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The Cost and Effectiveness of the Multi-Service Distributed Training Testbed (MDT2) for Training Close Air Support

Jesse Orlansky
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PREFACE

This study was conducted for the Office of the Under Secretary of Defense for Personnel and Readiness under a task entitled "Cost-Effectiveness Study of the Multi-Service Distributed Training Testbed (MDT2)." Technical cognizance for this task was assigned to Dr. Henry Simpson of the Defense Manpower Data Center, Seaside, California, an agency of OUSD (P&R). The point of contact for OUSD (P&R) was Donald Johnson. Technical liaison was maintained with Dr. Franklin L. Moses of the Army Research Institute for the Behavioral and Social Scienes, Alexandria, Virginia. Dr. Moses serves as the Project Director for the MDT2 project.

James F. Love helped us understand and interpret data collected during exercises conducted on the MDT2 system. His contribution to developing the training objectives used in the close air support exercises is also acknowledged. Larry L. Meliza of the Army Research Institute provided information concerning the Unit Performance Assessment System (UPAS) capabilities and data collected using UPAS during MDT2. Daniel J. Dwyer of the Naval Air Warfare Center Training Systems Division, and Jennifer E. Fowlkes of Enzion Technology briefed us on process-oriented performance measurement used during MDT2. Angelo Mirabella of the Army Research Institute reviewed the system assessment methodology and data from the MDT2 exercises.

Herbert H. Bell, Dexter Fletcher, Stanley A. Horowitz, James F. Love, Franklin L. Moses, and Henry A. Simpson reviewed a draft of this paper; we gratefully acknowledge their helpful comments.

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SUMMARY

PURPOSE

The purpose of this study was to determine the effectiveness and cost of the Multi-Service Training Testbed (MDT2). MDT2 is the first system to link simulators of different Services in an interactive network. This network provides multi-Service training for a common mission.

In one 5-day exercise held May 1994 and a second held February 1995, the MDT2 was used to train personnel in Close Air Support (CAS). Eight different types of simulators representing friendly and enemy forces were linked to conduct exercises modeled after those that take place at the National Training Center, Fort Irwin, California. Participating in the exercise were Army, Marine Corps, and Air Force personnel and simulators at three different locations, plus recording and observation facilities at a fourth location.

FINDINGS

We found strong evidence on the utility of distributed interactive simulation as a significant way to provide complex multi-Service training:

- As measured by (1) adherence to procedures that ensure coordination and synchronization of multi-Service forces and (2) by battle damage, performance improved.
- The cost of CAS training using simulators is one-tenth that of training through field exercises.

Verification that this improved performance would carry over into live exercises is needed, but such confirmation was beyond the scope of this effort. At present, there is little evidence that the skills needed for multi-Service CAS receive sufficient training in any form.

THE FUTURE

As more simulators are built to standards that support interoperability, it will become increasingly convenient to create many different types of networks for use in training and development. Such simulator networks could achieve a larger range of applications and usage within and between the Services.

I. INTRODUCTION

This paper provides estimates of the effectiveness and cost of the Multi–Service Distributed Training Testbed (MDT2). In this paper, effectiveness is the extent to which training in MDT2 improves the ability of people to perform a multi-Service mission, using Close Air Support (CAS) as a prototype. Cost is the cost of conducting CAS training in the MDT2 simulation compared to that of similar training in live exercises at the National Training Center (NTC).

The MDT2 is a developmental prototype that connects eight types of simulators in four locations around the United States so that multi-Service units can interact with each other in real time to conduct combat exercises against simulated enemy forces. At this time, it is configured to support training of Army, Marine Corps, and Air Force personnel and units in CAS. In effect, distributed interactive simulation (DIS) permits exercises to be conducted as if dispersed participants were together on an instrumented range.

The capability of the MDT2 system to train personnel in CAS was tested in 5-day trials in May 1994 and February 1995. Data and observations collected in those trials provided much of the information used in this paper. The cost analysis compares the costs of conducting such training in the MDT2 and at the NTC.

II. BACKGROUND

Collective training helps skilled individuals learn how to operate together as crews and units; this training takes place primarily in operational units. Collective training is preparation for combat, and it often involves live field exercises, preferably against an opposing force on an instrumented range. An instrumented range, such as the National Training Center at Fort Irwin, California, provides information on the positions and movements of opposing vehicles, numbers of shots and types of weapons fired by one vehicle against another, hits and misses—i.e., the types of information needed to assess what happened and why in after action reviews (AARs). The use of actual equipment and live munitions is important to building group competence as well as confidence in the weapon systems with which our troops will fight. The opposing force introduces a degree of uncertainty about what an enemy force might do in actual combat; instrumentation on the range provides objective information needed for after action review of what actually happened. Many of the features of live field exercises can now be replicated in a DIS system such as with the MDT2. Furthermore, a number of operations that are not trained in live field exercises due to peacetime safety restrictions can be trained in a DIS environment. DIS also improves the reliability and scope of information needed for after action assessments.

Even though readiness has the highest priority for the United States military forces, the services have reduced the amount of field training (called Operating Tempo or OPTEMPO) because of its relatively high costs, reduced availability of ranges, and restrictions due to the impact of exercises on the environment. The total cost of OPTEMPO for all services in FY 1991 was estimated to be $21.4 billion, not a negligible item in the defense budget (Angier, Alluisi, and Horowitz, 1992). At the same time, the remarkable development of DIS over the last decade provides an alternative way to conduct selected aspects of collective training at reduced overall costs. Cost reductions are achieved by avoiding travel costs and travel time to ranges as well as by reducing the costs of equipment, acquisition and maintenance, ammunition, fuel, and expendables needed for training.

The use of simulators in military training is not a new idea—sand tables have been used for centuries for planning battles. The first flight simulators were designed soon after the Wright brothers flew; the Sanders Teacher and the Antoinette Trainer were both available in 1910 (Adorian, Staynes and Bolton, 1979). Recent advances in computing capability, communications, and computer image generation (exemplified by the Internet and the World Wide Web), together with lower acquisition and operating costs, have given us DIS. DIS provides the ability to link many simulators—regardless of location—and allows them to operate together in real time as if the participants were in the same location. Over 30 demonstrations of this capability, some on a world-wide scale, have taken place since 1987.

SIMNET (Simulator Networking) is the best known example of a DIS system in the Department of Defense. It includes simulators of tactical command posts and of about 250 Abrams tanks and Bradley Fighting Vehicles, as well as recording and playback facilities, in 8 locations, including Fort Knox, Fort Hood, and Grafenwoehr, Germany. Separate exercises can be conducted on different terrains at each facility, or all facilities can operate together on the same terrain. This system is an acknowledged success, and it will soon be supplemented by the Close Combat Tactical Trainer (CCTT), an advanced and more capable system with about 560 simulators at 12 fixed locations and 12 mobile sets for temporary locations. SIMNET is the first system to achieve routine "true interactive simulator networking for collective training of combat skills in military units from mechanized platoons to battalions" (Alluisi, 1991). It was designed for and is limited to the Army. Other than a number of technology demonstrations, MDT2 is the first system—actually a testbed of a possible system—to support collective training of units from different services on a common mission, that of CAS. This was achievable only by solving several engineering and technical problems.

Parts of the SIMNET system that were used in MDT2, e.g., simulators of tanks, semi-automated enemy forces (SAFOR), and the Tactical Operations Center (TOC), could obviously communicate and interact with each other because they were designed to do so. That was not the case for the Air Force and Marine Corps components that are vital to CAS. For example, the F-16 simulators needed additional DIS capability; a Network Interface Unit had to be developed for the Deployed Forward Observer/Modular Unit Laser Equipment (DFO/MULE); and an improved DIS translator was needed at Fort Knox.

Another major challenge was that, although the Army, Air Force, and Marine Corps have specific training manuals for use in training their own roles in Close Air Support, no multi-Service or joint training manuals were available to specify training objectives and standards for the performance of key inter-Service procedures required for collaboration and synchronization on a battlefield. As a consequence, non-official training objectives and standards were developed from doctrinally correct tactics, techniques, and procedures to provide a basis for training and evaluation in the MDT2 trials. Examples include procedures needed to establish airspace coordination areas, methods to identify targets during CAS operations and to pass target updates to higher headquarters (see Appendix A). Though non-official, the Close Air Support training program was developed by subject matter experts with considerable experience with this mission and was reviewed by two multi-Service organizations, the Air Land Sea Application Center and the Air Ground Operations School.

A. DISTRIBUTED INTERACTIVE SIMULATION

DIS involves the networking of simulators for common operations. The generic term "simulation" actually refers to three types of simulation:

- Virtual simulation— real people in simulated equipment
- Live simulation— real people using real equipment
- Constructive simulation— simulated people using simulated equipment.

Primarily, virtual simulation was used in this study of CAS in MDT2, although the use of SAFOR is an example of constructive simulation.

Distributed interactive simulation operates on the following principles (Bell, 1995):

1. There is no central computer that maintains absolute truth and tells each simulator how its actions influence others.
2. Each simulator, with its own computer, transmits the truth about its state, movements, and actions. Receiving simulators determine whether that information is relevant to them and, if so, what effect it has on them.
3. Information about non-changing objects (e.g., terrain) is known by all simulators and therefore is not transmitted between simulators. Each simulator broadcasts its unique state, movements, and actions to all other simulators using standard Protocol Data Units (PDUs).
4. Each simulator calculates or "dead-reckons" the positions of all other simulators in its vicinity. Each simulator also maintains a dead-reckoning model of itself and regularly compares its actual state with the dead-reckoned model. Whenever a significant difference exists between the actual and dead-reckoned states, the simulator broadcasts state-update information.

5. Each simulator creates an appropriate environmental representation based on the information received from other simulators and its own state information. Each simulator creates its own virtual world using standard simulator technologies (i.e., computer image generation, display, communication, and host computers.)

The number of entities that can participate in a battle is limited now to about 100,000 because of bandwidth and other limitations. The term "entity" includes not only vehicles that move, but objects, such as bridges or buildings, that change their state if they are hit by a weapon.

B. MEASUREMENT OF UNIT PERFORMANCE

To estimate the effectiveness of the MDT2 for training military units to perform the CAS mission, one must be able to measure various aspects of unit performance. A production model provides a useful basis for measurement:

Input—Process—Output

where *input* represents resources, such as facilities, funds, personnel, and time; *process* describes the extent to which personnel practiced specified training tasks and programs; and *output* represents performance capability, in such terms as targets hit or missed.

C. PROCESS-ORIENTED MEASURES

The measurement of performance of military units in exercises, such as at the NTC, has been the subject of some investigation. In 1987, the Army Research Institute started an effort to identify factors that influence unit performance at the NTC. The goal was to determine how "Army units can best be manned, led, and trained to maximize their combat readiness" (Holz, O'Mara, and Keesling, in Holz, Hiller and McFann, 1994). Data on unit combat performance collected at the NTC were used as criteria for "determinants," i.e., predictor variables. Holz et al. compared performance of units at the NTC to their activities before coming to the NTC. This comparison was then used to determine what personnel and training factors distinguished high performing units at the NTC from low performing units. Surveys, interviews with the brigade and battalion commanders and their staffs, group interviews and questionnaires administered to unit personnel within the companies, and records regarding unit training plans and personnel were used to establish a baseline. During the NTC rotation, the Observer/Controllers (O/C) used special rating forms to assess unit performance during each exercise. Rank order of brigade training was found to be positively correlated with measures from the NTC instrumented range (Core Instrumentation System, CIS) which measures hits and kills as registered by the Multiple Integrated Laser Engagement System (MILES) used at NTC.

Fowlkes, Lane, Salas, Franz, and Oser (1994) developed TARGETs (Targeted Acceptable Responses to Generated Events or Tasks); it is an event-based procedure for measuring team performance. TARGETs are behaviors that, if present, can be observed by O/Cs; observers need not be subject-matter experts but must be well-trained in the use of the TARGETs instrument. In a test reported by Fowlkes et al., the inter-rater agreement was high for two observers viewing videotapes of aircrew behaviors during an effectiveness evaluation of aircrew coordination training. The observers were required to state if the event which signaled a given behavior was present or absent. Observers agreed on 411 of 425 (97 percent) possible judgments that an event was present. If the event was judged to be present, the two observers stated whether a crew performed or did not perform the required behavior. The observers agreed on 357 out of the 400 TARGETs (89 percent) for cases in which both had judged that the behavior was present. An important characteristic of TARGETs is that a list of appropriate behaviors for each task can be established *a priori* and presented in a checklist format on the dimensions of team work (Fowlkes et al., 1994).

D. AFTER ACTION REVIEW (AAR)

The Army's preferred method of providing feedback to participants after training exercises is the AAR (Meliza, Bessemer, and Hiller, 1994). General Paul F. Gorman, USA (Retired), has said that the Army's willingness to conduct objective and frank discussions of how well military units performed in combat exercises has been a major contribution to its improved performance after its experience in Vietnam (private communication). To be effective, the AAR must focus on critical actions which could have a direct effect on the outcome of a mission. The process involves the principal participants in the exercise and a review leader discussing the critical elements of mission planning, preparation, and execution. Meliza, Bessemer, and Hiller (1994) discuss the use of the Unit Performance Assessment System (UPAS) to conduct AARs. The UPAS integrates DIS network data with non-network data such as specific mission, enemy, friendly troops, terrain, and time. This combination of information is needed during an AAR to interpret casualty and position data collected from the DIS network.

III. EFFECTIVENESS

A. THE EXERCISES

1. Subjects

A total of 19 personnel participated in each battalion task force exercise against a regimental-size enemy, played by SAFOR controlled by military experts. Fourteen drivers and gunners manning the tank and Bradley simulators at Fort Knox were also part of the blue force but did not participate in training multi-Service CAS tactics or procedures. Two sets of exercises were conducted, each over a period of 5 days. The first day was used to familiarize all participants with the scenario, DIS environment, and the exercise plan. Defensive exercises were conducted on the second and fourth days; offensive exercises were conducted on the third and fifth days.

2. Equipment

a. MDT2 Simulators

The MDT2 system used existing simulators at several locations, as shown in Table III-1. In a technical description of these simulators, Bell (1995) and Bell et al. (1996) noted that although the hardware and software of the simulators were modified to enable them to share a common area of terrain and to minimize functional differences in the several fields of view, there were significant differences in the fidelity and ground area displayed in the various simulators. These differences resulted in substantial constraints on the design of the training scenarios that could be used in the exercise. The most significant problem was caused by differences in the different computer image generators and display systems, which led to differences in the number of moving vehicles that could be displayed. The DFO/MULE could display a maximum of five vehicles, while the tank simulators could display an almost unlimited number. Consequently, the exercises were modified to limit the number of vehicles that could come into the DFO/MULE's field of vision. This took up a very small portion of the battlefield. The moving entities that the

F-16 simulators could handle at any point in time was 60, and therefore limited MDT2 training to the battalion task force level rather than the preferred brigade level.

Table III-1. Simulators Used in MDT2

Simulators and Service	Trainees	Location
Tactical Operations Center (TOC) Army M1 Abrams Tanks M2 Bradley Fighting Vehicles Army	Key staff members to include Tactical Air Control Party Command Group to include Air Liaison Officer or Enlisted Terminal Attack Controller Task Force Scouts Company Commander and Exec	Mounted Warfare Test Bed, Fort Knox, KY
Semi-Automated Forces (SAFOR) (enemy and friendly, constructive simulation)[1] Army		
F-16 aircraft simulators Air Force	Attack Pilots	Armstrong Laboratory Mesa, AZ
Deployed Forward Observer/Module Unit Laser Equipment (DFO/MULE) Laser Target Designator Marine Corps	Ground Forward Air Controller and Laser Team	
Helmet mounted display simulator OV-10 aircraft simulator Air Force Marine Corps	Airborne Forward Air Controller	Naval Air Warfare Center Patuxent River, MD
Recording and observation		Institute for Defense Analyses Alexandria, VA Armstrong Laboratory Mesa, AZ Mounted Warfare Test Bed, Fort Knox, KY

[1] Modular SAFOR (MODSAF) used in 1995 exercises.

b. Network

Two communications networks linked the simulators. One network, the DSInet (Distributed Simulation Internet), connected U.S. Army simulators at the Mounted Warfare Test Bed (MWTB) at Fort Knox, Kentucky; U.S. Marine Corps simulators at the U.S. Naval Air Warfare Center (NAWC) at Patuxent River, Maryland; and the data recording and observation facilities at the Institute for Defense Analyses (IDA), Alexandria, Virginia. The other network, a commercial T-1 line, connected NAWC to the U.S. Air Force F-16 simulators and to the Marine Corps DFO/MULE simulator at the Air Force Armstrong Laboratory in Mesa, Arizona. The integration of the two networks resulted in a fully integrated wide area network (WAN) in which all sites shared a common terrain data base, that of the NTC.

c. Exercise Scenarios

An offensive and defensive scenario were developed to test training CAS with the MDT2. The missions called for integrating CAS with the fires and movement of an armored battalion task force which was part of an Army brigade attached to a Marine Expeditionary Force. Supporting CAS were a Marine airborne forward air controller (AFAC) in an OV-10 observation aircraft, a Marine DFO/MULE laser target designator team with a ground forward air controller (FAC), and an Air Force tactical air control party (TACP) and F-16 attack pilots. Several of the CAS missions involved using laser-guided bombs dropped by the F-16s on enemy targets designated by the Marine laser designator team.

Each offensive battle started with the movement of the battalion task force and TACP trainees in their SIMNET vehicle simulators. There were seven simulators: one each for the battalion commander, enlisted tactical air controller (ETAC), company team commander, company executive officer, and fire support team chief; two for the scout section. The DFO/MULE team was put into its pre-selected laser designating position. Three SAFOR tank platoons were "tethered" to the company commander and company executive officer vehicles. The other three companies of the task force were scripted using O/Cs to provide the command group with appropriate situational updates on the battalion radio nets. A reinforced company-sized enemy element was played by red SAFOR with their flank and second echelon units being scripted as intelligence inputs from the O/Cs to the battalion tactical operations center (TOC).

In the blue force defensive mission, the same size blue force was used, while the red force, played entirely by SAFOR, was about three times as large. Both scenarios, with a three-to-one size advantage to the offensive force, conform to conventional military doctrine.

Two MDT2 exercises were conducted: one on 23–26 May 1994 (Phase I) and another on 13–17 February 1995 (Phase II). A system test to establish a technical baseline was planned to take place before the Phase I exercise. Due to the schedule delays and the unreliability of the DSInet, no satisfactory system test was conducted before the first exercises took place, and as a result, the technical performance of the MDT2 system was inadequate during the May 1994 exercise (Moses, 1995).

d. May 1994 Exercise (Phase I)

During these five days, the network system, but not the simulators, was very unreliable. Consequently, the project director and the O/Cs had to use radio-transmitters to enable the exercise to be completed, which limited the number of trials and amount of data that could be collected.

e. February 1995 Exercise (Phase II)

For the February 1995 exercise, the length of the CAS scenario was between 1.5 and 2.0 hours for each of the five days. Between three and five CAS missions were flown during each day. Each CAS mission was divided into a planning phase, a contact point (CP) phase, and an attack phase. The offensive scenario was conducted on days 1, 3, and 5 and the defensive scenario on days 2 and 4. Day 1 was also used to familiarize the participants with the procedure and data to be collected.

B. PERFORMANCE MEASUREMENT

1. Process-Oriented Performance Measures

Two process-oriented performance measurement tools provided diagnostic performance feedback during the AARs and determined trends in performance across the training days: TARGETs and TOM (Teamwork Observation Measure) (Dwyer, Oser, and Fowlkes, 1995). TARGETs was used to evaluate adequacy of performance in MDT2 training trials. Seven subject matter experts (SME's) located at the three sites served as O/Cs and provided inputs to the TARGETs and TOM instruments. At the completion of each day's trials, an AAR was held for all participants by means of a video teleconference. The participants received feedback based on data collected by the O/Cs using TARGETs and TOM performance-measuring instruments and based on electronic data from the SIMNET system.

For the MDT2 exercise, 25 training objectives for CAS were developed. These objectives focused on the interservice interactions among the Army, Air Force, and Marine Corps personnel required to perform the CAS mission. A checklist was developed for the

25 training objectives and the tasks within each objective. The appropriate behaviors for each task were defined prior to the exercise.

TOM measures were made on each CAS mission (Dwyer, Oser, and Fowlkes, 1995). The inter-Service actions were rated for each of three phases on four dimensions (Planning, Contact Point, and Attack: communication, coordination, adaptability, and situational awareness in the exercise). Table III-2 shows the definitions by phase and dimension.

Table III-2. Definitions of Phases and Dimensions of the Teamwork Observation Measures (TOM)

Phases:

The PLANNING PHASE refers to the planning that is done before the scenario actually starts, continues through STARTEX, and lasts until the aircraft arrive at the CP. (Planning can also take place after the aircraft arrive at the CP when unforeseen or unplanned conditions occur.)

The CONTACT POINT PHASE begins when the aircraft arrive at the CP and lasts until the aircraft depart the CP.

The ATTACK PHASE starts when the aircraft depart the CP and lasts until the aircraft egress the area.

Dimensions:

COMMUNICATION involves the exchange of information between two or more team members in a prescribed manner, using **correct format** and **proper terminology**. Communications should be **clear**, **concise**, and **accurate**. **Acknowledgment** of communications is also critical.

COORDINATION refers to team members executing the tasks in an integrated, cohesive, and timely manner. Critical factors include **synchronization of actions**, **timely passing of information**, and **familiarity with others' job needs**.

SITUATIONAL AWARENESS refers to the ability to develop and maintain an accurate perception of the surrounding environment. This includes **maintaining the big picture**, **identifying potential problem areas in advance**, **being aware of the resources available**, and **providing information before it is needed**.

ADAPTABILITY refers to the team's ability to effectively and efficiently maintain task performance despite changes that may occur during the mission. A team's adaptability is evidenced by the members' ability to **have back up plans available**, **making smooth transitions to back up plans**, and **quickly adjusting to situational changes**.

Source: MDT2 Teamwork Observation Measures (TOM) (no date)

The teamwork dimensions were divided into subdimensions. For example, the communication dimension was subdivided into Format, Terminology, Clarity/Concise/ Accurate and Acknowledgments.

The subdimensions are shown in Table III-3, which was also the score sheet. The O/Cs rated how well the participants interacted with each other on the dimensions of teamwork. A four-point rating scale was used: 1, Needs work; 2, Satisfactory; 3, Very good; and 4, Outstanding.

Table III-3. Dimensions and Subdimensions of Teamwork Observation Measures

Phase	Communication	Team Coordination	Situational Awareness	Team Adaptability
Planning	Correct format Proper terminology Acknowledgments Other	Synchronized actions Timely passing of information Familiar with others' jobs Other	Maintained "big picture" Identified potential problem areas Aware of resources available Provided information in advance Other	Backup plans Smooth transition to backup plans Quickly adjusted to situational changes Other
Control Point	Correct format Proper terminology Acknowledgments Other	Synchronized actions Timely passing of information Familiar with others' jobs Other	Maintained "big picture" Identified potential problem areas Aware of resources available Provided information in advance Other	Back-up plans Smooth transition to back-up plans Quickly adjusted to situational changes Other
Attack	Correct format Proper terminology Acknowledgments Other	Synchronized actions Timely passing of information Familiar with others' jobs Other	Maintained "big picture" Identified potential problem areas Aware of resources available Provided information in advance Other	Back-up plans Smooth transition to back-up plans Quickly adjusted to situational changes Other

Source: MDT2 Teamwork Observation Measures (TOM) (no date)

2. After Action Review

The method used by the O/Cs at the NTC of "drawing out key learning points from the players" was used in the AARs:

> At the conclusion of each battle, the trainers and O/Cs gathered data, observations, and comments together to prepare performance feedback. Approximately 30–60 minutes later, a conference call among the sites enabled everyone to pool comments and to determine what significant collective interface problems occurred during the battle that needed to be brought out. Then, all participants were brought together in a conference to discuss the battle and visual/ audio replays that illustrated strengths and weaknesses of performance. (Moses, 1995)

The AARs started with summaries of the battle (the CAS missions) and the strengths and weaknesses during the planning and execution phases. This was followed by a detailed AAR of each CAS mission. During the discussion phase of the AAR, there was an opportunity for the participants to ask questions of other participants and of the O/Cs.

3. Outcome Measures

The Unit Performance Assessment System (UPAS) was designed to calculate and display performance measures and summary statistics associated with exercises in SIMNET (Meliza, Bessemer, Burnside, and Schechter, 1992; Meliza, 1993; and Meliza, Bessemer, and Tan, 1994). UPAS uses five data sources to analyze unit performance in a DIS environment (Meliza, 1993):

- network data,
- terrain data,
- unit plans for the operation,
- radio communications, and
- direct observation of soldier behavior.

It provides information on:

- vehicle appearance,
- vehicle status,
- status change,
- fire, indirect fire, and
- impact (vehicle or ground).

The UPAS and the PDU data streams collected and stored data during the 1995 MDT2 exercise. These later permitted the analysis of performance measures related to the combat outcomes in CAS. The following outcome measures were developed from these data: the number, timing and frequency of bombs released by the F-16s; the number of vehicles hit, damaged or destroyed; the percentage of bombs which resulted in a vehicle impact or a near impact; the number of bombs released causing damage or destruction; the timing and volume of artillery direct fires and CAS fires; and the timing and location of direct and supporting fire impacts (Meliza, 1995).

4. Outcome and Process Measures

The recorded exercise data tapes were examined to determine the number of enemy vehicles (tanks, BMPs and ZSU 23-4s) that were killed (destroyed) during one battle. This was done for days 2 through 5 for the 1994 and 1995 CAS training exercises (Love, 1995). The DSInet was unreliable during the 1994 exercises, and the O/Cs assumed the roles of the attack pilots in order to complete the mission. When the O/C correctly directed an aircraft to a target, the target was routinely destroyed by the O/C. As a result, all bombs dropped during the 1994 exercise hit the intended target and there were no CAS misses. The DSInet was more reliable during the 1995 exercise, but one problem remained. Because the simulators differed in how they reported terrain information, there were three or four attacks during which the bomb drops were perfectly coordinated and executed but the bombs missed the target. In these cases, the O/C destroyed the target and recorded a hit. For the 1995 exercise, the number of CAS kills and misses equaled the total number of bombs dropped during the battle (exercise day) with one exception. During day 5, one enemy tank was hit by two bombs, which was recorded as one kill.

The Average Engagement Time was defined as the average time in minutes that it took for the attack aircraft to engage a set of targets. An engagement began when the first attack aircraft was cleared to the set of targets and was completed when the last attack aircraft dropped its bomb on that set of targets. The average engagement time included re-attack on the same set of targets. The DSInet data tapes were examined after the battle for each day to determine the average engagement time for days 2 through 5 for the 1994 and 1995 CAS training exercises.

For each day during the 1994 and 1995 exercises, the O/Cs observed and rated the trainees' performance in terms of tactics, techniques and procedures (Fire Support Synchronization Factor). The judgments were recorded for each training objective on the TARGETs and TOM performance measurement instruments. At the conclusion of each exercise day, O/Cs discussed and consolidated these judgments. After the discussion, the Senior Trainer reviewed the data to prepare for the AAR. Following this review, the Senior Trainer judged the relative combat proficiency of the trainees for that exercise day based on the following:

- how well the trainees integrated CAS in the planning process,
- how well they controlled the aircraft in the area,
- how well they executed their plan, and
- how well they reacted to unforeseen problems on the battlefield.

Integrating CAS in the planning process involved developing synchronization exercise matrices, employing fire control mesaures, devising and using airspace control measures, conducting rehearsals and adjusting plans, and synchronizing CAS and other fire support with maneuvers.

The Senior Trainer provided subjective ratings of the trainees' performance in tactics, techniques and procedures necessary to plan and execute maneuver operations (Maneuver Synchronization Factor). The ratings for the 1994 and the 1995 CAS training exercises represent the relative proficiency at the end of each exercise day.

5. User Reactions

Subjective reactions of the participants, trainers, and O/Cs were obtained following both the May 1994 and the February 1995 MDT2 exercises. The same methodology was used for both exercises. The analysis attempted to answer the following questions (Mirabella, 1995, 1996):

- How well did MDT2 work, what needs to be fixed or improved?
- What value can MDT2 add to the military training cycle?

The training value was evaluated using five criteria:

- need for this type of training
- credibility
- multi-Service value
- role in the military training cycle
- expected impact

Respondents rated these criteria on a questionnaire that used a six point scale:

1—Strongly agree
2—Moderately agree
3—Slightly agree
4—Slightly disagree
5—Moderately disagree
6—Strongly disagree

The survey was administered to 31 subjects who were players and to O/Cs at all MDT2 sites. The questionnaire had multiple items for each issue; there were 12 total items. The 1995 questionnaire was administered at the end of training. Blank lines were provided after each item for comments; a total of 175 comments were received. Exit interviews were used to supplement the questionnaire.

C. RESULTS

1. Process-Oriented Performance Measurement

The process-oriented performance measurements were reported by Dwyer, Oser, and Fowlkes (1995) and by Dwyer, Fowlkes, Oser, and Salas (1996). They presented data for each of the three phases (Planning, Contact Point, and Attack) of the CAS mission for the February 1995 exercise. We discuss data for both the TARGETs and the TOM performance measurement tools below.

a. The Planning Phase

Figure III-1 presents the TARGETs and TOM data for the planning phase for the functional areas of Target Selection, Airspace Coordination Areas, Control of Aircraft, Synchronization and an overall performance measure (Dwyer et al., 1995). The three O/Cs at Fort Knox provided the data; the inter-rater reliability was r = .95. The data point for each day is the mean percent correct for all O/Cs across all CAS missions for that day. The trends in Figure III-1 indicate that performance improved during the 5-day exercise as a function of MDT2 practice. Target Selection was about 90 percent correct on day 1, about 99 percent correct on day 2, and remained high for days 3 to 5. Maintenance and control of Airspace Coordination Areas (ACA), on the other hand, started at approximately 38 percent correct, reached about 99 percent correct on day 3, and remained high for days 4 and 5. Control of Aircraft was about 50 percent correct on day 1, increased to about 78 percent correct for days 2 and 3, and leveled off between 93-97 percent correct for days 4 and 5. Dwyer et al. (1995) summarize these data as follows, "All components except Control of Aircraft appeared to asymptote at high levels by day 3; performance related to the Control of Aircraft peaked on day 4 before declining slightly on day 5."

The TOM data were collected by two O/Cs at Fort Knox for Communication, Coordination, Situational Awareness, Adaptability, and an Overall Performance Score (Dwyer et al., 1995). The data points for each day were the mean of the ratings of the two O/Cs for all CAS missions for that day; inter-rater reliability was r = 0.79. With the exception of communication, the ratings are about 1.5 (less than satisfactory) for day 1 and increased to about 3.3 (between very good and outstanding) for day 4. The trend is approximately linear. With the exception of a slight improvement in situational awareness, there was no change from day 4 to day 5. The rating of the communication function decreased for day 2 from 2.4 to about 1.8. Dwyer et al. (1995) indicated that specific examples of the communication decline were addressed in the AAR following day 2.

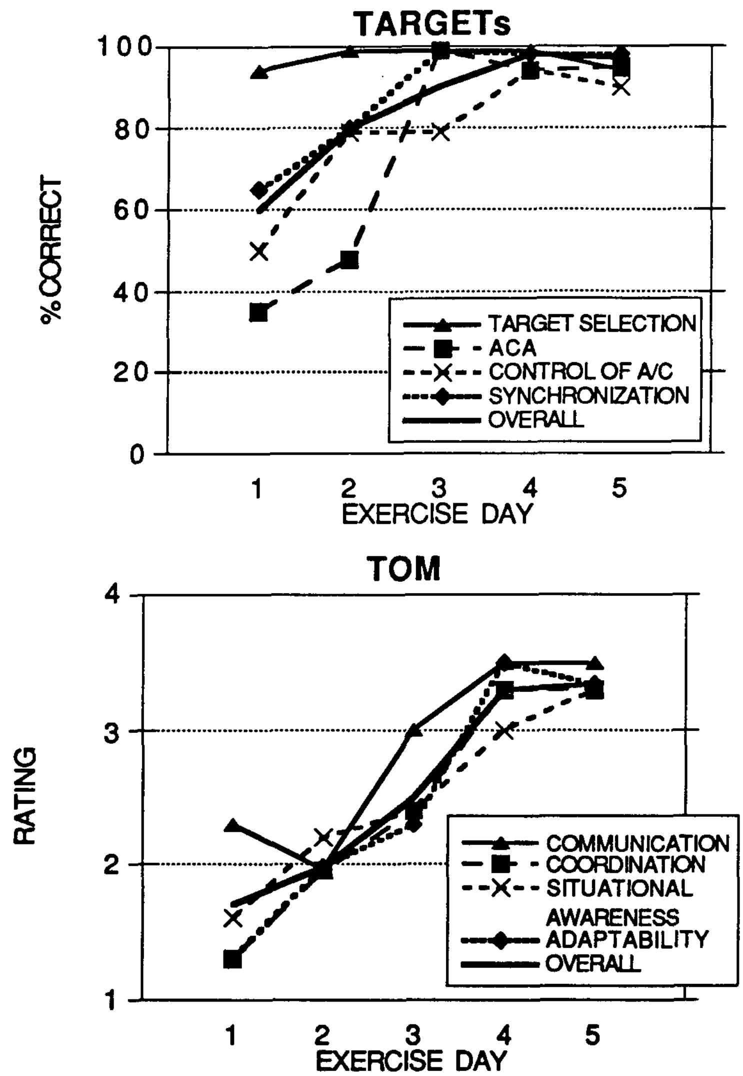


Figure III-1. Planning Phase

b. The Contact Point Phase

Five O/Cs (two at Fort Knox, two at the Armstrong Lab, and one at Patuxent River) provided the TARGETs data for the CP phase. Figure III-2 (Dwyer et al., 1995) shows the data. Each data point for Fort Knox represents the mean percent correct for two O/Cs of all CAS attacks flown on each day. Four CAS missions were flown on day 1, five on days 2, 3, and 4, and three on day 5. Each data point for the other sites represent the mean percent correct by one O/C for all CAS missions flown each day. All O/C scores were very high on day 1, but some improvement was found during the exercise. For day 5, the final scores were between 90–100 percent correct.

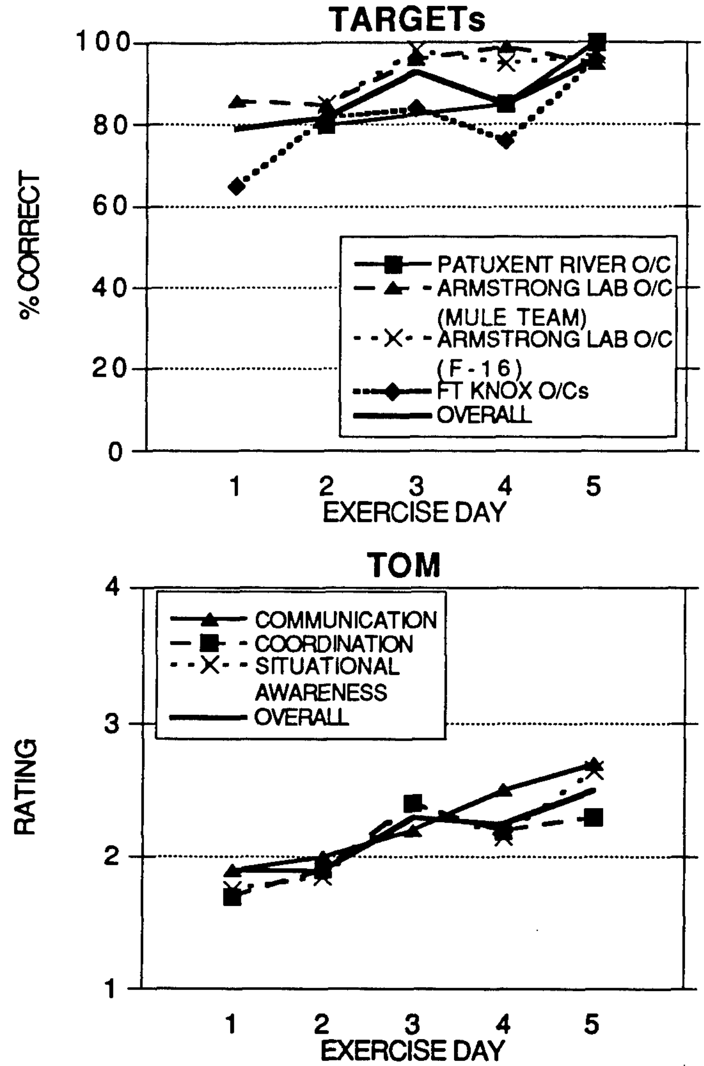


Figure III-2. Contact Point Phase

For the TOM data, all areas were rated below 2 (satisfactory) for days 1 and 2 and above 2 for days 3, 4, and 5 (see Figure III-2). The improvement in the TOM ratings for the CP phase over the exercise was much smaller than those seen in the planning phase. Dwyer et al. observed the difference between the relatively high performance during the CP phase for the TARGETs data and the relatively low performance for the TOM data. They suggested that "there was considerable room for improvement in all areas measured" (Dwyer et al., 1995). Even though the required tasks were performed according to the TARGETs data, the TOM data suggests that communication, coordination, and situational awareness could have been improved.

c. Attack Phase

The same five O/Cs as in the CP phase provided the TARGETs data for the attack phase (Figure III-3). The inter-rater reliability for the Fort Knox site was r = .75. The participants at the Fort Knox site showed significant improvement over the 5 days from a score of about 40 percent correct on day 1 to a score approaching 90 percent correct on day 5. The OV-10 participant and the DFO/MULE team showed improvement over the 4 days, but the initial scores were close to 80 percent correct, and there was less room for improvement (ceiling effect). The F-16 participants' scores were consistently high for the 4 days.

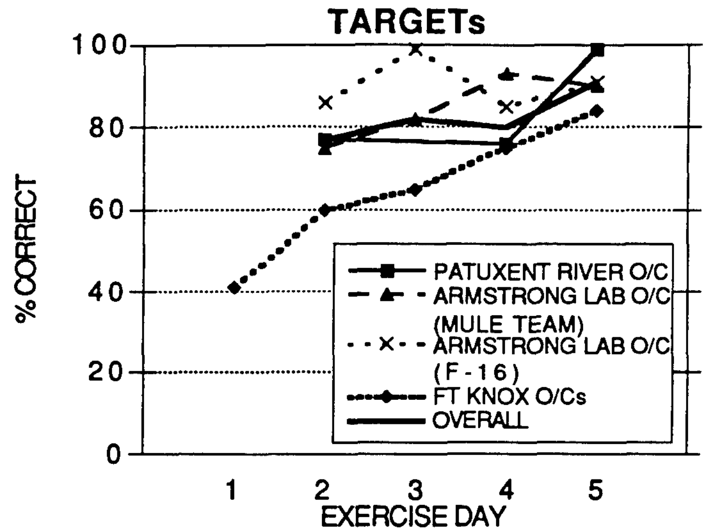
One O/C at Fort Knox provided the TOM data for the Attack Phase shown in Figure III-3. Five participants were rated: the Air Liaison Officer, the Fire Support Officer, the Air Forward Air Controller, the DFO/MULE Team, and the F-16 pilots. All initial ratings were below satisfactory, but all ratings on days 3, 4, and 5 were satisfactory or very good. Clearly, performance improved for all five participants.

2. Outcome Measures

The outcome measures for the MDT2 exercise for the February 1995 exercise included the following:

- the number of bombs released;
- the timing of bomb releases;
- the frequency of bomb releases;
- the number of enemy vehicles hit, damaged, or destroyed;
- the percentage of bombs resulting in a vehicle impact or proximate impact;
- the number of bomb releases resulting in damage or destruction;
- timing and volume of artillery direct fires and CAS fires; and
- the timing and locations of direct and supporting fire impacts (Meliza, 1995).

These are the types of data needed to assess the military value of training in a MDT2-like facility. The data show clear trends in performance related to amount of training even though UPAS, the source of the data, was occasionally erratic.



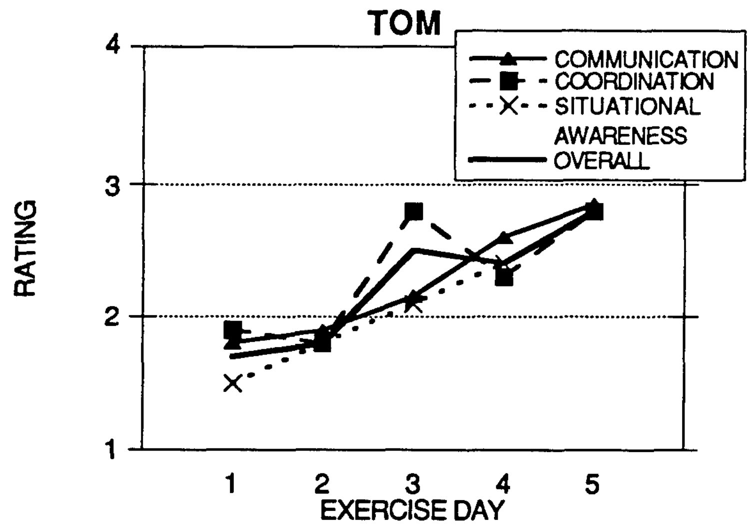


Figure III-3. Attack Phase

a. Number of Bombs Released

Table III-4 shows the number of CAS bombs released by F-16 pilots for each exercise day during the February 1995 exercise (Meliza, 1995). On day 1, the orientation day, only four bombs were released. Comparing bombs dropped during offense (days 3 and 5), there is an increase in bomb release from 11 to 14 bombs over the 2 days. On the defensive trials, there is an increase from 10 on day 2 to 19 on day 4.

b. Frequency of Bombs Released

Table III-4 provides data on bombing performance over the 5 days of the February 1995 exercises (Meliza, 1995). The mean number of bombs released per mission increased for both the offensive and the defensive scenarios. For day 1, there was 1.0 mean release per mission. On offense, the mean bomb releases increased from 3.7 on day 3 to 4.7 on day 5. For the defensive scenario, the bomb releases increased from 2.5 on day 2 to 3.8 on day 4. For day 1, there were no missions with three or more releases, but the percent of missions with three or more releases increased from 66 percent on day 3 to 100 percent on day 5 for the offensive scenario and from 50 percednt on day 2 to 80 percent on day 4 for the defensive scenario. The mean time between bomb releases was 18:31 on day 1. The mean time decreased to 3:39 and 4:12 for days 3 and 5, respectively, for the offensive scenarios. For the defensive scenarios, the mean time between bombs released decreased from 7:12 (day 2) to 4:15 (day 4). The number of releases separated by less than 1 minute also increased for both offensive and defensive scenarios. There were no releases separated by less than 1 minute on day 1, but there were 5 and 10, respectively, on days 3 and 5 (offensive); for day 2 and day 4 the increase was from 2 to 11. Each measure strongly suggests that training using MDT2 increases the capability of a multi-Service team to perform the CAS mission.

Table III-4. Bombing Performance, February 1995 Exercise

	Exercise Day				
Performance Measure	1	2	3	4	5
Number of bombs released per day	4	10	11	19	14
Mean releases per mission	1.0	2.5	3.7	3.8	4.7
% of missions with three or more releases	0	50	66	80	100
Mean time between releases (minutes: seconds)	18:31	7:12	3:39	4:15	4:12
Number of releases separated by less than 1 minute	0	2	5	11	10

c. Number of Enemy Vehicles Hit, Damaged, or Destroyed

Meliza (1995) reported that this measure was unreliable. On analysis, the data stream failed to match the observations reported by O/Cs. The latter indicated damage and destruction that was not reflected in the automated data stream. The discrepancy was caused by missing Change Status PDUs. The Number or Percentage of Bomb Releases Resulting in Damage or Destruction measure also was unreliable due to missing Indirect Fire PDUs and Status Change PDUs. The percentage of bombs resulting in vehicle impact or proximate impact could potentially be used to determine CAS accuracy, but these measures were not calculated for MDT2 (Meliza, 1995).

3. Outcome and Process Data

Tables III-5 and III-6 show outcome and process data for day 2 through day 5 for the 1994 and 1995 CAS training exercises (Love, 1995). Included in both tables are CAS Kills, CAS Misses, Average Engagement Time, Fire Support Synchronization Factor, and Maneuver Synchronization Factor for the defensive scenarios (days 2 and 4) and for the offensive scenarios (days 3 and 5).

Table III-5. May 1994 MDT2 CAS Training Exercise

Performance Measure	Exercise Day			
	2 (Defense)	3 (Offense)	4 (Defense)	5 (Offense)
CAS Kills	3	10	7	8
CAS Misses	n/a	n/a	n/a	n/a
Average Engagement Time	6 min	5 min	5 min	5 min
Fire Support Synchronization Factor	0.50	0.75	1.00	1.25
Maneuver Synchronization Factor	0.25	0.25	0.50	0.50

n/a = not available

Table III-6. February 1995 MDT2 CAS Training Exercise

Performance Measure	Exercise Day			
	2 (Defense)	3 (Offense)	4 (Defense)	5 (Offense)
CAS Kills	3	5	7	9
CAS Misses	3	5	5	2
Average Engagement Time	4 min	3 min	2 min	1.5 min
Fire Support Synchronization Factor	1	2	3	3.5
Maneuver Synchronization Factor	1	1.5	1.5	1.5

a. CAS Kills and Misses

CAS Kills in 1994 showed an increase for the defensive scenario but not for the offensive scenario. CAS Kills increased from three to seven for days 2 and 4, respectively. CAS Kills for day 3, however, were larger than day 5 (10 and 8, respectively).

In 1995, CAS Kills increased for both the defensive and the offensive scenarios. CAS Kills increased from three to seven for days 2 and 4, respectively, in the defensive scenario and from five to nine for days 3 and 5, respectively, during the offensive scenarios. The percentage of bombs hitting the target increased slightly (from 50 percent to 58 percent) for the defensive scenario, but the increase for the offensive scenario was substantial (50 percent to 82 percent).

b. Average Engagement Time

There was essentially no decrease in the average engagement time across the exercise days for the 1994 exercise, but the average engagement time decreased substantially for both defense and offense in 1995. The average engagement time decreased from 4 minutes to 2 minutes for days 2 and 4 (defense), respectively, and from 3 minutes to 1.5 minutes for days 3 and 5 (offense), respectively.

c. Fire Support Synchronization Factor

The proficiency level for day 2 for the 1995 exercise (Fire Support Synchronization Factor of 1) was used as the baseline level of proficiency for days 3, 4, and 5 in 1995 and for days 2, 3, 4, and 5 in 1994. The subjective judgments for this factor showed modest improvement for both defense and offense for 1994. For defense, day 2 was 0.5 or one-half of baseline, and day 4 was 1 or equal to baseline. For offense, day 3 was below baseline (0.75) but day 5 was above baseline (1.25). In 1995, improvements in the Fire Support Synchronization Factor above the baseline were 2 (day 3), 3 (day 4), and 3.5 (day 5). For defensive days, the factor increased from 1 on day 2 to 3 on day 4. For offense, there was an increase from 2 on day 3 to 3.5 on day 5.

d. Maneuver Synchronization Factor

The Maneuver Synchronization Factor of 1 for day 2 in 1995 was used as the baseline. This factor showed a modest increase for both 1994 and 1995. All 4 days of 1994 were below the rating of the baseline, but an increase was found for both defense (.25 to .5 for days 2 and 4, respectively) and offense (.25 to .5 for days 3 and 5, respectively). In 1995, days 3, 4, and 5 were rated at 1.5 compared to the baseline of 1 for day 2.

4. User Reactions

Table III-7 summarizes the comparative data for the post-training opinion surveys conducted after the 1994 and 1995 exercises (Mirabella, 1995, 1996). Five issues were addressed:

- need
- credibility
- multi-Service value
- role in training cycle
- expected impact

The percentage of respondents who agreed that the MDT2 was an effective trainer for CAS was high for the categories of need, multi-Service value, role in the training cycle, and expected impact for both years (84–97 percent agreement for 1994 and 74–100 percent for 1995). The percentage who agreed with the three survey items which pertained to credibility was high for 1994 (77–94 percent) but lower for 1995 (53–69 percent). The effectiveness of MDT2 as an trainer for CAS changed from 81 percent favorable in 1994 to 55 percent in 1995. Judgment on the realism of skill training using MDT2 compared with command training centers (item 15) decreased from 94 percent in 1994 to 69 percent in 1995. Finally, agreement with the question which concerned the realism of CAS tactics using MDT2 compared with field exercises or exercises at Command Training Centers (item 16) decreased from 77 percent in 1994 to 53 percent in 1995. An analysis of the survey data by site indicated that the decrease in the "credibility" rating in 1995 came from Fort Knox (armor) and NAWC (Air FAC) (Mirabella, 1995). This seems due to concerns about the lack of tactical realism, such as unrealistic operational orders, intelligence information and planning, maneuver areas, detection range casualties, and threat capability, and the inaccuracy of some of the training objectives. The decline in positive ratings may be due to more more extensive experience with SIMNET at Fort Knox or variation that often occurs with small samples. The respondents judged that the MDT2 training added to their prior training and helped them reach their objectives (Mirabella, 1995, 1996).

Table III-7. Results of Opinion Survey

Issue	Survey Item (31 subjects each year, across all sites)	% Agree 1994	% Agree 1995
Need	The opportunity provided by MDT2 to practice with personnel from other services is necessary for training CAS	90	90
	MDT2 is a good training system for CAS because it focuses on critical training needs	90	74
	Given the chance, I would like to train with the MDT2 on a period basis	94	83
Credibility	MDT2 can be an effective trainer for CAS with only a few minor modifications	81	55
	A positive aspect of MDT2 is that it gives more realistic feedback on CAS kills than in field exercises or at Combat training centers	94	69
	I can apply more realistic CAS tactics in MDT2 that I can in field exercises or at CTCs	77	53
Multi-Service Value	Experience on MDT2 wil make me better able to interact with members of other services to plan for and execute CAS missionsin combat	90	90
	Training with MDT2 will give me a better understanding of the jobs and role of personnel from other services in planning and conducting CAS	84	87
Role in Training Cycle	Experience on MDT2 will better prepare me for field exercises on CAS missions, such as those at Air Warrior and NTC	87	90
	Training on MDT2 can supplement service-specific CAS training	87	77
Expected Impact	The training that MDT2 provides can be applied directly to combat	97	100
	Estimate the extent to which your experience with MDT2 has affected your ability to perform your role in a mission that uses CAS	93	94

IV. COST ANALYSIS

This chapter describes two cost analyses concerning the use of simulation as a training method. The first analysis compares the costs of running the Phase I and Phase II MDT2 exercises analyzed in terms of effectiveness earlier in this report. This analysis focuses on the reduction of engineering development cost—the cost of developing the software protocols for the simulators and the network used to link them—between Phases I and II. The greater the reduction in these costs, the more we may expect the costs of simulation to fall in the future, and the more attractive this method of training will become as a partner with field exercises in training strategies.

The second analysis deals directly with the costs of conducting simulation and field exercises. Two cases are considered, MDT2 and Aircraft only. The first compares the costs of a hypothetical simulation and a field exercise that use forces that are similar in scale and sized at the company level. Holding the scale of the operation constant makes it easier to interpret the relative costs of the two exercises. The exercises for this case are modeled after the MDT2 exercise, but are scaled up to a company-level exercise, the smallest unit that is actually trained at the National Training Center (NTC). We assume that the early problems of setting up simulations have been solved, and have therefore omitted the substantial engineering development costs that were required in the MDT2 exercises.

Because the Base Case is built around company-level forces, it compares units that are able to train ground-level maneuvers in addition to CAS. The two additional cases are designed to estimate the marginal cost of CAS. The cases vary in the assumption of what other training is occurring at the same time. In the MDT2 case, we assume that the company-level simulations and field exercises considered in the Base Case have been planned for purposes of training ground forces, and that CAS can be added to the training mission of the exercises by simply adding the several aircraft that would participate in the close air support. The costs for this case are limited to those for the aircraft alone.

In the Aircraft Only case, we assume that a ground-level exercise is *not* being planned, and that those who are planning simulation or field exercises to train CAS must therefore provide some limited ground forces. The forces are sized at the level of those used in the MDT2 exercises described before. The field exercise for this case thus includes much smaller ground forces than the smallest, company-level exercises that are actually trained at NTC. Although the case therefore lacks a degree of realism in this respect, it has been included in the analysis to obtain cost estimates in parallel with the MDT2 effectiveness estimates discussed earlier.

Throughout the chapter all costs are in thousands of then-year dollars. The costs were not adjusted for inflation since they are all from a recent 3-year period, and adjusting for the currently small 3-percent inflation rates would not have affected the results. Nor would the results have been affected by converting the costs to present values, using the 2.7-percent discount rate currently mandated for 3-year studies by the Office of Management and Budget.

A. COST OF MDT2 EXERCISES

This section compares the costs of the two MDT2 exercises. Table IV-1 shows the tasks for which the costs are reported. Although the two phases used somewhat different taxonomies, the costs can be compared because the Phase II tasks are groups of Phase I tasks. Note that we call the costs of setting up the network and developing the protocols for the simulators (task 3 of the Phase II categories) engineering development. This term is used here as a general description and not as a synonym for the formal Budget category of 6.4, "Engineering Development."

The costs of Phases I and II are shown in Tables IV-2 and IV-3, using the categories shown in Table IV-1. The figures were obtained from Dr. Franklin Moses, the Program Manager of the MDT2 program at the Army Research Institute. The sources of the funds are the Defense Modeling and Simulation Office (DMSO) and direct appropriations to each Service. The figures show the Services that received the funds, not necessarily those that ultimately used them. The Navy figures include those for the Marine Corps; a small amount of funds spent by IDA for observation are omitted.

The $200,000 Navy overrun in Phase II was paid for by the Army. The Air Force overrun—$300,000 plus the cost of 119 hours of lost time evaluated at $400 per hour—was caused by problems with the DSINet[1] at Armstrong Laboratory. The Phase II costs are the MDT2 budget for FY 1994 found in Appendix A to the MDT2 Phase II project plan.

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1 "MDT2 FY93 Budget," memo of 7-12-93 by Daines of Eagle Technology, Inc.

Table IV-1. Categories for Describing the Phase I and II MDT2 Exercises

Phase I tasks

1. Develop the training objectives
2. Develop the training scenarios
3. Design the performance and feedback instruments
4. Set up the DSI network[1]
5. Integrate the simulators[2]
6. Conduct the exercise[3]

Phase II tasks

Phase II tasks	Phase I tasks
1. Determine the training objectives and scenarios	1,2
2. Design the performance and feedback instruments	3
3. Set up the DSI network[1] and integrate the simulators[2]	4,5
4. Conduct the exercise[3]	6

1 Primarily hardware. MDT2 used the DSINet.

2 Software protocols and test and evaluation.

3 Operating the system, collecting and analyzing the data, recommending improvements to the DSInet and the exercise, and writing reports.

The costs in Tables IV-2 and IV-3 are compared in Table IV-4 using the task categories of Phase II. For example, the $400,000 in Table IV-4 for spending in task 1 in Phase I is the sum of $250,000 and $150,000, the costs shown in Table IV-2 for tasks 1 and 2 using the Phase I categories.

The figures in Table IV-4 indicate that the cost of engineering development, task 3, was substantially less in Phase II. Although both exercises took the same time (5 days) and involved the same scenarios and numbers of trainees, Phase II cost less than 40 percent of Phase I. Tasks 1 and 2, the training preparation tasks, also cost much less in Phase II. The cost of actually conducting the exercise, task 4, was about the same in both phases, as expected.

Table IV-5 groups tasks 1, 2, and 4 as training and task 3 as engineering development. The table highlights the fact that the engineering development costs fell substantially in Phase II. Such reductions in the cost of running simulations increase its attractiveness as a contributor, along with field exercises, to the training mission.

Table IV-2. **Costs of Phase I MDT2 Exercise (May 23–27, 1994)**

Tasks	Expenditure ($ thousands) DMSO	Service	Service Overrun	Total
Army				
1 Training Objectives	50	200		250
2 Training Scenarios	100	50		150
3 Performance Instruments	250	980		1,230
4 Set Up Network				
5 Integrate Simulators	696	100	200	996
6 Conduct Exercise	125	50		175
Navy				
1 Training Objectives				
2 Training Scenarios				
3 Performance Instruments	275	500		775
4 Set Up Network				
5 Integrate Simulators	343	550		893
6 Conduct Exercise		50		50
Air Force				
1 Training Objectives				
2 Training Scenarios				
3 Performance Instruments				
4 Set Up Network	345	350		695
5 Integrate Simulators	488	800	348	1,636
6 Conduct Exercise	43	50		93
Total	2,715	3,680	548	6,943
Summary by task				
1 Training Objectives	50	200	0	250
2 Training Scenarios	100	50	0	150
3 Performance Instruments	525	1,480	0	2,005
4 Set Up Network	345	350	0	695
5 Integrate Simulators	1,527	1,450	548	3,525
6 Conduct Exercise	168	150	0	318
Total	2,715	3,680	548	6,943

Table IV-3. Costs of Phase II MDT2 Exercise (February 13–17, 1995)

Tasks	Expenditure ($ thousands) DMSO	Service	Total
Army			
1 Training Objectives and Scenarios	50	100	150
2 Performance and Feedback Instruments	50	200	250
3 DSI Network and Integrate Simulators		200	200
4 Conduct Exercise	80	130	210
Navy			
1 Training Objectives and Scenarios			
2 Performance and Feedback Instruments	100	150	250
3 DSI Network and Integrate Simulators	50	200	250
4 Conduct Exercise	30	50	80
Air Force			
1 Training Objectives and Scenarios			
2 Performance and Feedback Instruments			
3 DSI Network and Integrate Simulators	300	400	700
4 Conduct Exercise	30	60	90
Total	690	1,490	2,180
Summary by task			
1 Training Objectives and Scenarios	50	100	150
2 Performance and Feedback Instruments	150	350	500
3 DSI Network and Integrate Simulators	350	800	1,150
4 Conduct Exercise	140	240	380
Total	690	1,490	2,180

Table IV-4. Distribution of Costs by Task in Phase I and II

Tasks (Phase II categories)	Phase I Costs: Cost ($ thousands)	Phase I Costs: Percent	Phase II Costs: Cost ($ thousands)	Phase II Costs: Percent	Ratio of Phase II to Phase I Cost
1. Determine the training objectives and scenarios	400	5.8	150	6.9	0.38
2. Design the performance and feedback instruments	2,005	28.9	500	22.9	0.25
3. Set up the DIS network, integrate the simulators, and test	4,220	60.8	1,150	52.8	0.27
4. Conduct the exercise	318	4.5	380	17.4	1.19
Total	6,943	100.0	2,180	100.0	0.31

Task 1. Testing the system, operating the system, collecting the data, assessing the contribution of the exercise to training.

Task 2. Recommending improvements to the DIS network and the exercise, and writing reports.

Table IV-5. Training vs. Engineering Costs in Phase I and Phase II Exercises

	Phase I		Phase II	
	Cost ($ thousands)	Percent	Cost ($ thousands)	Percent
Engineering Development	4,220	60.8	1,150	52.8
Training	2,723	39.2	1,030	47.2
Total	6,943	100.0	2,180	100.0

As an incidental point, $800,000 was spent in Phase II for several activities other than the tasks of preparing and conducting the simulations listed in the previous tables. These additional funds, which are not included in these tables, covered the following tasks: preparation of MDT2 data for in-house and external publications, holding team meetings to discuss the simulations, making the results of the exercises available to Service projects, planning future training readiness exerecises, and conducting research on distributed simulation exercises of air-to-air combat.

B. COST OF SIMULATION vs. FIELD EXERCISES

1. Introduction, Base Case

For purposes of comparison, we constructed hypothetical simulation and field CAS exercises that use the same sizes of friendly and enemy forces, and that are run for the same length of time. We then describe the participants of the two exercises, estimate the personnel and equipment operating costs of the simulation and field exercises, and compare the results. As mentioned earlier, costs are in thousands of then-year dollars, unadjusted for inflation or discounting. Capital costs (procurement and depreciation) were omitted. The analysis involves no procurement because we assume that the simulations and field exercises analyzed in the study would be performed with existing systems. We omitted depreciation because new simulators cost only approximately 10 percent of the cost of new weapons. Assuming that simulators and real weapons have similar lifetimes, including their depreciation costs would only support the findings of the analysis that simulation costs about one-tenth the cost of field exercises.[2]

2 The tank simulators used in the two MDT2 simulations were similar to those used in SimNet. They cost $200,000–250,000, only 7–8 percent of the $3 million for a new M1 tank. Even the new CCTT tank simulator (the Close Combat Tactical Training System) planned for production in 3–5 years will

2. Participants

Table IV-6 lists the participants in the exercises. The forces include those used in the past MDT2 simulations of CAS—key operations personnel from a battalion tactical operation center (TOC), tanks, Bradleys, F-16s, air FAC, and MULE. However, we augmented the two tanks used by the battalion commander and the ETAC and the two tanks used together with "tethered" blue SAFOR to simulate a tank company in MDT2, because, given the high fixed costs of conducting field exercises, training commands do not run field exercises at less than company strength.

The six Air Force F-16s and pilots used in the field exercise would be used in rotation to provide two aircraft at any given time during the 5-day exercise. Thus, only two F-16 simulators are needed. OA-10 aircraft are currently used for the forward air controller (FAC) mission. The DFO/MULE is a three-man, laser target designator team.

The opposing forces in the simulation are all SAFOR (Semi-Automated Forces), i.e., controllers at computer terminals who use software to simulate many-man forces. SAFOR may alter or correct what automated forces sometimes do, such as move through a tree or jump off a bridge. The exercises are administered by O/Cs and Subject Matter Experts (SMEs). The opposing forces were not given aircraft or a DFO/MULE.

Table IV-6. Participants in Simulation and Field Exercise

		Simulation	Field Exercise
Friendly forces	Battalion TOC slice	No major equipment	No major equipment
	Tank Company	16 manned simulators	16 manned weapons
	F-16s	2 manned simulators	6 manned weapons
	OA-10 FAC	1 manned simulator	1 manned weapon
	DFO/MULE	1 manned simulator	1 manned weapon
Opposing forces	1 Battalion TOC slice	SAFOR	Manned weapons
	1 Tank company	SAFOR	Manned weapons
Exercise administration		O/Cs and SMEs	O/Cs and SMEs

only cost about $350,000, or 12 percent of the cost of an M1. The F-16 simulators used in the MDT2 simulations cost about $350,000, one percent of the $25 million cost of a new F-16. The Air Force is developing a new simulator that will cost approximately $25 million. It has 6 degrees of freedom and a dome that provides high fidelity visuals, which might be especially productive for individual training. We assume that they would not be especially productive for multi-Service close air support.

The costs of the exercises—personnel costs through travel of the participants and operating costs through transportation of the equipment—depend on the location of the home stations of the forces. First, consider the transportation costs. For this hypothetical simulation analysis, we assume only that the simulators are located at training bases, and thus require no transportation for the participants. We assume that the equipment for the field exercise, however, would need 2 days for movement to the NTC (1 day at each end). Although the Army keeps an inventory of tanks at NTC for both friendly and opposing sides in field exercises, we allowed 2 days to cover the delays in moving the tanks from storage areas to the exercise area. We assume that the F-16s, the FAC, and the DFO/MULE would be stationed within a day's travel of NTC (the F-16s at Nellis Air Force Base, Las Vegas, or other home bases).

Regarding personnel costs, we assumed no travel costs for the simulation since the simulators would be collocated with the trainees at training bases. For the field exercise, the operators of the friendly weapons might come from training bases distant from NTC. The operators for the friendly tanks, for example, would be stationed at the training base at Fort Riley, Kansas. We therefore allowed the operators of the friendly forces 4 days of travel to NTC (2 days at either end). The operators for the opposing tanks, the only weapons of the opposing forces, are stationed at the NTC (along with their vehicles) and require no travel time.

Although Table IV-6 shows that the simulation and field exercises use the same friendly combatant force sizes (the two F-16 simulators and six F-16 aircraft would each train six pilots), we included costs in the field exercise for the support personnel and equipment required to fuel and maintain the tanks and aircraft. There exist no simulators for these support operations, although they could be modeled by SAFOR at a negligible increase in cost. The costs of these support resources have a major effect on the relative costs of the simulation and field exercises.

Another point concerns the difference between the missions of interest in the MDT2 exercises and those of the forces shown in Table IV-6. Given the presence of a full tank company, the simulation and field exercises can train both maneuver and other combat operations in addition to CAS, which was the principal concern of the MDT2 simulation.

A final point on the exercises represented in Table IV-6 concerns the relative numbers of friendly and opposing Army tank forces. For both exercises they are the same. Actual field exercises, however, usually train both offensive and defensive operations, which have different ratios of opposing to friendly forces. Following the standard assumption that a 3:1 advantage in forces is needed for successful offensive actions, field exercises normally use a ratio of 3:1 for friendly to opposing forces in offensive operations, and a ratio of 1:3 in defensive operations. We will show at the end of this chapter that using these force ratios for offensive and defensive operations would only strengthen our findings that simulation is much less costly than field exercises.

3. Simulation

a. Personnel costs

The personnel costs of the simulation and field exercises consist of civilian and military personnel wages during the 5 days of the exercise. We estimated the wage costs by applying the standard wage rates shown in Table IV-7 to the numbers of people involved. The costs for military personnel in Table IV-7 are average pay and allowances for active forces in the Continental United States. These data were obtained from the Force Cost Model developed for the Army Cost and Economic Analysis Center in Falls Church, Virginia.

Table IV-7. Military and Civilian Annual Wage Rates

	Annual Pay and Allowances ($ thousands)	Including 20% Overhead Rate ($ thousands)
Military		
E1	17.9	21.5
E2	20.2	24.2
E3	21.4	25.7
E4	27.3	32.8
E5	33.1	39.7
E6	37.6	45.1
E7	44.6	53.5
E8	51.2	61.4
E9	60.6	72.7
O1	35.7	42.8
O2	47.9	57.5
O3	60.3	72.4
O4	76.2	91.4
O5	88.1	105.7
O6	106.9	128.3
Civilian	80.0	96.0

An average professional wage rate is used for civilian personnel. Both military and civilian rates were increased by a 20 percent overhead cost to cover services such as secretary and utilities. Civilian wages are included under personnel costs, although such costs are funded under Operations and Maintenance (O&M) appropriations in DoD budgeting. We include wages for military personnel in the analysis to capture the benefits of the reduction in travel and transportation time for simulation training. A reduction in training time would not lead to a reduction in military force levels, which are set for wartime needs; it would, however, release military personnel for other useful tasks, and their wages are a proxy measure for the value of these tasks.

Table IV-8 shows the results of applying the wage rates to the numbers of personnel. The annual wage costs from Table IV-7 are first divided by 260 working days per year to obtain the costs per day, and then multiplied by 5, the number of days for the exercise, yielding the final costs in the last column.

b. Operating Costs

We derived the operating costs of the simulation using historical costs from the MDT2 exercises: the expenditures for the use of the simulators, shown in Table IV-9, and the costs of setting up the T-1 lines for the network, shown in Table IV-10. The simulators had been bought by DoD and given to a contractor organization for maintenance and operation for Service training exercises. The simulator costs in Table IV-9 are thus the lease costs paid to the contractor, which exclude capital costs (procurement or depreciation). We converted these lease costs to daily costs per simulator by dividing by the number of simulators in the lease by the number of days specified and then by 1,000, to convert to thousands of dollars. The daily operating cost for the DFO/MULE is higher than that for the tanks because it is an initial prototype. There are no transportation costs since the simulators are assumed to be located at training bases. We assume that the operating costs of the computers used by the TOC and SAFOR personnel are negligible.

We assume that these historical costs for simulators and the network are typical enough to serve as a reasonable estimate for the present analysis. In Table IV-11 we use them to estimate the operating costs for the simulation. The daily costs of the simulators are multiplied by the number of simulators and by five, the number of days in the present analysis. (The MDT2 costs that are expressed per week are later converted to daily costs for comparison with the daily costs of actual weapons.) The operating costs of SAFOR are assumed to be negligible and are omitted.

Table IV-8. Personnel Costs of Simulation

	Number of Personnel	Rank	Cost per Day ($ thousands)	Days per Exercise	Cost per Exercise ($ thousands)
Friendly Forces					
Army Battalion Tactical Operations Center (TOC)					
Commander	1	O5	0.41	5	2.03
S-3	1	O4	0.35	5	1.76
S-2	1	O3	0.28	5	1.39
Fire support officer	1	O3	0.28	5	1.39
Assistant S-3	1	O3	0.28	5	1.39
Fire support NCO	1	E6	0.17	5	0.87
USAF tactical air control party					
Air liaison officer (ALO)	1	O4	0.35	5	1.76
Enlisted terminal attack controller	1	E6	0.17	5	0.87
Total TOC	8				11.46
Army Tank Company					
Command tanks (2)					
Commander	1	O3	0.28	5	1.39
Executive officer	1	O2	0.22	5	1.11
Driver	2	E7	0.41	5	2.06
Gunner	2	E5	0.31	5	1.53
Fire support team chief	1	E7	0.21	5	1.03
Bradley Fighting Vehicles (2)					
Scouts	2	O2	0.44	5	2.21
Drivers	2	E6	0.35	5	1.74
Gunners	2	E5	0.31	5	1.53
Company tanks (12)				5	
Commanders (12)	12	3 O2s, 3 E7s, 6 E6s	2.32	5	11.62
Drivers	12	E7	2.47	5	12.35
Gunners	12	E5	1.83	5	9.17
Total tank company	49				45.71
USAF F-16 attack pilots	2	O3	0.56	5	2.78
USMC OA-10 Air Forward Air Controller (FAC)	1	O4	0.35	5	1.76
USMC DFO/MULE					
Operator	1	O2	0.22	5	1.11
Forward observer	1	E6	0.17	5	0.87
Ground forward air controller	1	E6	0.17	5	0.87
Total MULE	3				2.84
Total Friendly forces	67				64.56

	Number of Personnel	Rank	Cost per Day ($ thousands)	Days per Exercise	Cost per Exercise ($ thousands)
Opposing Forces					
1 Battalion TOC SAFOR	1	Civilian	0.37	5	1.85
1 Tank Company SAFOR	1	Civilian	0.37	5	1.85
Total opposing forces	2				3.69
Exercise Administrators (O/Cs and SMEs)	10	1 O5, 2 O4s, 3 O3s, 4 civilians	3.42	5	17.10

Table IV-9. Operating Costs of the Simulators Used in the MDT2 Exercises

	Lease Data For MDT2	Cost per Day ($ thousands)
Tank	$30,000 per week for 7 simulators	0.860
F-16	$3,200 per day for 2 simulators	1.600
OA-10	$1,600 per day for 1 simulator	1.600
MULE	$10,000 per week for 1 simulator	2.000

Source: Dr. Franklin Moses of the Army Research Institute.

Table IV-10. Costs of Setting up the T-1 Line in the MDT2 Exercises (Phase II)

	Number	Unit cost ($ thousands)	Total ($ thousands)
KG-194 (including encryption device, power supply, and rack)	2	7.13	14.25
Ethernet bridge for Fort Knox	1	5.00	5.00
Ethernet bridge interface board	1	1.50	1.50
T-1 CSU/DSU for Fort Knox	1	1.50	1.50
T-1 CSU/DSU for Patuxent River	1	1.50	1.50
T-1 installation	1	4.30	4.30
T-1 monthly cost	8	6.31	50.51
Miscellaneous cabling	1	0.50	0.50
Total			79.06

Source: Dr. Franklin Moses of the Army Research Institute.

Table IV-11. Operating Costs of Simulation for the 5-Day MDT2 Exercise

	Number	Operating Cost per Simulator per Day ($ thousands)	Days per Exercise	Cost per Exercise ($ thousands)
Friendly forces				
Tanks	16	0.860	5	68.80
F-16s	2	1.600	5	16.00
OA-10s	1	1.600	5	8.00
DFO/MULE	1	0.250	5	10.00
Total friendly forces				102.80
Opposing forces				0.00
Exercise administration				
Electronics network				79.06

Source: Dr. Franklin Moses of the Army Research Institute.

4. Field Exercise

a. Personnel Costs

In Table IV-12 the personnel costs for the field exercise are based on the annual personnel costs for the individual units shown in the first column. These are direct costs obtained from Service documents such as the Army's Force Cost Model mentioned earlier. These costs include expenditures not only for the combatant forces but also for substantial logistics and other direct support without which fighting units cannot operate, either in battle or exercise. However, consistent with the costs of the simulation, we have not added in allowances for recruiting, training, retirement, or base operations support.

We converted the annual personnel costs into daily costs per weapon by dividing by the number of weapons in each unit and by 260 working days per year. We included the personnel costs for all six F-16s on the grounds that all six pilots would be involved each day. Only two aircraft would fly at any given time, but all six would be needed to cover a full exercise day by rotation. One F-16 could not fly the entire day because of maintenance considerations. Each pilot, moreover, would have to spend some time during the day on briefings and de-briefings associated with the exercise. Because costs for the OA-10 aircraft were not available, costs for the A-10A were used instead. The OA-10 is a modified version of the A-10A, and the costs are therefore similar.

Table IV-12. Personnel Costs for the 5-Day CAS Field Exercise

	Unit Data			Exercise Data				
	Annual Personnel Cost per Unit ($ thousands)	Number of Weapons	Personnel Cost per Weapon per Day ($ thousands)	Number of Weapons	Exercise Time (Days)	Travel Time (Days)	Cost per Exercise ($ thousands)	Number of Personnel
Friendly forces								
TOC					5	4	11.09	6
Tank company	2,064	16	0.496	16	5	4	71.45	63
F-16 squadron	22,420	18	4.791	6	5	4	258.69	64
OA-10 squadron	13,891	12	4.452	1	5	4	40.07	29
MULE team	356	1	1.369	1	5	4	12.32	4
				Total friendly forces			393.62	166
Opposing forces								
TOC							11.09	6
Tank company	2,064	16	0.496	16	5	0	71.45	63
							82.54	69
Exercise administration							17.11	10

The daily costs per weapon were multiplied by the numbers of weapons in the exercise and by the time for the exercise (5 days) plus air travel of the trainees to the exercise site from training bases such as Fort Riley for the tank personnel (2 days on each end). The personnel to man the opposing tanks are permanently stationed at NTC, and thus require no travel.

b. Operating Costs

In Table IV-13 the weapon operating costs are based on annual direct OPTEMPO operating costs for the military units. (We assume that operating costs for the computer terminals used by the TOC are negligible.) As with the personnel costs, these unit operating costs include expenditures for logistical support. These costs are divided by the numbers of weapons in each unit to obtain annual costs per weapon. Because operating costs are higher than average on the days devoted to exercises, we scaled down the annual costs to daily costs using individual weapon activity levels, rather than using the number of days per year (as in Table IV-12). For example, the annual cost of the tanks was divided by 800 miles, the nominal annual OPTEMPO activity level for tanks, and multiplied by 50 miles per day, the daily activity level assumed for the exercise. The daily activity levels shown in Table IV-13 are based on exercise experience. We estimated the costs for the DFO/MULE, which includes an armored personnel carrier, at half the cost for a tank.

Table IV-13. Operating Costs for the 5-Day CAS Field Exercise

	Unit Data						Exercise Data			
	Annual OPTEMPO Cost per Unit ($ thousands)	Number of Weapons	Number of OPTEMPO Miles or Flying Hours per Year	OPTEMPO Cost per Weapon per Mile or Flying Hour ($ thousands)	Number of Miles or Flying Hours per Day	OPTEMPO Cost per Weapon per Day ($ thousands)	Number of Weapons	Number of Days per Exercise	Number of Days for Travel	Cost per Exercise ($ thousands)
Friendly forces										
TOC										--
Tank company	2,563	16	800	0.200	50	10.012	16	5	2	1,121.31
F-16 squadron	7,589	18	357	1.181	5	5.905	2	5	2	82.67
OA-10 squadron	6,635	12	442	1.251	5	6.255	1	5	2	43.78
DFO/MULE team				0.100	50	5.006	1	5	2	35.04
Total										1,282.81
Opposing forces										
TOC										0.00
Tank company	2,563	16	800	0.200	50	10.012	16	5	2	1,121.31
Total										1,121.31
Exercise administration										0.00

We multiplied the daily costs per weapon by the number of weapons (including the two Bradley Fighting Vehicles with the tanks) and by the 5 days for the exercise plus 2 days for transporting the weapons to the exercise fields. The tanks are stored at permanent shelters at NTC, and the aircraft fly from Nellis Air Force Base or other nearby training fields.

5. Summary of Numerical Results

The final costs of the exercises, summarized in Table IV-14, show that the field exercise costs over 10 times as much as the simulation. There are three major reasons for this result:

- Support resources. Although both exercises involve the same combatant units and number of combatant personnel, only the field exercise includes logistic support resources. To understand the role of these resources in the overall results, note that the field exercise has over three times as many people as the simulation.

Table IV-14. Summary: Number of Personnel and Costs for Simulation and Field Exercises (5-Day CAS)

	Total Number of Personnel		
	Simulation	Field Exercise	Ratio
FRIENDLY	63	166	
OPPOSING	2	69	
O/CS/SMES	10	10	
TOTAL	75	245	3.3
TOTAL COST ($ thousands)			
Friendly			
Personnel	$65	$394	
Operating	$103	$1,283	
Opposing			
Personnel	$4	$83	
Operating	--	$1,121	
Exercise administration			
Personnel	$17	$17	
Operating	$79	--	
Total			
Personnel	$85	$493	5.8
Operating	$182	$2,404	13.2
Total	$267	$2,897	10.8
COST PER PERSON TRAINED ($ thousands)	$3.6	$11.8	

- Travel and transportation. The people and weapons in the field exercise require substantial travel and transportation costs that are not required for distributed simulation. Eliminating travel costs from the personnel costs of the field exercise in Table IV-12 reduces the ratio of total personnel costs between the two types of exercise from 5.8 to 3.4, approximately the ratio of the total numbers of people. Eliminating the transportation costs in Table IV-13 reduces the ratio of operating costs substantially, from 13.2 to 9.4.
- Simulator and weapon operating costs. Real weapons are much more costly to operate than simulators. Tables IV-11 and IV-13 show that for the four types of forces (tanks, F-16s, OA-10s, and MULEs), the real weapons are 11.8, 3.7, 3.9, and 20.0 times, respectively, as costly as the simulators.

The calculations we have described so far assume equal numbers of friendly and opposing Army forces. However, as we mentioned earlier, actual field exercises are often run with different ratios of these forces, corresponding to offensive and defensive operations. Table IV-15 shows the results of separate calculations for these two types of operations. On the standard assumption that attackers need a 3:1 advantage for success, the costs of the opposing forces in Table IV-14 are multiplied by 1/3 and 3, for offensive and defensive operations, respectiely. The costs of the friendly forces are held constant for convenience. The new cost ratios of field exercise to simulation are 7.9 for offensive operations and 19.3 for defensive operations. For an exercise consisting of offensive and defensive operations of equal duration, the cost ratio is 13.6 [(7.9 + 19.3)/2]. This value is *36 percent higher* than the cost ratio of 10 in Table IV-14. Most of the increase is due to the changes in the costs of the field exercise; the costs of the simulation hardly change because of the small contribution of the opposing forces to total cost.

6. MDT2 AND AIRCRAFT ONLY

The Base Case just analyzed consists of company-level ground forces as well as aircraft, and is thus able to train ground maneuver missions as well as CAS. This section presents an analysis of two cases that are designed to estimate the marginal cost of CAS.

Table IV-15. Costs of Offensive vs. Defensive Operations (Costs in Thousands of Dollars)

	Offensive Operations			Defensive Operations			Average		
	Simulation	Field Exercise	Ratio	Simulation	Field Exercise	Ratio	Simulation	Field Exercise	Ratio
Friendly forces									
Personnel	$65	$394		$65	$394				
Operating	$103	$1,283		$103	$1,283				
Opposing forces									
Personnel	$1	$28		$11	$248				
Operating		$374			$3,364				
Exercise administration									
Personnel	$17	$17		$17	$17				
Operating	$79			$79					
Total									
Personnel	$83	$438	5.3	$93	$658	7.1	$88	$548	6.2
Operating	$182	$1,657	9.1	$182	$4,647	25.6	$182	$3,152	17.3
Total	$265	$2,095	7.9	$275	$5,305	19.3	$270	$3,700	13.6

The MDT2 case is modeled after the forces in the MDT2 exercises analyzed earlier in this report. It assumes that ground forces are not otherwise available for ground exercises, so that the CAS exercise we are analyzing must bring along a minimum amount of ground forces that are needed to train close air support. Relative to the Base Case, the number of friendly and opposing tanks is reduced from 16 to 5, and all other forces are retained: the F-16s, FAC, MULE in the friendly forces, and the people for exercise administration. The Aircraft Only case assumes that a major, company-level ground exercise has been planned, and the only forces one must add for training CAS are the two F-16s and OA-10 forward air controller.

Table IV-16 shows costs for these latter cases and for the Base Case. The costs are the averages of those for offensive and defensive operations, where the opposing offensive and defensive force costs are multiplied by 1/3 and 3, respectively.

Table IV-16. Summary of All Cases (Costs InThousands of Dollars)

	Base Case			MDT2			Aircraft Only		
	Simulation	Field Exercise	Ratio	Simulation	Field Exercise	Ratio	Simulation	Field Exercise	Ratio
Personnel	85	493	5.8	45	395	8.7	22	299	13.8
Operating	182	2,404	13.2	135	827	6.1	24	126	5.3
Total	267	2,897	10.8	180	1,222	6.8	46	425	9.3

As expected, the costs of simulation and field exercise in the MDT2 and Aircraft Only cases—the cases that focus only on the marginal costs of CAS—are substantially smaller than those for the Base Case. The important observation for this study, however, is that the field exercise is still substantially more costly than the simulation, but with a smaller ratio than in the Base Case. There are two reasons for this: (1) it costs much more money to operate a real tank for a day than to run a tank simulator for a day, and (2) this ratio is much higher for tanks than for the F-16s, OA-10, and MULE.[3] (Aircraft cost more to operate per hour than tanks do per mile, but we have assumed that tanks are operated many more miles than F-16s hours are flown during the exercise day.)

If the calculations are repeated for the offensive and defensive operations and averaged, the ratio of field exercise to simulation rises for the MDT2 case, as it did for the Base Case shown in Table IV-15 above. The new ratio is 8.0. (There is no rise in the Aircraft Only case, which contains no opposing forces.) In short, whether we are considering CAS with either company-level or minimum ground forces, simulations appear to cost approximately one-tenth as much as field exercises.

7. Caveats, Discussion, and Policy Implications

An obvious question is whether our principal finding is general—whether all field exercises would prove much more costly than simulations involving similar forces for CAS exercises. We see no apparent biases in the way we have constructed the exercises for analysis, which suggests that our finding may be fairly general, although we have not made additional tests.

Another question concerns the policy implications of the analysis. If field exercises are, indeed, more costly than simulations of the same size and type, does that suggest that simulation is thereby a more efficient training mechanism than field exercises? This question cannot be resolved by cost comparisons without effectiveness data. Because of the absence of effectiveness data for field exercises, we were not able to consider an optimum combination of simulation and field exercises in a CAS training program.

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3 To illustrate with a hypothetical example, suppose that the daily operating costs of 2 real F-16s and 16 real tanks—the force levels for the Base Case—are 2 and 100, respectively, and that the costs of 2 F-16s and 16 tank simulators are 1 and 10, respectively. Thus, the real tanks are 10 times more costly than the simulator tanks, and the ratio of real to simulator tanks is greater than the ratio of real to simulator aircraft. The ratio of total costs of F-16s and tanks in the field exercise to those of the simulation is thus (2+100)/(1+10), or approximately 10. If the number of tanks is now reduced from 16 to 5, as it is in the MDT2 case, the ratio of real-to-simulator total costs becomes (2+31.25)/(1+3.125), or 8.1.

V. DISCUSSION

The MDT2 system, as its name indicates, is a testbed intended to explore the potential utility of linking simulators of different Services to support training on a common mission, in this case, CAS. Because not all of the simulators used in the MDT2 testbed had been designed to communicate with each other, interface units had to be developed to permit aircraft, ground vehicles, tanks, and target designators to exchange information so that they could see each other's actions on a common terrain—selected here to be the Army's NTC at Fort Irwin, California. Interface problems had to be solved before questions related to the utility of multi-Service training could be addressed; problems with communications, engineering, and software incompatibilities will diminish as new simulators are built to standards now established for DIS systems.

Although each Service conducts training on its own roles and missions in CAS, insufficient attention has been given to training objectives dominated by issues of inter-Service communication, coordination, and synchronization. In fact, the MDT2 program found it necessary to compile a list of 25 training objectives and subordinate tasks that must be performed to support both multi-Service training and evaluation of CAS exercises. It is clear that all of these background capabilities and objectives must be developed and tested before the main purpose of using DIS for multi-Service training can be addressed. It must be emphasized that the MDT2 is a functional prototype, an initial engineering version (dominated by what equipment was available), and not a mature, fully-developed system. Nevertheless, it was possible to conduct tests that permitted us to evaluate the potential effectiveness and cost of such a system for CAS training and thereby provide a baseline for estimating the utility of more fully developed, networked simulations for training multi-Service and joint operations.

The data clearly show that performance improved over the course of an exercise. This applies to each phase of the exercise (planning, contact point, and attack), to offensive and defensive missions, and to performance assessed by both process and output measures. The process measures evaluated conformance to specified procedures with regard to function (e.g., target selection and synchronization) and participants (e.g., pilots and target designators). The output data also show that performance improved with practice on such measures as kills, reduction in time to engage, and measures of synchronization for fire support and maneuver. Personnel who participated in the exercises were generally favorable to MDT2 as a method of training CAS, although some participants had reservations about its "credibility" (the performance data, of course, suggest the opposite).

An analysis of the costs of training CAS in MDT2 or at the NTC suggests that the latter would cost over 10 times as much as comparable training in MDT2.[4] Costs for training at the NTC are larger because of expenditures for transportation of people and equipment, higher operating and support costs of equipment in the field (compared to those for simulators), and the larger number of support people needed in a field exercise. The cost of the second set of exercises was about half of that for the first, suggesting that the cost of training in MDT2 would decrease as the design and experience with this type of system increases.

An important qualification must be noted: the effectiveness of the MDT2 to train the CAS mission has been demonstrated only in the simulator. The extent to which personnel trained in MDT2 can also perform well in CAS field exercises remains to be demonstrated, and it is unwarranted to assume otherwise. Note also the relatively large disparity in the costs of using an MDT2-like system for training CAS rather than the NTC. MDT2 (or any simulator) should not be thought of as a substitute for live training. Rather, the critical question is to determine the best and most cost-effective combination of virtual, live and constructive training for various types of missions.

These points need further clarification. It is generally accepted that the effectiveness of a simulator should be evaluated by the extent to which skills learned there are demonstrated in the real world of an exercise or use of an actual weapon; this is called "transfer." (Transfer to actual combat is rarely mentioned.) This approach is based on an incomplete paradigm. Simulation is not simply a reduced version of a field exercise (or use of an actual weapon, such as an airplane or a tank). It may provide opportunities for training not available in the real world, such as large-scale exercises, firing dangerous weapons (e.g., chemicals), engine-out maneuvers in aircraft, using and not exposing classified weapons, operating in poor weather, or practicing maneuvers that would spoil the environment. Simulation also provides accurate feedback and performance measures.

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4 To provide a baseline for estimating costs, this analysis assumes that the offensive and defensive forces were of equal size.

To summarize, simulation and actual exercises each have some unique capabilities with, of course, some overlap. Different aspects of warfighting can be uniquely trained by each method. Development of a practical (perhaps even optimal) combination of the two to provide preparation for warfighting is an essential and generally missing ingredient in planning for military training. Development of a methodology for determining optimal combinations for specific missions should be vigorously pursued.

In addition to its potential role in training, MDT2-like systems provide a means of preparing for and estimating training readiness for particular missions. Rapid generation of new scenarios as crises become apparent and evaluation of performance as training progresses promise useful indications of training readiness.

The MDT2 is also the first example of a DIS developed and evaluated empirically for multi-Service training on a common mission. Many of the problems that had to be solved (and their costs) to make the different simulators able to interoperate do not have to be repeated if the MDT2 is used for further tests or actual training. Some of these same problems will no longer exist when and if future simulators are designed to support interoperability with other simulators, regardless of mission.

A recent report describes the use of a distributed, networked simulation to train operators of a fire control panel. The Army Research Laboratory, Aberdeen, Maryland, developed a distributed Fire Support Command and Control Testbed (FSC2) and used it to evaluate the training effectiveness of a prototype Fire Control Panel Trainer for the Multiple Launch Rocket System (Bouwens, Ching, and Pierce, 1996). The testbed linked manned simulators (virtual simulation), combat models (constructive simulations), and actual equipment (live simulation) at Aberdeen Proving Ground, Maryland, and Fort Sill, Oklahoma.

The scenario for evaluating the training effectiveness of the fire control panel represented a force-on-force battle driven by CIMUL8, a computer-based model that generated call-for-fire messages at the battery fire direction center (Copenhaver, Ching, and Pierce, 1996). At the start of the exercise, the self-propelled launcher-loader was located at a hide point. Using the Fire Control Panel Trainer, operators were required to perform all of the steps necessary to direct the launcher to the point requested by the fire direction center, fire the mission, and move the launcher to a second hide point. A run consisted of two missions, after which directions would be given to stow the weapon. Thirty students at Fort Sill performed three runs each within a period of about 2 hours. Data were collected on the response time and the number of errors for each run. Response time per mission decreased from about 4 to 3 minutes and errors were reduced from about 1 to 0.4 per mission. Learning clearly took place. Although this test provided only a limited amount of training (that may be called "initial learning"), soldiers, on average, were able to meet the time criterion for an acceptable level of performance after the second scenario run. No information is available on the retention of these skills (e.g., a week or a month later) or on their transference to actual field exercises. No cost analysis was performed.

Simulation architectures and communication protocols currently undergoing development will enable many different types of simulators to be linked together relatively easily and in an ad hoc fashion to support particular (and often narrow) training requirements. When such capabilities become available, there will be less need for simulators committed to a single use. In any case, single-use simulators are cost-effective only when used frequently enough to justify their cost. The need for single-use simulators will decline as a new generation of interoperable simulators becomes available. These simulators will be available around the clock for a variety of purposes both within and between the services. The MDT2, then, is notable for being the first working example of such a future system.

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GLOSSARY

AAR	After Action Review
ACA	Airspace Coordination Areas
AFAC	Airborne Forward Air Controller
AGOS	Air-Ground Operations School
AL	Armstrong Laboratory, Air Force
AL/HRA	Armstrong Laboratory/Aircrew Training Resources Division
ALO	Air Liaison Officer
ALSA	Air, Land, Sea Application Center
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ATR	After Training Review
BN	Battalion
CAS	Close Air Support
CCTT	Close Combat Tactical Trainer
CIG	Computer Image Generator
CIMUL8	a non-interactive simulation driver (proprietary by BDM International, Inc.)
CP	Contact Point
DDR&E	Director Defense Research and Engineering
DFO/MULE	Deployed Forward Observer/Modular Unit Laser Equipment
DIS	Distributed Interactive Simulation
DMDC	Defense Manpower Data Center
DMSO	Defense Modeling and Simulation Office
DSInet	Distributed Simulation Internet
ETAC	Enlisted Terminal Attack Controller
FAC	Forward Air Controller
FCPT	Fire Control Panel Trainer
FIST	Fire Support Team
FSC2	Fire Support Command and Control Testbed
FSO	Fire Support Officer
FTX	Field Training Exercise
IDA	Institute for Defense Analyses

MCCDC	Marine Corps Combat Development Command
MDT2	Multi-Service Distributed Training Testbed
MLRS	Multiple Launch Rocket System
MODSAF	Modular SAFOR
MOE	Measure of Effectiveness
MOP	Measure of Performance
MWTB	Mounted Warfare Test Bed
NAWC	Naval Air Warfare Center, Patuxent River, Maryland
NAWCAD	Naval Air Warfare Center, Aircraft Division
NAWCTSD	Naval Air Warfare Center, Training Systems Division
NIU	Network Interface Unit
NTC	National Training Center
O&M	Operations and Maintenance
O/C	Observer/Controller
OPTEMPO	Operating Tempo
OUSD	Office of the Under Secretary of Defense
PDU	Protocol Data Unit
PVD	Plan View Display
SAFOR	Semi-automated Forces
SEAD	Suppression of Enemy Air Defense
SIMNET	Simulator Networking
SME	Subject Matter Expert
TAC-A	Tactical Air Controller–Airborne
TACP	Tactical Air Control Party
TARGETs	Targeted Acceptable Response to Generated Events or Tasks
TF	Task Force
TOC	Tactical Operations Center
TOM	Teamwork Observation Measure
TTP	Tactics, Techniques, and Procedures
UPAS	Unit Performance Assessment System
VTC	Video-teleconference
WAN	Wide Area Network

APPENDIX A

CLOSE AIR SUPPORT TRAINING OBJECTIVES

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CLOSE AIR SUPPORT TRAINING OBJECTIVES

Source: Franklin L. Moses
Multi-Service Distributed Training Testbed
Phase I: Overview and Lessons Learned
Army Research Institute, Alexandria, VA
March 1995 (Draft)

Table 1. Training Objectives: Critical Tasks at Multi-Service Interfaces (source: Bell, H.H., D.J. Dwyer, L.L. Meliza et al., 1996 draft)

Number	Title
1	Determine battalion mission intent and concept of operation
2	Determine the enemy situation
3	Develop CAS target priorities
4	Develop priority of intelligence collection assets to detect CAS targets
5	Integrate CAS and other fire support elements with maneuver actions
6	Institute fire support control/coordination measures
7	Initiate airspace coordination areas (ACAs)
8	Incorporate SEAD in the fire plan
9	Protect laser team
10	Prepare a decision synchronization matrix
11	Establish methods to identify targets during CAS operations
12	Establish methods to identify friendly troops during CAS operations
13	Conduct a fire support/CAS rehearsal
14	Pass preplanned CAS targets to higher headquarters
15	Prioritize all CAS requests from subordinate commanders
16	Pass immediate targets and on-call target updates to higher headquarters
17	Provide initial brief to pilots and controllers
18	Update airborne pilots as necessary
19	Perform communications check among all fire support and CAS participants
20	Control CAS air attack
21	Confirm status of friendly air defense
22	Arrive on station and establish initial communications
23	Synchronize CAS attack with other direct and indirect fires
24	Conduct CAS attack
25	Return from and assess CAS mission

APPENDIX B

REFERENCE MATERIAL PREPARED BY THE MDT2 TEAM

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REFERENCE MATERIAL PREPARED BY THE MDT2 TEAM

Read-a-Head Packet for Multi-Service Distributed Training Testbed (MDT2), 13-17 February 1995 Exercise
- MDT2 Information Paper
- CAS Overview
- Training Objectives
- Scenario
- After Action Reviews
- Exercise Schedule

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Assessment of User Reactions to Close Air Support (CAS) Training:
Preliminary Results and Recommendations for Designing Fielded System
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13. ABSTRACT ***(Maximum 180 words)***

The Multi-Service Distributed Training Testbed (MDT2) is a network of eight Army, Marine Corps, and Air Force simulators (tanks, aircraft, target designator, and tactical operations center) in different locations that can operate together as if all were engaging an enemy at the same location. All are involved in the mission of close air support. Two sets of exercises were conducted, each lasting 5 days. The results show that performance improved, as shown by measures of battle damage, synchronization of forces, and adherence to coordination procedures. Several comparisons of the costs of conducting training for close air support using this type of simulation or participation in field exercises favors simulation by a factor of ten. The findings provide strong evidence for the utility of distributed interactive simulation as a way to provide multi-Service training.

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Distributed interactive simulation, multi-Service training, training effectiveness, training cost, training cost-effectiveness.

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