A DIS NETWORK FOR EVALUATING TRAINING SYSTEMS EFFECTIVENESS

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ABSTRACT

Distributed Interactive Simulation (DIS) has recently received widespread acceptance in the DoD community as the standard for networking simulations. Although DIS has its roots in interfacing virtual simulations (entity level, typically man-in-the-loop training), it is also being adapted for use with constructive simulations (wargame and analysis) and live simulations (real, fielded equipment). This paper describes a DIS network combining live constructive and virtual simulations. The live simulation components, provided by fielded command and control equipment, were able to interact with a constructive simulation called CIMUL8™ and a part task trainer (virtual simulation) for training in Multiple Launch Rocket System (MLRS) Fire Control Panel operations. Besides providing the first demonstration of its kind, this configuration was used for the purpose of evaluating a new training system (the MLRS Fire Control Panel Trainer (FCPT)) using real equipment inputs as well as inputs from a constructive simulation representation of the real equipment. The paper will describe the design of the evaluation, present some preliminary training evaluation results, and make recommendations for future use of the system for evaluation. The paper will also recommend additions to the DIS standards for better support of similar test systems.

About the Authors

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INTRODUCTION

In an era of rapid change and shrinking budgets, the use of simulations and simulators gives the military a capability to refine doctrine, test and validate tactics and modernize weapons systems to ensure things work *before* implementing changes. A variety of simulations and simulators are being developed by the Army in support of Field Artillery, fire support command and control, and weapon systems. Simulations and simulators are proving effective in decision making in system design; developing tactics, techniques, and procedures for system employment; identifying and resolving system-related MANPRINT issues; and providing more cost-effective training.

Many of the simulations and simulators developed to support either research or training were not designed to be interactive. The use of simulations or simulators in sterile, non-interactive environments increases the artificiality associated with the research and training and decreases the fidelity or external validity of both. Training individuals or individual crews to perform specific tasks does not guarantee they will have the ability to operate as members of a crew or task force. A Defense Science Board Report states:

> *"The Services train individual soldiers, sailors, airmen, and marines and provide highly trained combat units and do a very good job. [...But] some things we don't do well. First and foremost among these is the training and exercising of large, joint, or combined forces to fight on short notice."*[1]

What is required is a method to simulate the interconnectedness of battlefield operating systems -- command and control and weapons -- and the subsequent "fog of war" by introducing the same complexity and uncertainty into our use of simulations and simulators as will be apparent on the battlefield of the 21st century. The answer is in Advanced Distributed Simulation, as achieved through the Distributed Interactive Simulation standards:

> *"We believe that Advanced Distributed Simulation (ADS) technology is here today, and that this technology can provide the means to:*
>
> - o *improve training and readiness substantially*
> - o *create an environment for operational and technical innovation for revolutionary improvements*
> - o *transform the acquisition process from within"*[2]

The U.S. Army Field Artillery School is currently involved in the development and fielding of fire support command and control systems and weapon systems. These systems are significantly better than predecessor systems, but are also significantly more complex to operate. At the same time, budgets are being slashed. Thus, it is imperative that more be done with less by developing simulations and simulators to be used during the acquisition and fielding of command and control systems such as the future fire control system, the Advanced Field Artillery Tactical Data System (AFATDS) and the Interim Fire Support Automation System (IFSAS), and current and future weapon systems such as the MLRS, Paladin, and the Advanced Field Artillery System (AFAS). This approach was supported by the Army Chief of Staff, General Gordon R. Sullivan, who in his presentation at the May 1993 AUSA Louisiana Maneuvers Symposium stated:

[1]Defense Science Board Report, "Impact of Advanced Distributed Simulation on Readiness, Training, and Prototyping," January 1993.

[2]Ibid.

"Distributed Interactive Simulations hold great promise for compressing the acquisition cycle and removing much of the frustration from our acquisition system. Simulation lets us see and touch the acquisition cycle. I believe we can collectively help change our heel-toe cold war system to a more responsive - and more cost effective - process."

To this end, the Army Research Laboratory (ARL) sponsored a research project to instrument the Depth and Simultaneous Attack (D & SA) Battle Lab with Fire Support command and control equipment. All equipment utilized in this project used the Distributed Interactive Simulation (DIS) protocols on a Local Area Network (LAN) and will eventually be connected to the Defense Simulation Internet (DSI). The purpose of this capability is to simulate realistic battlefield communications conditions for research and training. Devices that have been integrated into this simulation capability include: The CIMUL8™ / SPECT8™ / DISIP8™ (hereafter referred to as CIMUL8™) simulation system, two (2) Forward Entry Devices (FEDs), a Lightweight Computer Unit (LCU) running the MLRS Battery Fire Direction System (FDS) software, and a new desktop version of the MLRS Fire Control Panel Trainer (FCPT).

A second focus of this research project was to examine the extent to which training can benefit from this environment while retaining requirements for achieving established levels for proficiency. The integration of these devices onto an instrumented LAN permits the conduct of realistic Fire Support exercises which are able to be conducted in conjunction with any DIS compatible simulation using real soldiers performing tasks in the laboratory as they would in the field. Thus, the Army can begin to address, in a cost effective manner, issues related to doctrine, tactics, materiel, organization, leadership and soldiers before committing to doctrinal changes, costly acquisition programs, or extensive reorganizations. In particular, it permits evaluation of training devices in a simulated battlefield environment while allowing the collection of human performance data in a virtual setting.

SYSTEM REQUIREMENTS

The system developed for this program was required to link fielded command and control (C2) equipment, unmodified, to an MLRS FCPT device and a constructive simulation system called CIMUL8™. This integrated system allows the constructive simulation system to create and maintain a scenario consisting of simulated elements generated by the constructive simulation, the MLRS FCPT and the network interfaces to the C2 equipment (FEDS and the FDS). Operators of the C2 equipment transmit C2 data across the network to other C2 equipment and eventually to the MLRS FCPT. A data logger collects command and control information from the network for later analysis.

This network interconnection provided the MLRS FCPT trainer with realistic inputs to initiate an MLRS mission. The live C2 equipment is also available for training within the DIS environment.

Technical Requirements

The greatest technical challenge of this program was to provide a DIS interface for the command and control equipment. The interface had to be flexible and reusable for a number of devices. It also had to provide the ADS environment (created by the networking of simulations and equipment) the DIS information that is required by other participants but not normally part of the information generated by the C2 equipment.

Figure 1 shows the configuration of the network.

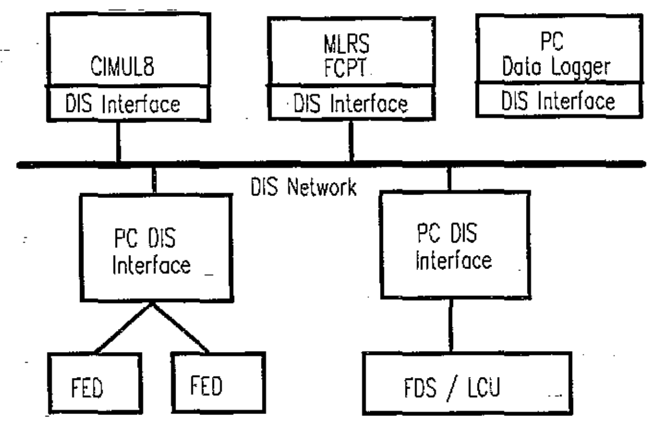

Figure 1
Network Configuration for ARL/Ft Sill

The PC interface had to provide a means to collect C2 signals from the C2 equipment, package it in a DIS Protocol Data Unit (PDU), and send it onto the local area network (LAN). It also had to do the reverse for incoming messages. DIS PDUs with command and control information were received by the interface from

The PC interface needed to have an FSK modem that could connect to the field wire interface. Since FSK modems are not commercial off-the-shelf (COTS) items a special modem had to be utilized. Such FSK modem boards had been available in the past for PCs running SCO UNIX. Since our system was running under DOS, we required the same functionality for a DOS environment. TELOS was developing a DOS version of the modem board and provided a Beta version of the TELOS Signal Master™ board as the FSK modem for the PCs. Two boards were used, each with two communication channels. One board served the two FEDs. The other board was dedicated to the FDS which required two communications channels; the 6-character net which provided communications to the FEDs and the 11-character net which provided communications to the launcher. This approach is shown in Figure 2.

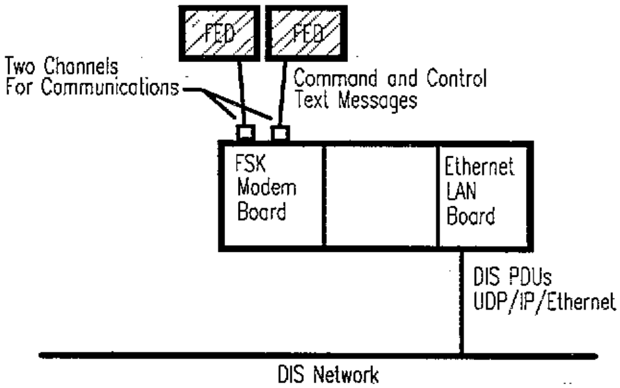

Figure 2
PC Interface to C2 Equipment

In this configuration, the FEDs would send a C2 message through the two wire interface to the FSK modem board of the PC interface. The modem board "strips off" the communication protocols and stores the ASCII text of the C2 message in memory. The developed interface software reads the ASCII text message and sends out the appropriate transmitter and signal PDUs to the DIS network via the Ethernet LAN board. The ASCII text message is included as data in the signal PDU.

Two DIS standards were implemented. The DIS PDU standard version 2.0.3 was used for the PDU formats. The draft standard for Communication Architecture for DIS was also used. The widespread use of both standards provided assurance of maximum compatibility with other systems. An Interface Control Document (ICD) was developed for the project to specify the DIS interface requirements for all the systems on the network. This ensured that the individual systems implemented the DIS standards in a consistent manner. These requirements are summarized below:

The PDU standard was implemented with the following guidelines and assumptions:

- o Only the DIS PDUs required to simulate the integrated system were implemented. These included: Entity State, Fire, Detonation, Transmitter, and Signal PDUs.
- o Command and Control messages were communicated using Transmitter and Signal PDUs. Receiver PDUs were not required for this implementation.
- o Entity State PDUs were issued on behalf of the entity containing or controlling the transmitting device (FED or FDS), for the MLRS launcher, and additional friendly and opposing forces represented by the constructive simulation. Articulated parts were not represented.
- o Fire and Detonation information associated with the munition fired by the MLRS FCPT was communicated using the Fire PDU and Detonation PDU. In addition, positional information and movement of the launcher represented by the FCPT were represented using Entity State PDUs.
- o Simulation of the actual radios along with associated jamming, noise, interference, etc. was not represented in this integrated system. It is assumed that the devices send and receive perfect signals. The interface will distinguish between radio frequencies, therefore incoming PDUs must show the correct frequency in order to be passed on to the C2 equipment.
- o FED and FDS related entities did not maneuver while the simulation was running. There is an offline capability to "Beam" the FED and FDS entities to various locations on the battlefield.

The Communication Architecture for DIS (CADIS) draft standard version 1.0 was chosen for use with this interface. Protocols used on the local area network were:

Application, Presentation & Session Layers:	DIS 2.0.3
Transport & Network Layer:	UDP/IP (CADIS 1.0)
Data Link Layer:	Ethernet
Physical Layer:	Ethernet

After the individual systems had implemented the DIS standard according to the system ICD, a week of integration testing was performed to ensure that CIMUL8[TM], the MLRS FCPT, and the C2 equipment were able to interoperate correctly.

A technical demonstration was carried out to show the interoperability of the system. A scenario was developed demonstrating close operations beginning with target identification by a Forward Observer (FO) and ending with the launch of six rockets by the MLRS FCPT. One FED was used to represent the FO and the other FED represented the Fire Support Team (FST). The MLRS Fire Battery Fire Direction Center was represented with the Lightweight Computer Unit (LCU) running the Battery FDS software. MLRS launcher actions were simulated by the MLRS FCPT. CIMUL8 provided a graphics view of the battle, using icons to shown the location of the various participants (FO, FIST, FDC and launcher) along with simulation of other friendly and opposing forces. In addition, weapons fire was graphically displayed by CIMUL8 based on the receipt of DIS PDUs from the network.

The sequence of events for this demonstration is shown in Figure 3.

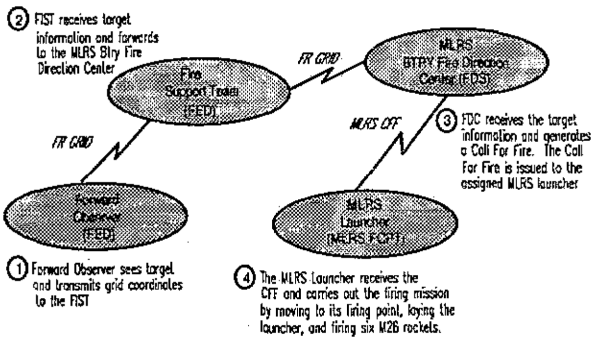

Figure 3
Scenario Events for System Demo

TRAINING EFFECTIVENESS EVALUATION DESIGN

Since this was the first known use of DIS for training system evaluation, there were no designs to follow. Standard TEE type data were gathered by adapting a network data logger to gather training data from the network instead of directly from the training device. This affords the advantage that the training device does not have to be especially equipped or programmed for data collection if it already has a DIS network interface. It also allows the collection of such data from the live equipment on the network, potentially allowing an investigation of training effectiveness of the actual equipment.

A total of 30 soldiers, half of whom were MLRS Fire Direction Center (FDC) operators and the other half MLRS crew members, served to support the TEE as student subjects. Each of the students trained on the FCPT in the configuration described in previous paragraphs. Data on the soldier performance was gathered through a combination of collected network data and evaluator observation.

SMEs from the Gunnery Department, most of whom were MLRS instructors, also supported the TEE. The SMEs reviewed the experimental scenario for tactical accuracy and realism. They also provided time criterion estimates used to evaluate soldiers' performance, evaluated the fidelity of the FCPT, and furnished input about the utility of the FCPT for training in the simulation environment.

Data collected for the TEE included the following:

<u>Time Data</u>: Response time data was automatically captured by a PC datalogging program as each student proceeded through three experimental simulation scenario runs on the FCPT. The data logger time-tagged the point in time at which the subject at the FCPT transmitted the Fire Mission "Will Comply" signal back to the Battery FDC indicating fire mission start time. The data logger also time-tagged the point at which the soldier fired the first rocket of the mission, indicating fire mission end time. There were two fire missions per simulation run. Response time data were defined as the amount of time soldiers required to successfully perform all steps of a fire mission. The criterion times were subjectively established by the SMEs, based on their experience.

Error Data: Error data was obtained through observation. As each soldier proceeded through the experimental simulation scenarios on the FCPT, a trained research assistant noted any keystroke errors committed by the soldier, and recorded these on a standard data collection form. It would be advantageous for future experiments to have the error data collected by the data logger as well.

Student Questionnaire. Questionnaires were administered to soldiers at the end of each training session. The questionnaire assessed soldiers' attitude about training simulators and their views on the FCPT in the DIS environment.

SME Questionnaire. SMEs typically reported in groups of two or three to evaluate the FCPT in the simulation environment. They were briefed on the simulation system and the purpose of their participation in the study. Following this introduction, each SME was given the opportunity to proceed through the same simulation scenario on the FCPT that soldiers experienced as well as performing any other actions that they wanted to perform on the FCPT. After completing their exercises, SMEs were asked to provide estimates of the expected performance time for soldiers performing the experimental simulation scenarios so that soldiers' performance time data could be evaluated relative to a performance standard.

Evaluation of the Physical Characteristics of the FCPT. A human factors evaluation of the physical characteristics of the FCPT was also conducted. The critical internal components of the FCPT including the disk drive and internal computer components, the fidelity of the FCPT screen, and the soldier-machine interface were examined by a Human Factors Specialist.

THE EXPERIMENT

Although the FEDs were a part of the network, in order to reduce the number of operators required to carry out the experiment, CIMUL8™ was used to generate the FR GRID (Fire Request using Grid Coordinates) messages that would normally be sent by the FEDs. The experimental simulation scenario proceeded as follows:

- CIMUL8™ initiated a force-on-force battle simulation. A few minutes into the battle, CIMUL8™ generated command and control FR GRID messages that were transmitted onto the network and received as CALL FOR FIRE (CFF) messages at the Battery Fire Direction Center (FDC). The first CFF was then relayed to the FCPT as a Fire Mission.

- The receipt of the fire mission by the FCPT was indicated by an alarm signal, which meant the MLRS FCPT had received a C2 message. The soldier was required to respond by pressing the appropriate keys that would cause a "WILL COMPLY" message to be issued to the FDS. At this point in the scenario, the Self-Propelled Launcher Loader (SPLL) was positioned at a Hide Point. The soldier was required to perform all the necessary keystrokes to move the SPLL to the Fire Point requested by the FDC and then fire the mission.

- After firing the mission and performing the proper keystrokes to stow the weapon, the solder performed the keystrokes necessary to move the SPLL to a second Hide Point as requested by the FDC, at which point the soldier received a second Fire Mission. The soldier then performed all the keystrokes necessary to move the SPLL to a second Fire Point as requested, and fire a second mission. After stowing the weapon, the mission was ended and the first run concluded.

- Each soldier repeated the experimental simulation scenario three times.

EXPERIMENTAL CONCLUSIONS

Results

A variety of analyses were performed on the data collected including: a) analyses of variance on the performance time data collected by the data logger, and error data collected through observation, b) descriptive statistics for the time, error, and questionnaire data, and c) content analyses for the open-ended questionnaire items.

The analyses of the time data showed that there was a clear learning trend (Figure 4). Soldiers required substantially less time to perform the fire missions with increased practice over the three scenario runs. It is also noteworthy that a much greater percentage of soldiers were able to meet the performance time criterion in Run 3 (87%) compared to Run 2 (70%) and Run 1 (30%).

By the final scenario run, soldiers performed their missions almost flawlessly (Figure 5). A much greater percentage of soldiers committed no errors by Run 3 (64%) as compared with Run 2 (32%) and Run 1 (4.5%). This is particularly meaningful since the error rate decreases concurrently with decreases in response time. Thus, no time-error tradeoff was demonstrated.

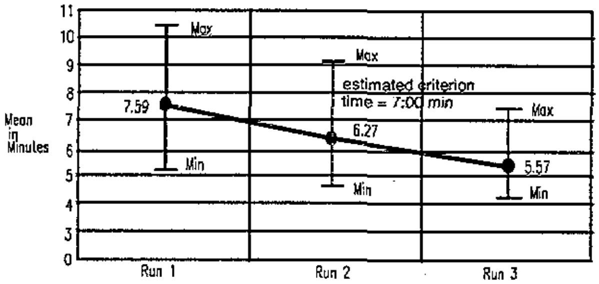

Figure 4
Response times for students

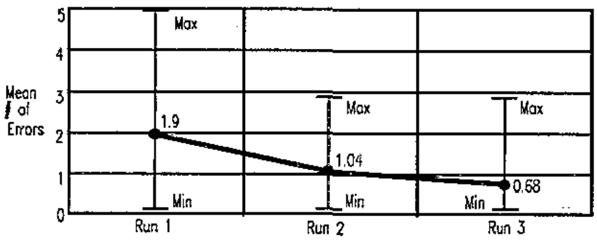

Figure 5
Errors Committed Students

In response to the questionnaires, soldiers viewed their training on the FCPT in a simulation network environment very positively and would recommend this type of training for fellow soldiers. This was not surprising based on the expressed views of solders during their training sessions. On average, they seemed both curious and excited about the prospects of future training in such an environment.

The SMEs also viewed the FCPT in the simulation network environment very favorably. Their responses indicated a positive attitude about the utility of the FCPT as a training device that, in a simulation environment, could effectively supplement and maintain soldier training. The SMEs also indicated that this environment provided added realism with FDS and launcher interactions represented. They felt that because tasks such as communications with the FDC and fire missions were more lifelike, soldiers would develop a greater level of confidence in their abilities to perform these tasks in the field.

The SMEs also pointed out that training on the FCPT in this environment could supplement field training and classroom knowledge and could be used without extensive planning (e.g. training on an "as needed" basis). They also saw the system providing a potentially significant training benefit to the National Guard units who, because of future time and training cost constraints, may not otherwise have sufficient hands-on training opportunities.

As part of the TEE, a human factors evaluation was conducted on the physical characteristics of the FCPT. The device presented a realistic view of the actual FCP except for simulation of vehicle moves. The FCPT currently simulates vehicle moves by trainees pressing a "MOVE" button on the panel. This method, although better than an "automatic move", in which vehicle moves are not simulated at all, does not provide users with a visual image of the move action as it occurs. It is therefore recommended that the FCPT be upgraded to include a graphic display of vehicle move actions that would create a higher degree of realism.

Based on the information gathered during the TEE, the feasibility and effectiveness of training in the DIS environment appears promising. Data collected on soldier performance clearly demonstrate that significant early learning occurs for students training on the MLRS FCPT in the network environment.

The general outlook that soldiers and SMEs had toward the training system was also encouraging. Soldiers viewed training on the FCPT in this DIS environment very positively and felt confident that it could help them and others do their job more effectively. SMEs believe that the integrated FCPT provides superior realism and could serve as an effective training tool for supplementing early learning as well as refresher training.

Future Work

Aside from the abundance of positive information that was gathered over the course of the TEE, some potential research initiatives clearly remain. Most notable during the TEE was the lack of an automated data collection capability. The data collection process was substantially limited by the current data collection capabilities of the DIS implementation. The data that were captured represent a small fraction of data available for capture. The potential certainly exists (e.g., Kaye & Copenhaver (1992)) for automated collection, reduction and analysis of a variety of performance data including total time, mission segment time, keystrokes, errors (including when they occur), and accuracy. The proposed system should also have the flexibility to allow the insertion of system-specific performance measures (i.e., specific to the device on the DIS network) that could supply feedback to the student and allow instructors to track student performance. This data collection system would provide a means to obtain and analyze performance data from the operation of any military device that is integrated into the DIS network.

The Simulation Management (SIMAN) PDU development in the DIS community has taken a significant step toward addressing the data capture requirements for experimental use of a DIS network. The next step is to build this capability into the trainer itself in order to send key datum for collection via the DIS network.

Further exploration is also required in the area of integrating other real world command and control devices into the DIS network. By design, the interface used to support the current C2 devices can be implemented to support other C2 devices, and could serve as a means to test the interaction of new and developing command, control and communications (C3) technologies. The interface could also be utilized to allow new and developing systems (e.g. Advanced Field Artillery Tactical Data System (AFATDS), the Improved Data Modem (IDM), and the Aviation Mission Planning System (AMPS)) to test their capabilities with existing systems in the DIS environment.

DIS Accomplishments and Recommendations

The DIS network interface developed for the FEDs and the FDS represents the first time that real, unmodified battlefield command and control equipment has been interfaced to the synthetic environment using DIS. This has allowed real equipment to operate with simulations in a laboratory environment. With the eventual installation of a Wide Area Network (WAN) the lab assets will have the capability to participate in DIS exercises with participants located at remote locations.

This effort served as a proof of principle that: a) a training device can be successfully integrated into a DIS environment together with actual military command and control devices and b) performance data can be captured and analyzed from a training device operating in that environment.

In conclusion, a significant step has been taken toward bringing real world command and control systems into the synthetic environment for training, testing, evaluation, and data collection purposes. This TEE has provided a unique opportunity to investigate another advantage of DIS applications. The present findings provide the basis for further exploring the DIS environment as a training and research instrument.

We believe that DIS technology holds great promise for the future of training and system evaluation.

ACKNOWLEDGMENTS

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