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Innovative Analytic Techniques for Distributed Interactive Simulation (DIS)

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PREFACE

This Central Research Project is based on a prior IDA study for the Balanced Technology Initiative Office. That study provided not just the methodology discussed in Chapter III, but more importantly served as the foundation for the analytic techniques described in this document. The members of that study team included: Dr. Richard E. Schwartz, project leader, Dr. Peter S. Brooks, Dr. Frederic A. Miercort, Dr. David Spalding, and Ms. Marchelle M. Stahl.

The authors thank the reviewers for their assistance--Dr. Peter S. Brooks and Dr. William J. Hurley--and also Dr. Jesse Orlansky for his comments. Ms. Paula B. Greer provided editorial assistance.

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I. INTRODUCTION

This paper describes a general analytic methodology for processing and manipulating distributed interactive simulation (DIS) data derived from one or more exercises. This is introduced by a case study describing how simulation network (SIMNET) data were used in support of a specific analysis. The case study both illustrates the general methodology and serves as an example of how SIMNET (as well as DIS) data, operational data, and modeling results can be combined to produce meaningful analytic results.

A note on nomenclature: DIS has multiple definitions. The narrowest use of DIS refers to exercises that use the DIS 1.0 or 2.x protocols. These protocols define the format and structure of communications among various simulations or manned simulators. DIS is also used in a broader sense to describe any simulation that is distributed and interactive, e.g., Janus.

In this paper, DIS will be used in the narrowest sense. The predecessor to DIS was the SIMNET protocol [also the name of the Defense Advanced Research Projects Agency (DARPA) program that sponsored its development]. SIMNET is used when referring to specific exercises conducted using the SIMNET protocol.

The paper begins with an abbreviated description of DIS, highlighting only those aspects relevant to this paper. The second section describes the use of SIMNET data to evaluate the potential operational value of two proposed weapon systems.

The third section describes an analytic methodology that focuses on exploiting DIS data from previously recorded exercises to produce results for issues other than those for which the exercise was originally planned. This approach assumes that, for some systems and for some issues (examples are discussed later in the section), instead of planning and executing a computer simulation analysis or a live DIS experiment, one can develop interesting insights and results from archived SIMNET or DIS exercises originally conducted for other purposes, e.g., training. Many SIMNET and DIS exercises have been archived and are available for this use, representing a huge database of manned battles. In addition, if a full-scale live experiment is conducted, the techniques described in this paper can be used to extend the results.

Three techniques for processing and analyzing DIS data are discussed. The first technique, basic processing of DIS data, is used to develop measures of tactical or statistical interest from one or more DIS exercises. The second technique involves imposing a model on a DIS exercise, thereby introducing a new system into the battle after it has occurred. In the third technique, a DIS exercise is replayed to a crew in a manned simulator that can then participate in the previously recorded battle. These techniques and their associated limitations and advantages are discussed in detail. Illustrative applications of each are presented. As large-scale manned distributed simulation technology matures, the applications and importance of these techniques will grow.

II. BACKGROUND

SIMNET was initiated by DARPA in 1983 to develop and demonstrate--through a synthesis of computer, computer networking, and display technologies--manned simulators for tactical simulation and training. Unlike highly realistic, complex, and expensive manned simulators that are used to train individuals or crews in the operation of a vehicle, SIMNET was designed to train crews (that already know how to operate a vehicle) to fight a battle. Each simulator is relatively inexpensive. SIMNET emphasizes the interactions among the many vehicles present on a battlefield, so that many manned simulators are needed to conduct a simulated battle. The information (primarily visual images) that would be available to a crew on a battlefield and the controls (primarily movement and weapons controls) available to a crew to fight a battle are simulated.

The SIMNET program ended in 1990, and responsibility for the program and the simulators developed by DARPA to date was passed to the Army. DARPA and the Services, primarily the Army, have continued to invest in the technology and an updated protocol, DIS, has been introduced and continues to evolve. DIS simulators are conceptually similar to their SIMNET counterparts but differ in some important aspects. In addition to using the newer protocol, they tend to be of higher fidelity and often have more sophisticated image generators that create better visual effects. SIMNET simulators are still in use, principally in the training community.

A. OPERATIONAL CONFIGURATION & CAPABILITIES

In DIS, computer-generated entities (vehicles or weapons) under human control interact in real time. Battlefield entities are typically created and controlled by manned simulators, although other programs can accomplish that also. The various programs and simulators controlling entities communicate with each other by sending data in a specific format over a common network.

As an example of a DIS battle, suppose a trial is to be made with a defensive force of 5 tanks and an attacking force of 15 tanks. The five tank simulators may be located at

Fort Knox and the offensive force in Germany. However, the terrain over which the battle occurs might be an Army training range in California.

Each simulator in this example represents a tank. Current tank simulators represent the inside of the M1, but they may be given different characteristics by modifying their software. For example, they might have different mobility or fire control characteristics, weapon effectiveness, etc. The unit commander on each side is able to communicate with his subordinates by radio. The fidelity of the simulator (i.e., how realistic the workstations are and the degree to which combat effects such as movement, vibration, and sound are simulated) is a function of investment. Some may be much more realistic than others in the same network.

As vehicles move, each broadcasts its current position and status to the others in the network. Line of sight (LOS) for the selected terrain and range determine when each vehicle appears on the display screen of other simulators. The picture displayed is controlled by the software, so different representations may be used for friendly and enemy units. When the crew detects and identifies an enemy unit, and decides to fire, each crew member goes through the firing sequence for his station. The simulators have a full crew--a commander, driver, gunner, and loader--although some of these could be simulated rather than actual. At the appropriate command, a round is fired. This information is passed to all other vehicles so that the software may decide whether to display the firing signature. The computer of the firing unit then calculates the probability of hit depending on the range and exposure of the target, the type of round and target, and the accuracy of the fire control solution and weapon. If the target is hit, this information is passed to the computer of the target. A representation of the hit is shown on the graphics of all vehicles that can see it. The unit that is hit calculates the extent of the damage.

In the same trial one of the simulators could be a command post (CP). The CP would receive information from its units in the field as they detect the enemy or as their status changes. For example, they may need fuel, ammo, or maintenance. They can report this and the CP unit schedules the action, or the unit may request fire support, with new simulators entering the game to provide artillery fire or close air support.

B. MANNED SIMULATORS

Manned simulators are physical mock-ups of the interior of the vehicle they are intended to represent. The simulators include physical representations of crew quarters, including controls needed for vehicle movement and weapons systems. A sound system provides battlefield and vehicle machinery noise, and a visual display system shows a battlefield image to the crew. Vehicle or turret movement is simulated by changes in the visual presentation to the crew.

Each simulator includes computer equipment that stores and processes a digitized terrain database. The display system shows this terrain and superimposes on it images of moving tanks, missiles, explosions, etc., as needed to simulate the dynamic battle. Each simulator generates its own imagery and very short messages [called protocol data units (PDUs)] to communicate its position and status to the other simulators. Processing digital simulated imagery in real time requires substantial computational power, and the display systems are the most sophisticated parts of the simulators. The tank simulators have displays for the different vision blocks of the tank but not for open hatch views. A tank's visual range is limited to about 3.5 kilometers (km), and the terrain polygons are generated typically from elevation data for points separated by 125 meters. These limitations are not inherent but represent practical cost and technology constraints.

Digitized terrain is typically derived from Defense Mapping Agency data. Most terrain databases are rectangular, covering about 50 to 100 km on a side. Each vehicle controls its own (simulated) movement over the terrain. Factors such as fuel and terrain slope are considered. Based on the messages it receives during the battle, each simulator presents appropriate visual displays and determines the damage it sustains if hit.

C. COMPUTER-GENERATED FORCES

In addition to manned simulators, battlefield entities may be controlled by computer-generated forces (CGF). CGF programs allow an operator to control various echelons (e.g., companies or battalions) of simulated vehicles. These vehicles are represented entirely by software and not by manned simulators. The CGF operator/commander provides higher level commands, e.g., routes to follow, and the software controls the detailed operation of the vehicles (including motion and weapons fire). CGF interact with other DIS elements in the same way as manned simulators. CGF cannot be distinguished from manned simulator vehicles by their appearance, and the goal is to make them indistinguishable on the basis of behavior; this goal has not been fully achieved.

D. DATA COLLECTION

PDUs broadcast over the network by manned simulators, CGF, or other programs are captured and recorded by a program called a logger. This program tags each PDU with a time stamp and writes the data to either a tape or a disk. These data files constitute a complete record of the observable interactions that occur during a DIS exercise. Data on internal activities such as weapons aiming are not collected. The exercise can be reenacted by "playing back" these data records over a network. Such playbacks are indistinguishable from real-time observations of the actual exercise by nonparticipants.

In order to analyze DIS data, they must be extracted from the data files created by the logger. Identifying particular PDU types is straightforward, so that some information (e.g., weapons fired, tanks killed) is easily obtained. Other information, such as intervisibility, is not directly recorded and must be determined.

In addition to logger files, generally one or more of the following types of data are collected during an exercise. These data are less amenable to computer-based analysis than logger files but they may contain important information. They are mentioned here for completeness but are not discussed further in this paper.

- Voice recordings of radio traffic--Typically groups of simulators are linked by a CB radio, and radio traffic over one or more channels is often recorded during an exercise.
- Video recordings of operators--In some exercises, cameras in the simulators record operator actions to provide data for human factors evaluation.
- Data collected by observers--Observers may be stationed in simulators, sometimes doubling as crew members, to record actions of the operators.
- Interviews with participants--Interviews may be conducted before and after an exercise. These provide information about the backgrounds and capabilities of the participants, their opinions on the realism of the simulation, and simulator ergonomics.

E. STRENGTHS AND WEAKNESSES OF MANNED DIS

The strength of manned DIS exercises is the incorporation of human interactions and decision-making in simulated combat. In DIS as in real life, soldiers have imperfect information on which to base their decisions: vehicle positions are estimated, identification friend or foe (IFF) is inaccurate, etc. Decision-making takes place at two levels. The lower level involves the interaction among the crew and between the crew and a simulator. Software defines the capabilities of the vehicle simulated and the way in which it will respond to operator commands. The operator decides how to use the vehicle/simulator: how to maneuver, where to stop, when to fire, what to fire at. At a more aggregate level, commanders at the same or different levels communicate with each other over radio networks. Tactical responsibility is assigned at various levels: vehicle commander, platoon, and company commander, etc.

DIS can be used to address broad issues, such as the effect that an innovative weapon, munitions, or set of tactics might have on the battle. Examples of this are the Counter Target Acquisition System test, which evaluated the opportunity for an enemy laser system to attack pilots' vision, and the M1A2 Block II tests that measured the effect of various components (a commander's thermal viewer, an accurate positioning system, and an inter-vehicle position communication system) on the performance of the M1A2. Command and control issues can also be evaluated.

DIS exercises produce data about weapon or munition performance, such as the probability of killing a particular target type or the number of rounds required to destroy a particular target. However, certain performance parameters, e.g., the probability of kill given a hit for a particular round, are inputs to a DIS exercise and therefore cannot be outputs. The point to note is that using DIS does not allow for estimation of performance parameters of individual systems that are independent of their operators; rather, DIS can be used to measure the effect of those parameters under the conditions of the exercise including human control.

In addition, DIS exercises provide data for various human factors issues. Some issues are in the category of operator workload and performance: how long it takes an operator to complete a certain task or how accurately the task is performed. Other issues relate to simulator ergonomics and the effectiveness of the man-machine interface.

DIS suffers from the following limitations, which make it difficult to use for analytic experiments:

- Low Fidelity Graphics--The cost of a computer image generator is an important factor in overall simulator cost. Typically, lower cost generators are used and the resulting images are somewhat lacking in realism. This makes results on operator detection and identification of targets highly suspect. (This may be offset by combining results from DIS exercises with results from field tests as described in the next section. Alternatively, if one can establish that detection and identification in DIS is easier than in real life, then it may be useful to view DIS results as an upper bound on potential operational results.)
- Low Fidelity Models--Simulators are designed for a variety of purposes and the underlying system models may not support the fidelity needed for a given analytic experiment.
- Terrain--Most terrain databases represent terrain by flat adjacent 125-meter x 125-meter polygons, which meet in sharp edges. More detailed terrain is desired for specific applications, such as evaluating various terrain traversal algorithms for unmanned ground vehicles (UGVs). Dynamic terrain, which changes as the battle unfolds, e.g., becoming pocked from munitions' impacts on the ground, is just starting to be used but is not widespread.
- Inadequate Data Collection for Analysis--The DIS and SIMNET protocols' main focus is to support the correct visual displays on a simulator. Detailed information about internal system behaviour is not part of the protocol and is generally not available. For many experiments, simulators are modified to produce additional data beyond that required by protocol.

III. CASE STUDY: EVALUATION OF FIBER OPTIC GUIDED (FOG) WEAPON CONCEPTS

A. BACKGROUND

In 1991, IDA undertook a study for the Balanced Technology Initiative Office to assess the potential operational value of two FOG weapon concepts: mortar rounds in two calibers--81 mm [denoted FOG-MP(81)] and 120 mm [denoted FOG-MP(120)]--and a helicopter-launched missile (denoted FOG-HM).

FOG munitions have three components: a projectile with an imaging sensor, a control station, and a fiber optic cable. As the FOG projectile flies out, the fiber optic cable is payed out behind it. During fly-out, images of the battlefield are transmitted from the projectile's sensor to the control station where they are displayed to an operator. The operator searches the scene for targets, performs IFF, selects a target, and locks the projectile onto the target. The operator enters appropriate commands for these actions into the control console, which then transmits control signals through the fiber optic cable to the FOG projectile.

The dependence on the human operator to detect and select targets is both the principal advantage and the principal disadvantage of FOG systems. Benefits may include: last-minute IFF to minimize friendly losses, visual target detection and aimpoint selection to destroy specific targets with minimal collateral damage, and the opportunity to gain incidental intelligence during projectile fly-out. The disadvantage is that the gunner's involvement limits the rate of target engagement.

Because the gunner plays a major role in the performance of fiber optic systems, the analytic approach was oriented toward the use of data from tests of two Army ground-launched FOG systems; the FOG missile (FOG-M) and its successor, the Non-Line-of-Sight (NLOS) missile:

- An initial operational evaluation (IOE) of the FOG-M was conducted at Redstone Arsenal, Alabama, and White Sands Missile Range, New Mexico, between September 1988 and September 1989. The IOE included captive carry flight tests of the seeker designed to evaluate the gunner's ability to detect a target presented in the sensor's field of view (FOV). The sensor was mounted on the underside of an airplane and flown in a way that would bring targets (both tanks and hovering helicopters) into the sensor FOV. The sensor imagery was displayed to the gunner who attempted to detect the target and lock on to it. The IOE also included live missile firings to evaluate the missile's ability to hit a target after lock-on. The IOE has been described and analyzed by Richardson et al (1989).

- The NLOS/SIMNET evaluation, using manned NLOS simulators, was conducted in April 1991 at the Fort Rucker, Alabama, SIMNET site by the Army Operational Test and Evaluation Command (OPTEC). One purpose of the evaluation was to determine the effect of different conditions on target availability for the NLOS missile. The primary question was, given different time delays between target acquisition by a sensor or forward observer and the cueing of the NLOS gunner to that target, would the target still be available for detection by the time the missile arrived at the cued target location? OPTEC published the results in 1992.
- Because the major portion of the analysis, described later in this section, was based on the NLOS/SIMNET data, some background on the NLOS/SIMNET evaluation is necessary.

B. THE NLOS/SIMNET EVALUATION

One purpose of the NLOS/SIMNET evaluation was to determine the effect of various conditions, primarily cue delay, on target availability for the NLOS missile. The cue delay is the time interval between the acquisition of the target by a sensor or forward observer and receipt of a target cue by the NLOS gunner. The issue is whether a given cue delay allows sufficient time for the NLOS missile to get to the target area and find the target. A target is available for detection if one or more target vehicles is within the sensor FOV, within the maximum sensor detection range, and within LOS of the projectile, irrespective of whether or not the gunner actually detects and engages the target.

Two identical NLOS simulators were developed for the evaluation. Figure 1 depicts an NLOS simulator. The simulator represents the cab of a High Mobility Multipurpose Wheeled Vehicle (HMMWV); the NLOS missile is intended to be launched from the rear of the vehicle. In front of the cab is a large curved screen that displays the SIMNET battlefield as it would appear looking through the HMMWV's windshield.

Eight hundred forty (840) single shot trials were run to provide data for analysis. Each trial began with the HMMWV emplaced on the battlefield; the NLOS missile cannot be fired while the vehicle is in motion. The gunner was seated in the simulator, awaiting a target cue. The cue, coming over a radio or through the NLOS computer located in front of the gunner, would describe the type of target, armor or rotary wing, and the location of the initial target sighting. (Although 4 to 190 seconds had passed since that sighting, the gunner was not told the age of the information). The gunner would enter information into his NLOS computer and fire the missile. After a 20-second delay, the missile would be launched.

During missile fly-out, the gunner watched the small screen in front of him. This displayed the view of the SIMNET battlefield as seen from the simulated TV sensor located in the nose of the missile. The missile is programmed with a default flight path to the cued target location and with a default sensor sweep pattern, so all that was required of the gunner was to watch the screen, detect a target, and lock on to the target. However, the gunner could take manual control of the missile or sensor using the joystick located on the armrest, and in most trials, he did. (One purpose of the analysis, described below, was to determine the effect of manual seeker/missile control on target availability.) Each trial ended when the missile hit either the ground or a target.

OPTEC provided the NLOS/SIMNET test plan and copies of the 21 DataLogger tapes used to record the 840 trials and patiently answered many questions about the test. Data on 705 of the trials were usable but data on the remaining 135 trials were flawed, primarily due to errors in the simulators.

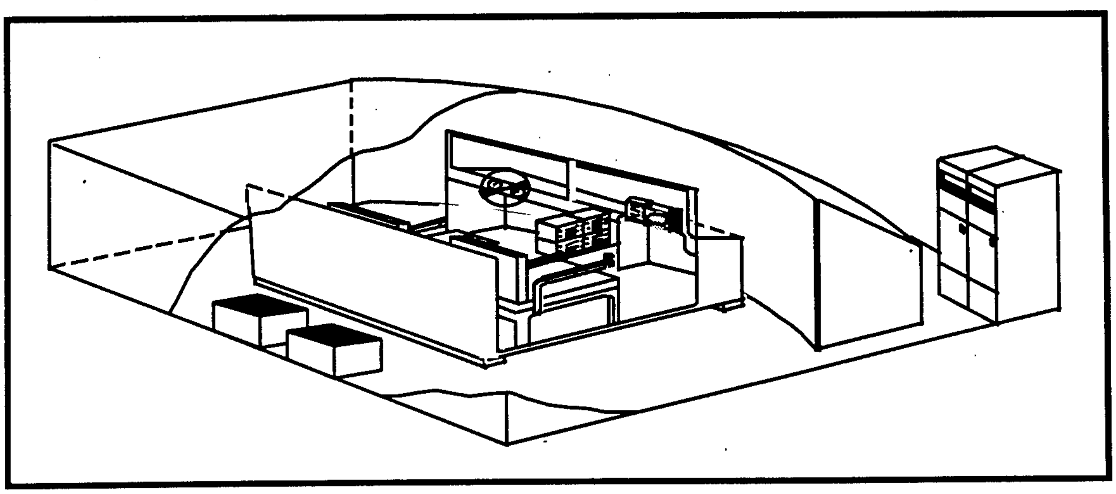

Figure 1. NLOS Simulator

C. OVERVIEW OF THE ANALYTIC APPROACH

The engagement performance of the FOG mortar round and the FOG-HM were defined to be the probability of successful single shot engagement [P(SSE)]. This is the product of the following terms:

- The probability that a target is available for detection
- The probability that the target is detected and locked onto given that it is available
- The probability that the target is hit given that it is locked onto
- The probability that the target is killed given that it is hit.

At the outset of the study, suitable estimates were available or derivable for the last three terms but not for the probability of target availability. Therefore, developing a P(SSE) for each FOG concept required developing an estimate of target availability. These estimates were based on data from the NLOS/SIMNET evaluation.

Figure 2 is an overview of the analysis. There are four parts to the analysis:

- Determining target availability for the NLOS missile in the SIMNET evaluation and the effect of different conditions on target availability
- Determining the effect of operator control on NLOS target availability
- Developing an estimate of target availability for the FOG concepts, based on NLOS/SIMNET data
- Combining the estimate of target availability with estimates of the three other terms to create a P(SSE) for each of the FOG concepts.

In describing the analysis, emphasis is placed on the methodology; some illustrative results are presented.

1. NLOS Target Availability

Referring to box 1 in Figure 2, the first step in the analysis was to process the NLOS/SIMNET data and determine target availability. General purpose processing software was developed to read the DataLogger tapes, determine the positions of all vehicles and missiles for each second of each trial, compute target availability for each trial, and produce other processed data for each trial.

Target availability is computed at each second in a trial in the following way. First, from the SIMNET data on a DataLogger tape, the program determines the location of all the vehicles in the trial and the location of the NLOS missile relative to the digitized terrain. (A digitized version of Fort Hunter-Liggett, California, was used in the NLOS/SIMNET evaluation and therefore in the availability calculations.) It calculates the missile's sensor FOV, projects it onto the terrain, and determines whether any vehicles are within the sensor FOV. If so, it then calculates whether intervisibility exists between the sensor and each vehicle in the FOV. It also computes whether the range to each vehicle in the FOV is less than the sensor's (specified) maximum detection range.

The availability program produces a variety of information about each trial. From these data, the 705 trial outcomes were compiled in various ways to indicate the factors that were important in determining target availability.

On average, targets were available for detection in 46 percent of the trials.

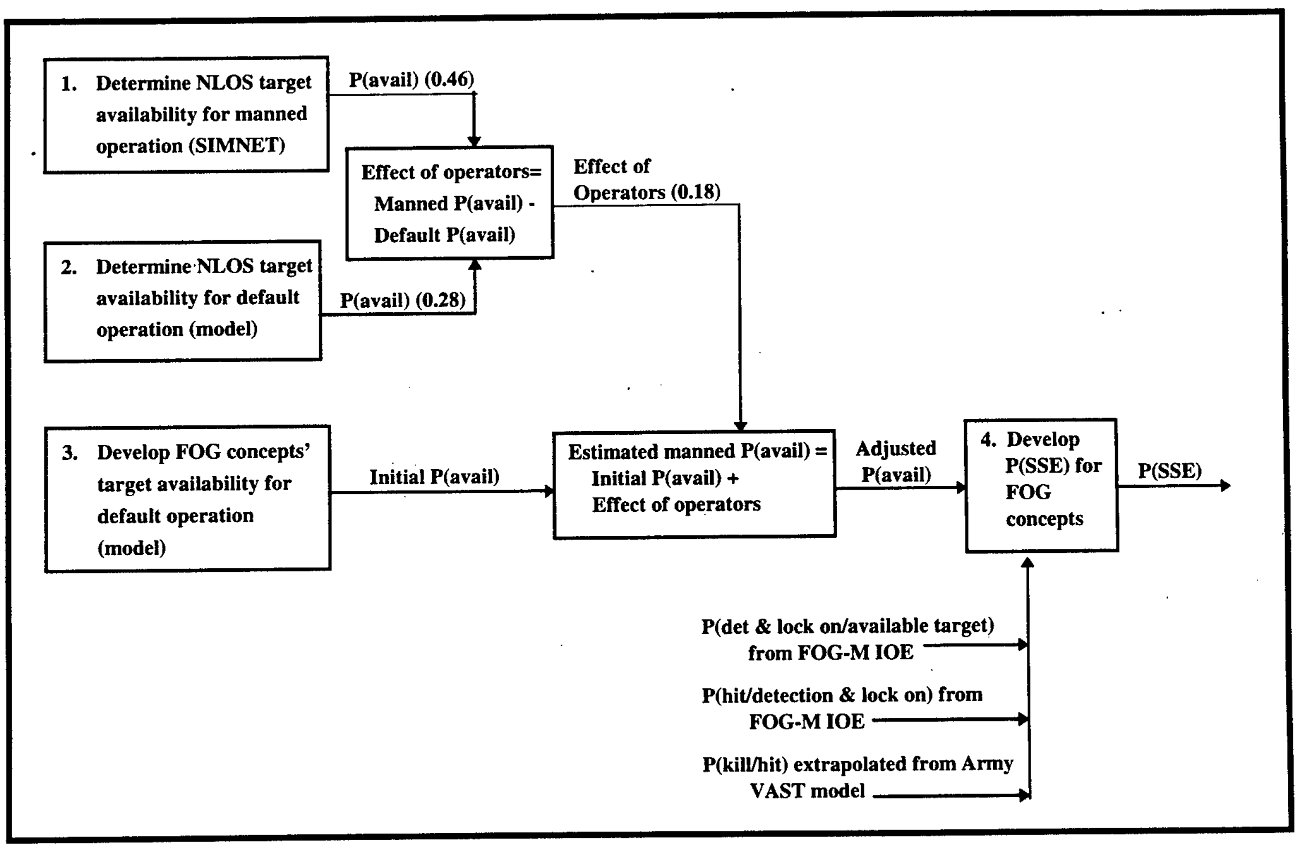

Figure 2. Analysis Overview

Table 1 shows the influence of cue delay, cue type, and target type on target availability. Target availability is high with a cue delay of less than 40 seconds, and low with cue delays of 40 seconds or more. Table 2 describes the method of target acquisition that was represented by each cue delay. The NLOS missile has high target availability when cues are either provided in the auto mode or by a forward observer calling targets directly to the NLOS unit. In addition to using those target acquisition methods listed in Table 2 with short cue delays, other ways to improve target availability would be to significantly decrease the delay between giving the command (electro-mechanically) for the missile to fire and the actual launch of the missile, or to provide the NLOS with a dedicated target acquisition capability, such as an unmanned air vehicle (UAV).

Table 1. (U) Fraction of Trials in Which NLOS Target Was Available By Target Type, Cue Type, Cue Delay

Target Type	Cue Type	Cue Delay (sec) 4	15	40	85	140	190
Rotary	Auto	53/58 (0.91)	44/59 (0.75)	30/60 (0.50)			
	Manual		24/30 (0.80)	24/60 (0.40)	118/294 (0.40)	4/59 (0.07)	2/30 (0.07)
Armor	Manual				12/25 (0.48)		11/30 (0.37)

Table 2. (U) Cueing Data Source by Mode and Delay

Cue Mode	Cue Delay (sec)	Data Source
Auto	4	Forward Area Air Defense System Command Control and Intelligence sensor
	15	Non-Cooperative Target Recognition sensor
	40	Included for analytic purposes
Manual	15	Forward observer-quick fire cue
	40	Line-of-Sight-Forward-Heavy sensor or element within a task force
	85	Manual SHORAD Control System
	140	Included for analytic purposes
	190	Forward observer

An unanticipated and interesting result from this portion of the analysis is the effect of gunner background on target availability. Table 3 shows, for each of eight gunners used in the evaluation, the number of trials in which the gunner had a target available for detection divided by the total number of trials in which the gunner participated, and the gunner's background. Gunner performance varied widely. The best gunner found targets available for detection in 61 percent of his trials, while the worst gunner found targets available for detection in 34 percent of his trials. Based on interviews with the gunners, it was found that the two best gunners had the longest experience with their NLOS platoons, had previous field test experience with the FOG-M (the prototype version of the NLOS missile), and had previous computer experience. This suggests that gunner training will be an important factor influencing the effectiveness of FOG weapons, should such a system be deployed.

Table 3. (U) NLOS Target Availability by Gunner ID and Background

Gunner ID	Successful Trials/Total Trials	Time With NLOS Unit (Months)	NLOS Test Experience	Computer Background (Y/N)
6	61/100 (0.61)	36	Initial Operational Evaluation	Y
3	51/91 (0.56)	13	Field Training Exercise	Y
8	41/83 (0.49)	6	None	N
7	40/84 (0.48)	6	None	Y
4	38/96 (0.40)	5	None	N
5	39/102 (0.38)	3	None	N
1	25/70 (0.36)	11	None	N
2	27/79 (0.34)	10	None	N

2. Effect of Operator Control on NLOS Target Availability

The second step in the analysis, labeled box 2 in Figure 2, was to determine the effect of operator control on target availability. This was done by comparing target availability outcomes of the 705 manned NLOS/SIMNET trials to target availability outcomes for the same 705 trials where the actual NLOS seeker orientation and missile path were replaced with their default behavior.

Consistent with the actual NLOS missile, in the SIMNET trials, the missile was programmed to fly out to the cued target location without any intervention required by the operator. The missile would behave according to the missile model contained within the simulator software. The default behavior of the seeker was also programmed into the simulator software. However, if the operator chose to do so, he could fly the missile manually and/or move the seeker manually. This terminated the default operation of the missile or seeker. Thus, in each SIMNET trial, any variation from the default operation of the missile and seeker is due to the operator's taking control.

To establish what each trial's outcome would have been if the missile and seeker always followed the default behavior, a deterministic model of the default NLOS missile fly-out and seeker behavior was developed based on documentation of the NLOS simulator software. This model was run for each of the 705 NLOS/SIMNET trials, using the same initial conditions that had been used for each SIMNET trial. The missile was launched at the same time by the model as it had been launched in the SIMNET trial, and it was flown to the cued target location for that trial. For each trial, the output of the model was the default missile flight path and the default seeker orientation for that trial.

Target availability was then computed for this hypothetical trial by using the model-produced fly-out path and seeker orientation along with the SIMNET data on target paths and the Fort Hunter-Liggett digitized terrain as inputs to the availability program. This program performed the FOV, LOS, and range calculations using the altered missile location and sensor orientation with the actual target paths for a trial.

The effect of the operator on target availability is measured by the difference in outcome between the 705 SIMNET trials where the operator could take control of the missile and seeker, and the 705 trials where the missile and seeker performed in their default fashion. Average target availability is 0.46 for the SIMNET trials and 0.28 for the modeled trials. Thus the average effect of human operation in the NLOS/SIMNET evaluation is to increase availability by 0.18 (i.e., 0.46-0.28).

Operators improved target availability in two ways. First, they searched for targets that had moved away from the cued target location by the time the missile arrived there. This is not part of the default missile behavior. Second, in some trials where the gunners were given additional information about the target, e.g., in which direction it had been moving when it was first acquired, its speed, and the time since it was acquired, they could sometimes use that information to successfully predict where the missile could intercept the target. A third way operators may have improved target availability was by developing preplanned missile flight paths to anticipated target areas during mission planning. If target cues were for these areas and the preplanned path was used, it may have improved target availability by flying the missile along more likely target paths. No data were recorded to gauge this.

Although the overall effect of the operators was to increase target availability, they decreased it slightly in trials where the target was approximately stationary. In these trials, the model had slightly better availability results, achieved by flying to the cued target location which was also the actual target location. In these trials, any operator control could only move the missile path away from the cued and actual target location.

3. Extrapolating NLOS Target Availability to FOG Concepts

To produce a probability of target availability for the FOG concepts, the technique described in the preceding section of combining a model-produced projectile flight path and sensor orientation with SIMNET target paths and terrain was used. In Figure 2, this process starts with box 3. Target availability results for the NLOS missile could not be used directly for the FOG concepts due to differences in ranges and trajectories among the NLOS, FOG-MP(81), FOG-MP(120), and FOG-HM.

A deterministic model describing the behavior of both the FOG projectile and its seeker was developed for each FOG concept. Each model was run for different SIMNET trials and relevant conditions were varied. These conditions were sensor FOV, sensor look-down angle, time to launch, range to target, and the maximum detection range of the sensor. Each model run produced a FOG projectile path and its seeker orientation. These were input to the target availability program together with appropriate SIMNET target paths and terrain. The target availability program produced a series of curves plotting the probability of a target's being available for detection against each of the independent variables.

These results are likely to underestimate target availability, given the increase in target availability of the NLOS missile between manned trials and trials with default missile and seeker behavior. The availability results for the FOG concepts are therefore scaled to reflect the potential operator contribution to target availability by adding 0.18 to the average P(avail) for each concept. This method of adjustment was chosen for simplicity and illustration; it could be refined, e.g., by decomposing the trials into disjoint sets of similar trials and calculating a separate adjustment for each set of trials.

Figure 3 shows two curves for the probability of target availability versus delay to launch for the FOG-MP(120). The delay to launch is the interval between initial target acquisition and the launch of the mortar round. (The time of initial target acquisition is found in the NLOS/SIMNET trials.) The launch time was varied from 10 seconds to 110 seconds after initial target acquisition in 20-second increments. In Figure 3, the FOG-MP(120) is assumed to have a 9°x12° sensor FOV and a 1.7-km maximum sensor detection range. The lower curve is the probability of target availability based on model results only. The upper dashed curve is the adjusted probability of target availability; 0.18 has been added to reflect the potential operator contribution to availability.

Availability in Figure 3 generally decreases as the delay to launch increases because targets do not appear in the sensor FOV. The extra dip in availability at the 50- and 70-second launch delays is due to the shape of one of the target paths. This path was a semicircle with both end points close to a line drawn from the mortar launch site to the cued target location. Hence, the targets are furthest away from the mortar launch-cued location line for the intermediate length delays.

D. CREATION OF P(SSE)

For each FOG concept, the P(SSE) is the product of the adjusted probability of target availability and other conditional probabilities from field test and model data, as shown in box 4 of Figure 2. The data sources for the three remaining conditional probabilities--detection and lock-on given availability, hit given lock-on, and kill given hit--are described below.

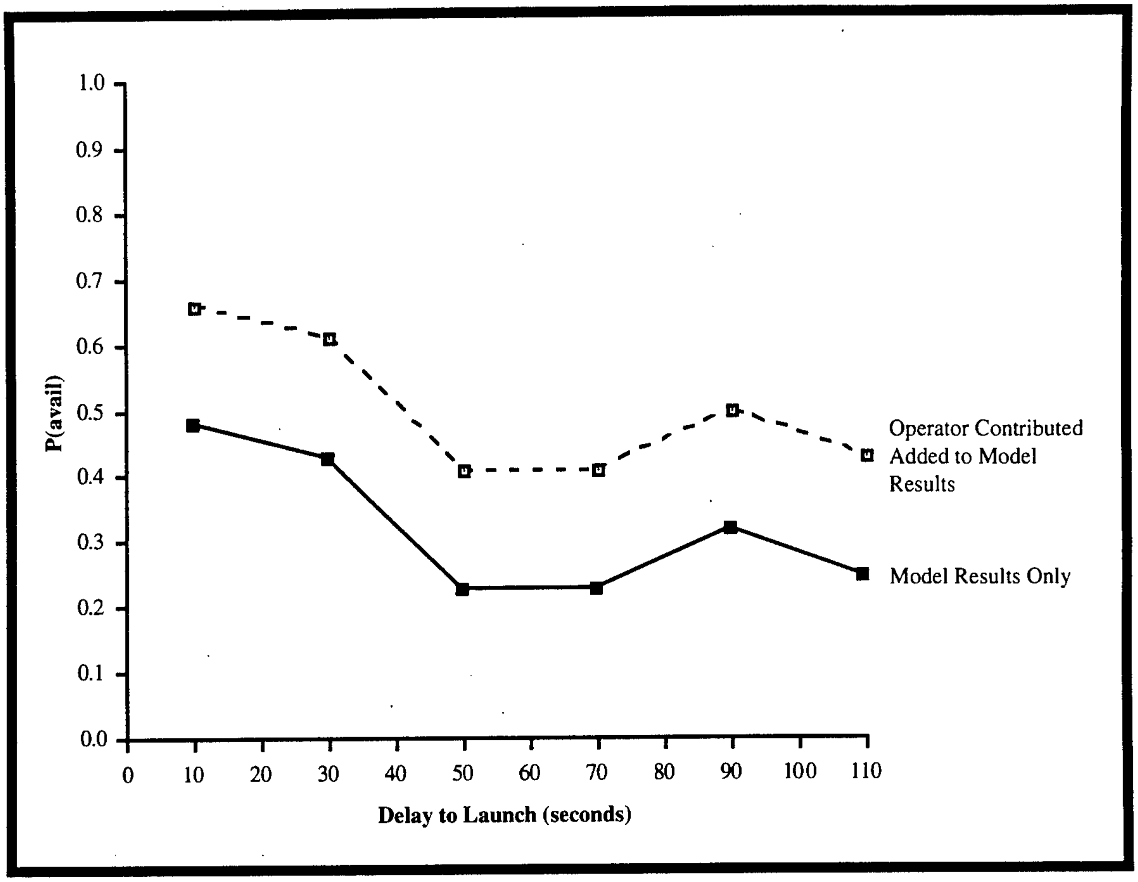

Figure 3. Sample Probabilities of Target Availability vs. Delay to Launch for FOG-MP(120)

1. Target Detection and Lock-On

The probability that the gunner detects and locks on to the target is based on results from the FOG-M IOE. One purpose of the IOE was to determine the operator's ability to detect and lock onto a target, given a target presented in the sensor FOV. The results provide estimates of the average conditional probability that an armor target is detected and locked onto and the average conditional probability that a rotary wing target is detected and locked onto, for the backgrounds against which the targets were presented and their state (moving or stationary).

2. Target Hit

The probability that an armor or rotary wing target was hit given that it had been locked onto was also evaluated during the FOG-M IOE. These values are used for the FOG mortar rounds and helicopter-launched missile under the assumption that they depend on the autotracker software that maintains lock on and on the maneuver capability of the projectile. Preliminary analysis of the FOG concepts indicates their maneuver capability would not be a limiting factor against the targets used in this analysis.

3. Target Kill

The probability that an armor target is killed given that it has been hit is based on data from runs of the U.S. Army Ballistics Research Laboratory Vulnerability Analysis of Surface Targets (VAST) model. The data of interest are probabilities of kill given hit for 4-inch, 5-inch, and 6-inch shaped-charge warheads against various tanks. Values for specific FOG systems are produced by extrapolating from or interpolating between appropriate probabilities.

Data for the probability of killing a rotary wing target given a hit were not available, but this was assumed to be 0.90 for the FOG-HM.

The NLOS/SIMNET tests were well suited to the analytic method just described of combining a modeled system with SIMNET data. One reason is the close similarity of NLOS to the FOG weapon concepts of interest. Another reason is that the NLOS/SIMNET test consisted of many small vignettes (trials) and was not concerned with how the outcomes of the vignettes affected a larger battle. Nevertheless, the method of developing a model and asking how the system (e.g., a UAV) or procedure (e.g., an engagement rule) represented by the model would have behaved in previous SIMNET exercises is not limited to the NLOS/SIMNET data. This technique is generalized and explored further in the following chapter.

IV. METHODOLOGY: THREE TECHNIQUES FOR ANALYZING DIS EXERCISES

The methodology developed for the FOG weapon analysis has been expanded and generalized, producing three analytic techniques for analyzing DIS exercises.

One technique is simply extracting and combining data from one or more prior exercises to develop measures of effectiveness (MOEs). In addition to providing insight into the original exercise(s), these MOEs might be of general tactical or methodological interest.

The second technique is to impose a model on a DIS exercise. Data for systems produced from a source other than DIS (e.g., a deterministic model) can be applied to DIS data, subject to certain data format and logical constraints.

In the third technique, a logger file is replayed to operator(s) in a manned simulator who operate the simulated system on the previously recorded battlefield. It will appear as though the battle is occurring at that instant, subject to the limitations discussed below.

In addition to describing the three techniques and providing examples, this section also explores the following (perhaps paradoxical) proposition: The method applied to NLOS/SIMNET data and its extension to the replaying of prior SIMNET or DIS exercises through a manned simulator is both severely limited and extremely rich in its potential applicability.

The method has two major limitations. First, a prior exercise is history. While the logger data for that exercise or the data derived from that tape can be altered, the extent to which that can be done sensibly is very limited. In the main, what happened in the prior exercise may be reinterpreted to reflect the effect of a new system but cannot be changed. Hence, the tactics on both sides do not include any consideration of the new system.

As another example of this limitation, the engagement rules, fly-out, guidance, and lethality of a new missile can be modeled and applied to a prior exercise. The targets can be engaged by the model just as if the new missile had been present in the original exercise. The impact point of the missile can be determined, and the damage to the target can be calculated exactly as it would be in a DIS exercise. But the target does not die. It continues to fight until the point in the battle where it was originally killed or until the conclusion of the exercise. One might take the analysis a step further by looking at the kills subsequently caused by a target engaged by the model and using this as a measure of the value of killing that target. But this ignores the fact that killing a target may affect many things that could invalidate this measure (e.g., another enemy vehicle might fill the role of that target if it were killed).

As a consequence of this limitation the proposed methodology cannot be used to answer questions of overall force effectiveness associated with a new system. Questions of which side would win or what the overall force exchange ratio would be and similar force effectiveness questions are beyond the reach of the basic methodology, although incorporating military judgments into the replay methodology can extend its reach. On the other hand, questions concerned with opportunities for using a new system and with the expected performance of the system if used in various situations can often be addressed by the methodology. In this case, the analysis of the new system is being done in situations that resulted from human behavior and decisions.

The second major limitation is that a model of a system (or a procedure) is limited in the extent to which it portrays the human involvement required for operation of that system. The prior DIS exercise is being used to capture the human element in the situations to which the model will be applied. But the model itself lacks the human dimension. In any given analysis this may or may not be a disqualifying limitation.

There are at least four ways of partially overcoming this limitation. The first is illustrated by the FOG weapon analysis. It proved possible to estimate the difference between a deterministic model and a manned simulation in the NLOS trials. It was then assumed that this difference could be extrapolated to other FOG systems. (It remains to be seen whether this trick depends on a set of fortuitous circumstances that is unlikely to occur very often.) The second approach illustrated by the FOG analyses is to use field test data to complement the analysis of prior DIS exercises. A third approach is to use military expertise to help determine how the system being modeled could have been used in prior DIS exercises and the contribution it could have made to the battle.

The fourth approach is to replay a exercise to a crew in a manned simulator. For example, the characteristics of an NLOS simulator could be modified to represent a different FOG weapon and those NLOS trials appropriate to the new system could be played through the modified simulator. In this example, the crew probably could not tell that the exercise was not occurring for the first time. In more complex exercises, the crew could probably be fooled for awhile, but for some systems, the inability to affect the battle would gradually reveal the fact that the exercise was being replayed.

In spite of these limitations, the FOG weapon analysis suggests that, with enough care in working within and getting around the limitations, useful results can be obtained. The methodology used for that study both allowed the NLOS/SIMNET test results to be extended in ways not planned for in the test, e.g., the comparison of manned versus modeled default missile and seeker operation, and also, by using the NLOS/SIMNET data, was an order of magnitude less expensive than the SIMNET test itself.

A. BASIC PROCESSING

Basic processing is used to develop results from one's own DIS exercise or to develop results from a prior exercise to be applied or extrapolated to a system or issue other than those for which the test had originally been performed.

In addition, certain general tactical knowledge or information that may help to calibrate DIS results can be gained from previous exercises. Some examples include the following:

- Time and range required to detect and identify targets
- Duration of LOS among vehicles and between missiles and vehicles
- Movement patterns of vehicles: average speeds, paths, and areas of terrain used
- Frequency of overkill
- Probability of multiple targets available for engagement given one target available
- Variation in operator or crew effectiveness.

Some of the results may not correspond well to operational results, such as target detection and identification and terrain-related measures, since they depend on the current computer image generators and terrain database. These results should be collected.

Comparisons with field test data should be tracked as SIMNET and DIS technology is upgraded and displays and terrain become more realistic.

Conceptually, the data reduction approach applied by IDA to several SIMNET evaluations consists of three steps. First, a subset of data describing all vehicle and missile positions, munition impact locations (ground or vehicles), and vehicles killed is extracted from one or more logger files. Second, these data are used to construct a state space describing the x,y,z positions of all vehicles and missiles at every second. Third, the MOEs are calculated based on information in the state space and on the information describing munition impacts and vehicles killed. These MOEs might be killer/victim scoreboards, target availability measures, or average vehicle speeds. In addition, data describing the state space are written. If multiple exercises are used, the entire process is repeated for each exercise.

The data output describing the state space can be inputs to a graphing program that depicts vehicle and/or missile paths over time or second-by-second. Plots of vehicle/missile positions can help the analyst understand the geometry of the battlefield engagements, which are interesting and varied. As an example, for the NLOS/SIMNET evaluation, the position of the targets and the NLOS missile were plotted over time for individual trials. This provided insight into gunner search strategies on trials where the target was not available for detection at the cued target location. The gunner might veer off to the left or right and search an adjacent area, or the gunner might fly in an ever-widening spiral to locate the target. The effectiveness of the various strategies was not studied, but the data to support that work are available.

If it is desired to include the time dimension in plots, snapshot plots depicting vehicle positions at a specific time can be developed, or parts of an exercise can be animated. Both methods are straightforward once the state space of the vehicles has been created.

B. IMPOSING A NEW SYSTEM ON A DIS EXERCISE

1. Method

A new system is added to an existing DIS exercise by providing data about that system as an additional input to the state space derived from a logger file and then calculating MOEs based on the augmented state space.

More specifically, a second-by-second listing of the system's x,y,z positions on the battlefield must be produced. If the system employs a sensor, then the sensor orientation and FOV at each second must also be produced. These positions become inputs to the creation of the state space from which MOEs are developed.

The system's positions can be produced from any source such as a separate model or simulation. For example, a model of the fly-out of a new missile could be developed, producing a set of x,y,z positions describing the missile's trajectory. This set of positions, along with DIS data, could be used to create the state space and then develop MOEs.

Because of the inability, noted above, to change the vehicles' behavior in a prior exercise, particularly the inability to kill a vehicle, it can be useful to subdivide an exercise into smaller segments or vignettes. The effect of the new system can be calculated separately for each vignette. By choosing appropriately sized vignettes, the problem of modifying the behavior of vehicles that would have been affected by a new system is minimized.

2. Applications

- Effect of Operator on System Performance

For a variety of systems that rely heavily on operator control, the effect of the operator on system performance can be measured by comparing results from a manned DIS experiment with results obtained by replacing the manned system (from the same experiment) with a deterministic version of the system produced from a model. An example of this, determining the effect of human operation on target availability for the NLOS missile, was described in the previous section. This type of comparison can provide some understanding of the contribution of the operator to system performance and the circumstances under which operator-controlled operation is most or least useful. For newer systems, such as unmanned vehicles (UVs), either air, ground, or underwater, and FOG systems, where the way in which the operator employs the system may not be well understood, performing a DIS experiment with an operator, comparing the results to a deterministic model, and combining that comparison with a detailed review of operator techniques may help refine tactics or procedures for system use.

- Adding New Deterministic Systems

A modeled deterministic system can be added to a prior exercise without replacing an existing system. In this case, the DIS exercise supplies the battlefield vehicles, their movement and interaction, and the terrain. The analysis generates the model of the new system and rules that determine its use in the DIS exercise. By computing performance-related MOEs such as target availability and vehicles hit, competing system characteristics can be evaluated, e.g., what range is most appropriate; what kind of search algorithm for an autonomous round is most effective; for an airborne system, what flight path (trajectory, speed, and altitude) is most effective?

This approach could also be used to assess target acquisition opportunities for UAVs and the value of the intelligence information they would acquire. Military personnel would review the scenarios of one or more existing DIS exercises (they would not know the actual course or outcome of the battle), determine UAV launch sites, and preplan UAV flight paths over the battlefield. A model would generate the second-by-second description of the flight paths and would describe the sensor FOV and orientation. The state space would be constructed using the UAV path and sensor characteristics from the model and the paths of the DIS vehicles from the prior exercise.

A number of measures for target acquisition could be computed. First, target availability for the UAV could be calculated. The effect of different UAV characteristics on target availability can be determined by varying different parameters in the model, such as sensor FOV or scan pattern, or the altitude, speed, or range of the UAV, and then repeating the process of running the model, constructing the state space, and computing target availability. After an estimate of target availability is developed, it could be combined with estimates of operator detection rates for available targets to estimate how many targets might have been acquired by an operator. Performing availability calculations for the ground vehicles in the prior exercise(s) as well as for the UAVs would determine whether targets become available to the UAVs before they are available to ground vehicles, and if so, how much earlier they are available.

The value of the intelligence information acquired by the UAVs could be assessed in the following ways. The percentage of vehicles on each side (red or blue) available to each UAV could be calculated, in order to understand how much of the battlefield was available to the UAVs. Information on targets acquired by the UAV could be provided to military personnel who then would be asked to identify enemy units, predict future target locations, and make maneuver decisions, e.g., where and when to reinforce. Their answers could be compared to events in the prior exercise(s) to assess how the information from the UAV could have affected the battle.

The advantage of this approach is that it allows the analyst to go significantly beyond the limited types of manned simulators currently available. In addition, many parameters can be quickly varied in a controlled way that makes it easier to determine the effect of each condition on system performance. For example, conditions varied in the FOG projectile models described in the case study were sensor FOV size, sensor lookdown angle, time to launch, range to target, and the maximum detection range of the sensor. Many other conditions (target location, projectile altitude inflight, etc.) could have been varied in the modeling. In addition, the SIMNET data could have been altered. The target paths could have been moved to a different area on the terrain database, the target speed could have been increased or decreased, or the number of vehicles in the target array could have been increased or decreased. This approach is inexpensive, and relatively easy and fast to implement. Performing the same number of trials in a DIS exercise would be far more expensive and time-consuming.

This approach is most readily used for questions that involve looking at the battlefield, such as engagement opportunities for weapon systems or reconnaissance, surveillance, and target acquisition (RSTA) opportunities for surveillance systems.

C. REPLAYING DIS EXERCISES

1. Method

Replaying a prior DIS exercise to an operator (or crew) seated at a simulator or the Stealth vehicle allows the viewer to assume the position of any simulator (friend or foe) and see the battle exactly as the simulator occupant did or to move freely over the battlefield and observe the action from any position and altitude. In its simplest form, the simulator or Stealth vehicle is used as a display device. The operator watches the tape (as noted earlier he may or may not perceive that the battle was previously recorded) and performs assigned tasks. Data are collected on his performance and form the basis for MOEs. In a more complex form, the operator could view a prior exercise through a simulator and he would be able to use the simulator as a weapon system on the battlefield. The simulator could represent a currently simulated vehicle type, or it could be modified to represent a new vehicle type.

This technique differs from the previous techniques in two important respects. First, using a simulator with a previously recorded DIS logger file generates a new logger file that adds the new simulator packets to all the previously recorded packets. This tape can then be analyzed and MOEs developed using the state space technique described earlier. Second, using an operator or crew in a simulator allows human behavior to enter directly into the new analysis. The operator's decisions (where and when to move, where and when to fire) can be recorded; however, this method is still limited in that the effect of those decisions on other vehicles must be inferred. The vehicles in the previously recorded exercise cannot be affected by the simulated system (except analytically).

For simplicity, the applications presented below describe replaying one exercise to an operator or crew. In fact, it is possible and potentially more interesting to replay a number of exercises to the operator or crew. This allows operator performance and, where applicable, system performance to be tested and evaluated in a variety of combat situations. Different exercises may occur on different terrain and involve different kinds of vehicles, force sizes, and missions.

Theoretically, this approach can be scaled up in a variety of ways. A command and control (C2) radio network operated by other people can be added; more manned simulators or CGF or other simulated components can be added. Any added component that generates packets will have those packets recorded by the logger file program and these packets will also become part of a new logger file. However, sensible limits on such additions have not been developed. Moreover, the larger the scope, the closer the exercise gets to a full-scale live DIS experiment. At some point, it would be only marginally more time consuming and expensive to perform an entirely new experiment that would yield more results.

2. Applications

- Target Acquisition for UAVs

The ability of UAVs to acquire targets can be assessed, varying the level of cueing information they receive from none (the UAV is simply performing routine reconnaissance) to specific, information about numbers of enemy units, their positions and direction of movement, and the time of the sighting. Similar to the UAV example in the last subsection, military personnel could review the scenario of a prior exercise and determine initial locations for the UAV. Instead of preplanning the UAV flight path, however, they might assign a RSTA mission to the UAV simulator operator. He would receive a cue to a possible area of enemy movement and fly the UAV to that area. Possible MOEs might be how efficiently does the UAV reach the location; how many blue and red vehicles are available along the way and how many does the operator correctly detect and identify; how does a delay in cueing the UAV affect the availability of targets; how does the time to the cued location affect target availability; and how do the UAV endurance, range, and sensor characteristics affect its performance. In addition, operator search tactics can be analyzed and compared.

An extension of this experiment would be to assess the effectiveness of the C2 network that relays the target acquisition information to a firing system and the effects of attacking the targets acquired by the UAV.

- Assessment of NLOS/UAV Pairing

To assess the potential combat contribution of the NLOS cued by a UAV, a prior exercise could be replayed through both a UAV simulator and an NLOS simulator. The UAV operator would fly over the battlefield searching for targets and would radio target cues to the NLOS simulator operator either directly or through a C2 network. The NLOS operator would fly one or more missiles to the cued target location and engage the target(s).

Target availability MOEs for the UAV like those described in the preceding example could be assessed, varying the scenario (by varying the prior exercise or by using different parts of an exercise) and varying simulator operators. Target availability for the NLOS could be similarly assessed. In addition, the effect of different NLOS/UAV integration concepts on NLOS target availability, target detection, identification, hits, and kills could be explored. A base case might be established with the UAV operator radioing targets directly to the NLOS operator. Other C2 configurations might be assessed using live C2 networks, if C2 operator workloads are realistic, or a cue delay might represent the effect of the target cue passing through a C2 network.

Insight into the combat contribution of the NLOS could be gained by (analytically) determining the number of targets the NLOS would have hit and killed and then determining how those losses (that presumably would have occurred beyond the direct-fire battle) would have altered force ratios in the direct-fire battle.

This example can be generalized to evaluate the effect of various C2 configurations on other kinds of weapon systems.

The advantages of this approach are that it incorporates many aspects of human capabilities and decision-making into the analysis, with a smaller time and cost commitment than a live experiment. In addition, a number of SIMNET and DIS exercises have been archived and the logger files are readily available.

D. DISCUSSION

Compared to computer simulations, analysis based on prior DIS exercises incorporates many more aspects of human behavior and decision-making. Moreover, such analysis can be done quickly and at a low cost, using readily available facilities and software. In contrast, planning and conducting a new manned DIS exercise is expensive and time consuming. Analysis of prior exercises should be considered as a way to build on the investment of others, including routine investments in replicated training exercises. Many SIMNET and DIS exercises have been archived, representing hours of battle employing a large variety and number of forces. The archived logger files can be processed using commonly available hardware. The software for processing can be developed in any language and is fairly straightforward.

In addition to evaluating the effect of new systems by using a model with prior DIS exercises or replaying exercises through a manned simulator, these techniques can be used to expand the results available from one's own exercises. Because of limits on time and other resources, in a typical DIS exercise a relatively small number of parameters are varied. Additional parameter variations can be accomplished analytically by applying these techniques to the logged data from the exercise. The live DIS exercise can focus on those parameters that depend most heavily on human involvement. Thus, a larger set of results is obtained by combining the explicit results of the exercise with the results obtained by using these techniques.

The two major limitations of the methodology have been discussed extensively. First is the fact that the history represented by a prior DIS exercise can only be changed in very limited ways. Second, the analysis of a new system using a prior exercise does not include human operation of the new system if it is represented by a model. Even if the new system is represented by a simulator through which the prior exercise is played, some important aspects of human operation are likely to be lost.

The FOG weapon analysis based on the NLOS/SIMNET test shows that, in at least one case, it was possible to obtain interesting and useful results by analyzing a previously conducted SIMNET test. Though admittedly a special case, this paper has tried to show that, with care and ingenuity, a surprisingly large range of questions can be addressed with a similar analytic approach. If this is true, then the importance of this approach is bound to increase as existing manned distributed simulations are improved and new ones are developed.

Barriers to wider use of this approach include the lack of documentation on exercise post-processing and the limited number of carefully archived exercises relative to the number of exercise hours played. These methods would be more easily implemented if portable, simple software for the basic tasks of reading and interpreting packets and performing standard calculations (e.g., LOS calculations with the terrain database) were available. Archiving of tapes should be performed more consistently and completely. Currently, SIMNET-D sites archive most logger files for 2 years. SIMNET-T policy varies by site. In addition to the logger files, other kinds of materials such as test plans and scenario descriptions must also be archived.

As well as archiving logger data, results from processing those tapes should also be archived. This would establish a database of results from a variety of exercises. These results would aid understanding of how DIS simulators behave and how operators behave in DIS.

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Appendix A

GLOSSARY

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C2	command and control
CGF	computer-generated forces
CP	command post
DARPA	Defense Advanced Research Projects Agency
DIS	distributed interactive simulation
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IFF	identification friend or foe
IOE	initial operational evaluation
FOG	fiber optic guided
FOG-M	fiber optic guided missiles
FOV	field of view
km	kilometer
LOS	line of sight
MOE	measure of effectiveness
NLOS	non-line of sight
OPTEC	Operational Test and Evaluation Command

P(SSE)	probability of single shot engagement
PDU	protocol data unit
RSTA	reconnaissance, surveillance, and target acquisition
SHORAD	short-range air defense
SIMNET	simulation network
UAV	unmanned air vehicle
UGV	unmanned ground vehicle
UV	unmanned vehicle
VAST	Vulnerability Analysis of Surface Targets

Appendix B

REFERENCES

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REFERENCES

1. Department of the Army, U.S. Army Operational Evaluation Command, Abbreviated Operational Assessment (AOA) of the Forward Area Air Defense Non-Line of Sight System (NLOS) Conducted on the Defense Simulation Network (SIMNET), Memorandum dated 20 March 1992.

2. Richardson, G. Donald, Robert W. Anthony, Mark J. Brusich, Steve Warner, 1989, *The Fiber Optic Guided Missile (FOG-M) System (U), Volume I: Operational Assessment and Test Results (U)*, IDA Paper P-2224, Institute for Defense Analyses, SECRET.

3. Schwartz, Richard E., Peter S. Brooks, Frederic A. Miercort, David Spalding, Marchelle M. Stahl, Fredrick E. Saxe, 1992, *Evaluation of Fiber Optic Guided Weapon Concepts (U)*, IDA Paper P-2682, Institute for Defense Analyses, SECRET.

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Appendix C

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13. ABSTRACT *(Maximum 200 words)*

The use of distributed interactive simulation (DIS) for analytic purposes is relatively new and few analytic tools and techniques have been developed. This paper describes three techniques for analyzing data from SIMNET or DIS exercises beginning with a case study describing the use of SIMNET data to evaluate fiber optic guided weapon concepts. From that work, three techniques for analyzing data tapes from SIMNET or DIS exercises have evolved. The techniques are: statistical data analysis, imposing a model on the DIS data, and replaying an exercise to a crew in a simulator. These techniques can be used to extend results from a DIS exercise (for example, sensitivity analyses can be produced) or they can be used to exploit data from previously recorded DIS exercises to produce results for issues other than those for which the exercise was originally conducted. The paper describes each technique in detail and illustrates each with a series of examples to demonstrate that, for some systems and some issues, one can develop interesting insights and results from archived SIMNET or DIS exercises.

14. SUBJECT TERMS

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