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ARMY SCIENCE BOARD

1991 SUMMER STUDY

FINAL REPORT

ARMY SIMULATION STRATEGY

DECEMBER 1991

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The 1991 Army Science Board (ASB) Summer Study on Army Simulation Strategy was tasked by the Assistant Secretary of the Army for Research, Development, and Acquisition on 29 January 1991. A group of thirteen Army Science Board members was formed to address the terms of reference, which included:

- Assess the status of modeling and simulation technology and identify technology barriers and/or enhancement opportunities.
- Examine payoffs and benefits, and define the role of distributed simulation in training.
- Evaluate the use of modeling and simulation in the development and testing of concepts, systems and doctrine.
- Define a research, development, and acquisition investment strategy that leads to the desired future simulation capability.

The full study group held four two-day meetings at the Pentagon, plus one each at Ft. Leavenworth, Kansas, and Ft. Knox, Kentucky. Panels on Training, Development, and Technology made numerous visits to other government and private sector organizations involved in the development and use of simulation techniques

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The study group found the use of simulation to be increasingly wide-spread and critically important in all phases of Army activities. This increasing use of simulation is driven both by needs resulting from constrained funding, test range and training space limitations, and the increasing cost and complexity of systems, and by the opportunities afforded by new simulation capabilities.

While the study group strongly endorsed the development and use of simulation for training, combat development, material acquisition, and testing, it believes that the current Army program is too tentative and fragmented. Particular areas of concern are:

- Rather than build on SIMNET, the Army program is undertaking a fresh start with CATT and BDS-D.
- CATT and BDS-D are being pursued as separate, independent efforts rather than as a single, integrated program.
- CCTT (a second-generation armor/mechanized capability) is being pursued first, with DA funding. It is to be expanded "later" to CATT by adding aviation and air defense simulators, if and when these are funded by the respective proponents. This approach unduly delays the creation of a much needed combined arms training environment.

As the Army's use of simulation becomes increasingly wide-spread, the need for consistent, valid data bases and models becomes even more critical. Centralized control and accreditation of data bases and models is required to achieve valid and consistent results throughout the Army and to build confidence in the use of the Electronic Battlefield.

The study group concluded that the Electronic Battlefield, as defined in this report, can revolutionize the Army's way of doing business in training, development, testing, readiness and operations, and probably in many other areas. In so doing, it can either save substantial money, with discipline, while allowing today's levels of performance to be sustained, or it can radically improve performance at today's level of funding.

Consequently, the study group strongly recommended that the Secretary of the Army and Chief of Staff lead the Army into adoption of the Electronic Battlefield as rapidly as possible. In doing so, it should be clear that:

- The technology and its application have been demonstrated and there are no technological barriers;
- This is a major engineering effort. The Electronic Battlefield should be viewed as a constantly evolving system and must maintain integrity and validity as it evolves;
- The other services have undertaken SIMNET-based demonstrations and this technology is generally recognized as the basis for a joint Electronic Battlefield. The Army should continue to lead the way.

In response to these broad conclusions, observations, and findings, the study group specifically recommended that the Army:

- Aggressively adopt the Electronic Battlefield for training, with emphasis at the outset on achieving a combined arms capability, including armor/mechanized, aviation, and air defense at the battalion task force level.
- Require restructuring of the CATT/CCTT program to evolve from the current SIMNET capability in phases that gradually upgrade existing facilities and functionality.
- Require simulation in the form of electronic prototypes throughout all phases of the force development and materiel acquisition processes. Mandate the Electronic Battlefield as a primary test environment for early evaluation of operational utility.
- Establish a single manager for the development and operation of the Electronic Battlefield, with the requisite resources and authority
- Develop and accredit a set of consistent data bases and models for use in the Electronic Battlefield under the direction of the Electronic Battlefield manager.
- Focus Army resources on the application of simulation technology to Army-specific problems, leaving research and development of underlying technologies to outside (DARPA and private sector) programs.

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EXECUTIVE SUMMARY

The 1991 Army Science Board (ASB) Summer Study on Army Simulation Strategy was tasked by the Assistant Secretary of the Army for Research, Development, and Acquisition on 29 January 1991. A group of thirteen Army Science Board members was formed to address the terms of reference, which included:

- Assess the status of modeling and simulation technology and identify technology barriers and/or enhancement opportunities.
- Examine payoffs and benefits, and define the role of distributed simulation in training.
- Evaluate the use of modeling and simulation in the development and testing of concepts, systems and doctrine.
- Define a research, development, and acquisition investment strategy that leads to the desired future simulation capability.

The full study group held four two-day meetings at the Pentagon, plus one each at Ft. Leavenworth, Kansas, and Ft. Knox, Kentucky. Panels on Training, Development, and Technology made numerous visits to other government and private sector organizations involved in the development and use of simulation techniques. The information gathered in these meetings was synthesized into a study report during a two-week session at Hampton, Virginia.

The study group found the use of simulation to be increasingly wide-spread and critically important in all phases of Army activities. This increasing use of simulation is driven both by needs resulting from constrained funding, test range and training space limitations, and the increasing cost and complexity of systems, and by the opportunities afforded by new simulation capabilities.

The study group adopted the term "Electronic Battlefield" to represent a single, comprehensive simulation environment which can support combat development, system acquisition, test and evaluation, training, and mission planning and rehearsal, including both Army-specific and joint operations. In this report, the term "Electronic Battlefield" is variously used to describe this environment, the process which utilizes the environment to accomplish objectives, and a program for funding and managing the development and operation of this environment.

The enabling technology for this comprehensive Electronic Battlefield is distributed interactive simulation (DIS), developed and demonstrated by the DARPA/Army SIMNET program. DIS allows a large number of various types and geographically-distributed simulations to interact in a common simulated battlefield environment. SIMNET has proven itself for training, in both single element and combined arms configurations, and as a test environment to support the development of new technologies and systems.

Based on the DIS approach developed and demonstrated by SIMNET, the Army has initiated two follow-on programs: CATT (Combined Arms Tactical Trainer), an expanded and improved training system which initially consists of CCTT (Close Combat Tactical Trainer), but will be upgraded by the addition of aviation and air defense simulators; and BDS-D (Battlefield Distributed Simulation - Developmental) to support the simulation requirements of the combat and system development activities.

While the study group strongly endorses the development and use of simulation for training, combat development, materiel acquisition, and testing, it believes that the current Army program is too tentative and fragmented. Particular areas of concern are:

- Rather than build on SIMNET, the Army program is undertaking a fresh start with CATT and BDS-D.

- CATT and BDS-D are being pursued as separate, independent efforts rather than as a single, integrated program.

- CCTT (a second-generation armor/mechanized capability) is being pursued first, with DA funding. It is to be expanded "later" to CATT by adding aviation and air defense simulators, if and when these are funded by the respective proponents through OPTEMPO reductions. This approach unduly delays the creation of a much needed combined arms training environment.

As the Army's use of simulation becomes increasingly wide-spread, the need for consistent, valid data bases and models becomes even more critical. Centralized control and accreditation of data bases and models is required to achieve valid and consistent results throughout the Army and to build confidence in the use of the Electronic Battlefield.

The study group found that the Army's use of simulation is not paced by the availability of the requisite technology; rapid advances are being made by DARPA and private sector activities in the most important technologies, e.g., displays, networks, and processing.

The study group concluded that the Electronic Battlefield, as defined in this report, can revolutionize the Army's way of doing business in training, development, testing, readiness and operations, and probably in many other areas. In so doing, it can either save substantial money, with discipline, while allowing today's levels of performance to be sustained, or it can radically improve performance at today's level of funding.

Consequently, the study group strongly recommends that the Secretary of the Army and Chief of Staff lead the Army into adoption of the Electronic Battlefield as rapidly as possible. In doing so, it should be clear that:

- The technology and its application have been demonstrated and there are no technological barriers;

- This is a major engineering effort. The Electronic Battlefield should be viewed as a constantly evolving system and must maintain integrity and validity as it evolves;

- The other services have undertaken SIMNET-based demonstrations and this technology is generally recognized as the basis for a joint Electronic Battlefield. The Army should continue to lead the way.

Achieving these broad goals will require substantial investment, particularly in the training areas, where large numbers of simulators are required. It seems clear that the use of the Electronic Battlefield can create substantial savings, but that these will be available in the outyears, while investment must be in the near term.

In response to these broad conclusions, observations, and findings, the study group specifically recommends that the Army:

- Aggressively adopt the Electronic Battlefield for training, with emphasis at the outset on achieving a combined arms capability, including armor/mechanized, aviation, and air defense at the battalion task force level.

- Require restructuring of the CATT/CCTT program to evolve from the current SIMNET capability in phases that gradually upgrade existing facilities and functionality. Start with modest upgrades prioritized to be consistent with achievable funding rates such that capabilities are reached in a timely fashion. (This is in contrast with the current plan to retain the concept and implement a significantly upgraded version with complete new hardware and software.)

- Require simulation in the form of electronic prototypes throughout all phases of the force development and materiel acquisition processes. Mandate the Electronic Battlefield as a primary test environment for early evaluation of operational utility. This will cause program managers to develop the simulators required for operational testing and, subsequently, for training.

- Establish a single manager for the development and operation of the Electronic Battlefield, with the requisite resources and authority. This manager should develop and operate the Electronic Battlefield as a single activity, which will support both the training (CATT) and development (BDS-D) functions. The single manager also should manage the procurement of systems currently under the CATT and BDS-D programs.

- Develop and accredit a set of consistent data bases and models for use in the Electronic Battlefield under the direction of the Electronic Battlefield manager.

- Focus Army resources on the application of simulation technology to Army-specific problems, leaving research and development of underlying technologies to outside (DARPA and private sector) programs.

These recommended actions are intended to focus on two fundamental goals, namely:

- Develop the capability to conduct the most effective combined arms training at the company/battalion/brigade level.

- Institute the requirement for simulation, both high fidelity and low resolution, to support FDT&E throughout the development and life cycle of all major systems.

PROBLEM STATEMENT

In the tasking letter (Appendix A) to the Army Science Board dated 29 January 1991, the background of the problem was defined as follows:

> In the last several years, the Department of Defense (DoD) and the Congress demonstrated an increasing interest in the use and application of computer simulations. At the DoD level, a 1988 Defense Science Board (DSB) Task Force issued a report on "Computer Applications to Training and Wargaming". In 1989, the DoD Inspector General (IG) issued a report on "Wargaming Activities in DoD". The House and Senate Committees on Armed Services (HASC and SASC) both mentioned management and the promotion of simulation and wargaming in DoD in their initial reports on the FY 91 budget. These reports, coupled with other considerations, led DoD to convene a study panel tasked to develop a DoD modeling and simulation policy. The recommendations of that study, currently being staffed, call for the formation of a DoD oversight group and the development of Service modeling and simulation Master Plans.
>
> Within the Army, simulation development efforts are escalating at a significant rate. For example, there are multiple efforts either seriously considered or actually under development, to generate man–in–the–loop, very high resolution combat simulations for use in training, combat development, and weapons system development and acquisition. Each of these efforts is extremely expensive. Some specific examples are: Close Combat Tactical Trainer (CCTT), Battlefield Distributed Simulation – Developmental (BDS–D), and Combined Arms Test Bed (CATB).
>
> The effective management of modeling and simulation activities requires a keen understanding of the leverage such new opportunities can offer at the time they are likely to become available. To assist in evaluating the most efficient and effective course of action for simulation in the future, the Army must conduct a comprehensive assessment of all alternative technologies conceivable.

Since the tasking letter was issued, several changes have occurred. First, development of the CATB has been suspended. Second, the Army has broadened the scope of CCTT to become the Combined Arms Tactical Trainer (CATT) (while still retaining the more limited CCTT as the first step in achieving a CATT). Third, the DoD has created and begun to staff the Defense Modeling and Simulation Office (DMSO). Finally, the Army has conducted many analyses (some in support of this study) to better define its modeling and simulation capabilities and initiatives.

TERMS OF REFERENCE

The Terms of Reference of this study, dated 29 January 1991 are attached as Appendix A. These describe, in some detail, the issues and questions to be addressed which are summarized as follows:

- Assess the status of modeling and simulation technology and identify technology barriers and enhancement opportunities.
- Examine payoffs and benefits and define the role of distributed simulation in training.
- Evaluate the use of modeling and simulation in development and testing of concepts, systems and doctrine.
- Define a research development and acquisition investment that leads to the desired future simulation capability.

SCOPE OF STUDY

Consistent with the Terms of Reference and our assessment of the major near–to–intermediate term issues, this study focused on the use of simulations (a term we use variably to refer to models, simulations, simulators and wargaming) in development and training. Specifically, in the area of System Development, we evaluated the use of simulations for: Concept Tradeoffs, Engineering Design and Analysis, System Development, Test and Evaluation, and Training Device Development. In the area of Force Development, we considered: Combat Development, Cost and Operational Effectiveness Analyses (COEA), Force Structure Development, and Training Development. In the area of Training, we evaluated the use of simulations for: Individual, Crew, and Team Training, Task Force Training, Command and Staff Training, and Joint Force Training. Addressed only in passing were the areas of Doctrine Development and Operations (Mission Planning, Mission Rehearsal, and Contingency Mission Planning). Further, the wide use of modeling and simulation for a broad range of other applications (e.g., Engineering, Logistics, Transportation, ...) was evaluated only enough to determine that our primary focus was appropriate. We fully expect all of these individual applications to merge, through simulation, more in the future than they do today.

This report provides an overview of our deliberations and assessments. A much more thorough discussion is included in three of the appendices reporting the extensive work by the three panels of the study. These appendices and the topics are:

Appendix C - Simulation in Development, Acquisition and Testing

Appendix D - Simulation Technology and Technology Investment Strategy

Appendix E - Simulation in Training

PARTICIPANTS

The Membership of the ASB Summer Study on Army Simulation Strategy was as follows:

Mr. Larry Lynn, Chairman
Mr. Paul Drouilhet, Vice Chairman

Technology Panel:

Mr. E. Brady (Chair)
Mr. Joseph Fox
Dr. Bruce Tarter
Mr. Martin Zimmerman

Acquisition Panel:

Dr. Peter Cherry (Chair)
Dr. William Evers
Dr. Foster Rich

Training Panel:

Dr. Allen Grum (Chair)
Mr. Dave Hardison
Gen John Pauly (USAF-Ret)
LTG Jack Woodmansee (USA-Ret)

The study was sponsored by Mr. Walter Hollis (DUSA/OR) and the Cognizant Deputy was Mr. George Singley (DASA/RDA), each of whom provided substantial guidance and assistance. Their offices were represented respectively by Colonel Gilbert Brauch and Mr. John Yuhas, the study Staff Assistants, who were full participants throughout.

The study panel sought to extend the views of the participants by having several very experienced persons hear our views, challenge our facts and logic, and nudge our inclinations. These included:

General Max Thurman (USA-Ret),
General Paul Gorman (USA-Ret),
MG Vern Lewis (USA-Ret), and
Dr. Phil Dickinson,

all of whom devoted several hours to listening to our results and offering critique and advice. In addition, technical expertise was provided by many including:

Colonel Jack Thorpe, DARPA
Colonel Jim Shiflett, DMSO
Dr. Ron Hofer, PM Trade
Mr. Joe Lacetera, LABCOM

The interactions with these persons, all of whom have more than once wrestled with the matters being examined in the study, were stimulating and rewarding, even if on occasion painful. The valuable assistance provided by these reviewers and advisors is gratefully acknowledged.

BACKGROUND

Simulation in Training Today

As we look at the situation today, it is apparent that most of our past efforts in training simulations have been directed toward providing effective tools in support of the various levels of command. These efforts have met with reasonable success and the Army has fielded, or is currently fielding, a meaningful array of training simulations, considering the funds committed to date. At this time, however, the Army is passing through a period of transition with regard to simulation brought about by a confluence of two major factors. The first is the greatly reduced overall funding which is being felt throughout DoD. Beyond the basic cost of training, per se, the reduced budget has also forced a reduction in Army force structure which puts an added premium on quality training to maximize the readiness of the reduced force. The second is the accelerated rate of technical advances being experienced in the simulations area which enhance their effectiveness in doing the many-faceted training job at an increasingly affordable expense. In essence, simulation technology is outpacing the ability of the Service to deal with it.

Simulations for training, can be considered in four groupings: individual and crew training, team and unit training, command and staff training and joint combined training. The first category is designed to teach the individual soldier and/or crew their required skills and to aid them in sustaining high proficiency in these skills. Some level of teamwork training is involved in the case of item crews. Examples of simulations currently in use include UCOFT, maintenance trainers and flight simulators.

Team and unit training devices are designed primarily to develop task force teamwork, although some individual training is also accomplished in the process. Command, control and communication is introduced in this type simulation and improvements in C? are often a bonus feature of their use. Examples of this category include PCOFT and SIMNET-T, both of which are popular and obtaining impressive results. Contained within SIMNET is the best example of the "Electronic Battlefield". With only limited exceptions, connections of other simulations into SIMNET do not exist at this time.

Simulations designed to provide command and staff training include force-on-force exercises which permit practice decision making and battle synchronization. Examples are CBS, BBS, and JANUS. The creation of simulated, believable, situations requiring hard tactical decisions by senior commanders is a particularly worthwhile feature of those simulations. Simulating the staff follow-up to these decisions is also extremely helpful.

Limited use has been made of current models to provide joint training, although they could be modified/expanded to do so. There are also stand-alone simulations specifically tailored to provide such joint training - e.g., models in use at the Warrior Preparation Center (WPC). Under current directives, models and simulations have been developed and funded under dual-tracks: system related and non-system related. Individual program managers are responsible for incorporating training devices and techniques which uniquely support their programs. Non-system related simulations are centrally managed and programmed through TRADOC. At this point, the trick is to see that they can play together and that the technical progress made through the years is translatable to support other functions, such as development, acquisition and testing.

Simulation in Development & Testing Today

We evaluated the use of simulation in development and testing today in three major areas: concept development, design and development, and test and evaluation.

Concept development has made heavy use of closed form simulations for many years. Recently, SIMNET–D has begun to demonstrate the potential of interactive simulation for increasing early involvement to discover, learn and quantify the capabilities of proposed new systems. An example is the development and refinement of tradeoffs in performance and operational procedures for the ADATS system prior to IOT&E.

Design and development programs have long used computer aided design simulations down to the part and component level as well as a variety of low– and high–resolution simulations for new systems. In recent years, they have begun using very comprehensive high–resolution, man–in–the–loop, hardware–in–the–loop simulations throughout the process. A specific recent example in which such simulation was critical, at least to the source selection, is that of the Comanche helicopter. Both LH competitors indicated that simulation was absolutely <u>necessary</u> to handle the complexity of the system. Without such simulation, a less capable weapon and more expensive system would have resulted. In addition, the LH competitors believed that such comprehensive simulations would greatly increase the likelihood that the first real unit would operate properly the first time and would not require what has become the traditional test/modify/retest cycle.

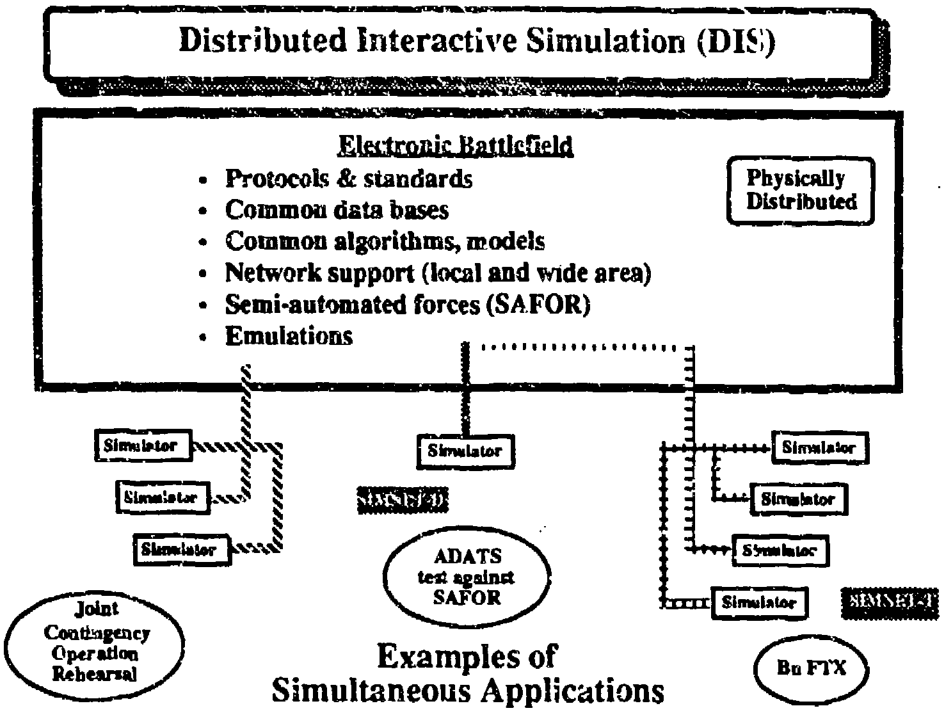
Test and evaluation efforts have only just begun to use simulation in test design and execution to increase "realism" at force levels. Perhaps more important is the opportunity for the development and test community to "experiment" with proposed systems in simulation both to evaluate their potential capabilities, training needs, employment concepts and to determine the most cost effective ways of validating such capabilities. A specific near term requirement is that for stimulators (essentially simulated real-world inputs), particularly for C^3I systems.

Many opportunities exist to use simulations to enable <u>more cost effective</u> development of <u>more capable systems</u> tested in a <u>more comprehensive</u> fashion. The use of simulations throughout the concept development, system design and development. and test and evaluation processes as a precursor to, and in some cases replacement for, specific steps in the current process should lead to more systematic, more reliable, and faster development. Substantial cost effectiveness enhancements should be realizable.

Distributed Interactive Simulation

Distributed Interactive Simulation (DIS) is a generalization of the SIMNET concept. It is an electronic battlefield which is defined by a set of protocols and standards; common data bases; common algorithms and models; both local and wide area network support; a robust capability for semi-automated forces (SAFOR); and the ability to emulate both new conceptual systems and existing weapons. It is not a computer or an array of software in a single physical place, but the distributed aggregate of those features described in the preceding sentence.

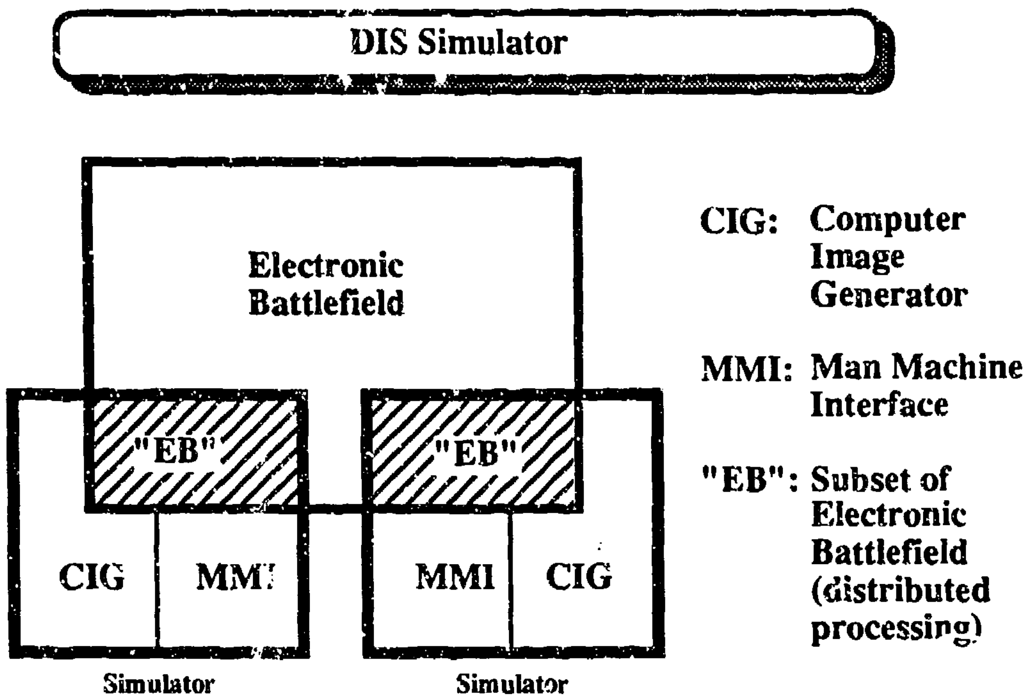
In this report, the term "Electronic Battlefield" is variously used to describe this environment, the process which utilizes the environment to accomplish objectives, and a program for funding and managing the development and operation of this environment.



Three different uses of DIS are illustrated, all of which could be carried out simultaneously, either as separate or combined operations. The first simulation could be a highly interactive joint contingency operation rehearsal. At the same time one could be doing an ADATS concept development test against a SAFOR (as in SIMNET-D). Concurrently, there could be a field training exercise using manned simulated battalions (as in SIMNET-T). These could all be occurring at different physical locations and be transparent to one another, but each would conform to the same set of protocols, standards, and data base requirements common to the DIS.

DIS Simulators

A distributed interactive simulator or simulation station is composed of three elements. First, there are the displays, controls and other devices that provide the human-machine interface. Next is the part of the simulator which generates the computer image, the hardware which provides visualization on the screen, as well as battlefield sounds and vibrations. Finally, there is the subset of the electronic battlefield which resides in the simulator to enable it to interact with other simulations conforming to the standard network protocols. Different elements of the electronic battlefield can reside in different simulators depending on the particular needs of the simulation.



Distributed Interactive Simulation for Training and Development

Simulator networking (SIMNET) was initiated by DARPA and pursued jointly by DARPA and the Army to demonstrate the feasibility of linking manned and unmanned weapon simulators in a computer network. Over time SIMNET was split into two programs. SIMNET-T (Training) was developed to examine the use of SIMNET technology in training troops, while SIMNET-D (Developmental) was designed to explore the use of the technology in activities relating to testing, materiel, combat and doctrine, and organizational development.

The main goal of SIMNET has been to create an electronic battlefield in which multiple and different simulations can interact with one another. The focus is on establishing a simulated world with a common set of standards, protocols, and network support, and developing the software to implement those protocols on various computers. The primary emphasis to date has been on SIMNET-T. Both SIMNET-T and SIMNET-D have successfully demonstrated the electronic battlefield with a number of simulators.

Current Army Programs in Distributed Interactive Simulations

The Army has a number of current programs in Distributed Interactive Simulations. SIMNET-T, the version of SIMNET focused on training, was transitioned to the Army in early 1990. It has 246 manned simulators running on nine operational sites. CATT (Combined Arms Tactical Trainer) is the follow on to SIMNET-T. Its goal is to provide an electronic battlefield environment for training collective battlefield tasks. It is intended, initially, to contain three elements. CCTT (Close Combat Tactical Trainer) is designed to train crew through battalion level collective tasks for tank, armored cavalry, and mechanized infantry units. AVCATT(Aviation CATT) will carry out similar functions for aviation, and ADCATT (Air Defense CATT) for air defense.

SIMNET-D is the version of SIMNET designed to support activities involving testing, materiel, combat and doctrine, and organizational development. It is in the process of transitioning to the Army. BDS-D (Battlefield Distributed Simulation-Developmental) is the follow on to SIMNET-D. Its goal is to build on the features and framework demonstrated in SIMNET-D to give the Army a cost-effective electronic augmentation to proof of principle demonstrations, field tests, and operational evaluations in all phases of force development.

In the panels's view there are no inherent technical reasons for the separation of SIMNET-T and SIMNET-D (or equivalently, CATT and BDS-D). On the other hand, there appears to be compelling reasons of purpose, efficiency, cost savings and planned usage that argue that the planned two separate simulations should, in fact, be part of a single system.

CATT: Current Army Plan

CATT (Combined Arms Tactical Trainer) is the follow-on to the SIMNET-T. It is designed to provide an electronic battlefield environment for training collective battlefield tasks. The current Army operational plan for CATT is to replace SIMNET-T with CCTT as it becomes available. Until that point SIMNET-T will be maintained but not upgraded. Within CATT, the first phase will focus exclusively on producing 546 CCTT simulators for the Armor/Mechanized forces. This will be carried out with Department of the Army funding. The combined arms elements, AVCATT and ADCATT, will be obtained at a later date if supported by the respective proponent schools in the face of probable direct OPTEMPO reductions to provide the funding.

In the opinion of the Panel, this plan is not the right one for the Army. The principal reasons for concern are:

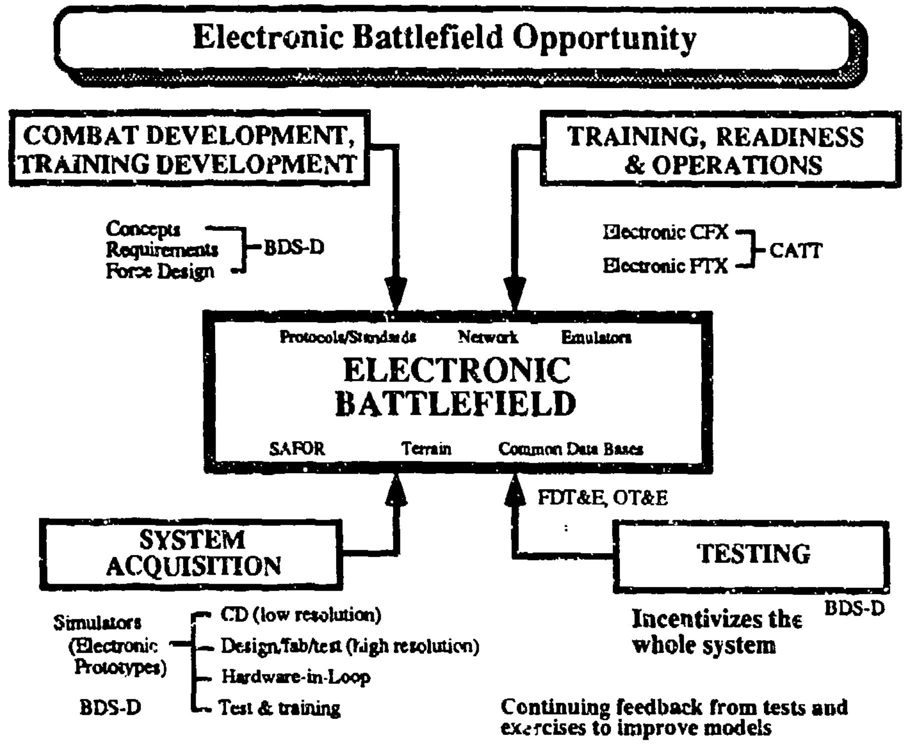
- It does not build on the established, working SIMNET-T in a evolutionary fashion, but rather, retains only the concept and defines a new system with significantly increased features.

- It does not allow upgrading of the existing system and stations during the years until the new CATT becomes available.

- It does not provide for combined arms training until after the turn of the century, since it concentrates all resources on building second generation armor/mechanized simulators before any aviation or air defense simulators.

- The CCTT elements (armor/mechanized) are "paid for" by the Department of the Army, but other combined arms elements must be "paid for" by proponent branches through offsets. This is in spite of the fact that the Army, not a branch, gains most from combined arms. Proponent branches of course do not provide funding packages but rather must agree to reduce OPTEMPO to fund.

- The 246 existing SIMNET-T stations are to be discarded as they are replaced even though it seems clear that good use can be made of as many stations as available for well over another decade.



The Electronic Battlefield

This chart shows how a dollar invested into the Electronic Battlefield (Electronic Battlefield) can be leveraged in the Army's combat and training developments, the system acquisition system, the testing community, and ultimately the training and readiness of the forces in the field.

Greater electronic experimentation in developing user requirements and in evaluating laboratory technology opportunities will help the Army understand which technological choices to make among the many that will be available. The use of early electronic prototyping will be an invaluable asset in refining the requirements, understanding how the technology will fit in the future army and appreciating what technological capability is necessary to make a measurably cost-effective contribution to the battlefield.

Once a program is established, the program manager can use a variety of prototypes to shorten the cycle and ensure that when he is ready to "bend metal", he's got it right. Evolving prototypes, basically lower resolution man-in-the-loop systems can keep providing insight to the current design and refining the final outcome. High resolution mock-ups, or perhaps even actual hardware in-the-loop can be evaluated under "realistic" battlefield conditions within the Electronic Battlefield.

To certify that the system is ready for production, the Army can exploit the ability of the Electronic Battlefield to measure the capabilities of the validated electronic prototype. However, data emerging from the entire acquisition cycle is fundamental to the Army's Continuous Comprehensive Evaluation system. The ability of the Electronic Battlefield to help identify key issues to be resolved in testing, and in training crews to fight effectively with the new capabilities, should add significantly to our testing capabilities. The ultimate product to the soldiers is the production of a mature hardware design complete with training simulations to support the forces in the field.

The capability of the Combined Arms Tactical Trainer to provide more repetitions of training exercises with low-cost, low resolution training sets offers an opportunity for greater force readiness. The potential for connecting the BBS/CBS command post exercises is an interesting option that should be incorporated if the technology permits with marginal costs.

In a broader sense, the Electronic Battlefield extends a service across, not only all the arms of the Army, but also the service sectors. The Electronic Battlefield is also a facilitator of jointness; it is the window to joint readiness, mission planing, and even mission rehearsals. The Army's entry into the Electronic Battlefield should be the leader for other services to emulate.

Implementation of the Electronic Battlefield

The implementation of the Electronic Battlefield does not require any break-through in technology. This technology has been demonstrated in SIMNET and is ready to be deployed. There are, however, challenges in engineering and challenges in continuing to product improve the capabilities. For example, better terrain representation, night visualizations, more realistic semi-automated force behavior, higher resolution graphics, etc. are needed. There is a need to pick a team of the right people, provide them with authority, adequate resources and a clear mandate from the highest levels, and let them lead the way into the Electronic Battlefield.

We believe that the next few years will be critical in getting started. We would resist the current view of the Army to discard the SIMNET products and start anew; we think it more prudent to build on success.

Finally, although the costs of the Electronic Battlefield are substantial, the contribution to all parts of the Army transcend, we believe, the near term costs and argue persuasively for the Army to fund this effort and move boldly in this direction.

Funding the Electronic Battlefield

As so often happens, acquiring the Electronic Battlefield presents both a cost savings opportunity and a serious financing problem during the near-years. The investments in the training area are large because of the number of simulators involved. The cost of the Electronic Battlefield itself is relatively small. The savings will clearly be substantial, but occur in the out years.

There is little doubt that the costs to develop and test many major new systems could be lower if the Electronic Battlefield were available for use. There is also little doubt that the cost to train to a particular skill level would be lower if Electronic Battlefield were available for use. It will, of course, require discipline if the Army is to save money since the natural goal of most participants is to improve performance. The expenditure of a given level of resources would result in better equipment and better training were the Electronic Battlefield available for use. Nonetheless, the near-term cost issues remain, and the costs are large enough that they can be managed only by decisions of the senior leaders of the Army.

What the Army much needs to do is to decide that the capability of the Electronic Battlefield is to be acquired as an Army-wide continuing asset, and at what rate its introduction can be afforded. Then, within those constraints, elements of the Electronic Battlefield should be acquired, maintained, and upgraded in an evolutionary manner.

Given the near-term funding challenges, incremental growth upgrades to the current SIMNET system, leading to the desired full capabilities of BDS and CATT, seem a very attractive option in comparison to the currently planned initiatives to acquire BDS and CATT as new systems.

Conclusions

From what has been said thus far, the most basic conclusion of the study should be perfectly plain: The members of the study team believe that the approach we have called the Electronic Battlefield can make major improvements in the way the Army does development, testing, and training. It can result in either reduced costs over time, or improved performance, or a combination of both.

Thus, the study team members conclude that the Secretary of the Army and Chief of Staff now should decide that the Army will proceed as rapidly as possible within funding constraints to acquire and use the simulation tools that we have called the Electronic Battlefield.

Issues

1. **Training on the Electronic Battlefield**
2. **Development and Testing on the Electronic Battlefield**
3. **Managing the Electronic Battlefield**
4. **Data Base and Model Quality**
5. **Technology Investment Strategy**

The five major issues and corresponding findings and recommendations are presented in the order indicated above.

ISSUE 1: Training on the Electronic Battlefield

FINDINGS

- **Current plan does not meet needs in timely fashion**
- **Current approach delays combined arms training**
- **SIMNET-T being maintained, probably can be upgraded**
  - **≈$250M invested**
  - **Documentation "red herring" (<$10M)**

RECOMMENDATIONS

- **Aggressively adopt the Electronic Battlefield technology for collective combined arms training**
  - **Review program structure**
  - **Combined arms focus at outset (Bn CFX to start)**
  - **Army initiative and funding, not branch dependent**
  - **Build on SIMNET-T**

The Army's experience with electronic simulations such as the Unit Conduct of Fire Trainer (UCOFT) has resulted in significant increases in gunner proficiency (a factor of 2 in time to kill) with fewer live firings and decreased cost. Although UCOFT is a stand-alone simulation trainer, the Panel strongly believes that this is no aberration and that UCOFT is a harbinger of benefits that will accrue to all Electronic Battlefield training.

The Army's exploitation of SIMNET-T is the Combined Arms Tactical Trainer (CATT) program. The CATT program includes an armor/mechanized cavalry trainer (CCTT); an air defense combat trainer (ADCATT); an aviation trainer (AVCATT); and numerous upgrades to the functionality found within the SIMNET trainers. The CATT program provides 546 second generation armor/mechanized cavalry simulators (the CCTT) before a first generation capability for the other combat trainers. Providing the numerous upgrades for CATT results in a program that leads to fielding of the trainers in the year 2001. First generation trainers for the other branches will require in excess of 10 years for fielding. The Army has long, and wisely, emphasized the importance of combined arms training. A delay of ten years or more forecloses the opportunities afforded by training on the Electronic Battlefield to an entire generation of soldiers.

There are at least three factors that contribute to the delay in providing a combined arms training capability. The first is funding. DA is providing the funds for buying the 546 CCTT's. Funding for the other trainers is to be provided for by the proponent branches through OPTEMPO reductions. There appears to be insufficient incentive for an individual branch to step forward and expedite fielding of a trainer; the benefits are Army-wide.

A second cause of delay is the Army's plan to "discard" SIMNET and start from "square zero". An Army decision calls for maintenance of the present SIMNET simulators, but no upgrade of these simulators. Developers do not plan to use the present 246 simulators and $250 million investment as a base for evolutionary growth of new functions. The rationale for this approach is the allegation that it is "cheaper to buy new than to upgrade." Lack of documentation is cited as one major reason for this belief. Yet there is conflicting, reasonably persuasive evidence that the documentation is now adequate, and that this view preceded an investment of $2.5M to upgrade the documentation. The highest estimate the Panel heard of the cost to document the software was $10 million, surely less than the amount to write the program from a zero base. The panel believes that upgrade is possible and highly desirable.

The third cause of delay is the degree of upgrade demanded of CATT. This requires additional R&D and increases the cost substantially, correspondingly stretching the schedule. The inherent modularity of DIS permits and encourages an evolutionary approach in which upgrades can be introduced when priorities and funding permit.

We recommend the Army enthusiastically adopt electronic training as a major part of its training strategy. This benefit is so important that the Army should be willing to forego OPTEMPO, as well as other funds to finance the new modes of training. The Army should adopt a combined arms simulation strategy from the outset and should look for a scheme that would provide at least a combined arms capability at the Battalion Command Field Exercise (CFX) level at the earliest possible moment. The benefits are to the entire Army and, therefore, the Army should fund these programs at the DA level and should undertake cost effective actions that build on existing SIMNET hardware and software.

Appendix E provides substantially more discussion about the use of simulation in training and expands on the overview presented here.

ISSUE 2: Development and Testing on the EB

FINDINGS

- **Continuous, comprehensive evaluation of systems at every development stage will produce substantial savings**
- **Recommendations of the 1988 ASB Study and the 1989 DSB Summer Study on "Improving T&E Effectiveness" remain valid**
- **Milestone criteria of electronic prototypes on the Electronic Battlefield will strongly incentivize the development system**

RECOMMENDATIONS

- **Mandate use and sharing of electronic prototyping through all stages of system development**
- **Adopt policy to put major emphasis on testing in the Electronic Battlefield to determine value as a weapon system, including milestone-pass testing**

We believe the Army should take the steps necessary to put combat development, system acquisition, and testing into the Electronic Battlefield. In particular, the Army should mandate the use of electronic prototyping throughout all stages of system development. At early stages, low-resolution electronic prototypes, with only the essential features of a new system, should be created by the combat and force development communities to fully define the requirements for the new system. In this way, unnecessary, and often costly, requirements can be eliminated and misunderstandings between the user and materiel development communities can be minimized. Building upon the earlier electronic prototypes, the developer should then use low, medium, and high resolution electronic prototypes throughout the design process to evaluate alternatives, conduct trades, and refine designs before incurring the expense of fabricating hardware. Refined versions, where appropriate, should be provided back to the combat developers for their continued use and participation with the materiel development community as system definition proceeds. As hardware is fabricated, it should be incorporated into the high resolution, man-in-the-loop simulators to evaluate its performance. Program Managers should be required to conduct confirmation tests prior to each milestone in the acquisition process in order to revalidate the system under development. Finally, for FDT&E and Operational Testing, electronic prototypes should be used both as a preview of all possible required physical tests and as an extension beyond physical testing capability. Physical testing should only be used for limited confirmation tests in key areas and for testing factors (such as reliability) that cannot reasonably be conducted with electronic prototypes. This requires a fundamental change in policy towards FDT&E and OT, one which will probably have to evolve over time as electronic prototype testing proves itself. Post-deployment testing on the Electronic Battlefield can provide critical, cost effective inputs to the product improvement decision process.

The use of electronic prototyping throughout the acquisition process is essential to taking full advantage of the potential of the Electronic Battlefield. Such prototypes need the Electronic Battlefield to fully exercise their potential capabilities.

At this time, the Army has plugged developers into the existing Electronic Battlefield (SIMNET–D) only to a very limited extent, and the use of high–resolution, man–in–the–loop simulators is not uniform across major system programs.

It is our expectation that the use of low, moderate, and high–resolution simulators will encourage continuous, comprehensive evaluation of systems at every stage of the development process, and post–deployment. The result of such evaluation should be substantial cost savings in the concept development, system design and development, test and evaluation, and product improvement process.

To date, user and test community use of and involvement in simulation initiatives remain limited despite recommendations of the 1988 ASB and the 1989 DSB Summer Study on "Improving T&E Effectiveness". The pressures to adopt simulation (funding, range availability, safety, etc.) are, if anything, greater today than they were in 1989. The Army must make better use of simulation in T&E.

The development community must be fully incentivized to use electronic prototypes throughout the process. We propose that this be done by requiring that developing systems undergo electronic prototype tests prior to each formal milestone of the acquisition process.

Appendix C expands on the overview of simulations in development and testing presented here.

ISSUE 3: Managing the Electronic Battlefield

FINDING

- **The principal Army programs, CATT and BDS-D, are on separate management and programmatic paths**
- **Army should continue to lead the way; other Services now adopting**

RECOMMENDATIONS

- **Designate a single manager for the single Electronic Battlefield and provide resources, authority required**
- **Make CATT, BDS-D and SIMNET extensions of the same Electronic Battlefield**
- **Support DMSO in leading to one joint Electronic Battlefield**

Having asserted our view that utilization of the Electronic Battlefield will revolutionize the Army's training, development, and testing activities, there remains the issue of organizing properly to create this revolution. The Study Group believes that the current Army scheme of having separate programs and management for the CATT and BDS-D programs is dysfunctional and will defeat, rather than achieve the promise of synergy that we foresee. We believe that a single manager should be put in charge of the Electronic Battlefield -- its design, its fielding, and its operation -- as a service system to be used by the numerous Army customers. We believe that the two key existing programs (CATT and BDS-D) should be combined by making them extensions of the Electronic Battlefield. We would also see this manager as the key official who would resolve the issues of whether and how to upgrade SIMNET or to retire it as the current plan envisages. This manager, as we will show in greater detail below, should lead one of the Army's main thrusts for achieving jointness in our warfighting approach through a simulation capability that meshes with similar capabilities in the other services. We see the Army leading the other services with this technology and using this manager as a key point of contact for similar managers in other services and with the new Defense Models and Simulation Office. We see this manager and his/her office performing the functions listed on the following chart.

ISSUE 3: Managing the EB (cont'd)

The Single Manager Should:

- **Operate the Electronic Battlefield and provide services to the entire Army involving:**
  - Daily management of large, dynamic software and data base library
  - Operation of distributed computing network
  - Assure, via directive authority, integrity of standards, protocols and validity of the data bases and models
- **Continuously evolve capabilities by introducing new technology in evolutionary manner**
- **Interface with J7/J8, DMSO for joint compatibility (Army POC)**
- **Manage CATT, BDS-D and upgrade of SIMNET as elements of DIS**

Since this software will be distributed throughout the Army, industry, and academia, this manager must be the configuration control manager of the data bases and the operator of the distributed services required by the users.

The single manager must also direct continuous upgrading to introduce evolving new technology into the system. We believe that the pace of development in this area will make this task one of using existing opportunities and of making engineering choices rather than a new R&D effort to bridge existing technological barriers.

The single manager will need to be the "policeman" of the system with respect to giving the equivalent of the "Good Housekeeping Seal" to configuration models of users systems that wish to interact throughout the system, and the keeper of the standards and protocols that form the electronic gateway into the Electronic Battlefield.

Initially we see this single manager as directing the procurement of CATT, BDS-D, and whatever actions are required for SIMNET.

Finally, this manager is the key point of contact with the DMSO and the Electronic Battlefield of the other services. Our recommendation on the configuration of this single management office is shown on the following chart.

ISSUE 3: Managing the EB(cont'd)

Establishing the Single Manager

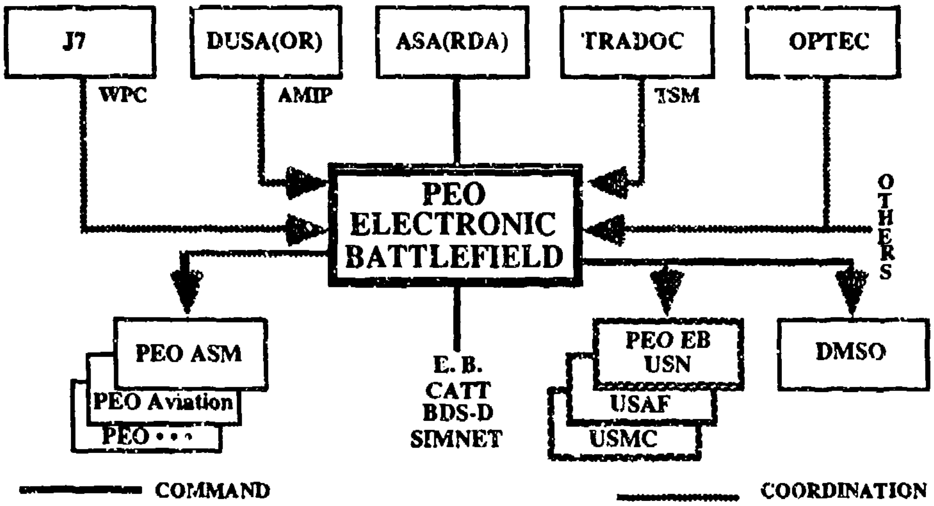
- **Requires innovative manager, imaginative technologist, policeman and diplomat (spans user-developer)**
- **Initial emphasis: management, engineering, operations**
- **Resources to execute**
- **Rank to participate in decision processes (e.g., ASARC)**
- **Suggest**
  - **Flag officer PEO**
  - **Civilian Deputy PEO to assure continuity**
  - **Small, elite staff**
  - **Contractor support to provide expertise, continuity**

We believe that the most effective way of developing this revolutionary capability is with a flag officer PEO who combines the attributes of a visionary technologist with the business sense of a solid manager and the stubbornness of a policeman to keep the system in a configuration stage of continuous technology insertion, and daily operation.

While the PEO could easily be an SES, it seems to us that the first 3-5 years of this effort argue for the usage of a "green suit" to carry credibility across the various segments of our Army. We see this office as a small, lean management cell supported by other parts of the Army and assisted in the day to day operation of the system by contractors or possibly an FFRDC.

The overall "wiring diagram" of how this PEO fits into the Army is shown on the following chart.

ISSUE #3 PEO Chain of Command



We show the PEO of the Electronic Battlefield reporting in the usual manner to the ASA (RDA) with directive authority over the electronic "innards" of the Electronic Battlefield and its distribution, with responsibilities for the procurement of CATT, BDS-D, and upgrade of SIMNET. The PEO-EB is a little different in having responsibility for operation of a service as well as its development and procurement.

This PEO-EB must coordinate with the PEOs for other major systems, such as the ASM PEO, to ensure the provision of standards/protocols, and the electronic "gateway", through which that PEO would be required to interface his evolving electronic prototype to operate in the Electronic Battlefield.

We show PEO-EB in a coordinative relationship with multiple elements of the entire Army community. The TRADOC community makes its requirements known and prioritized in the standard manner through a TRADOC System Manager, via the DCSOPS prioritization process. Connectivity with the Joint Staff and other CINCS (e.g. to work with the Joint Warfare Center and Warrior Preparation Center) is essential.

Routine continuous interaction with the development and testing community will be required to decide how to electronically portray a valid replication of each new technology weapon on the Electronic Battlefield. This is the domain of the Army's PEO-EB.

ISSUE 4: Data Base and Model Quality

FINDINGS

- **The power of Electronic Battlefield depends critically on availability of quality data bases, models and their corresponding credibility**
  - **With prospective explosion of use, quality is even more important than ever before**

RECOMMENDATIONS

- **Develop and "certify" a set of consistent data bases and models for use in the Electronic Battlefield**

There is often inconsistency in the results obtained by different simulations. For example, command and staff exercises, mission planning, and tactics and doctrine development should, but do not always arrive at the same conclusion when engaged on the same tactical problem. The differences frequently result from the use of different data bases. With the proliferation of simulation as a ubiquitous Army tool, both the quality and consistency of the data base library will take on paramount importance for the value of the simulations. In addition, the current terrain data base, which is critical for realistic Army simulations, is quite inadequate for Army needs and little progress in either quantity or focus is evident.

The Army also needs to develop a process and discipline to ensure quality of data across the total spectrum of model use. This should be a prime task for the manager of the electronic battlefield.

Finally, there are a limited number of models that will be widely used in the Electronic Battlefield. The Electronic Battlefield manager should assure that these are "certified" to ensure validity and consistency. Any others available centrally from the Electronic Battlefield database, should be labeled "not certified"; this latter approach allows the introduction of new concepts for examination and testing, before they can reasonably be validated.

ISSUE 5: Technology Investment Strategy

FINDINGS

- **Rapid advances are being made in key underlying technology areas**
  - Graphic displays
  - Massively parallel processors
  - Human/machine interaction
  - Wideband networks
- **Software exploitation of these new capabilities is the challenge**

RECOMMENDATION

- **Adopt a strategy of exploiting technology that is developed elsewhere and do not invest in technology development for modeling and simulation except for specific Army-unique needs**

Extraordinarily rapid advances in key underlying electronic technologies have been made during the past decade. Four areas that have significant impact for the Army's simulation needs are graphic displays, wideband networks, massively parallel processors, and human/machine interactions. The hardware capabilities in these areas are strongly driven by the commercial world, and should out-pace the Army's ability to exploit them. It is clear that these enabling technologies will provide an opportunity for orders of magnitude improvement in the overall simulation capability.

As has been true since the beginning of the computer era, software exploitation of the new capabilities is likely to significantly lag hardware advances. This occurs in two ways. First, the direct utilization of new technologies (e.g. transferring code to parallel computers) is a labor intensive, deliberate process. Secondly, the innovative use of these capabilities entails substantial education and experimental familiarity to understand the power of these new technologies. For example, massively parallel machines connected through high bandwidth networks could make possible very high fidelity force-on-force engagements using high resolution individual item simulations.

Because of the existing strong commercial impetus for technology development, we strongly recommend that the Army utilize technology advances made in the outside world. Virtually all of the hardware and much of the software vital for modeling and simulation will be available in the market place. Some software will need to be developed for critical Army-specific applications, but even in these cases an effort should be made to share such software throughout the Army community. Economics should drive the software decision path: first, reuse it, and evolve it; next, buy it; and as a last resort, create it.

Appendix D provides a considerably expanded discussion of simulation technology and the panel's views on investment strategy.

Other Issues

- **Embedded training**
- **Quantification of value of DIS in training**
- **Availability of terrain data bases**
- **Evolution of SAFOR and AFOR**

During the course of the study a number of matters came up that were judged to be very important, but less central to the main focus of the study than those that have been discussed. We have now enumerated four of these. The appendices deal with these in more detail.

- The use of simulations for training caused the matter of embedded training to be discussed often. The policies seem about right, but the interpretation and implementation need attention to sure that the practice does not go so far as to insist on embedded trainers where inappropriate.

- The simulators such as COFT and SIMNET afford an unprecedented opportunity to capture metrics that can be used to tell how skills improve, what kind of training activities pay off, and indeed how "cost-effective" such devices are in comparison with conventional training approaches. The Army should commit to the exploitation of this potential. The wherewithal for data capture must be integral to the design of future electronic training aids, and a program for analysis established.

- A high resolution terrain data base is absolutely necessary for use in Distributed Interactive Simulations. Currently, the data is available for only selected areas - enough to support training in a number of different "representative" terrains, but not nearly enough to support the wide and rapid use of these tools for operational planning and mission rehearsal. The time between demand and supply of data for new areas is too long - DMA simply does not have the production capability for rapid response. The Army must add to the pressures that in the end can cause a change in terrain digital data availability. Attention should be given to the potential for integrating data from non-DMA sources, e.g. Spot, Landsat, and the Soviet System.

- A very central notion in the Distributed Interactive Simulation is the use of unmanned representations of forces under the interactive command and control of a few persons, the so-called Semi-Automated Forces (SAFOR). This is a powerful concept, but requires very careful implementation; models of the processes represented are not simple, or easily understood and checked. In consequence, few persons, for example, currently have any in-depth understanding of the SAFOR embedded in SIMNET. As the efforts to exploit Distributed Interactive Simulations proceed, it will be important that SAFOR, and its totally automated version AFOR, be subjected to careful scrutiny and configuration management. The alternative will be loss of quality, erosion of confidence, and failure to achieve the potential of the Electronic Battlefield. This will require continuing attention by the manager of the Electronic Battlefield.

Summary

- **Army will rely more on simulations than in past**
- **Simulations are ready for exploitation**
- **Trick is to orchestrate; difficult but critical job**
- **Will cross all major commands, branches, Services**
- **If done right, should lead to**
  - **Smarter requirements**
  - **Better materiel**
  - **Better trained units**
  - **Better operational support**
  - **Savings for Army as a whole**
- **We urge you to move out rapidly**

This discussion has covered a quite large number of matters regarding the Army's use of models and simulation in development, testing, and training activities. We have tried to be clear on a number of points and will now reiterate:

- The Army will have to, and can, rely more on simulations than in the past.
- The technologies are ready to permit acquisition of the simulations needed.
- The manager of the Electronic Battlefield will have to create and promulgate a vision, a plan, and the process. It will be up to this manager to help the Army define its objective system.
- It will not be easy to design and develop the system and overall simulations needed; careful orchestration and incremental steps to evolve from workable, usable, early versions are essential. Although this is an evolutionary approach to development; bold leadership can assure early fielding of significantly enhanced capabilities.
- As with the operations they represent, the simulators will cross Army branches, commands, and involve the systems operated by other Services. This is complex but, done right, simulations will result in smarter requirements, better materiel, better trained soldiers, leaders, and units, and better operational support for mission planning and recharged -- and in longer term produce substantial dollar savings for the Army as a whole.

We urge approval of our recommendations and prompt initiation of action.

Key Points Regarding Electronic Battlefield

- **Combined Arms Training**
  - DA vice proponent funding
- **Primary emphasis in testing on electronic prototypes in Electronic Battlefield**
  - Electronic prototypes at all stages of development
- **Single Manager**
  - Empower with the Secretary of the Army mandate

Three points are central, and warrant special attention:

- The largest payoff of simulation to training in the future is apt to come from the new opportunity to train more elements of combined arms operations more often, with fewer constraints, and in more varied simulated battle conditions, than has been possible in the traditional FTXs.
- The process of development of major materiel systems normally should involve experimentation and testing using electronic prototypes operating on the Electronic Battlefield at every stage of development from requirements generation to testing of production articles. Testing of real items in real environments will, of course, remain necessary, but that testing will benefit from complementary and supplementary tests done using simulated items in simulated environments early and often in the development process.
- In order to ensure that the Army gains the full potential of the Electronic Battlefield and its Distributed Interactive Simulation, someone must be in charge. The Army needs a single manager.

APPENDIX A

TERMS OF REFERENCE

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, DC 20310-0103

29 JAN 1991

Dr. Duane A. Adams
Chair, Army Science Board
Associate Dean
School of Computer Science
Carnegie Mellon University
Pittsburgh, Pensylvania 15213

Dear Dr. Adams:

You are requested to initiate an Army Science Board (ASB) 1991 Summer Study on "Army Simulation Strategy." This study should address, as a minimum, the Terms of Reference (TOR) described below, but the ASB members appointed should consider the TOR as guidelines and may include in their discussions related issues deemed important or suggested by the Sponsor. Modifications to the TOR must be coordinated with the ASB office.

I. Background

a. In the last several years, the Department of Defense (DoD) and the Congress demonstrated an increasing interest in the use and application of computer simulations. At the DoD level, a 1988 Defense Science Board (DSB) Task Force issued a report on "Computer Applications to Training and Wargaming." In 1989, the DoD Inspector General (IG) issued a report on "Wargaming Activities in DoD." The House and Senate Committees on Armed Services (HASC and SASC) both mentioned management and the promotion of simulation and wargaming in DoD in their initial reports on the FY 91 budget. These reports, coupled with other considerations, led DoD to convene a study panel tasked to develop a DoD modeling and simulation policy. The recommendations of that study, currently being staffed, call for the formation of a DoD oversight group and the development of Service modeling and simulation Master Plans.

b. Within the Army, simulation development efforts are escalating at a significant rate. For instance, there are multiple efforts either seriously considered or actually under development, to generate man-in-the-loop, very high resolution combat simulations for use in training, combat development, and weapons system development and acquisition. Each of these efforts is extremely expensive. Some specific examples are: Close Combat Tactical Trainer (CCTT), Battlefield Distributed Simulation - Developmental (BDS-D), and Combined Arms Test Bed (CATB).

c. The effective management of modeling and simulation activities requires a keen understanding of the leverage such new opportunities can offer at the time they are likely to become available. To assist in evaluating the most efficient and effective course of action for simulation in the future, the Army must conduct a comprehensive assessment of all alternate technologies conceivable.

II. Terms of Reference

a. Assess the status of modeling and simulation technologies currently available or under development and identify technology barriers. Project future technologies which will enhance the state-of-the-art of modeling and simulation across the functional areas of system and concept development, developmental and operational testing, training, and analysis of concepts, doctrine, and force structure. What management, policy, and Research and Development (R&D) investment strategy will best enable the Army to capitalize on the opportunities offered by simulation technologies? What benefits can be realized and what measures can be used to quantify the benefits? What kind of methodologies and techniques are required for the verification and validation of results obtained in order to establish confidence in the model selected? What methods/procedures and planning should be considered as related to Operations and Support (O&S) of simulation systems?

b. Specifically, assess the status of the technology of distributed simulation and simulation networks; identify technology barriers, and project future technologies which will enhance the utility of simulation for training and development of systems, concepts, and doctrine. What roles are appropriate for distributed simulation and simulation networks in the Army?

c. How effective can current and projected future technologies be in training the Army and improving force readiness? Can skills and readiness be improved at reduced cost and training time? To what extent can realism be achieved and to what levels are verification and validation needed?

d. Can the technologies identified be effectively used for development and testing of systems, concepts, and doctrine? Can models be developed which are able to accept changes in hardware systems and/or environmental conditions?

e. Provide a plan that projects the research, development, and acquisition strategy required that leads toward the simulation capability the Army should have 10 and 20 years into the future. The plan should indicate the relative state of technology required, incremental or significant improvements needed, the risks involved in achieving the capabilities desired, and a precursory assessment of the affordability.

III. Study Support

The Deputy Under Secretary of the Army for Operation Research, Mr. Walter W. Hollis, will sponsor the study. The Cognizant Deputy will be Mr. George T. Singley III. The designated Army Staff Assistants are Mr. John Yuhas (lead) and COL Gilbert Brauch (assist).

IV. Schedule

The Study Panel will begin its work immediately and conclude the effort at the 10-day summarization and report writing session tentatively scheduled during the end of July 1991. The exact time and location will be coordinated by the ASB. As a first step, the Study Chairman should prepare a study plan and present that plan to the Sponsor and the Executive Secretary.

V. Special Provisions

It is not anticipated that the inquiry will go into any "particular matters" within the meaning of Section 208, Title 18, of the United States Code.

Sincerely,

Stephen K. Conver
Assistant Secretary of the Army
(Research, Development and Acquisition)

13 February 1991

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ARMY SIMULATION STRATEGY

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APPENDIX C

ACQUISITION PANEL

INTRODUCTION

This appendix presents a subset of the results and recommendations of the Army Science Board Summer Study which addressed the Army Simulation Strategy. Specifically, the results and recommendations were produced by a subpanel which investigated the use of simulation in the acquisition and test and evaluation processes. The subpanel was chaired by Dr. W. Peter Cherry and included Dr. William H. Evers, Jr. and Dr. W. Foster Rich. Mr. Verne L. Lynn, the chair of the summer study, participated in the subpanel's activities, as did Mr. John Yuhas who also provided valuable support in the role of Army Staff Assistant.

In addition to participating in the meetings of the panel, the subpanel organized a series of meetings with Army agencies and defense contractors. Included were:

- Boeing-Sikorsky, Stratford, Connecticut
  - RAH-66 Program
- McDonnell Douglas Helicopter Company, Mesa, Arizona
  - AH-64 Program
  - LH Program
- General Dynamics Land Systems, Warren, Michigan
  - M1 Program
  - Block III Program
- Tank Automotive Command, Warren, Michigan
  - M1 Program
  - Armor Systems Design and Development

In addition to these visits, members of the subpanel met with representatives of the Environmental Research Institute of Michigan to discuss low observable and stealth simulation issues, and with Dr. Ernest Seglie, Chief Science Advisor for the Director of Operational Test and Evaluation, OSD to discuss test and evaluation. Mr. Jack Krings, formerly Director, OT&E/OSD, also contributed to discussions of the role of simulation in the test and evaluation process.

Review of the material presented and made available to the subpanel led to the following general observations of the use of simulations and models in the acquisition process and test and evaluation processes:

> Advances in computer technology have precipitated a proliferation of models and simulations. Configuration control and maintenance of common data bases remains a problem.
>
> In the early stages of the acquisition process, i.e., during concept development, combat developers rely on system-on-system and force-on-force models (both systemic and analyst-in-the-loop) to support generation of requirements. User involvement in these early stages is not as effective as it should be. On occasion it is detrimental. A principal reason for this is that users lack means of developing insight and making informed decisions. SIMNET-D has demonstrated that Distributed Interactive Simulations (DIS) provide a means of involving the user early, thus complementing current approaches and offering the

potential of improving both the extent and effectiveness of user input to concept development and requirements generation.

High resolution man-in-the-loop simulators are now a necessary component of the design and development process for major systems. The complexity of systems has grown to the point where it is impossible to perform the design and development processes without high resolution simulators and the analytic models and simulations of Computer Aided Design (CAD). Compared to the design and development of the Army's current generation of systems, user involvement in these phases of the acquisition process is now somewhat better, but there remains room for improvement.

The requirement for the use of simulations and models to support test and evaluation (Developmental, Operational and Force Development) has been recognized, and the first steps have been taken, albeit tentatively. The availability of ranges and facilities, the costs and time required to test prototypes, and the complexity of the modern battlefield make this use essential. It will contribute to accelerating and improving the acquisition process.

Distributed Interactive Simulation (DIS) technology appears to offer potential improvements to problems of development of effective, informed user participation, deferment of test and evaluation beyond the point where results can quickly and inexpensively influence design, and inability to test over the full range of technical and tactical performance parameters. DIS can support improvements to the system acquisition process from concept development through deployment to product improvement, i.e., throughout the life cycle.

The materiel acquisition process can be viewed as one in which requirements, concepts, designs and prototypes are refined in a sequence of progressively more detailed and comprehensive tests and evaluations. Given this perspective, and the fact that both of the systems and their concepts of employment have become increasingly complex, the subpanel suggests that the Army adopt the following goal:

The Army should exercise and evaluate evolving systems on a virtual electronic battlefield throughout the acquisition process and life cycle.

To achieve that goal the subpanel makes the following recommendations:

Develop a Distributed Interactive Simulation to support the system acquisition process for major systems. The Battlefield Distributed Simulation-Developmental (BDS-D) is intended to play this role. It should be part of a single DIS initiative which includes both training and developmental applications.

Emphasize the use of man-in-the-loop electronic prototypes in combat developments and the requirements generation processes. Involve the user through BDS-D, using its simulators as electronic prototypes.

Mandate the use of high resolution man-in-loop and hardware-in-the-loop electronic prototypes throughout the development process: engineering design and development, production, and product improvement. During the design and development process, supplement the detailed design simulator with a sequence of progressively more defined low resolution electronic prototypes for use in BDS-D, culminating in an electronic prototype suitable for use in support of FDT&E. Continue user involvement by utilizing these electronic prototypes to establish the tactical performance envelope and to test and evaluate early on a virtual battlefield. Require that the Program Manager fund the development of all electronic prototypes used in these phases and ensure that appropriate prototypes remain available for product improvement and tactical and doctrinal evolution throughout the system life cycle.

Mandate the use of electronic prototypes, and the virtual battlefield, as part of DT, OT and FDT&E. Ensure that Army and DoD policies accommodate this paradigm shift.

Base the development of BDS-D on the anticipated requirements to support combat development, system design and development, and test and evaluation over the next 10 to 15 years. Ensure that necessary capabilities, e.g., terrain data bases, Semi-Automated Forces, electromagnetic and natural environments, etc., are available to meet the system specific needs of the developmental and test organizations.

STATE OF THE ART

This section presents an assessment of the current status of computer simulations and models in the context of the system acquisition process. The acquisition process encompasses requirements generation, concept development, engineering design and development, production, and fielding as well as product improvement. Integrated into these components or phases is a test and evaluation process designed to develop more precise knowledge of the system and the degree to which it meets requirements and specifications.

Broadly speaking, the acquisition process can be viewed as one in which concepts, designs, and prototypes are subjected to a sequence of progressively more detailed and comprehensive tests and evaluations. Based on test and evaluation results and on other information and factors, the concepts, designs and prototypes are repeatedly refined. It is in this sequence of tests and evaluations that simulations and models play a role of critical importance. The growing complexity of systems, weapons and otherwise, makes the use of models and simulations a necessary part of the acquisition process. Major systems cannot be designed without them.

The status of simulation technology employed in the acquisition process and in test and evaluation programs is most evident in recent military aircraft programs. In the case of the Advanced Tactical Fighter (ATF), high resolution man-in-the-loop and hardware-in-the-loop simulators were employed to such an extent that parts of the test and evaluation program emphasize validating the simulators and simulator results, rather than identifying problems and confirming that requirements have been achieved. The Army's LH program, utilizing a different acquisition strategy, provides a similar example. High resolution man-in-the-loop simulations, were used in an "electronic fly-off" which contributed to source selection. Both competitors in the LH program reported that simulation was a necessary component of their design activities, implying that the designs could not have been completed without it. Both were confident that should a prototype have been constructed to their design, testing would have produced few, if any, surprises and a very high likelihood of achieving design goals with that first prototype. There is no reason to believe that the practices of the aviation developers should not be applied to other Army systems; in fact, there is evidence that will be the case in the Armor System Modernization (ASM) program.

The LH and ASM programs provide evidence for the value of simulation in the design and development of major weapon systems. Much less evidence is available of the use of simulation in the design and development of major C^3I systems such as the ATCCS, but the requirement is clearly present. The Army's record in designing, developing and fielding computer-supported C^3I systems is not outstanding. CCIS-70, TOS and BETA are examples of programs in the past 25 years; interviews examined by the panel suggest that the record of MCS in DESERT STORM was less than outstanding. There is a need for an easily exercised means to experiment with conceptual C^3I systems to obtain user input and identify shortfalls before prototypes are assembled, focusing on how and how well commanders and their staffs accomplish the functions of command, control and intelligence when provided with different types of computer support. OPTEC is developing simulations and simulators to support test and evaluation of ATCCS and other C^3I systems, but the need to support the generation of functional requirements and the evaluation of alternative concepts early in the acquisition process remains. Interactive simulations capable of meeting this requirement are well within the state-of-the-art.

The benefits of simulation in the acquisition process can be understood if the design and development process were considered to be an iterative one in which designs for parts, components, assemblies, subsystems, and systems are proposed and then evaluated and tested, with the test results used as a basis for refining the design or selecting an alternative. One can argue that for the current generation of Army systems, this sequence of test and evaluation was performed by fabricating prototypes and conducting laboratory or field tests. The cost of this process, the time required, the extent of the technical performance envelopes, and the range of potential tactical and operational situations precluded comprehensive testing; as a consequence, design shortfalls surfaced late in the process, sufficiently late to make correction costly, if affordable at all. The next generation of Army systems will substitute simulation for early fabrication. Designs will be developed and tested as electronic or computer prototypes. The process will thus be relatively less expensive, earlier, and more comprehensive than otherwise would have been the case. The resulting systems will be fielded with fewer performance shortfalls.

CURRENT CAPABILITIES

Review of the use of simulations in the acquisition and test and evaluation processes indicates that, while significant advances have been made, opportunities for improvement remain. These are briefly discussed in the remainder of this section.

System-on-System and Force-on-Force Simulations

The generation of functional requirements relies heavily on system-on-system and force-on-force simulations. These simulations are employed at numerous Army agencies and by industry. Force-on-force and system-on-system simulations, with or without analyst intervention during execution, will continue to play an important role in the acquisition process. They will be used to explore issues associated with force effectiveness at the division, corps, and echelons above corps levels; at a lower level, running much faster than "combat time", they will provide a means of rapidly screening materiel, tactical, doctrinal, and organizational alternatives and quantifying the differences between them. In the context of test and evaluation, such simulations can be used to generate stimuli for and responses to actions taken by operators or crews at the system level, as well as provide a large context for participating soldiers and units.

Problems remain with these simulations: representations of command, control and intelligence (C^2I) and human behavior are much less credible than desired, and processes such as Electronic Warfare and stealth, as well as chemical and biological warfare, are poorly represented if at all. The Army must continue its efforts to overcome these problems if the simulations are to provide valid and credible support in the system development and test and evaluation processes.

Without exception, representatives from industry who briefed the subpanel expressed the need for a common set of data for these simulations: data describing scenarios, tactics, threat systems, and friendly systems. The maintenance and availability of a common data set would contribute to ensuring that all participants in the generation of functional requirements and design specifications would share the same perspective and thus avoid wasted effort.

If the "user" is defined to be the combat soldier who will operate, maintain, or support a system, then the current generation of Army system-on-system and force-on-force models are "user unfriendly". They were constructed to be used by analysts, and their algorithms and logic are in many cases not easily explained. Users question validity and credibility. In addition, the performance and behavior of individuals, crews, and teams is not represented well. As a consequence, the participation of the user in the early stages of requirements generation and concept development has been and continues to be much less effective than desired.

The user can provide valuable input as to what is feasible in combat, what is easily countered or exploited, and what makes sense in terms of tactics and concepts of employment. In the absence of this input, there is a danger that functional requirements and the designs which respond to those requirements will be found to be inappropriate later in the design and development process. The later such problems are identified the greater the cost of correction and the cost of potential performance foregone. User involvement is thus critical, and it must be increased. System-on-system and force-on-force models are essential and can be made more "user friendly", but other means of involving the user must be found.

High Resolution, Man-in-the-Loop Simulations

Because of the increased complexity of systems and the battlefield on which they are employed, the use of high resolution, man-in-the-loop simulators has become a necessary part of the design and development of major weapon systems. These simulators, using computer technology, have evolved from the traditional static mock-ups of major weapon systems. They typically include high fidelity representations of crew stations and employ computer-generated imagery, with some including moving bases.

High resolution simulators, such as those employed in the LH program, are intended to replicate, as precisely as is possible, the performance of a proposed or alternative system design. As such, they incorporate software or electronic representations of components, assemblies, and subsystems. As designs progress, hardware components are substituted for their electronic analog.

Throughout the design and development process, high resolution, man-in-the-loop simulators contribute to "building it right the first time". By operating the simulator, or electronic prototype, on a virtual battlefield the designer and developer are able to expose the design to battlefield situations and environments. They can exploit opportunities and correct shortfalls before fabrication. The acquisition process will be accelerated. It may take less time for much more complex systems, or it will take the same time. In the opinion of the LH competitors, the duration of the LH design activity paralleled that of past rotary wing designs, but for a system that was approximately twenty-five percent more complex. It was their view that simulators made this possible.

The high resolution simulators employed for the Army to date have functioned as independent systems. Representation of the behavior and responses of threat and friendly systems in the simulated battlefield is accomplished by means of manned controller stations and, to a lesser extent, by means of algorithms and logic. The tactical situations in which the performances of simulated designs are evaluated have been narrowly defined: the duration of simulated encounters is usually brief, and the number of entities included is relatively small. There are arguments for, and advantages to, expanding the scope and resolution of the simulated battlefield. Such an expansion would provide a more comprehensive stream of stimuli to the operators, a larger set of potential actions, and a wider range of feedback from the battlefield. While use of the simulators during design focuses heavily on carefully designed and controlled tests, there are advantages to be gained from consideration of longer and more realistic missions and greater degrees of free play and user interaction.

Expansion of the simulated battlefield is also necessary to accommodate such systems as J-STARS and ATACMS which respond to and impact on a wide range of entities distributed over large geographic areas. Expansion can be made by means of additional algorithms, logic and data and by adding manned simulators. The resolution of such additional simulators could range from controller workstations to high resolution man-in-the-loop, hardware-in-the-loop. Given the current state-of-the-art of models and simulations of human performance and behavior, there appear to be clear advantages to utilizing a greater number of man-in-the-loop workstations or low resolution simulators, relying on high resolution only when necessary.

High resolution man-in-the-loop simulators should be used in the design of any major Army system. Indeed, the use of such simulators is necessary to handle the complexity of such systems. The resources needed to develop the simulators are small relative to total program costs. Where Computer Image Generation (CIG) is required, it may be a cost driver, but the costs of high resolution CIG are steadily decreasing. Moving bases may or may not be desirable; when incorporated they, too, are cost drivers, but will become less expensive and more capable. Software is a third driver; it, too, will have a decreasing cost impact.

It is not clear that high resolution man-in-the-loop simulators are fully integrated into those phases of the acquisition process which follow initial design, i.e., engineering development, test and evaluation, and, later, product improvement. The benefits are such that this integration should be accomplished. A high resolution man-in-the-loop simulator, once developed for a system, should be kept available throughout the system life cycle and modified to reflect design changes and upgrades. It should always be available for use in analyzing the impact of changes on the operational battlefield, the development of tactical or organizational responses, and to support the product improvement process.

Distributed Interactive Simulation

The Army's current generation of weapon systems is the result of acquisition programs that were initiated, for the most part, ten or more years ago. Simulations which at that time represented the state of the art contributed to these programs. Advances in computational capacity and memory availability have been applied to enhance these simulations, which were typically closed form or analyst-in-the-loop methodologies. As noted earlier in this appendix, these simulations were and continue to be constructed for and used by analysts. User confidence in their results is often low. The Distributed Interactive Simulation concept, demonstrated in the DARPA/Army SIMNET program, offers the user a means of participating in analyses and studies that, properly applied, may contribute to overcoming this lack of confidence.

DIS, as demonstrated in the SIMNET program, is based upon a distributed network of simulators. It employs object oriented programming. SIMNET, in a configuration called SIMNET-D, has been applied in combat development activities at Fort Knox and at Fort Rucker. The SIMNET concept is currently proceeding in two versions: a training version, The Combined Arms Tactical Trainer (CATT), and a developmental version, the Battlefield Distributed Simulation-Developmental (BDS-D).

BDS-D is a network of low resolution manned simulators which embody the operational characteristics of the systems they represent. BDS-D also includes Semi-Automated Forces (SAFOR). SAFOR simulates the presence and actions of groups of one or more item systems, i.e., with a controller-in-the-loop SAFOR simulates performance, behavior, and command and control of virtual systems which interact with the manned simulators on a virtual or electronic battlefield.

Given an appropriate implementation, BDS-D applied in combat development will facilitate user involvement. Users will be able to explore concepts and generate more appropriate requirements while at the same time considering tactical and operational issues. Upon entry to the engineering design and development phase, the level of user involvement can be maintained. As design details emerge, low resolution simulators can be modified or developed to reflect them and then employed by users to explore performance and examine tactical and organizational issues in greater detail. BDS-D will facilitate identification of critical issues for developmental and operational testing and it will offer a means of conducting force-on-force tests to supplement FDT&E using simulators which embody the operational performance parameters of the actual systems. On the BDS-D battlefield the simulated systems can fight a wide range of different threats under conditions (safety, range availability, cost, etc.) that preclude field testing but which represent both typical and atypical combat conditions. In short, test and evaluation will be more comprehensive, and relative to today's practices, could be earlier in the acquisition process. Finally, BDS-D will be useful after a system is fielded, in support of product improvement initiatives.

BDS-D does not yet exist, and there are several dimensions of the program that should be defined more precisely. First, it is not clear how many manned simulators will be procured nor where they will be installed. Given the growth of computer technology, connecting 1,000 or more manned simulators and including more than 1,000 SAFOR entities is probably well within the state of the art. BDS-D is intended to provide at least a Battalion Task Force slice as an initial capability. The question of how large a battlefield is required beyond this remains open. A corps level context is necessary to address many issues associated with Combat Support, Combat Service Support and C³I systems; however, it is not clear what minimum size of unit needs to be individually represented in such a simulation.

Second, there remain some questions associated with implementing BDS-D. The key to the DIS concept, and thus CATT and BDS-D, is the novel implementation of object-oriented programming employed. In essence, each system on the BDS-D electronic battlefield is an object. Each object is either implemented in hardware/software (the manned simulators) or in software with limited man-in-the-loop control (SAFOR). Each object maintains cognizance over its own "world" (terrain, system status, entities in view, etc.), calculates changes in that world due to exogenous or endogenous influences, and communicates those changes to all other objects on the network via a message packet.

Message packets from all other objects on the network provide a means of identifying and incorporating exogenous events and conditions. Algorithms, logic and, in the case of manned simulators, operator input provide endogenous factors. All hardware/ software objects are their own computational devices; software objects are implemented in small groupings on one or more micro-computers. DIS thus distributes processing. Since processing capacity is growing both larger and less expensive this strategy has intuitive appeal.

Several questions associated with this implementation must be resolved. Packet size and update frequencies interact with network capacity. Once a packet size has been chosen, it will undoubtedly be adequate for most systems represented. However, it is possible to envision the addition of new systems or new subsystems to systems already represented in BDS-D which would require that packet size be expanded and that data elements and software be added to every system object on the network. It is also possible to envision the addition of systems with capabilities which would require the expanded resolution of such basic data as terrain. Concomitant changes to the software present in every object will also be required to represent the tactical and operational impact of a new capability in just one system.

Problems of this sort are particularly relevant to efforts to simultaneously play high and low resolution simulators on the same electronic battlefield. The lowest common denominator of required resolution may be higher than that typically played. Low resolution objects must be given data of sufficient resolution to allow them to adapt to the presence and impact of the system represented in the high resolution simulator. The value of integrating high and low resolution simulators is clearly positive; the costs are not precisely defined.

Third, the SAFOR portion of BDS-D is critical to its credibility and usefulness. SAFOR represents command and control and behavior. Representations of these processes present a challenge to the models and simulations used in analysis and elsewhere, and they will present a similar challenge to BDS-D. In this regard, it is not clear whether objects will continue to be instantiated only at the item system level or whether BDS-D will include, for example, battalion, brigade or division objects. Should the latter be the case, questions of disaggregation and aggregation must be addressed. These questions have been a major problem, as yet unsolved, in the models and simulations used in analysis.

Fourth, the operating costs of BDS-D remain vague. In estimating these costs BDS-D is perhaps best treated as a test range. Making a BDS-D "run" will require that simulators be configured to match the design alternatives considered, that appropriate SAFOR for future friendly and threat systems be put in place, and that any changes required to adequately represent new capabilities be made in BDS-D as a whole. Given these activities are accomplished, some time may be required for operator (and SAFOR) training to preclude learning effects. Once these preparations are completed, one or more "runs for credit" (replicated to establish statistical validity) can be made in real time. Following analysis of results, designs, tactics and/or organizations may be changed and the process repeated.

These activities all take time and require resources. Some may, on occasion, be far from routine. It is possible to envision concepts which, if represented appropriately in BDS-D, would require changes to the basic features of the system, in addition to configuring the simulators, and updating the SAFOR. The costs of these activities, the time consumed, and the degree of management required are not clear at this time, but they will be substantial.

Design Aids

It is worth noting that there has been significant growth in the use of simulations and models as aids to design components and predict performance. These aids are part of Computer Aided Design and Concurrent Engineering. They are critical to the design of complex weapon systems, and significant efforts are being devoted to their development and use in the Army and in the defense industry.

Two application areas for design aids are worthy of comment. First, it is not clear that comprehensive versions of such aids and associated simulations are available to support designs which utilize EW and stealth technologies or technologies which reduce vulnerability to chemical and biological weapons. Second, although considerable advances have been made, aids which address human factors issues are not as mature as their counterparts for, for example, mechanical or electrical components and subsystems. While high resolution man-in-the-loop techniques can support operator/crew station design, the issues of maintenance and support interfaces remain important. In this area improved design aids would be a significant addition to the CAD/CALS systems employed in the acquisition process.

SUMMARY

The state of the art of simulation technology employed in the acquisition process has grown significantly since the Army designed and developed its current generation of weapon systems. Simulations now are critical components of the acquisition process; their use will shorten it and ensure, with a higher degree of confidence, that the first complete prototype will meet the Army's requirements. Moreover, simulations will provide the Army with an earlier and better understanding of such systems to include related tactics, doctrine, and organizations. Advances in computer hardware and software technologies have made possible the progress in modeling and simulation capability over the past ten years. The DIS concept is a particularly good example of this progress: it distributes processing and memory and links entities over a network, and it employs object oriented programming. DIS is not the only example: system-on-system and force-on-force models are more comprehensive and easier to develop and use, and processing capacity has facilitated significant increases in the scope and power of CAD. Shortfalls remain, but they are not intractable. The Army should act to ensure that it takes advantage of current modeling and simulation capabilities and fosters continued development of these now critical components of the acquisition and test and evaluation processes.

SIMULATION SUPPORT FOR THE ACQUISITION PROCESS: A PLAN FOR THE FUTURE

The Terms of Reference of this Summer Study require the panel to "provide a plan that projects the research, development and acquisition strategy required to realize the simulation capability the Army should have 10 to 20 years into the future". This section provides the subpanel's contributions to that plan.

Any plan must have a goal or objective and, in the context of simulation support for the acquisition process, such a goal follows naturally from a perspective of the acquisition process as one which relies on a sequence of progressively more detailed and comprehensive tests and evaluations. The subpanel suggests that the Army establish the following goal:

For any major system, test and evaluate the evolving system on a virtual electronic battlefield throughout the acquisition process and the system life cycle.

This goal is intended to encompass all phases of the life cycle from concept development and requirements generation through design, development, production, and fielding to product improvement. It should include operations, maintenance, and support in any theater or situation in which the Army may be required to conduct operations.

There are important benefits to be derived from attaining this goal, including:

increased "user" involvement throughout the acquisition process,

better definition of functional requirements with early understanding of tactical, operational and organizational issues,

early identification of design shortfalls with corrections applied before specifications are completed and fabrication begun,

more comprehensive and more efficient test and evaluation programs, including DT, OT, and FDT&E, and

more thorough examination of materiel, doctrinal, organizational and training alternatives in the Product Improvement process for fielded systems.

The Army and industry have already taken actions which constitute progress toward this goal. Developers who briefed the subpanel indicated that simulation was now a necessary component of the design and development of complex weapon systems. Briefers from the test and evaluation community reported a similar requirement for test and evaluation, consistent with the recommendations of an earlier (1988) ASB study and the 1989 DSB Task Force on Improving Test and Evaluation Effectiveness. In the case of the design and development, neither time nor funds are available to support a fabricate-test process. In the case of the test and evaluation, the scope of many systems precludes testing throughout the performance envelope irrespective of the cost and availability of ranges and facilities. Simulation, or test and evaluation on a virtual battlefield, will allow the Army to determine valid and appropriate requirements and to "build its systems right the first time" avoiding the problems that have plagued the acquisition process to the present day.

Given the goal of test and evaluation on a virtual battlefield and the fact that the first steps toward this goal have been taken, it should be noted that the Army cannot leave progress to chance. In the remainder of this section a number of actions are proposed which should accelerate progress and provide capabilities to support system development and acquisition through the next 10 to 20 years.

RECOMMENDED ACTIONS

In order to achieve the goal suggested above the Army should take a number of actions. One of these, the development of a Distributed Interactive Simulation, is overarching. It puts in place a means of potentially increasing the quality and improving the timing of user involvement throughout the system life cycle. The remainder are tied to different activities or phases of the life cycle from the generation of requirements to product improvement.

Develop a Distributed Interactive Simulation

The Army should develop a distributed interactive simulation to support the system acquisition process for major systems. BDS-D should be designed and developed to fill this role. As such it should be utilized in all phases of the acquisition process from the generation of functional requirements and concept exploration through design and development and test and evaluation, as well as in support of product improvement. BDS-D should focus on facilitating user participation throughout the acquisition process, emphasizing operational performance and the development of sound and appropriate tactical and organizational concepts. In this regard the resolution of the manned simulators employed in BDS-D should be chosen to provide the degree of fidelity necessary to support user participation and the consideration of operational performance. Higher resolution should be added only when required to provide this support.

BDS-D should have sufficient scope to support the acquisition of major weapon systems as well as other major systems developed for combat support and combat service support including command, control and intelligence. It should provide a means of evaluating the impact of such factors as Electronic Warfare, low observables and stealth, chemical and biological warfare and the natural environment on system functional requirements, design specifications and operational performance. By so doing it will support the Army's ability to develop and field systems of increasing complexity. It will, properly applied, contribute to improvements in the acquisition process, in particular proper definition of functional requirements and identification and correction of design shortfalls early in the process when inexpensive solutions can be found. BDS-D will contribute to the Army's ability to "do it right the first time".

Emphasize the Use of Man-in-the-Loop Electronic Prototypes in Combat Developments and Requirements Generation

The Army should emphasize and encourage the use of man-in-the-loop electronic prototypes in combat development and requirements generation for appropriate major systems as a complement the techniques and tools already in use. Specifically the Army should field to combat developers low-resolution, rapidly re-configurable, manned simulators for use in BDS-D. The simulators should be used to "electronically prototype" materiel concepts. These electronic prototypes should then be employed in BDS-D to explore operational performance, and tactical and organizational issues, leading to functional requirements which incorporate a full range of user input. The functional requirements which result should be more appropriate, and tactical and organizational issues should be identified and better understood.

Mandate the Use of High Resolution Man-in-the-Loop and Hardware-in-the-Loop Electronic Prototypes

The Army should mandate the use of high resolution man-in-the-loop electronic prototypes throughout the development process: engineering design and development, test and evaluation, and product improvement. As designs mature, hardware-in-the-loop should be integrated as appropriate into these high resolution electronic prototypes so that they represent with high fidelity the response of the design to any stimuli and provide appropriate feedback to any action taken by operators, maintainers or support personnel.

In contrast to the electronic prototypes recommended for concept exploration and requirements generation, which represent operational performance, the high resolution simulators recommended here must provide a faithful reproduction of technical performance. They are intended to support detailed design trades and establish, with high confidence, the anticipated performance of the system in any battlefield situations in which it may operate. As such, particularly during the design phase, they will be used in a standalone mode with carefully controlled test conditions. In such a mode high resolution representations of the tactical situation and battlefield environment may be provided by other high resolution simulators, by low resolution workstations and by special purpose algorithms and data. In other modes it will be beneficial to integrate these prototypes into BDS-D. Accordingly they should be designed to comply with BDS-D standards and protocols.

High resolution man-in-the-loop and hardware-in-the-loop electronic prototypes of major systems should be funded by Program Managers. They should be maintained throughout the system life cycle and continually updated to reflect design changes. They should be employed when appropriate in DT, OT and FDT&E.

In parallel with the development and use of the high resolution electronic prototype, the Program Manager should fund the development of lower resolution simulators for BDS-D. These simulators should represent the tactical and operational performance of the emerging design and serve as a means of maintaining user involvement and supporting developmental and operational testing. Sufficient numbers of these simulators should be procured to support FDT&E.

High resolution man-in-the-loop simulation is now a necessary component of the design and development of major systems; necessary to handle the complexity of these systems and to avoid costly design errors. These simulators and their low resolution BDS-D counterparts will ensure that user involvement is maintained throughout the design and development processes. Their use will contribute to more effective DT and OT programs; critical issues will be identified early and appropriate test and evaluation activities can be performed and carried out. DT and OT which employ the electronic prototypes will also be more comprehensive; issues for which cost, range availability, safety, etc., preclude field testing can be explored on the BDS-D electronic battlefield.

Mandate the use of Electronic Prototypes and the Electronic Battlefiel in FDT&E

The Army should mandate the use of electronic prototypes and BDS-D in FDT&E for all major systems. This action will contribute significantly to the scope and effectiveness of FDT&E. Use of the electronic prototypes will facilitate early identification of critical test issues which must be tested with troops and equipment in the field. Use of the electronic prototypes and BDS-D will add to the scope of FDT&E; it will provide a mechanism for examining issues that, for reasons of cost, safety, etc., cannot be tested in the field. Finally, if the Army sets an exit criteria which requires use of electronic prototypes and BDS-D, it will contribute to the development of those prototypes and their use in the design and development phases of the acquisition process.

In implementing this recommendation the Army must be cognizant of current policies, both its own and those of DoD, which govern test and evaluation. The Army must ensure that these policies accommodate much greater reliance on simulation to extend the results of live fire and field tests.

Base the Development of BDS-D on Anticipated Requirements

Over the next 10 to 15 years the Army will develop test and field a new generation of systems, including the RAH-66, the ATCCS, and elements of the ASM. Each of these system programs would realize substantial benefits from the use of BDS-D. The Army should therefore synchronize the development of BDS-D with a prioritized list of anticipated applications derived from the milestones and phases of its major acquisition programs. The initial capabilities of BDS-D pertain to close combat, relevant to RAH-66 and ASM. The need to support programs such as ATCCS or UAV may be more important, if so the BDS-D development program should be altered accordingly.

SECONDARY ISSUES

The concept of a comprehensive virtual battlefield includes representation of all battlefield processes and environmental conditions. Such representations are required to conduct analyses and evaluations of concepts and alternative designs, to provide a complete set of stimuli and feedback for high resolution man-in-the-loop simulators, and to support test and evaluation. The Army should continue its ongoing efforts to expand and improve such representations or process models. Several are worthy of note at this time, others will emerge in the future.

Representations of command and control and soldier performance are recognized as a shortfall in virtually all simulations and models. The BDS-D overcomes this shortfall to a certain extent by using operators in simulated systems and by using controllers in a SAFOR mode. As long as the number of systems present on a BDS-D battlefield is relatively small, this approach is feasible. However, as the number of systems grows, the demand for controllers will become prohibitive unless SAFOR modules can realistically represent the command and control of units and formations, and the behavior of "virtual" systems and soldiers in those units and formations. High priority should be assigned to research to improve models and simulations of command and control and behavior. BDS-D will be a major user of such research and, at the same time, a testbed for it.

A second and related set of processes requiring representation in simulations and models are those associated with the "electromagnetic battlefield", including but not restricted to electronic warfare. The dynamics of the electromagnetic battlefield are important and will become more significant in the future as low observable and stealth technologies are incorporated in designs and the requirements for coordinated action among systems become more critical. At the levels of classification in which the subpanel conducted its activities, representations of the electromagnetic battlefield and electronic warfare were rudimentary at best and usually omitted. The Army should act, in the near term, to overcome this shortfall. Chemical and biological warfare should receive a similar level of emphasis.

Investigating command control, intelligence, electronic warfare and chemical and biological warfare, and incorporating representations of these processes in models and simulations, have been significant activities in the Army's analysis agencies for over 25 years. Those agencies have also dealt extensively with the issues of aggregation and the interfaces between high and low resolution simulations. The goal of these efforts has been and continues to be the improvement of the models and simulations used in Army analysis. The knowledge and expertise built up in the analysis agencies is directly relevant to development of BDS-D. The design and implementation of SAFOR logic is one example; the use of single objects corresponding to units such as battalions, brigades, or divisions is another example of areas in which that knowledge and expertise should be brought to bear. The development of BDS-D would also benefit from other expertise present in the Army analysis organizations. For example, those organizations have extensive experience in applying their models and simulations in concept exploration and requirements generation.

Consequently, they are familiar with the time required to develop data and define concepts and the iterative processes of exploring the value of different system capabilities and determining appropriate tactics and organizations. It is not clear that early development of distributed interactive simulations made use of the knowledge and expertise available in the analysis agencies, nor is it clear that that knowledge and expertise will be applied in the development of BDS-D. The Army should act to ensure that its analysis agencies play a suitable role in that development.

Computer Aided Design (CAD) systems, Concurrent Engineering (CE) techniques, and Computer Aided Logistics Support (CALS) represent systems and techniques that include simulations and analytics models. Industry has adopted these techniques, and their use in Army Materiel Command is widespread. Capabilities will undergo continuous enhancement, for the most part independent of the Army. Nonetheless there are domains, for example, armor, large caliber gun systems, and heavy tracked vehicles, in which the Army should continue to support the development and enhancement of design aids. As technologies critical to the Army mature, the Army should ensure that design aids appropriate to those technologies are available within its RDA organizations and in industry.

Verification, validation, and accreditation of all simulations is, and will continue to be, an issue. In the case of high resolution computer prototypes, in distributed simulations, and in computer aided design routines, the issue is partially overcome by the fact that models or simulations of well defined physical processes usually rest upon theory and data. The degree to which the simulated processes are faithfully represented can be determined; those instances in which simulated processes occur outside of the theoretical or experimental envelope should be identifiable and manageable.

Verification and validation and accreditation of simulated human behavior, including command and control, remains a challenge. This challenge is particularly significant for BDS-D. If it is to represent the entities on a division or corps level battlefield, it will rarely, if at all, have the luxury of manning simulators of all the vehicles and systems of the combat arms and combat support and combat service support organizations However, as noted earlier, BDS-D will provide a testbed for research in this domain supplementing current Army efforts, e.g., those based on training center data.

In the case of other Army simulations, such as CASTFOREM, FORCEM, or VIC, verification, validation, and accreditation remain important. These simulations, and others like them, will continue to play a major role in establishing the context for generation of functional requirements and examining issues related to force level effectiveness. Accreditation of simulations and data is necessary to ensure that different Army agencies and industrial users employing such simulations in the acquisition process all work from common data and process representations that the Army understands.

AFFORDABILITY

Estimates of the size of the military simulation market vary, but it is not unreasonable to assume it will exceed one billion dollars annually by the end of the century. Simulations used in the acquisition and test and evaluation processes will form a portion of this market, but that portion will be small relative to that associated with training. One can thus argue that training applications will pace development and technology growth; the acquisition process will benefit accordingly.

In the context of the subpanel's activities and conclusions, simulation is a necessary component of the acquisition process. Thus the Army cannot avoid funding development and use, particularly of high resolution man-in-the-loop simulators. Such simulators are not prohibitively expensive relative to total program costs, and systems as complex as those to be acquired in the future cannot be successfully designed without them.

A similar situation exists in test and evaluation. The Army cannot afford to conduct comprehensive testing. It is too costly and in many cases it is infeasible. Test programs must be designed so as to focus on and resolve critical issues in tests of actual hardware and units. Simulation will contribute to identifying such issues early in the design and development process; it will also provide a mechanism for comprehensive testing in which the performance envelope of a system can be explored, the boundaries of the envelope can be identified and the full potential, tactical and operational, of the system can be employed.

CONCLUSIONS

Simulation is now a necessary component of the acquisition process. The Army should take actions to exploit simulation technology in all of its system acquisition programs throughout system life cycles. High resolution man-in-the-loop simulators are critical to successfully designing and developing complex systems. Distributed Interactive Simulations will become critical for test and evaluation, particularly FDTE. Distributed Interactive Simulation will complement, but not replace, other techniques in concept exploration, demonstration and validation, and full-scale development.

As a goal, the Army should pursue test and evaluation on a virtual battlefield throughout the acquisition process. In a sense, the Army has no option but to pursue this goal; it should do so in a carefully managed and cost effective way to ensure comprehensive capabilities are available when required by the acquisition programs of the next 20 years.

APPENDIX D

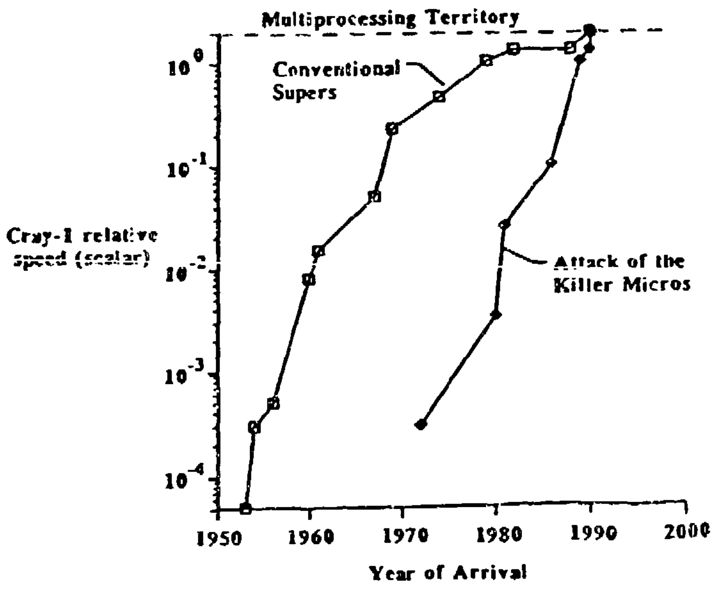
TECHNOLOGY PANEL

FINDING 1. RAPID ADVANCES ARE BEING MADE IN KEY UNDERLYING TECHNOLOGIES.

Over roughly the past decade, there have been three technological revolutions that have produced qualitative changes in the ability to construct electronic simulators. First, progress in ultra large scale integration of circuits has dramatically increased the circuit density. The computer–on a chip has become a reality. Secondly, this technology made possible the personal computer revolution in which both the power, cost, availability and ease of use of computing technology was captured in individual machines that formerly were accessible only to large organizations. Finally, the capability to utilize this technology in many identical units is now being expressed in massively parallel systems. All of this technology explosion has been and will continue to be driven by the commercial marketplace. However, its availability has transformed the technical landscape in which the Army can envision carrying out its future simulations and simulators. There are four specific areas in which the technology has particularly strong implications for simulation needs.

Massively Parallel Computers

Inherent physical and architectural constraints dictate that future advances in computer power will come from utilizing many similar computational units in parallel rather that from a single cpu. The capability of the identical units has grown exponentially over the past several years so that the performance of the single element is now approaching that of a modern super computer. As shown in the chart below the scalar power of an individual chip (i.e., a microcomputer) is comparable with that of a supercomputer. Within the next several years the same will be true for vector processing chips. Equally rapid growth is expected to continue well into the next decade.



There are many kinds of parallel computers differing primarily in the required level of communication among the individual units.However, from the Army's view, the important point is that several orders of magnitude increase in computing power will be available at fractions of the cost of current technology. This extensive capability will be available in low end and mid-range personal computers and workstations, as well as producing a much more powerful supercomputer. Assuming that the software can be developed to utilize this spectrum of machines, the Army will be able to do hi-fi simulation of complex systems or devices at one end and very rapid turnaround, lower fidelity but still realistic simulations on the level of the individual soldier.

It is also evident that, in principle, many of the most important Army simulations (such as force-on-force) are extremely well adapted to a parallel processing representation since that in fact describes the real world.

Displays

The realism of visual displays will benefit greatly from HDTV technology. Display technology is advancing rapidly, and is being strongly driven by other than Army needs. Far more information will be represented on one screen than with present technology. What to show and when the human limit to absorb is reached, are more pressing questions than what can be presented at a reasonable cost.

Human-Machine Interaction

It has been estimated that 70% of new processing power from the faster processors will be directed at the user interface. Voice input and output, speech recognition, "command gloves", eye tracing cursors, and head mounted displays all combine to enable a science fiction like capability that will be on us in no time.

These technologies are racing at us. We must begin to cope with them in a systematic way, so that the simulations will be realistic and expansive enough to answer the key questions that will arise as to the value, not of any one of these new techniques or tools, but from the combination of two, three, or four in a single weapon system or command and control console. Unless we assemble a team with this mission, we will be stumbling with impaired vision into the new battlefield.

Networks

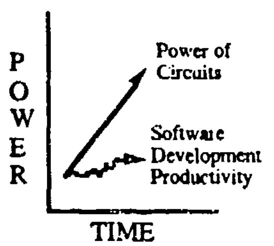
Currently, most simulations are done within one "locality" where all of the information exchange occurs on local area networks (e.g. ETHERNETS) with rates in the 10 mbps range. As the use of simulation increases the required rates will grow by several orders of magnitude so that band-widths must increase accordingly. It appears that fiber optic systems under development (such as FDDI) will provide adequate bandwidth for local area network applications. For wide-area networks (also known as long-haul), the principal drivers are multi-national, multi-service communications and the Army should be able to utilize these broader function networks for its long haul (wide area networks) interactions. DARPA will almost certainly be the primary stimulus for developing such networks, (e.g. TWBnet in the near term) although the Army will need to ensure that its local area nets follow the standards and protocols necessary for attaching to the wide area nets.

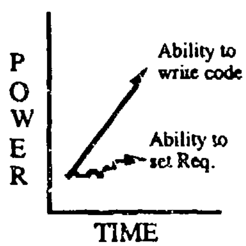
FINDING 2. SOFTWARE EXPLOITATION WILL LAG

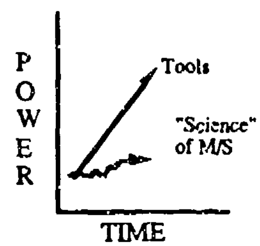
Software is highly complex. Its complexity is primarily the result of attempting to develop a conceptual construct of a functional need that must be both highly precise and detailed in its definition. We seem not to be able to do that very well. This inherent complexity has resulted in only incremental improvements in the way we use software to solve our problems. When we contrast the software improvements to the technological improvements in hardware – at least six orders of magnitude over the last three decades – there is a natural frustration at the slow rate of progress in software exploitation. The chart below schematically illustrates the lags in both function and construction that lead to this difference.

Relative Rates of Progress

SOFTWARE		UNDERSTANDING
CONSTRUCTION	FUNCTION	OF M/S
How to build software	What the Software is to tell the computer/system to do	How to use tools to create models/simulations
This shows that the ability to develop software lags behind the ability to produce circuits.	This shows that Requirements Definitions lag behind the ability to create code.	This shows that the power of available tools is outpacing the understanding of the discipline of modeling and simulation.







Software, as a technology, has not lacked major attempts to find silver bullets. Design models, top-down programming, new languages, and operating systems have all been attempts to improve effectiveness and efficiency of software development. Interestingly, the primary focus of these efforts is to improve the production of code and not to simplify the construct of the functional problem.

Although far from silver bullets, there appear to be capabilities now available that will improve the Army's ability to produce appropriate software:

- Dictate the use of established standards, e.g. languages, data, design tools, as a means of simplifying the production of code.
- Use rule based expert systems to capitalize on the intellectual and experience base of the experts in the area of functional interest.

- Use object-oriented programming – the design basis for TRAC's highly regarded EAGLE model – as a means of achieving early and disciplined development of hierarchically-based problems. Object-oriented programming offers a number of other major attributes including ease of maintenance, and clarity of design. It is a design and programming technique that offers great promise to the software developer.

There are two primary means of achieving large improvements in the development of software based systems.

Do not develop software but acquire it from others ; i.e., do not build, but buy. Software reutilization is only now perceived as a primary means of avoiding the costly and laborious efforts in the software life cycle. The Army STAMIS community has recognized the need and has an initiative underway, entitled RAPID, that evaluates,validates, and distributes software modules to its software developers. The modeling and simulation community should follow STAMIS's lead towards using RAPID or creating a similar capability. In a proactive manner, functionally acceptable and operational software should be made available to everyone in the modeling and simulation community.

Software should be recognized as an entity that will gain value over time through its continued use. Software terminology has changed in time to reflect this thought process. Software was "written," then it was "built" and now it is "grown."

Software improves through the iterative process that takes place through use by many different entities and organizations in different environments. There is always a tendency to believe that the way to improve software is to begin anew.The Army should follow present industry–wide practice to iterate software as a means of ensuring its refinement.

FINDING 3. UNDERSTANDING OF MODELING AND SIMULATION, ITS USE, AND HOW/WHEN TO INTRODUCE NEW ADVANCES WILL LAG

An expanded discipline of Modeling/Simulation (M/S) is needed to adequately monitor the high fidelity models of the designers of major new weapon systems, and to construct and utilize CATT and BDS–D. New technology is roaring down the delivery paths – graphics, networks, parallelism, and Human-Machine Interface – and the ability to efficiently utilize these advances in a timely way to a great extent depends on a clean and efficient discipline of models and simulation. In the year 2005 we should be able to have a review of a model that not only addresses the fidelity of the model, but also the construction of the model. Questions such as "does this model have the main parts of a model clearly defined and separately implemented?" should be addressed.

A discipline of models will allow a more rapid introduction of new technology from the component world. The discipline, along with better software technology, will allow for much faster updates, fixes, and changes. It will allow for faster audit and review. It will greatly reduce the cost of maintaining the model/simulation.

The Army should designate Center(s)[1] of Excellence for M/S and charge the Center with the formulation of the discipline of M/S and the creation of standards for M/S. This will be a lengthy process, which will evolve over time and which will be conducted in cooperation with other DOD, service, and university authorities. The Center will be tasked to participate in major audits and to assist in the assessment of major models, both vendor and Army models. The Center will be tasked to provide leadership in the articulation of the future desired capabilities in M/S.

[1] Throughout the remainder of this section Center will refer to one or more Centers.

The Center should be attached to existing facilities now in being and should be funded to do research and development, and to participate in standard--setting activities outside and within DoD.

The Center should be reviewed at least yearly. Questions such as "What is the value of man in the loop in a simulation of a force on force?" and "How do we intermix high and low fidelity models?" should be expected to be answered.

FINDING 4. AVAILABILITY OF DIGITAL TERRAIN DATA BASES IS IMPORTANT AND IS CURRENTLY INADQUATE

The modeling and simulation community is dependent on the availability of digital terrain data for those geographical areas of planned contingencies. It is obviously highly advantageous to be able to train including the rehearsal of missions on the actual terrain upon which the force may fight. At present there is a serious backlog at DMA with the result that simulated training is being performed with generic – not contingency specific terrain information. The problem is many fold: prior European emphasis, limited availability of high resolution maps, and limited DMA resources.

The Army must be persuasive at Joint Service and OSD forums of its need for increased availability of digital terrain data – specifically to satisfy high priority contingencies. An associated shortfall in the Army's means of capitalizing on digital terrain data is the Army's relative inactivity in terrain standards efforts. Joint forums have been established to define appropriate standards. Although the Army leads the DOD in the development and utilization of distributed interactive simulation, the same cannot be true for its standards activities. To achieve a true balance, the Army needs to be more active in digital terrain standards.

FINDING 5. PROGRESS IN MODELING CRITICAL UNDERLYING PHENOMENOLOGY IS THE KEY TO CREATING HIGH RESOLUTION SIMULATIONS.

Increased electronic simulation capability alone is not sufficient to achieve satisfactorily high fidelity resolution of Army systems or devices. If the individual items, components, or interactions are poorly characterized, this can invalidate the results of an ostensibly higher level, high fidelity simulation. Consequently, there must be a significant effort to achieve adequate quality in the description of the underlying phenomenology.

Much of the basic phenomenology work is funded outside the Army (e.g. by DARPA), and much of it has historical origins that now represents "conventional wisdom". However, there are phenomena which have special impact on Army systems (such as dynamic terrain or behavior of reactive armor), and those whose performance characteristics are described by empirical, low-resolution models (such as kill probabilities for particular weapons).

We believe that the Army should assay the phenomenological models underlying its important simulations, and focus its resources on bringing the low resolution ones up to sufficient accuracy. This could mean reassessing performance data bases, targeting specific physical phenomenon for focused experimental/theoretical research, or carrying out sensitivity studies to identify high leverage areas for further study. In all cases emphasis should be on applied work directed at achieving a necessary level of accuracy, not tech base development for its own sake.

SCOPE OF STUDY. The technology panel was chaired by Mr. Edward Brady, and the members were Mr. Joseph Fox, Dr. Bruce Tarter, and Mr. Martin Zimmerman. In addition to the full panel briefings, we held the following special sessions:

Mitre Corporation. Briefing by BBN on SIMNET and on concepts and technologies relevant to future Army simulation needs.

Lawrence Livermore National Laboratory. Presentations on computing technology in the coming decade; the national environment in supercomputing; electronic changes in the DoD procurement process; and discussion of the algorithms and methodology involved in force-on-force simulations (Using JANUS as an illustrative example).

Ames Research Center. Discussions on modeling/simulation by members of the Aeroflight Dynamics Directorate, AVSCOM, with particular emphasis on flight control simulation.

APPENDIX E

TRAINING

INTRODUCTION

The Army Focus of June, 1991, states:

> ***Training is the cornerstone of readiness. As such, the Army is firmly committed to continuing tough, demanding and realistic training for the entire force. Training will remain the Army's top priority.***

The DOD's Interim Report to Congress on the Conduct of the Persian Gulf Conflict addresses the contributions of training to the success of DESERT STORM:

> ***The high quality of training was one of the most important contributions to the success of the Gulf operation. US Service and Joint training centers and exercises of many varieties provided realistic operational experiences that proved useful in the Gulf theater.***

The simple fact that actual combat can not be accomplished in training, leads to the complexity of combat training. This is not a new problem. Gorman ("The Military Value of Training," IDA, November, 1990) notes "...the Romans trained so that their drills were bloodless battles, and their battles bloody drills, and that the ancient Chinese correctly perceived that they could trade sweat evoked by arduous training for blood drawn by an enemy's edged weapon." The squad drill of the Revolutionary Army was a mimic of what was expected to be maneuvers on the field of battle. The practice of musketry was intended to develop the psycho–motor skills necessary to incapacitate foes in battle. Today, however, there are a number of factors that make preparation for battle ever more difficult. These include:

- more complex weapons systems
- greater weapon systems range and lethality
- limited training areas
- limited training time and dollars
- heightened environmental concerns
- uncertain theaters of employment
- certainty of a "joint" environment

These challenges can be partially offset by advanced simulation technology. These include:

- cheaper and more powerful computers
- well educated young soldiers who are aficionados of video games
- availability of data bases and high fidelity visual displays
- a largely computer literate officer corps

The Training Panel believes that the Distributed Interactive Simulator (DIS) technology offers a revolutionary opportunity to perform realistic combined arms training of our heavy battalion task forces on a realistic "Electronic Battlefield." This Electronic Battlefield can permit the incorporation of enemy air strikes, electronic warfare, and indirect fire to a degree never before achievable in other training exercises. This training opportunity offsets many of the inhibiting factors of training space and resources and offers the ability to train over any type of terrain. It is even possible to envisage the operational planning and mission rehearsal potential of this technology in preparation for a future Operation DESERT STORM.

DEFINITIONS

The following definitions are used by the Training Panel. These are not official definitions in the sense of being blessed by a document such as JCS Pub 1 or Webster's Dictionary. They are a reasonable description of terms necessary for the understanding of this report.

Model. A set of mathematical or logical functions that are programmed in a computer to represent combat and/or combat-related activities. There may be some opportunity for human interaction, but the preponderance of model activity is dictated by rules established as a priori by the modeler. JANUS is a typical example.

Simulation. A replication of combat or combat-related activities that would typically include a visual presentation of the environment and a physical representation of all or pieces of the weapon system or support equipment. As contrasted with a model, one would expect to see a great deal of human involvement in a simulation, far fewer fixed scenarios, and a preponderance of free play.

Simulator. Hardware that represents all or a piece of a weapon system. The crew compartment of SIMNET is a simulator.

Emulator. Computer code and computers that are used to play the role of items, units and organizations within a simulation.

Unit. An Army entity that is prescribed by a Table of Organization & Equipment. Units include squads, platoons, companies, and battalions.

Organization. A collection of units associated for a purpose and normally for a long duration. Examples include brigades, divisions, and corps.

Force. A collection of units and/or organizations associated for a purpose (typically a combat mission) and normally for a short duration. A battalion task force is an example.

Field Training Exercise. Units, organizations, or forces practicing combat activities in a training area such as the National Training Center.

Command Post Exercise. Training for commanders and staffs or units, organizations, or forces. These exercises emphasize command, control, decision making, and coordination of subordinate entities.

Command Field Exercise. Training for units, organizations, and forces where a small portion (perhaps a single leader or a team) acts as a surrogate for the entity.

PHILOSOPHY AND ORGANIZATION

The analysis and conclusions that follow are narrowly focused through a training prism. From that perspective, we hold strongly to these assertions:

- combat success is a function of the combined capabilities of the soldiers, the quality of their equipment, and the level of their proficiency
- training resources (time, terrain, dollars, etc.) are scarce and will become even more precious
- soldiers fight as members of a unit within a combined arms force
- units should train as units and as part of a combined arms force

In considering the application of models and simulation to training, we will consider both the institution and unit training environment, and within each environment, individual and collective training.

However, there is a third dimension needed, the size of the entity that is training. What may make sense for a platoon may be folly for a division. Finally, there needs to be a fourth dimension in that, while the Total Army is an enviable idealism, there are distinct differences in the training requirements and opportunities for the Active Components and the Reserve/Guard Components.

The chart below is an overview of the electronic training assets available or to be available to the Army.

Principal Army Training Simulations

	Operators/ Maintainers	Leaders/ Troops Troops	Cdrs/Staffs Leaders Staffs	Unit Cdrs Staffs	BDE/BN Cdrs Staffs	Corps/Div Cdrs Staffs
CORPS						XXXX
DIVISION						XXXX
BRIGADE					XXXX	XXXX
BATTALION			XXXX	XXXX	XXXX	....
COMPANY			XXXX	XXXX	....	....
PLATOON		XXXX	XXXX	XXXX	....	....
ITEM	XXXX	XXXX	XXXX	XXXX	....	....
	(Many)	COFTs	CCTT (SIMNET-T)	JANUS	BBS	CBS

SIMULATORS ◄ Electronic FTX ► ◄— Electronic CPX —►

TRAINING MODELS AND SIMULATIONS

This Section discusses the Army's use of models and simulations for training in TRADOC school houses and within unit environments or settings. It considers elements from individuals to Corps, both active and reserve components.

Individual Level -- Institutional Setting, Active and Reserve Component

Models. We are unaware of any models that are used within the "school houses" for individual training.

Simulations. We did not specifically address this topic with any TRADOC activity. However, we are aware from previous experiences that there are numerous simulations and simulators that are used for part task training, particularly to develop maintenance skills. We also saw a number of such devices during a visit to ECC International Corporation in Orlando. ECC trainers included:

- helicopter maintenance training simulator
- a variety of simulators for the maintenance of AH–1S Cobra sub–systems
- Tank Turret Operational Maintenance Trainers (TTOMT)
- M109 Howitzer Improvement Program (HIP) trainers
- Mobile Subscriber Equipment (MSE) simulators
- Generic Airborne Radar Maintenance Trainer
- Videodisc Gunnery Simulator (VIGS)

In general, these simulations are unsophisticated and sharply focused on a specific area of training. They are relatively cheap, reliable, and easy to use. They appear to provide effective training and allow self–paced instruction.

Our sole data point with the National Guard was with "rubber meets the road" level trainers. These Army officers were far more enthusiastic about VIGS than about SIMNET. VIGS is a suitcase-sized trainer that is easily moved from training site to training site. There is no need for an operator or for an on–site training assistant. The individual soldier simply dials up the training he desires and paces himself through a variety of gunnery exercises in a variety of different terrains and combat scenarios.

We would expect to see a normal evolution of these simulations through industry development without a large Army R&D support. The Army policy of requiring these devices be developed as a part of any weapon systems development is eminently sound.

While the process of evolving the requirements for these part task trainers, and non-systems training devices, is in place, the percentage of the Army investment account allocated to development of training devices appears to be on the order of one percent. A modest increase in this area, if adopted, would appear to have a high return on investment.

Individual Level, Unit Setting, Active and Reserve Components

Models. We are unaware of any models that are available within Army units for the purpose of individual training.

Simulations. As contrasted with what one would find at the "school houses", there are few simulators available within Army units for the training of individual soldiers. Marksmanship trainers are the exception, and they are viewed favorably by the units we contacted.

Team Level, Institutional Setting, Active and Reserve Components

Models. We are unaware of any models that are used for team training within the institutional training environment.

Simulations. The Conduct of Fire Trainer (COFT) is available within Army units for the training team at several TRADOC installations. In addition, SIMNET is available at a few TRADOC sites.

Team Training, Unit Setting

Models. We know of no models available within units for team training.

Simulations.

Active Components. COFT is widely available to each tank, cavalry, and mechanized battalions. This simulation has to be counted as a singular success. From a command perspective, it has saved training time and training ammunition. It provides the gunner and vehicle commander key skills that, heretofore, could only be achieved with a large number of live gunnery exercises. The individual gunner has voted with his feet; he goes to the COFT when he has the need and the opportunity to regain gunnery skills.

The COFT was meant to improve commander-gunner teamwork and psycho–motor skills. This it does admirably. It does not train the team in maneuver, coordination of fire, or other activities essential to successful tank–on–tank engagements. The interconnection of two COFT's to exercise the section and four COFT's to exercise the platoon are very worthwhile investments. The COFT has a number of routines that collect data that are metrics for gunnery proficiency. In addition, the COFT represents technologies of the 1970's. Today's young soldier is a video game connoisseur. He may quickly become disenchanted with the low resolution cartoon-like icons found in the current COFT. The graphics in the COFT, or its follow-on, need updating to provide more realistic terrain and a greater variety of terrains, an improvement that can in the future be afforded, thanks to advances in computer processing per dollar and improved graphics software.

Reserve/Guard Components. There are few combat units in the Reserve Force. However, combat units within the National Guard have access to COFT as well as MCOFT, a trailer mounted mobile version of the COFT. The units find the COFT and MCOFT to be effective trainers. However, both devices need a support staff that the Guard has difficulty resourcing.

Platoon Training, Institutional Setting. With the exception of special units, platoons are trained primarily in unit settings, not in training institutions.

Platoon Training, Unit Setting, Active and Reserve Components

Models. JANUS has the ability to be played at platoon level for training the platoon leader, but not for the purpose of training the entire platoon.

Simulations. SIMNET is used for platoon level training. The discussion of SIMNET is deferred to the section that discusses company level training.

Company Training, Unit Setting

Models. JANUS is available for training company commanders.

Simulations.

Active Forces. The Close Combat Tactical Trainer (CCTT), will be a superlative training means for company and platoon sized units. CCTT is a follow-on to the joint DARPA/Army SIMNET project that basically resulted in three components:

- a well designed and engineered set of standards, protocols, and architecture that will allow a large number of simulators and/or emulators to be connected in a common network.

- a set of simulators for the M1 tank, the M2 Fighting Vehicle, and dismounted infantry. In addition, there are a number of emulators for combat support and combat service support vehicles and systems. Combat is played on one of four terrain data bases.

- The technology to connect geographically separate sites by long line communication using microwave or satellite transmission.

CCTT will have better imagery than COFT. As does SIMNET, CCTT represents all of the crew of the M1 and the M2 in the simulator, captures measures of performance, and has the ability to "re–zero" the battle to allow analysis of alternate courses of action. The anecdotal evidence that CCTT, as represented by its precursor, SIMNET, will be a valuable training assist is overwhelming. Armored units from the 24th Mechanized Infantry Division, for example, deliberately sought out SIMNET training as an essential part of preparing for the DESERT STORM deployment. The Potomac Systems Engineering "Final Report of the Independent Verification and Validation (IV&V) of the SIMNET Model" states, "SIMNET is an excellent training device. When we have observed units training on SIMNET, we have seen enthusiastic soldiers attacking real training problems in a realistic way."

The perspectives and assessments of SIMNET, colored by organizational interests, vary. There is universal agreement that the logic and arrangement of the local network and the interchange and processing of data is a remarkable bit of engineering. Several commanders note that the current simulators lack features such as open hatch vision, and that better terrain representation is essential in a training simulator. DARPA, with a technology bias, has emphasized the long lines communication. As one briefer summarized his central themes, "The networks 'transport' warfighters at all levels to the virtual battlefield from their worldwide locations." This concept implies, for example, that an Air Cavalry troop at Fort Hood might train with a Mechanized Infantry unit at Fort Stewart. The wide area network capability to train geographically separate units is a commendable technological achievement, but we see only marginal training benefit. Again, soldiers and their leaders should train as they will fight--in their units as part of combined arms organizations with which they will operate.

The Army has an on-going procurement to develop and field 546 simulators in company and platoon-sized sets of CCTT's. The cost and effectiveness analysis was based on an equal cost basis and indicated that the Army could field these sets by giving up roughly 70 miles per M1 tank per year. This would defer deployment of essential combined arms elements (e.g., air defense, engineer, and aviation). We believe that the delay of these other combined arms elements, and the focus of CCTT procurement at the company team level is ill-advised.

Reserve Components. We initially accepted the notion of dispersed, yet linked, CCTT's as a valuable asset for the reserve forces. Figure 3 shows the location of the several units that constitute the 48th Mechanized Infantry Brigade of the Georgia National Guard. There is in excess of 300 miles separation between some of the units. Our hopes for long line link up were defeated by the pragmatism of this world. The separate locations are not resourced to handle SIMNET training. There are no barracks, no mess facilities, no maintenance or training support people, although the state has a central "school house" that does have these resources. We were unable to investigate this matter in sufficient detail to understand how a SIMNET-like simulation would fit the particular needs of reserve components.

Battalion Training, Unit Setting, Active and Reserve Forces

Models. JANUS and the Brigade and Battalion Simulation (BBS) have been used extensively to train Battalion commanders and their staffs in both the active and reserve forces. Both are able to inter-link geographically separate units through telephone hook ups. Both appear to be widely accepted, and highly regarded, within the Army.

Simulations. CATT is currently programmed to build on the CCTT company maneuver sets, and sequentially add selected combat and combat support elements as the Branch proponents can afford the development. The Training Panel's view is that the other combined arms elements should be developed as a priority, and that, if full Battalion Task Force sets can not be provided due to funding constraints, then the Army should still focus on the getting limited numbers of all elements of combined arms team of the Battalion Task Force. The sets would support a Battalion Command Field Exercise (CFX), or a company slice of a task force FTX.

In addition to developing combined arms systems to fit into the Battalion Task Force simulation, the CATT program must develop the suite of systems to allow selected members of the battle team to train their crews, platoons, flight sections, troops, companies, and batteries. The Artillery has described the need for a Closed Loop Artillery Simulator (CLASS). This device is designed to train the Artillery team to perform target acquisition, fire direction, and weapons delivery in a closed loop system. There is an allegation that CLASS may not be compatible with the evolving CATT. This would foreclose many of the advantages of the Electronic Battlefield. This Battlefield also offers opportunities to train the Engineer and EW systems of the Heavy Division. These opportunities have not been exploited by these Branches, and intellectual effort is required.

A casual review of the Basis of Issue (BOI) proposals for the ADCATT, AVCATT, and the Battalion CFX simulator requirements suggests that the BOI will need a "scrub" at a major review. Also there is no mention of the Line of Sight Anti-Tank (LOSAT) system, scheduled to enter the service in about 1997 as a replacement for the ITV, in the development plan or BOI.

Brigade Training, Unit Setting, Active and Reserve Forces

Models. BBS has been used successfully for training of Brigade staffs.

Simulations. There are no simulations planned for Brigade training. We are uncertain how far one might scale up a CCTT type trainer in the future. Brigade training is a possibility; it is not a surety. It is possible now, however, to have a Brigade level electronic Command Field Exercise using SIMNET.

Division Training, Unit Level, Active and Reserve Forces

Models. JANUS and the Corps Battle Simulation (CBS) have been used to train Division staffs.

Simulations. We see little evidence that simulations of the SIMNET-type can practically be scaled to this level. We again emphasize the primacy of the Divisions in the training role. They should be the "keepers" of the CATT for training battalion task force, but will rarely, if ever, try to have the whole division on simulators at any one time.

Corps and Echelons above Corps, Active and Reserve Components

Models. CBS has been used to exercise Corps staffs. In addition, there are a number of home grown models that are used at training centers such as the Warrior Preparation Center and the Joint Warfighting Center.

ASSOCIATED ISSUES

Embedded Training.

There is some uncertainty within the Army as to the interpretation of the Army policy on embedded training. While the directives signed by the VCSA and USA gave reasonable guidelines and a rational definition on embedded training, implementing directives in the ASM R&P are more rigid and less reasonable in interpreting the intent of the guidelines. In discussion with PM TRADE, we find a reasonable approach to their implementation of embedded training as the preferred choice, but also some concern that they might not be adhering to the party line.

We recommend that the Army leadership restate its position and encourage PMs, AMC, and TRADOC to approach each system individually to see what training functions can feasibly and cost-effectively be "embedded". The Army should make certain that the community understands the definition embedded, that "appended" devices or portions of devices also meet the stated preference for embedded, that it is virtually impossible to have embedded features at "no cost". The need for separate processors/storage/data bases and enabling devices, while potentially very cost-effective, are not without some cost. For example, the need to isolate training software from battle software may require separate software so as not to contaminate the regions used for work. The attractiveness of embedding reflectors used in tactical engagement simulators is potentially more than offset by the penalty assigned in terms of ease of enemy acquisition. All this suggests that significant intellectual effort must take place to get it right. To direct industry to embed these capabilities at no additional cost, and no decrease in availability, is not reasonable.

Logistics Training. The panel observed that logistics functions are portrayed sufficiently within SIMNET/CATT for these programs to be effective combat trainers. The functions are not portrayed in sufficient detail for CATT to be effective for logistics collective training. We have also been led to believe that logistics play is reasonably specific in the BBS/CBS CPX models. There is a divergence of opinion, but there is a body of thought that the fidelity and pace of activity for combat units at the NTC is a closer approximation of "real" war than that experienced by some of the combat service support units at NTC. We did sense a concern within some logistics spokesmen that there was inadequate attention being given to the use of models and simulations to train logistics units. The Training Panel did not have the opportunity to verify this allegation or to suggest remedial actions. This could be a subject for further deliberation.

The Future of SIMNET. SIMNET was originally a DARPA project and is now handed off to the Army. The Army's CATT project will eventually supplant SIMNET. Some of the statements we heard probably exaggerate the Army's position; however, an outside observer might well gain the impression the Army is going back to "square zero" in developing CATT and scrapping SIMNET. We were led to understand, for instance, that SIMNET simulators will be put in warehouses as soon as CCTT simulators become available and that no upgrade of SIMNET will be allowed. The current plan results in 546 CCTT simulators with 246 SIMNET-T simulators being warehoused. An obvious alternative, of course, would be to have 546 "First Class" CCTT simulators and 246 "Second Class" SIMNET simulators where "Second Class" might well mean something better than the present SIMNET-T trainers. We were told this "could not be done economically." We remain skeptical of this assertion and incline to the view that current SIMNET assets can be saved, used, and upgraded over an extended period of time.

Education. We did not study carefully the education in modeling/simulation that is given to officers in the branch basic and advanced courses and at the Command and General Staff College and the Army War College. We did find that models and simulations were part of the training at all levels of officer education. We do not feel that the purpose of the Army education system should be to produce modelers. We do feel the system should inculcate a culture that leads to an attitude that models and simulations are indispensable, and that one of the first tools to look for as an aid to problem solving and decision making should be a model/simulation. We did not find this philosophy in the education system. In fact, we were told that one of the Army schools uses models in the education of officers, but consciously tries to keep the officers unaware of the model use. We find this to be a self–defeating motivation.

Visual Displays.

The visual portrayal of the landscape and enemy/friendly troops and equipment is critical to training simulators as herein defined. We have already mentioned that the visual acuity in COFT can be improved. The display in SIMNET, while better, is also limited. The availability of the display is somewhat limited by the availability of suitable Defense Mapping Agency digital data bases. DMA apparently does not have the resources to expeditiously complete the digital map data bases that are needed. In addition, the current grid is 150 meters. This probably is satisfactory for general training, but it will not suffice should a commander use the simulation for operational planning/rehearsal. We foresee the marriage of graphics and models within the next five to ten years to the extent that a commander or staff member will be able to take an "electronic terrain walk" while using a model for training.

As a whole, while the panel did not get to talk to MG Bill Harmon, PEO Command and Control, one of the members of the panel did get a briefing by MG Harmon on his programs. We sense that the terrain data base requirements for ASAS and MCS should not be significantly different from the data base used for the electronic battlefield, and urge that this be considered as a necessary piece of both programs.

Training Metrics.

The Army has long recognized the difficulty in quantifying the benefits of training. What little quantification we saw during this study was not persuasive and signaled that more work is needed. We had pointed out that COFT captures data that is a measure of, or at least a surrogate for, gunnery proficiency. The generation and capture of such data should be part of CATT.

The Army has an enlightened attitude and has been quite chary in releasing any data from the NTC in order to preserve a true training environment and avoid any nuance that the Commander's report card (OER) will be predicated upon his success or failure against the OPFOR. In a sense, this is a commendable policy. Just as corporate data from the NTC has been collected in a "sanitized" manner at the Center for Army Lessons Learned (CALL) and has been distributed Army wide, there needs to be front end analysis done of the types of data that need to be captured by the CATT.

Strategic and Tactical Plans.

The Army has eased into electronic training in an evolutionary manner. Yet, models and simulations may be a revolution in training. This revolution may require a rethinking of the entire philosophy, method, and grand scheme of training.

This should start at the micro level. At the individual level, we now see electronic counterparts of training that have been around for many years. Would Table VIII, for instance, exist if the COFT had been available in World War II? Our hypothesis is no. The Army Research Institute has a limited program to examine some of the implications of electronic training, but it is not extensive or encompassing.

On the macro side the Army needs an overarching strategic plan to put all the pieces on the training tree. The TRADOC requirement for each proponent to develop CATS is a beginning. However, CATS has a very near term focus. A more discerning forward look is needed.

Operational Planning and Mission Rehearsal.

Operation planning and mission rehearsal are closely related to the training function. The opportunities foreseen for training enhancement also exist for operational planning and mission rehearsal. A commander could quickly analyze a number of Warfighting alternatives. His own people could be in simulators as the Blue Force. Other units could be in simulators as the Red Force, or the SAFOR could be used as the opposing force. The "playback" capability envisioned for CATT would allow the commander to restart the battle at any point in time. Once the commander has optimized his plan, a visual concept of operations could be developed for presentation to staff and subordinate commanders.

Visual displays exist today that can portray a building, for example, down to an individual window and door. Even finer granularity, if needed, will be available in the near future. This fidelity is dependent, of course, on possessing suitable geo-specific data bases. The simulation and simulators would allow rehearsal for missions as discrete as a SOF raid.

Joint and Combined Training.

Joint and combined training will become even more important in the coming years. DESERT STORM clearly demonstrated the leverage of effective joint/combined operations. An earlier Army Science Board Study, "Ad Hoc Sub Group on the Use of Army Combat Models for the Analysis and Training of Joint/Combined Operations", (January 1988) strongly urged the use of models and simulations for joint/combined operations. The recommendations of this study are still valid and deserve careful review and implementation.

The electronic battlefield will facilitate joint/combined training. The single manager can furnish the protocols, architecture, and procedures to other services and allies to allow easy entry and play on the Electronic Battlefield.

Models and Simulations for Light Forces/Special Forces.

How will the Army organize, equip, and operate its future light forces, to include Special Forces? How will it train the soldiers and their leaders?

About one-third of the active components of the near-future Army will be light force units. Possibly even a higher fraction of the Army will be light as the Army adjusts to the geo-political imperatives of the post-cold war world. So concerns for the effectiveness of light units is well placed, but not addressed much in SIMNET, DIS, CATT, BDS, etc., all of which are focused on equipping, training and operations of armored forces. In particular, the Special Forces appear to have important needs for simulations to support their training, operations planning, and mission rehearsals--needs largely unmet both by existing tools and those of currently envisaged developments to evolve SIMNET to a next-generation "electronic battlefield".

Several of the concepts and features common to the SIMNET/DIS/BDS/ "electronic battlefield" seem, at least on first look, to be applicable by extension to the needs of light forces:

- the critical need for and use of a geo-specific high-resolution terrain data base,
- a distributed processing, communication extensive architecture to support multiple players in a training environment,
- the use of a SAFOR, as a manpower reducing technique, to represent opposing forces "well-enough," and

- high-resolution graphics to enable participants to feel participation in the operations being simulated.

As noted above, the current SIMNET/CATT/BDS activities all are focused on elements of heavy, or armored, units. The scale of operations, i.e., speed of movements, range of weapons, size of battle areas, size of targets, etc., would differ, as would the data bases to generate adequate graphics of the operational areas, but, there is no fundamental reason why SIMNET-like simulation must be limited to heavy force operations. The Army should now initiate efforts, perhaps modest at first, to apply a SIMNET-like model to operations of Light/Special Force operations.

Budget Pressures.

The training Mission Area includes the three primary components. These are the CATT program, the several Combat Training Centers (CTC), and Nonsystem Training Devices (NSTD). The CATT program is roughly one-half funded. Even at this level the funding attention to CATT has devastated the CTC and NSTD programs. As examples, MILES units break at a rate of 10% per year in the field; **current Army funding allows replacement at a rate of 2% per year.** Needed live fire instrumentation at the Joint Readiness Training Center (JRTC) and NTC can not be procured at present funding level. The aging and obsolescent OPFOR vehicles are beginning to represent a "worn out" enemy rather than a real world threat.

Many of these programs represent "pay now–save later opportunities". Unfunded Army programs within the Training Mission Area offer the potential to reduce consumption of training ammunition and OPTEMPO mileage. Adequate funding would assure readiness at decreased future costs.

CONCLUSIONS

- We noted in the introduction a set of negative and positive factors that will shape the future direction of Army training. These imperatives leave little choice for the Army but to turn to simulation and other electronic-assisted training for a major portion of future training.

- Program Managers are responsible by charter for incorporating training devices and techniques into their programs. Part task trainers that have been developed as a part of weapon system development have a proven efficacy. Such initiatives should be continued and emphasized. Use of models and simulations as a primary means of training will require the PM to pay even more careful attention to his training responsibility. He/she undoubtedly will also be faced with a decreasing budget. It may be easy to cut training, This would be costly in the long haul, and must not occur..

- COFT is a superb trainer that is facing obsolescence. As a minimum, the visual display should be (and could affordably be) upgraded.

- SIMNET is an impressive engineering feat and the wave of the future for Army training. The long lines communication feature has little merit for training. A transition from SIMNET to CATT that attempts to maximize the value of the present SIMNET assets as opposed to a clean break, would to be prudent.

- CCTT is being procured in platoon sets for mechanized and armor units. Follow on modules of the more complete array necessary for a battalion task-force is considered a branch proponent responsibility. This should be changed. The Army should acquire now all of the parts of the CATT, matching the quanity produced to the resources available.

- FTX Training simulations beyond the battalion task force level probably are not practical within the next ten years. Brigade and division level Command Field Exercises will be feasible.

- Models have been effectively used for training staffs and commanders at all levels. Programming techniques such as object oriented programing and knowledge representation (AI) that are being used in new models, such as EAGLE, for example, have the potential to strengthen such training; enhanced graphics will support realistic command and staff training to the point that each commander and staff can make a "terrain walk" over the battlefield.

- Embedded training is not the answer to every training need. In many cases strap-ons or separate training aids may provide a more effective training approach.

- Logistics training has fallen behind combat training in the use of simulation and to a lesser extent in the use of training models.

- The Army education system has a mixed record in developing a mind set within the officer corps that models and simulations are a necessary and valuable problem-solving and decision-aiding set of tools.

- Visual displays are one key to simulations. Technology is coming to give high resolution displays at an acceptable cost. The quantity and quality of data bases to feed the processor/display technology must be aggressively managed or the data bases will become a limiting factor.

- Within the CATT and, indeed, throughout the Electronic Battlefield, the Army may have access to a rich reservoir of quantitative measures of training proficiency and data to refine other models.

- The tactical and strategic plans to use simulations as the spine of the training body are inadequate, to non-existent; they much need attention.

- Funding for CATT, even at the half funded level, has significantly impacted other Training Management Area programs.

RECOMMENDATIONS

The Army should:

- Remain the leader in the use of simulations for collective training and aggressively adopt the Electronic Battlefield as the central focus for its training.

- Adopt a Combined Arms focus from the outset of the CATT program and work to achieve an early Battalion CFX capability with a Battalion Task Force FTX capability as the ultimate goal.

- Electronic Battlefield should be achieved by "bill paying" from a number of activities including reduction of OPTEMPO, a decrease in field testing, and savings that will accrue as a result of compressing the development cycle.
- Build on SIMNET, a proven success, instead of starting with a "clean sheet" as envisaged in the present CATT program.

- Do the front end analysis to ensure that the training metrics are gathered and analyzed in the CATT training for use in the corporate data base.

- Communicate again to the field the logic of embedded training and insist on reasonable interpretation of this policy in future RFP's.

- State a vision of the future in which DIS tools will be available within units and organizations in the field to support the command and staff activities of operations planning and to enable the forces involved to gain pre-battle synthetic experience by rehearsing future operations.

- Furnish the protocols, procedures, and policies for entry into and use of the Electronic Battlefield to other services as quickly as possible.

ACKNOWLEDGEMENTS

The training panel consisted of:

Dr. Allen Grum, Chairman
Mr. David Hardison
General John Pauly (USAF, Ret)
LTG John Woodmansee (USA, Ret)

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PLACES VISITED OR BRIEFINGS SEPARATE FROM THE ENTIRE PANEL

- PM TRADE - ORLANDO, FL

- UNIVERSITY OF CENTRAL FLORIDA - ORLANDO, FL

- ECC Corporation - Orlando, FL

- Westinghouse - Daytona Beach, Fl

- Commander, US Army Reserves, The Pentagon
- 48th Mechanized Brigade, Macon, GA
- Army Training Support Center, Ft, Monroe, VA (briefed in Hampton)
- Deputy Chief of Staff for Training, TRADOC, Ft Monroe,VA

APPENDIX F

VERIFICATION, VALIDATION, ACCREDITATION OF MODELS AND SIMULATIONS

Expert, but subjective, judgment and opinions get embedded in models in subtle ways having profound implications.

Experience with model quality control has thus far been restricted primarily to the analysis organizations within the Army. Given the future uses of simulations and models as anticipated and recommended by the panels that examined acquisition, training, and test and evaluation, quality control certainly will become more critical; it also may become more difficult and more expensive.

One principal component of the panel's recommendations is the Electronic Battlefield. The core of the Electronic Battlefield is a collection of data, simulations, and models, together with the protocols and standards and network capacity, to allow users to fight on a virtual battlefield of their choice. Given the range of users and their reasons for using the Electronic Battlefield, it is critical that submodels and data be verified, validated, and accredited before they are admitted to the suite of accepted modules. Users will configure an environment, a threat, and a friendly force appropriate to the purpose of the simulation at hand. They will choose organizations, tactics, concepts of employment, and levels of performance for both threat and friendly forces. Their confidence in the validity of their simulated battle must be established and maintained. Similarly, for the confidence of those who use the results of the simulated battles to support decisions, ensuring consistency on the Electronic Battlefield, and establishing confidence in the validity of the results it produces, will require quality control. Given the range of users, and the nature of their requirements, quality control will be a major challenge.

INTENSIFIED PROBLEMS RELATED TO THE ELECTRONIC BATTLEFIELD

There are reasons to believe that the creation and extensive use of an "electronic battlefield", as proposed, will exacerbate some of the problems of quality control and at the same time suggestions that it will help solve others.

First, the more extensive use of simulations will imply increased dependence on this form of analysis. It will mean that information gained through the use of simulation will be used more widely, for more purposes, and by more people. Many military personnel will be apt to rely on their military judgment and intuition that the "experience" of the simulation feels about right, and that the results can be relied upon. Nonetheless, as more and more simulations interact, and are used for more purposes, there will be greater numbers of underlying mathematical models, software algorithms, and built-in hidden assumptions that we shall be depending upon as being reasonably correct. Therefore, the magnitude of the job, the complexity, and the need for quality assurance of models and simulations will increase.

Secondly, although this does not have to be the case, it seems likely that as simulation becomes more complex, more detailed, and more intertwined, fewer and fewer individuals will have a comprehensive insight into the underlying structure of a specific simulation. This will be true also of those who generate information they themselves are using. More and more people will be relying upon simulations they have never seen, have accessed only remotely, and have no idea as to who created them. A current example is the SAFOR used in SIMNET. Many persons feel comfortable with the SIMNET simulations, but do not have even the foggiest idea of how opposing and unmanned friendly forces are actually played. Both forces are important to simulation validity. In the future, analysts, designers, experimenters, and testers will be in this situation. Although information which is generated from good practice can be misunderstood or misused, it arguably is worse if it is generated from poor practice. In an era of distributed simulations being used as a central part of how the military does its business, a well-understood and well-managed program of quality assurance will become essential to maintaining confidence and trust in the use of simulation.

Thirdly, it is likely that as the military learn on simulations, train on simulations, and test on simulations, they will have less opportunity to calibrate their judgment in physical situations. (Having frequent wars under a variety of conditions would obviate concern about this issue.) Thus, we will be even less able to rely on field experiences as the key part of the quality assurance than we do now.

Even if military personnel remain reliably able to judge that the outcomes of large scale interacting simulation "don't feel right", we will be less and less able to identify why--unless we have a quality assurance program that judges individual simulations in the small as well as in the large.

Since this is the evolving situation, it is necessary that the efforts regarding quality assurance be intensified. This will increase cost, require considerable efforts continuously, and require that, over time, better methods for this activity be evolved. This process needs to be centrally managed, monitored, and enforced although it must be executed on a very decentralized basis. Only those simulations which meet the criteria of quality assurance program should be publicly available through the network or be used by entities interacting with others through the net unless explicitly agreed to the contrary by those involved. Also, results made publicly available should be labeled as to whether the simulation meets the criteria of the quality assurance program or not.

CONCLUSIONS

- Quality controls of models and simulations is a difficult problem that has existed from the first use of models.
- A wide spread use of simulations will intensify this problem.
- Techniques for verifying and validating large scale simulations are not well-understood and in some cases may not exist. For some simulations, the techniques may never exist.
- Adequate quality control will require significant resources. Time, qualified people, and dollars will be needed to assure quality control. Quality comes neither easily or cheaply.
- "Poor" simulations will result in loss of user confidence.

RECOMMENDATIONS

- Reorient the current model verification, validation, and accreditation (VVA) procedures to bring them more in line with the peculiar needs of Distributed Interactive Simulations with more emphasis on the suitability of the representation of reality, more emphasis on situational fidelity, and less acceptance of code checking as a sufficient condition for VVA.
- Require proponents to be responsible for the quality of models and simulation.
- Require the Single Manager to ensure that any interactive play on the Electronic Battlefield be limited to model and simulations that are accredited.

APPENDIX G

BRIEFINGS AND REFERENCES

I. FULL PANEL:

Hq DA Simulation Vision, 12 Feb 91, Mr. G. T. Singley, III, US Army, OASA(RDA)

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Army Model Improvement and Study Management Agency, 12 Feb 91, Colonel G. Brauch, US Army, DUSA(OR)

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Conduct of Fire Trainer	COFT
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DEPARTMENT OF THE ARMY
OFFICE OF THE UNDER SECRETARY
WASHINGTON, D.C. 20310-0102

16 March 1992

SAUS-OR

MEMORANDUM FOR THE EXECUTIVE SECRETARY, ARMY SCIENCE BOARD

SUBJECT: Sponsor's Memorandum of Acceptance: Report of Army Science Board 1991 Summer Study - "Army Simulation Strategy"

This report of the Army Science Board Summer Study entitled "Army Simulation Strategy" is the product of many hours of thoughtful and intense deliberation by the study group. The report clearly sets forth both a "Vision for the Future" and a strategy for achieving that vision.

The Army as an institution has embraced the vision for an Electronic Battlefield which the report portrays. We have initiated actions to establish centralized management of the acquisition, day-to-day operations and sustainment of the Electronic Battlefield. A process has been established for identifying the requirements for service from this "battlefield" and for prioritization of these. There are however, parts of the acquisition strategy recommended in this report with which we as an institution do not agree. This does not make the report any less valuable to us as we integrate this potentially powerful tool into the Army. The specifics of, and reasons for our departure from the recommended strategy for future acquisition of elements of the Electronic Battlefield will be addressed in subsequent reviews conducted for the senior Army leadership.

Walter W. Hollis

Walter W. Hollis
Deputy Under Secretary of the Army
for Operations Research

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