize the potential of current and future information technology architecture.

Though a great deal of DISA's efforts have been in the area of standardizing networking and software requirements, the agency has also published requirements for desktop computers. The basis for the requirement is the ability for computers within the DoD to run Global Command and Control System (GCCS) and Defense Message Service (DMS) application software. DISA last published the "minimum desktop personal computer configuration" in 1997. Having based their requirements on GCCS and DMS, DISA required PCs with 32 bit, 66MHz CPUs having a 12x speed CD-ROM and 24MB RAM. Additionally, DISA recommended MMX technology, 64-

[43] Ibid.

[44] Headquarters Department of The Army AR 25-1, "Army Information Management,"United States Army Publishing Agency,15 February 2000

bit bus CPUs with 16x speed CD-ROM and 32MB of RAM[45]. Based on the wording in the JTA list of standards the DISA requirements, promulgated to the Army, did not apply to computers being developed or procured off-the-shelf to execute simulations. They did, however, apply to computers being used virtually everywhere else throughout the Army to support and further the Defense Information Infrastructure. The M&S community alone promulgates specific standards for M&S applications and hardware.

As identified, the Standards and Technology component is the Army M&S component responsible for establishing standards. The standards focus not only on data structure, data storage and data transfer, but also include architecture, description of the battlespace, semi-automated forces and visualization. Annually the Standards Category Coordinators Workshop is sponsored by AMSO to identify, define, and resolve standards issues. Each year these coordinators publish their plans, which inform the Army's POM process. The primary focus by AMSO in its standards requirements is software oriented. Using object oriented modeling and design, AMSO has established standards for the interaction between objects within simulations and between different simulations programs. HLA identifies the object models to promote common understanding of simulated representations. HLA defines the functions required by simulations to interact with other simulations. Additionally the architecture specifies the infrastructure required to support interaction between simulations. HLA also specifies the interaction of simulations with infrastructure. The HLA establishes Run Time Infrastructure (RTI) requirements to manage the federations of simulations, objects, ownership, time and data distribution[46]. Within this scheme, individual simulations and federates (families of simulations) have ownership of objects, giving them authority over data and events of specified objects. The HLA includes some specific standards for data storage and data transfer, enabling the Army's

[45] Defense Information Systems Agency. "JIEO Report – 8300 Department of Defense Minimum Desktop Personal Computer Configuration",(, Joint Interoperability and Engineering Organization Center for Standards, Aug 1997). pages 2-6, 2-7

[46] Brant A.Chiekes, "Architecture / Reference Model Working Group,".(September 1997)

simulations to interact. The development and promulgation of HLA-compliant standards and developing specific types of models appear to be the primary focus of AMSO's efforts. The Army Simulations Master Plan defines the Architecture category as:

> The structure of components in a program/system, their relationships and principles and guidelines governing their design and evolution over time. Architecture includes the system framework and components that facilitate interoperability of all types of models and simulations, as well as facilitate reuse of M&S components. It encompasses virtual, constructive, and live simulations from ACR, RDA, and TEMO domains[47].

The definition shown above is focused, as expected, on the interoperability of models and simulations. There is, however, no mention of interoperability with systems outside the M&S realm. Without a focus toward gaining interoperability with systems outside the M&S architecture, the use of simulations developed by the Army and DoD may be limited to organizations having hardware fielded for the sole use of specific simulations, WARSIM, or CCTT.

WARSIM standards also focus on interoperability of models and simulations through software applications. The standards are reliant on the DoD HLA standards; the program uses "HLA-compliant databases, accessible through a combination of Commercial and Government Off-the-Shelf (COTS/GOTS) Database Management Systems (DBMS) capable of interactive data exchange during exercises." Additionally WARSIM is being designed to act within the family of Joint Simulations and represents the land component within the joint community's simulation. As a component of the JSIM the WARSIM Statement of Work requires the program to be "compliant with the JSIMS Architecture in a manner that best supports the Land DA's role in the JSIMS Alliance."[48] The Statement of Work and the Operational Requirements Document

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Internet, http://ltsc.ieee.org/ppt/brant_ppt/tsld001.htmaccessed 15 January 2002.

[47] The Army Model and Simulation Master Plan, Headquarters Department of The Army Office of the Deputy Chief of Staff for Operations and Plans and Office of the Deputy Under Secretary of the Army (Operations Research) (Army Model and Simulation Office, October, 1997) page B-1-1.

[48] STRICOM. "Statement of Work for Engineering and Manufacturing Development (EMD) of Warfighters' Simulation (WARSIM) 2000." (Orlando FL, 31 Jan 2002).

focus standards for WARSIM technology on being workable within the HLA network and capable of running WARSIM software. The WARSIM Operational Requirement Document specifies that "Computer Systems to host the modeling programs comprising the simulation, the interface process, and the databases will comply with current standards for open architecture and HLA."[49] There is no set standard, at the program level, for WARSIM computers. It would appear that WARSIM developers could continually adapt the latest and most powerful computers to their program. The technology being applied to the broadly defined requirements of WARSIM seem to be driven by software, database, and graphics requirements. The Statement of Work seems to encourage use of the latest technology and calls for the program to "continuously assess the state of new, emerging, and changing technologies and standards and…recommend plans for transition of those technologies and standards into the WARSIM 2000." [50] The requirement also calls for the development team to provide the government with an assessment of new standards and technology's advantages, disadvantages and risks. The Statement of Work does specify that the government will ultimately decide whether new technologies or standards will be used within WARSIM.[51] However, it appears that the government must rely heavily on the expertise of contractor's personnel to make the technical decisions.

OneSAF is reliant on other M&S programs for the computing hardware that the simulation and modeling applications use. As a software-only effort, the applicable standards are appropriately software related. Program development Requirements for OneSAF are outlined in the Operational Testbed Coding Standards (OTB). The OneSAF OTB outlines standards for library source files, programming style conventions, standards focused on improved portability of software, test programs, program documentation, error handling and formats for data base

[49] Lockheed Martin Corporation Information Systems. "Warfighters Simulation 2002 Operational Concept Document.", Orlando, Fl. Internet, http://www-leav.army.mil/nsc/warsim/ord/ops.htm#_Toc424372376 accessed 20 November 2001.

[50] Ibid, page 14

elements. The OTB also identifies standards and practices for software development focused on insuring that simulation elements can be more easily reused as the simulation architecture adapts and changes.[52] OneSAF incorporates many of the standards that ModSAF, its predecessor, used. These standards specifically identified the use of the DIS or SIMNET communications protocols to communicate "synthetic environment physical information."[53] It is plausible, however, that OneSAF applications might be developed on COTS computer hardware that is more advanced than that being applied to WARSIM or CCTT software. Were this the case, it is possible that only on fielding, a hardware limitation might prevent correct execution of OneSAF developed software. Without a hardware failure, and while WARSIM and the CCTT family maintain the software and networking standards, OneSAF should be able to operate seamlessly with them.

The CCTT specifications include some very precise standards. Within the specifications pages, program developers have identified mean time to failure standards for system components. Developers have identified specific physical components, displays, and even bolts required for specific simulators, such as the M1 Abrams simulators. In contrast, the standards for the computer systems are less exact. The "trainer system processing resource" consists of all computer system hardware and software. The contract specification requires that the system processing resource "shall meet all functional, operational simulation, control, processing, and design requirements of this specification." The specification further states that all computer hardware will be off-the-shelf technology, maximizing use of "common family of processors," with common system interfaces. Additionally, the specification identifies the requirement for "sufficient" installed memory to allow the computer to store and execute all operation elements of

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[51] Ibid

[52] Simulation, Training, and Instrumentation Command. "Software Development Plan Report/Results Of Analysis for the Onesaf Testbed Baseline Program Do 0097" Orlando, Florida 23 February 1999) Internet, http://www.onesaf.org/extint/sdp/sdp.html#_Toc436624386 accessed 10 January 2002.

[53] Lockheed Martin Corporation. "OneSAF Testbed Baseline Assessment (DO #0060) CDRL AB02 Final Report," Orlando , FL May 1998.

the simulation.[54] The specification also identifies the requirement for communications "between processors and between other portions of the system" and the channel capacity and speed to meet trainer performance specifications. These specifications seem very open ended. The technology required to operate the simulation can only be identified after all of the software development is finished. There is the potential under these guidelines that programmers can develop extremely resource intensive software that only the latest and greatest technology is capable of handling.

The theme of technology standards being applied to the M&S effort at this time appears simply to be that it can run the simulations being developed. The Army is encouraging the M&S community to continually assess and apply new technology toward ever more detailed simulations. This may have serious impacts on the interoperability of the M&S programs and the degree to which the simulations are portable onto other computing systems and networks. It is worthwhile to compare these types of standards to other efforts in the Army. Training and Doctrine Command (TRADOC) represents a large, diverse set of IT requirements and provides a basis for evaluating standards and the effect they may have on the interoperability of applications.

TRADOC has published a Plan for Reengineering Information Systems Modernization. This plan represents TRADOC efforts to upgrade networking and computing capabilities. Under this modernization plan, TRADOC has addressed its operational and technical architecture (information transport, computers and software), system architecture, communications infrastructure including networks, and common and functional applications. The cost for most commercially available software should be reduced through DoD efforts to buy

Year	Delete from Inventory	Minimum to Retain in Inventory	Items to Retain for Two More Years
2000	Pentium 60-90 MHz	Pentium 100-133 MHz	Pentium 233 MHz
2001	Pentium 100-166 MHz	Pentium 233 MHz	Pentium 300 MHz
2002	Pentium 233 MHz	Pentium 300 MHz	Pentium 450 MHz
2003	Pentium 300 MHz	Pentium 450 MHz	Pentium 600 MHz
2004	Pentium 450 MHz	Pentium 600 MHz	Pentium 750 MHz

[54] Lockheed Martin Corporation. "OneSAF Testbed Baseline Assessment DO #0060. CDRL AB02 Final Report." Orlando, FL. May 1998.

software under "Enterprise Software Agreements.[55] TRADOC establishes standards for software programs in an attempt to insure the greatest ability for data sharing while continuing to take advantage in upgrades. Having more than 48,000 PCs, TRADOC also has established standards for minimum PC capabilities. Included within this effort are minimum DoD desktop configurations and TRADOC preferred configurations. The preferred configuration includes 500MHz processor, 128 MB of RAM, 13GB hard drive, Ethernet LAN interface of 10/100 BaseT, and identifies drive, external port, and monitor capabilities. Additionally, TRADOC has identified, by processor capabilities, which PCs should be deleted from the inventory, the minimum capabilities to retain, and those that shall be held for two more years[56]. These categories of PC systems are identified through 2005. This same strategy has also been applied to server capabilities. Additionally the plan identifies the server hardware required to run Windows 2000 (the objective software for Windows-based systems), identifying minimum and recommended RAM, processor, and disk space. TRADOC has recognized the significant and continual cost of committing to upgrading PCs. This cost to TRADOC alone will be more than $16 million per year[57]. The cost of replacing computers is paid by separate activities throughout the Army. Given that the Army does not directly fund replacements, the degree to which installations modernize PCs varies. Recognizing this, TRADOC requires Program Mangers (PM) to coordinate prior to fielding any applications that are dependent upon PC availability. The overall cost is obviously significant.

Figure 6: TRADOC recommended PC replacement schedule

The cost associated with implementing and maintaining standards applies across the M&S effort as well. Greater cost seems likely in a situation in which there are no standards.

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[55] Department of Defense, Chief Information Officer CIO. "Acquiring Commercially Available Software." Policy Memorandum 12-8430. July 26, 2000. Internet. http://apps.fss.gsa.gov/schedules/Navy3.cfm accessed November 20 2001..

[56] TRADOC Pamphlet 25-73, Headquarter Department of The Army, Fort Monroe VA, 13 December 2000, page 43

[57] Ibid., page 44

These costs may be realized in a monetary sense, in man-hours, or in reengineering previous development efforts. The standards being applied in the M&S effort focus on the software side of development; there seem to be very few specific standards being applied to the hardware that can be used in the development and fielding of M&S programs. The standards may significantly reduce the Army's ability to decrease costs associated with simulation-based training.

FINDINGS

Simulation-based training has become a major emphasis in the Army's efforts to train commanders and staff. The Army determined that the current simulations were not capable of sharing program unique capabilities. The Army is now making a concerted effort to make simulations more interoperable. While most of the current simulation programs will continue to be used through 2005, CBS, TACSIM, CSSTSS, Janus, BBS and Spectrum all are due to be replaced by the Army's new family of simulations. The training goals and requirements that the Army is placing on simulation program development are naturally driving their efforts.

A review of the scope and training capabilities required for each of the Army's new simulations does not fully reveal their technology and software requirements. Program developers need a reasonable sense of the scope and specific training capabilities to guide their efforts. There are significant differences in scope between WARSIM and CBS. WARSIM must be capable of representing multiple sets of forces using up to ten different doctrinal sets to represent coalition operations. It must model the capabilities of joint forces to increase the quality of exercises wherein joint forces do not participate and allow theater/multi-corps warfare simulation. WARSIM will be used to train commanders and staffs at echelons division and above. OneSAF will be used for collective training through brigade-level, focusing on battalion. The focus of this effort is on modeling ground warfare, C4I, combat support, and combat service support, and the physical combat environment. Additionally, OneSAF will allow for course of action analysis and

incorporates some aspects of all battlefield operating systems. The CATT family of simulators and systems are designed to create a simulated environment that incorporates the internal physical environment of individual systems and the battlefield environment. These simulators can be linked to train leaders up to the battalion-level and can be linked with simulations equipment to represent other systems on the battlefield. The scope of these simulations seems to be fairly well defined; however, there are no specific envisioned training objectives apparent in the development documents, statements of work, directives and testbed requirements.

Absent specific training objectives for these programs, it is difficult to imagine how each can be evaluated as to their ability to meet the Army's needs at any given time. Training simulation should permit a wide range of decisions by the training audience and "represent their consequences with enough fidelity so that players are penalized for bad ones" and they "should force decisions at a pace characteristic of combat operations."[58] The degree to which simulations meet Army needs depends upon identification of the decisions and level of physical representation required. This lack of specific training objectives has serious impacts upon development efforts. At what point is the simulated environment equal to the task required? Program managers must be able to identify the needs of their projects by specifying the number of enemy and friendly entities that each must be able to represent. There appears to be no limit to the details inherent in weather, terrain, enemy forces, civilians, etc., that each program can work to achieve in representing the battlefield environment. The Army's efforts to develop standards that apply across the organization represent an enterprise-wide information technology architecture. This effort is an enterprise application architecture strategy. This architecture defined under an enterprise strategy should include:

- The approved Network, data, interface, and processing technologies and development tools

[58] William Payne, "Ground Battle Models" edited by Wayne P Hughes Jr, in Military Modeling, Military Operations Research Society, Alexander, VA Aug 1986, page 156.

- A strategy for integrating legacy systems and technologies into the application architecture
- An ongoing process for continuously reviewing the application architecture for currency and appropriateness
- An ongoing process for researching emerging technologies and making recommendations for their inclusion in the application architecture
- A process for analyzing requests for variances from the approved application architecture.[59]

The M&S architecture represents, in some measure, a departure from the Army's enterprise information technology architecture. Were it designed to be seamlessly integrated into the Army's existing architecture, the projects under the M&S domain would be expected to use or choose technologies based on the current and planned Army-wide architecture[60]. As it stands now, the systems being developed to run WARSIM do not fall in this category. The Statement of Work for WARSIM specifies that the program will model environmental effects including: "natural and related man-made physical conditions and effects including atmospheric, terrain, oceanographic, and space components for all climates world-wide; dynamic changes due to natural interactions (e.g. rain,); dynamic changes (e.g. destruction/construction of natural or man-made objects) due to organizational activities.[61] How can the program be effectively evaluated to determine that the fidelity of modeling efforts is sufficient? It would seem reasonable that a specific set of staff tasks and commander-oriented training objectives would help in evaluating these simulations.

Michael H. Abkin provided an opinion following the Model Acceptance Workshop in 1981 that models should be evaluated with respect to four factors. The four measures are verification (logical consistency), validation (consistency with real-world phenomena being modeled), clarity and workability. Abkin proffered clarity as the ability to represent a model's results unambiguously to users; workability "means the model is cost-effective in its use and that

[59] Jeffrey L Whitten and Lonnie D. Bentley. *System Analysis and Design Methods,* Irwin Mcgraw Hill, Saint Louis MO, page 370

[60] Ibid

[61] "Statement of Work for Engineering and Manufacturing Development (EMD) of Warfighters'

information generated by it and used in decision making has proven in practice to have contributed to better decisions.[62] Applying the concept of workability to training simulations, they should be both cost effective and contribute effectively to decision-making and evaluation in their training role. Using this method of evaluation, the workability for a simulation designed to train corps commanders and their staffs should be measured by how effective it is in meeting training objectives.

Without these training objectives, it is difficult to determine when a simulation truly meets the needs of the Army. The absence of good metrics to determine training value appears to focus simulation developers toward providing the most real simulation environments that they can provide. This in turn seems to focus them increasingly on the latest technology. This phenomenon might be mitigated by incorporating specific training objectives into development requirements together with expected capabilities in representing the physical environment. These requirements could be established both for the simulation version being developed and by establishing requirements for versions in years to come. Incorporating training objectives and minimum physical environment modeling standards may mitigate the drive toward employing the latest in technology and increase portability of simulation software across the Army.

Increasing portability of simulations across Army networks can help reduce costs associated with conducting simulation-based training. Cost-effectiveness must be measured by the cost relative to the training conducted. This cost should not only include the dollar-cost of developing and implementing a simulations but also in the cost of executing the simulation, including the personnel costs associated with a simulation exercise. There are generally three categories of personnel that a unit orcommand must provide to conduct collective training. They are the primary training audience (those whom training is focused on), the secondary training

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Simulation (WARSIM) 2000," 31 Jan 2002, US Army STRICOM Orlando FL, page 7

[62] Michael B Abkin, Correspondence in *Computer Modeling and Simulation: Principles of Good Practice*, by John McLeod, (Society for Computer Simulation, LaJolla, California, 1982), Page 25

audience (those who receive some training by the trainers, i.e. BCTP observers) and support personnel (conducting data and order input or logistical/administrative support).

The personnel cost of conducting training should not be measured solely by the number of personnel provided by the simulation community, but should include all personnel supporting training. Additionally the cost of each support person varies. A battalion commander taken away from his unit to execute division commands represents a greater cost than a soldier with fewer responsibilities. In many cases, the individual who inputs orders and commands are required to stay at a simulation center while an exercise is going on. This requires experienced personnel in command and support positions to effectively execute orders within the simulation. The Office of Technology Assessment did not consider these personnel costs significant as compared with the DoD operations and maintenance appropriation in 1995.[63] However, reduction of the number of man hours required to support simulation-based training would still be desirable and would free supporting soldiers to conduct their own training. Reducing personnel support costs seems to be in line with the Army's desire to move less troops and more digits. Ultimately individuals who are important to their units, battalion commanders, company commanders, platoon leaders, platoon sergeants, etc., become support personnel. They must be away from their leadership responsibilities for the training to occur.

Leaders could execute their training support responsibilities from their unit locations were it possible. These leaders could support exercises and perform leader tasks from their home station. Understanding that routinely each person works a 12-hour day, or less, in the simulation support role, allowing people to execute simulation input from the computers available at the unit would seem to be more cost effective and allow these soldiers to perform their leadership tasks. With the technology being employed within WARSIM, this does not seem possible at this time. The dual-Pentium processor systems that WARSIM is using to execute and input information into

[63] U.S. Congress, Office of Technology Assessment, *Distributed Interactive Simulation of Combat*, OTA-BP-ISS-151 (Washington, DC: U.S. Government Printing Office, September 1995), page 56

the simulation at this time, suggest that the average desktop in units today could not be used. Using the latest technology in WARSIM means that only individuals using equipment at the local simulations center or unit ABCS equipment will be able to participate.

All of the M&S systems do envision interacting with unit ABCS equipment. Effectively, this will allow units to directly interact with simulation software, removing some of the costs associated with inputting orders, moving units, conducting support and service support activities in the simulated environment. It does not, however, remove the necessity for supporting personnel to provide inputs to the system through simulation-provided equipment. It is not clear that these training support activities could be accomplished with ABCS equipment. At this time, the Army ABCS systems do not include the capabilities of dual Pentium 900 MHz processors. Army-wide computing equipment standards might also remove this impediment by either providing that the M&S community comply with specific Army-wide standards or by updating some unit PCs to equal those needed to run simulations.

The standards being employed in the development of M&S programs have implications for the portability of these systems, affecting what equipment and networks soldiers must use to participate. The Army's efforts to develop standards that apply across the organization represent an enterprise-wide information technology architecture. This effort is an enterprise application architecture strategy. The architecture defined under this strategy should include:

- The approved Network, data, interface, and processing technologies and development tools
- A strategy for integrating legacy systems and technologies into the application architecture
- An ongoing process for continuously reviewing the application architecture for currency and appropriateness
- An ongoing process for researching emerging technologies and making recommendations for their inclusion in the application architecture
- A process for analyzing requests for variances from the approved application architecture.[64]

[64] Jeffrey L Whitten and Lonnie D. Bentley. *System Analysis and Design Methods,* Irwin Mcgraw Hill, Saint Louis MO, page 370

The M&S architecture seems to represent, in some measure, a departure from the overall Army information technology architecture. Were it designed to be seamlessly integrated into the Army's existing architecture, the projects under the M&S domain would be expected to use or choose technologies based on the current and planned Army-wide architecture[65]. As it stands now, the systems being developed to run WARSIM do not fall in this category.

The current M&S systems are enclosed within their own architectures with very limited capability to interact with other simulations. The HLA being implemented will allow interaction between the three programs under development. Achieving large-scale distributed simulations running in real time has been difficult. This difficulty has been, in large part, to network technology. The HLA has significantly extended the number of simulation hosts that can be supported.[66] Implementing the HLA represents a leap forward in the Army's attempt to provide a common architecture for simulations. The HLA, however, is a diversion from the Architecture used throughout the Army on a day-to-day basis, DIS. To have the greatest portability it the systems developers should look to incorporating HLA into the DIS architecture, allowing systems outside the M&S architecture to run simulation software. Lacking standards that require the future simulations to be able to operate across the Army's current non-simulation networks and on anticipated Army-wide computer capabilities, it is likely that simulations will remain closed to participation outside of fielded units and simulation centers.

RECOMMENDATIONS

To allow the widest possible participation and increase the flexibility to commanders in executing collective training, the Army should attempt to provide greater standardization to the M&S community. Additionally, The Army should identify specific training objectives that

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[65] Ibid

[66] Dr. Stephen Zabele, "Abstract of Dynamic Interest Filtering for Optimal State Update Messaging" et al. Internet, http://www.simsysinc.com/EC_Abstracts1.htm accessed 10 January 2002.

simulation systems can be measured against. Finally, The Army should determine to what degree simulation activities should be executable from outside the M&S architecture. These steps would represent an even greater effort to maximize the Army's current technology and maximize the portability of simulation.

The Standardization efforts being applied to the M&S community seem to presume a need for the latest technology. This assumption must have the effect of limiting application portability to M&S procured/developed architecture. As TRADOC has implemented standards for computers operating outside M&S, the Army should consider establishing two sets of standards: one establishing the networking and technology requirements of applications to be implemented in the next delivery of M&S and a second for applications that will be under development. These standards would need to address maximum processor requirements and maximum networking capabilities, serving as a basis for allowing interoperability with networking and computing systems not purchased solely for M&S purposes. More specific standards could help insure that the simulations being delivered will be most widely usable.

The Army should make a conscious decision whether or not simulation applications should be executable from outside the M&S architecture. It would seem desirable for support personnel to be able to receive orders, requests, and reports, and input them from the desktop that they use day-to-day. There would obviously be concern that these personnel would be distracted by other events or require assistance in executing their simulation support responsibilities. Given that these personnel are often experienced leaders and subject matter experts, these concerns should be evaluated against the desire to have minimal impact on subordinate units not directly benefiting from the simulation training.

To help in developing these standards, the Army should develop a complete list of training objectives that each simulation is designed to support. The goal of a simulation is to represent real world events. Without identifying the specific training requirements it is difficult to imagine how developers can determine the fidelity required of simulations. The training

objectives would help both in identifying the fidelity required and provide the Army with a measurable way to evaluate simulation effectiveness. Identifying training objectives may also mitigate the drive to implement technology solutions that are beyond the capabilities computers available throughout the Army.

The set of simulations under development, WARSIM, OneSAF, and CATT, represent a leap forward for the Army. Developers are working hard to achieve the vision of linking simulations that will allow units from platoon through corps-level to participate in a simulation training event. The HLA and standards developed to implement an M&S-wide integrated architecture will make this possible. These simulations promise unheard of fidelity in representing the combat environment, and a valuable tool in conducting collective training. The Army should continue to evaluate the possibility and feasibility of making simulation software more widely executable, taking advantage of existing technology and network capabilities while looking forward to the ever increasing fidelity of simulated environments.

BIBLIOGRAPHY

Abkin, Michael B. Correspondence in *Computer Modeling and Simulation: Principles of Good Practice.* by John McLeod. Society for Computer Simulation. LaJolla, California, 1982.

Anderson, Doug STRICOM Chief Engineer Constructive Simulations and Rick Copeland. Lockheed WARSIM Chief Engineer, Interview by author, 18 January 2002 notes taken, STRICOM WARSIM office. Orlando, Florida.17 January 2002

"BBS Information Paper." 17 May 2001. Internet. http://www-leav.army.mil/nsc/famsim/bbs/infopaper.htm accessed 20 January 2002.

Chiekes. Brant A. "Architecture / Reference Model Working Group." September 1997. Internet. http://ltsc.ieee.org/ppt/brant_ppt/tsld001.htm accessed 15 January 2002.

"Close Combat Tactical Trainer." 10 April, 2000. Internet. http://www.stricom.army.mil/STRICOM/PM-CATT/CCTT/IOP/icd_web_1.html accessed 10 November, 2001.

"Combat Service Support Training Simulation System CSSTSS." 7 March 2000. Internet. http://www-leav.army.mil/nsc/famsim/csstss/index.htm accessed 21 November 2001.

Department of Defense. "Joint Technical Architecture List of Mandated and Emerging Standards." 2 April 2001. Internet. http://www-jta.itsi.disa.mil/jta/jtav4_dnld.html. accessed 12 December. 2001

_____. Chief Information Officer CIO. "Acquiring Commercially Available Software." Policy Memorandum 12-8430. July 26, 2000. Internet. http://apps.fss.gsa.gov/schedules/Navy3.cfm accessed November 20 2001.

Flynn, Larry Supervisory Logistics Management Specialist. TELCON. Telephonic interview by author. 24 Jan 2002. notes taken.

Hanes, Ray and Ramsey, Bob. Janus Systems Analyst. Interview by author. 1 November 2001 notes taken. Janus office. National Simulation Center. Fort Leavenworth, Kansas.

Headquarters Department of the Army. Army Regulation 5-11. *Management of Army Models and Simulations*. Washington DC, August 1997.

_____. Army Regulation 25-1. *Army Information Management.* United States Army Publishing Agency. 15 February 2000

_____. Office of the Deputy Chief of Staff for Operations and Plans and Office of the Deputy Under Secretary of the Army Operations Research. "The Army Model and Simulation Master Plan." Army Model and Simulation Office. October. 1997.

"High Level Architecture."Defense Model and Simulation Office Internet. http://www.dmso.mil/index.php?page=64/edu_trng/regional/core_mat/ accessed 10 January 2002

National Simulation Center. "Information Paper. Subject: Corps Battle Simulation CBS." Internet, http://www-leav.army.mil/nsc/famsim/cbs/info_pap.doc accessed 16 November 2001.

"Introduction to TACSIM." Internet. http://www-leav.army.mil/nsc/famsim/tacsim/intro.doc accessed 15 December 2001.

JANUS Information Paper. National Simulation Center. 10 April 2001. Internet www.leavenworth.army.mil/nsc accessed 10 November 2001.

"JCATS Joint Conflict & Tactical Simulation." 12 December 2001. Internet. http://www.jwfc.acom.mil/genpublic/jw500/jcats/ accessed 15 December 2001.

Defense Information Systems Agency. "JIEO Report – 8300 Department of Defense Minimum Desktop Personal Computer Configuration." Joint Interoperability and Engineering Organization Center for Standards. Aug 1997.

"Joint Simulation System" Internet. http://www.jsims.mil/about.html accessed 20 October 2001.

Lockheed Martin Corporation. "OneSAF Testbed Baseline Assessment DO #0060. CDRL AB02 Final Report." Orlando, FL. May 1998.

"Modeling and Simulation Websites for the Signaleer." Internet. http://team-signal.net/html/links39.htm#JSIMS accessed 20 December 2001.

National Simulation Center. Training Exercise Military Operations. "TEMO Investment Plan." Internet, http://www-leav.army.mil/temo/ accessed 10 November 2001.

"OneSAF information paper" Internet. http://www-leav.army.mil/nsc/nextgen/onesaf/13feb01.doc accessed 21 November 2001.

"OneSAF Operational Requirements Document." 27 February, 2001. Internet. http://www.onesaf.org/OneSAF_ORD_v1.1.FinalXXYYZZ.doc accessed 15 November 2001.

Payne, William "Ground Battle Models," ed. Wayne P Hughes Jr, in *Military Modeling.* Military Operations Research Society, Alexander, VA Aug 1986.

"Prime Item Development Specification for The Close Combat Tactical Trainer. Contract No. n61339-93-c-0004;" Lockheed Martin, Orlando FL 1999.

Sargent, David. telephonic interview by author. 23 Jan 2002.

"Software Development Plan Report/Results Of Analysis for the Onesaf Testbed Baseline Program Do 0097" Simulation, Training, and Instrumentation Command Orlando, Florida 23 February 1999. Internet. http://www.onesaf.org/extint/sdp/sdp.html#_Toc436624386 accessed 10 January 2002.

Taylor, James G, "An Introduction to Lanchester-Type Models of Warfare," in *Proceedings of the Workshop on Modeling and Simulation of Land Combat*, by Dr L. G. Callahan Jr. (School of Industrial and Systems Engineering, Georgia Tech Printing and Photographic Office, April 1985).

"TEMO Domain Management Plan," 14 March 2000, Intenet http://www.amso.army.mil/structure/domains/temo/plan/ accessed 16 February 1999.

Toms, Ralph A, Lauri Dobbs, and Jeffrey Pimper. *High Resolution Combat Simulations to Support Training for Close Combat Light Operations*. Lawrence Livermore National Laboratory, June 1990.

TRADOC Pamphlet 25-73, (Headquarter Department of The Army, Fort Monroe VA, 1December 2000)

"Training Device Mission Need Statement for Command and Control." Internet, http://www-leav.army.mil/nsc/warsim/mns.htm, accessed 10 November 2001.

"Training Device Requirement (TDR) for the Close Combat Tactical Trainer (CCTT)." STRICOM, 11 July 2000. Internet, http://www.stricom.army.mil/STRICOM/PM-CATT/CCTT/FILES/cctt_tdr_20000611.pdf accessed 10 November, 2001

"This is Spectrum," SPECTRUM the National Simulation Center. Internet, http://www.leavenworth.army.mil/nsc/famsim/spectrum/intro.htm#5 accessed 15 November 2001.

US Army STRICOM. "Statement of Work for Engineering and Manufacturing Development EMD. of Warfighters' Simulation WARSIM. 2000." Orlando FL, 31 Jan 2002.

U.S. Congress, Office of Technology Assessment. *Distributed Interactive Simulation of Combat*, OTA-BP-ISS-151. Washington, DC: U.S. Government Printing Office, September 1995.

"Warfighters Simulation 2002 Operational Concept Document." Lockheed Martin Corporation Information Systems, Orlando, Fl. Internet, http://www-leav.army.mil/nsc/warsim/ord/ops.htm#_Toc424372376 accessed 20 November 2001.

Whitten, Jeffrey L. and Lonnie D. Bentley. *System Analysis and Design Methods*, Irwin Mcgraw Hill, Saint Louis MO, 1998.

Zabele, Dr. Stephen ,"Abstract of Dynamic Interest Filtering for Optimal State Update Messaging" et al. Internet, http://www.simsysinc.com/EC_Abstracts1.htm accessed 10 January 2002.