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Distributed Embedded Simulation And Training Research: Realistic Fire On Target Effects

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Realistic Fire on Target Effects

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Terminology

AFIST	Abrams Full-Crew Interactive Simulator Trainer
AGS	Armored Gun System
ARL	Army Research Laboratories
BED	Battlefield Environment Directorate, ARL
BV/LD	Ballistic Vulnerability/Lethality Division, ARL
CCTT	Close Combat Tactical Trainer
CIG	computer image generator
CM	center of mass
COMBIC	Combined Obscuration Model for Battlefield Induced Contaminants
DIS	Distributed Interactive Simulation
DOD	Department of Defense
ES	Embedded Simulation
ET	Embedded Training
HE	high explosive
ICM	Improved Conventional Munitions
IG	Image Generator
INVEST	Inter-Vehicle Embedded Simulation Technology
IST	Institute for Simulation and Training
I/ITSEC	Interservice/Industry Training, Simulation and Education Conference
KE	kinetic energy
KEWERT	Kinetic Energy Weapons Effects in Real-Time
MCTFIST	Marine Corps Tank Full-Crew Interactive Simulator Trainer
MILES	Multiple Integrated Laser Engagement System
MUVES	Modular UNIX-based Vulnerability Estimation Suite
PDU	protocol data unit
PGS	Precision Gunnery System
P_k	probability of kill
$P_{k/e}$	probability of a kill given an encounter
$P_{k/h}$	probability of a kill given a hit
SEP	System Enhancement Package
SME	Subject Matter Expert
STOW	Synthetic Theater of War
STRICOM	U.S. Army Simulation, Training, and Instrumentation Command
TTES	Team Target Engagement Simulator
TWGSS	Tank Weapons Gunnery Simulation System

1.0 Project Overview

This project entailed research into portraying realistic fire on target effects in virtual training systems. In live training and combat environments, gunners observe their fire on and around a target to adjust the accuracy of their fire. Observing the effect of their efforts is a key aspect of gunnery training.

As the state of technology in weapons systems is improved, enhanced sighting systems such as the M1A2 System Enhancement Package (SEP) 30 Power Sight Magnification (30X) will allow gunners to more closely view the fire on target effects, gain detailed feedback on their previous efforts, and allow them to improve their skills. In contrast, the visual effects of direct fire, indirect fire, and mines on targets in today's virtual training systems may not always provide the crew of the weapons system positive training reinforcement.

This research project sought to gain a better understanding of the state of technology of fire on target effects in Virtual Training Systems, and the alternatives available to portray accurate visual effects of direct fire, indirect fire, and mines on targets. The research objective is to determine the usefulness of current virtual training systems to the Inter-Vehicle Embedded Simulation Technology (INVEST) Program and to investigate emerging technologies which may be useful to the INVEST Program.

1.1 Training and Simulation Requirement

The INVEST program will support training that ranges from individual training through crew training, up to and including force-on-force training at the battalion level. The fire on target effects virtual models must have the fidelity required to support the training needs at these levels.

Some of the primary objectives of crew level training will be Precision Gunnery Training, familiarization training, and sustainment training. Precision Gunnery Training requires the highest level of fidelity in the fire on target effects virtual models.

As mentioned, a key aspect of gunnery is the gunner's ability to observe and learn from each round fired on the target. Ideally, the gunner aims for the center of mass (CM) of the target, and the round impacts the target at or near the CM. Realistically though, a weapon may be fired when the crosshairs are off the CM due to various circumstances. In a live fire situation, this would cause the round to impact at some other location on the target, or even miss the target completely. The gunner most probably knows the location of the crosshairs at the time the weapon is fired; the gunner's ability to observe and note the result maximizes the learning opportunity from each round fired.

Embedded Simulation and Training should work in a similar manner. That is, the gunner should be able to observe and learn from each simulated round fired on the target. For positive training reinforcement and to maintain proficiency, the gunner should observe a unique and appropriate effect each time a munition is fired and the crosshairs are on a different portion of the target. If the target is missed, the gunner should also observe an appropriate damage effect where the munition impacts the environment. Future vehicle enhancements such as the M1A2 SEP 30X sight will allow the gunner to observe much higher levels of detail than previously seen on the battlefield or in training.

High fidelity and realistic fire on target effect virtual models are required for Embedded Training/Embedded Simulation (ET/ES) at the crew level. The platoon and company level training will focus on force-on-force and mission rehearsal training. In this type of training, the objectives involve unit coordination, maneuvers, tactics and objectives that focus on target detail to a lessor degree. High fidelity models may not be needed to complete the training mission in this environment.

1.2 Research Strategy

The research strategy used by the Institute for Simulation and Training (IST) included a review of recent papers and publications addressing the current status of the Department of Defense (DOD) modeling of weapons effects, and a review of ongoing research in the area of weapons effects. Additionally, this effort examined the weapons effects, vehicle models, and implementation of several closely related training devices including: the Abrams Full Crew Interactive Simulator Trainer (AFIST), Close Combat Tactical Trainer (CCTT), Synthetic Theater of War (STOW), and Tank Weapons Gunnery Simulation System Precision/Gunnery System (TWGSS/PGS). These weapons system trainers were selected because each has recently completed development, and have either been fielded or are currently being fielded.

IST completed a detailed review of the models, special effects, and documentation for models used in the CCTT. The methods used to select the fire on target effects for several systems, including CCTT and TWGSS, were analyzed. The objective of the reviews was to determine whether the fire on target effects provided the necessary level of fidelity for positive training reinforcement.

1.3 Vulnerability Model and Graphics Display Model

The development of realistic fire on target effects can be subdivided into two different areas; the Vulnerability Model and the Graphics Display Model. Both models must be high fidelity for the fire on target effects to be realistic and accurate. Some of the research efforts that were reviewed concentrated only on the Graphics Model, while other efforts addressed both models.

The Vulnerability Model determines what occurs given a hit on a target and typically provides some type of single, expected-value for the probability of a kill given a hit ($P_{k/h}$) as the final result. In the past, this simplified approach to vulnerability modeling has been used in simulations requiring real time performance due primarily to the computational complexity of munitions modeling. The training objective of the simulation being developed, and the small number of live fire test results available also contribute to the decision to use this Vulnerability Model.

Using the results of the Vulnerability Model, the Graphics Display Model creates and displays a representation of those effects for hits on the target, or the associated environmental effects in the event the target is missed. The effects displayed are often modeled from video taken during live fire testing and are limited for the same reasons as the Vulnerability Model.

2.0 Current Implementation of Models

2.1 CCTT Models

The CCTT Database Design Document provides an abundance of general information on the virtual models developed for that system[1]. (See Attachment A for a list of the CCTT models).

Additionally, each of the 94 models in the CCTT database is individually documented with a detailed Model Documentation Sheet[2]. The Model Documentation Sheet provides model identification by name, model number, description, inspection date, entity type, and database; resource information; interactive information; engineering notes; and 3-D plots. (See Attachment B for a sample Model Documentation Sheet). Each vehicle model has been designed from approved source material with the assistance and concurrence of U.S. Army subject matter experts; the models are fully validated. Model validation includes all the model states and special effects such as muzzle flashes, missile and rocket launches, fire and smoke, dust trails, and tracers[3].

2.1.1 Detailed Analysis of CCTT Models

The CCTT database contains a large library of well-documented moving Graphics Models that are primarily combat vehicles and aircraft. As detailed in the documentation, the models and their damaged or destroyed versions were developed with emphasis on two criteria: the need to minimize the number of polygons for each model and the need to model each entity using key recognition criteria[4]. The damaged or destroyed version of a model, such as a vehicle, is represented by several alternatives or levels of kill as detailed in the Compendium of Algorithms[5].

2.1.1.1 Variables Used by CCTT for Direct Fire

For the Vulnerability Model used with direct fire weapons, the host computer system calculates the probability of a kill given a hit ($P_{k/h}$). The variables considered for $P_{k/h}$ calculations in CCTT are the type of munition (for example, tank kinetic energy (KE) round, antitank guided missile, machine gun), the range, the target orientation, and the target exposure. The host computer then runs a Monte Carlo simulation using the $P_{k/h}$ and lethality estimates for the vehicle under fire. The damage and special effects models to be displayed are selected by the computer image generator (CIG) from a small library of damage models using the result of the Monte Carlo simulation.

2.1.1.2 Variables Used by CCTT for Indirect Fire

The special effects for indirect fire weapons are computed in similar manner. However, different factors are included in probability of kill (P_k) calculations each time a target is fired upon. The factors for indirect fire weapons include the impact location, the angle of fall, the fuse type (point detonating or proximity), the platform to target range, and the munition lethal area. The indirect fire weapons provide additional complexity by requiring a different damage function for each weapons class, high explosive (HE) or improved conventional munitions (ICM). Again, the fire effect model to be displayed is selected by the CIG as the result of the Monte Carlo simulation in the host computer with P_k and lethality estimates for the vehicle under fire.

2.1.1.3 Variables Used by CCTT for Minefields

The calculations for minefields include vehicle width, representative vehicle weight, distance into the minefield and density of the mines. The probability of a kill given an encounter ($P_{k/e}$) is then weighed against a Monte Carlo simulation in the host computer to determine which level of kill results. The fire effect model to be displayed is selected in the same manner as for direct and indirect fire.

2.1.1.4 Fire Effect Model Displays and Associated Special Effects

After the calculations for the direct fire, indirect fire, or mines, the CIG then displays a fire effect model. The fire effect model is one of three different damage models used to represent a Catastrophic Kill, Mobility Kill, Functional Kill, or Firepower Kill along with a detonation special effect, followed by smoke and fire effects. The damage models are either

- a physically altered version of the combat vehicle model to show damage,
- a version of the combat vehicle model which has been altered by adding texture to show a burned pattern where the damage occurred, or
- the destroyed version of a combat vehicle with added texture to show a burned pattern over the entire vehicle.

The detonations of the munitions are visualized by independent weapons-specific animated explosions, followed by smoke and fire effects. The detonation displayed is a function of the munitions' type and vehicle class with adjustments for fuels and weapons loading. Detonations are rapid and engulf the target vehicle. Once the detonation is complete, the damaged or destroyed model remains with smoke and fire effects. Aircraft models are an exception and do not have damaged or destroyed states. The aircraft models use smoke or smoke and fire to depict burning aircraft and represent the only damaged states for aircraft.

Other special effects such as muzzle flashes, missile and rocket launches, fire and smoke, dust trails, dirt blasts, and weapons blasts are animations attached to the vehicle models, or in the case of dirt blasts and weapons blasts, placed at the point of impact or detonation. Tracers are modeled as light points.

2.2 Abrams Full-Crew Interactive Simulator Trainer (AFIST) Models

The AFIST uses two-man portable appended devices to provide a training environment for the Abrams crew while in garrison. This system provides the user with a virtual battlefield visible through the combat vehicle's viewports and sights. The display system is mounted in front of the viewport or sight. The models used in AFIST were taken from another program, the U. S. Marine Corps Tank Full-Crew Interactive Simulator Trainer (MCTFIST), which developed models with higher polygon counts. The AFIST Graphical Models have higher detail than those of CCTT, however, AFIST uses the same Vulnerability Model as used in CCTT. Because the special effects are very similar, additional details on the AFIST will not be addressed in this report.

2.3 Synthetic Theater of War (STOW) Models

A design goal of the Dynamic Virtual Worlds in Distributed Interactive Simulations Project is to enable Synthetic Theater of War (STOW) system developers to add new environmental effects to the Synthetic Environment[6]. A review of Dynamic Virtual World Models found the Munition Smoke, Burning Vehicle Smoke, and Vehicular Dust of particular interest. The obscuration effects of smoke and dust are provided by the Combined Obscuration Model for Battlefield Induced Contaminants (COMBIC), which was developed by Army Research Laboratories (ARL)

Battlefield Environment Directorate (BED). The model is physics based using wind, humidity, temperature, and pressure on the aerosol yield, cloud buoyancy, transport, and diffusion. The COMBIC model uses two primary types of data: the environmental conditions and the obscurant source descriptions. The smoke and vehicle dust appear realistic in the video tape provided by Lockheed Martin.

2.4 Tank Weapons Gunnery Simulation System/Precision Gunnery System (TWGSS/PGS) Models

The TWGSS/PGS Program also incorporates appended equipment to provide a training solution, but in this case for live simulation. This system uses TWGSS equipped tanks, PGS equipped infantry/cavalry fighting vehicles, and a Multiple Integrated Laser Engagement System (MILES) to evaluate the effectiveness of firing engagements whether in a tank gunnery exercise or a tactical training environment.

TWGSS and PGS provide a display with a weapon effect simulation. A transceiver, part of the hardware composing the system, is preprogrammed with the physical and operational characteristics of the weapon it is simulating. Lasers are used to transmit pulses and receive reflections from targets. The transceiver determines the target position and transmits the point of impact, type of ammunition, and identity of the attacker to the target. A Retro Detector Unit on the target receives the information, and a Target Computer Unit then determines the result of the engagement based on a programmed Vulnerability Model.

The Vulnerability Model for TWGSS/PGS assigns P_k values to various locations on the combat vehicle. The locations and associated P_ks can be modified by the users with TCAD, a software package which is provided with the TWGSS/PGS system. TCAD allows a P_k to be assigned to a polygon representing a part of the vehicle's structure as shown in attachment C. TWGSS/PGS displays a detonation on target, splash on target, or in the event that the target is missed, a ground burst. Additionally, TWGSS/PGS has the capability to display damaged vehicles in some training modes.

3.0 Related Work

3.1 The Aberdeen Proving Ground (APG) Penetration Model

The U.S. Army Research Laboratory has developed a software package that integrates empirical models of kinetic energy (KE) effects on cultural features, specifically building structures, in real time combat situations[7]. The software system, called KEWERT for Kinetic Energy Weapon Effects in Real Time, uses a physics based methodology to model penetration for the weapons of interest. The developers established several assumptions to accomplish this effort:

- weapons of interest use kinetic energy to produce their effects. Blasts or shaped charge effects are not dealt with;
- material properties of the panels making up the buildings are homogenous and isotropic;
- if the penetration depth is less than the projected panel thickness, then no perforation has occurred, the panel is not damaged, and no holes are formed.

As the combat scenario proceeds, the KEWERT software is called when a Distributed Interactive Simulation (DIS) Detonation Protocol Data Unit (PDU) involving a kinetic energy weapon and a cultural feature is received. KEWERT uses the velocity, location, and weapon type from the

Detonation PDU, the round's diameter and mass from the Weapons Effect Table, and structure data from the Panels Table.

Three separate mathematical approaches are used to produce estimates of the penetration effects on panels made of wood, ceramic, and metal. The material type index in the Panels Table determines which model (wood, ceramic, or metal) will be used. The models calculate the penetration depth using the velocity, mass, location diameter, panel depth, material density, wall material parameter, and x, y, and z components of the wall. Once the penetration depth of the projectile is calculated, it is compared to panel thickness. If the penetration depth exceeds the panel depth, the weapon will perforate the panel. The graphics software then creates the appropriate sized hole by modifying the graphics structure of the building. If the projectile does not perforate the panel, no physical damage will be displayed or recorded, and the action as a result of the Detonation PDU is complete.

Before displaying the hole, the software must calculate the shape of the hole. The hole formed by the projectile is nearly always elliptical in shape, the exception being the projectile that impacts normal to the wall producing a circular hole. KEWERT passes information on the ellipse back to the calling program for display by the CIG. The CIG modifies the polygons representing the cultural feature penetrated by the weapon, and the hole is displayed in the panel.

3.2 The Million Facet Model

The Million Facet Program was started after Desert Storm when it was noted that Master Gunners were having difficulty assessing damage to targets the gunners had engaged. The problem arose because certain types of munitions provide little indication when they have impacted and killed the target, whereas the same munitions provide a large plume when hitting the dirt short of the target. The gunners, because there was no indication a target was destroyed, were firing additional munitions at previously killed targets. And conversely, since a munition short of the target made a huge plume, the gunners often misinterpreted this plume as a hit, perceived a kill, and ignored the enemy targets which were in fact undamaged[8].

Under the Million Facet Program, a vehicle damage model, a detonation model, and a fire model were developed for the Bradley M3 using video data gathered from actual tests on the T-72 tank. The Virtual Target was initially modeled with more than 850,000 facets (polygons), providing a very high level of detail. The facets are designed around components, and each component of the vehicle is separately modeled as a part that can be manipulated by the detonation of the munition. Each moving part on the combat vehicle is fully articulated. The simulation Graphics Model was developed for both the visual and infrared spectrum. The Graphics Model applies damage to the virtual target, but due to the high fidelity of the Graphics Model, this is not a real-time process. The Virtual Target is compatible with DIS and receives a Detonation PDU to initiate the detonation of the munition.

As the blast sequence is applied, the observer will see parts and components blown off the target vehicle. A physics based approach is used to depict the effect of the blast. This approach is not a Vulnerability Model, but in this case is a technique used to provide realism in the destruction of the vehicle. Blast fires and smoke effects are modeled from the video taken during tests and displayed from a graphics library.

At the completion of the simulation run, the damaged model is saved as part of a process to develop a special effects library. A video of the Million Facet Model is being developed and should be available during November 1997. Additionally, demonstrations are being planned for the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM) and

Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) in the FY98Q1. Documentation on the process is forthcoming[9].

Current work on this project involves "decimating" the 850,000 facet model down to a 140 facet model and applying the high resolution damaged texture and components to the 140 facet model. At this time, the model has been decimated to 1,400 facets for real-time display. In the near future, efforts will verify software compatibility with database architectures and formats.

This project is also investigating dynamic models for munitions which miss the target and impact the terrain. Plans call for mathematical analysis by the U.S. Army Corps of Engineers Waterways Experiment Station, followed by research into visual display of the special effect.

3.3 Dynamic Damage Model

IST has successfully implemented a physics based Dynamic Damage Model in another combat simulation, the Team Target Engagement Simulator (TTES), where Damageable Buildings were implemented in a virtual urban environment[10]. The dynamic structures permit a trainee to use explosive munitions in a completely arbitrary manner. The effect of the munitions is computed and displayed on the building. Depending on the charge used, a hole will appear in the building where the munition was detonated, and the hole will be properly sized for the weight of the munition and the wall properties. In addition, the hole is a true hole. One can see through the hole, walk through it, and fire a weapon through it. If the explosive charge does not penetrate the wall, a crater is formed.

Calculations for the Vulnerability Model in the TTES cannot be performed within the time constraints required for a real-time simulation, therefore algorithms based on empirical results and lookup tables were used. Damage computations consist of determining the effect of a munition on a particular component, modifying the component to accurately reflect the damage, and removing any unsupported components from the simulation.

3.4 Vulnerability Model

Deitz and Saucier provide analysis of the state of Vulnerability Models at the Ballistic Vulnerability/Lethality Division (BV/LD) of ARL in their work titled "Modeling Ballistic Live-Fire Events"[11].

The research of Deitz and Saucier indicates that very few vulnerability models reflect the variability intrinsic to many ballistic interactions. The existing models all terminate with a single, expected-value for the final result, rather than yielding statistical distributions of possible outcomes. Additionally, review of existing vulnerability models shows there are many ballistic effects such as blast, shock, fire, and toxic fumes that can cause significant damage, but are not modeled.

The Modular UNIX-based Vulnerability Estimation Suite (MUVES) Program is an improvement program that started at ARL in 1986. When finished, MUVES will model the:

- hit location
- penetration depth
- ballistic limit velocity
- penetrator breakup
- deflection of KE long rod penetrators

- ricochet angle of KE long rod penetrators
- spall and
- component P_k.

The first application for the MUVES Vulnerability Model will be the Armored Gun System (AGS). MUVES will continue to be a research model and as such will not run in real-time. However, this research could lead to a lower fidelity real-time model adequate for simulation and training needs. Other studies and research at BV/LD address shock-blast loading and resulting component damage.

4.0 Conclusions

The current CCTT models and their special effects are adequate for today's training devices and for demonstrations in conjunction with development of the INVEST Program. These models meet the training requirements for current systems, have detailed documentation, and are validated by source documents as well as Subject Matter Experts (SME).

5.0 Recommendations

The following recommendations and considerations are suggested based on the requirements detailed here, in conjunction with anticipated technology advancements.

5.1 Graphic Models

There are numerous research efforts within industry and government which are investigating Graphics Models for realistic fire effects on environmental features, cultural features, and combat vehicles. The research topics include blast size and shape, fire size and color, smoke, dust, craters, and other effects such as munitions impacting the soil and water. The efforts of industry and government in their research coupled with advances in computer hardware and CIGs will most probably provide more realistic graphic models and platforms for the models to run on before the INVEST Program reaches a production milestone. It is recommended that STRICOM monitor the research and development programs, making recommendations where necessary to support the INVEST Program. In order to meet training requirements detailed in this report, the INVEST Program should implement the most dynamic targets available that can be supported by the INVEST hardware.

The Million Facet Model Program has potential use as a test bed for research, especially its highest fidelity, the 850,000 facets. This modeling approach details items to the component level, which would facilitate a variety of research studies. Because of CIG requirements, this level of fidelity is not practical for the INVEST Program; however, other agencies within the U.S. Army may be able to leverage from its development and capability. The lower facet models, say 1,400 facets or less, may be practical for application in the INVEST Program for non-training applications. For example, using a model with this level of detail, the CIG could return the polygon which was hit for further analysis in a study involving ceramic armor.

5.2 Vulnerability Models

Several government laboratories are working toward a Vulnerability Model which is representative of the vehicle's characteristics when hit by a particular weapon. This research is extremely complex and time consuming. The product will be computationally intensive due to the complexity of the vehicle components and structure, and may never mature to an entirely physics based Vulnerability Model running in real-time. Nevertheless, INVEST should continue to monitor progress in this research.

5.3 New Equipment Models

The models viewed in this research project are legacy models. As developmental programs field new hardware, the model library will require appropriate additions for friendly and opposing forces. Those additions should be developed using the latest state of technology for Vulnerability and Graphics Models.

6.0 Issues

The lack of available technical data was a disappointment and hampered this research effort. Technical data is considered a requirement to validate the quality of the fire on target effect models. IST was unable to obtain source materials depicting actual results of combat vehicles coming under fire. The reason may be that most source material is recorded with a specific weapon under test impacting a component or a combat vehicle. The association of the weapon with a specific target renders the source materials classified.

IST also experienced difficulty in obtaining copies of developed models for evaluation. The researchers were able to arrange demonstrations at several local company offices; however, demonstrations outside IST limited the depth of IST's evaluation to the extent that a contractor allowed IST to view a model. One cannot assume that the contractors restricted IST's evaluation, but that an in-depth demonstration for IST's evaluation would have placed an expensive burden on the contractors involved. The models do exist in several different formats and as part of several different programs, without a central repository. It would be of benefit to the INVEST Program to have the models of interest available at a central repository for INVEST participants.

7.0 Recommendations for Further Research

Opportunities for additional research exist in the following areas:

- **Evaluation of the Million Facet Model with Low Cost Visuals.** This effort could contribute significantly to the INVEST Program. It would allow for the detailed evaluation of the Million Facet Model, checking the model for portability, for compatibility with terrain databases, and for training application. This would also provide a challenge for the Low Cost Visual Program.
- **Implementation of a Location based and Stochastic Vulnerability Model.** An alternative design for the fire on target special effects could more accurately depict the visual effects that gunners observe on and around the target to adjust their fire. The current CCTT implementation meets the training requirements of that system, but may lack the fidelity necessary for more precise gunnery training, especially with improvements under development such as the M1A2 SEP 30X sight. One consideration for improvement to special effects could be a location based and stochastic Damage Model which provides fire

on target effects based on the location of munition impact and the type/size of munition used. In this concept, the fire on target special effects would be based on less complex computations for each munition impacting the target vehicle. The visual effect would be a function of the location where the vehicle is hit. This is a technique similar that used in the TWGSS program.

- **Designation of IST as a distribution point for databases and models for the INVEST Program.** STRICOM could make arrangements to make a variety of models available in the repository for INVEST participants.

- **Evaluation of the size of an explosion as a function of the explosive charge of the weapon and angle of attack.** This would permit analysis of issues such as whether targets hit at an angle have the blast sprayed to the obtuse angle and if so, at what angle the blast is deflected.

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[8] Interview with Mr. Henry Jehan, Deputy PM, ITTS, STRICOM of October 6, 1997.
[9] Interview with Ms. Nikki Rawson, ITTS Program Office of October 8, 1997.
[10] C. Lisle, D Nelson, G. Prasad, and J. Ortiz, "AN IMPLEMENTATION OF DAMAGEABLE BUILDINGS IN A VIRTUAL ENVIRONMENT", Institute for Simulation and Training, University of Central Florida, Orlando, FL, Nov. 1996.
[11] P. Deitz and R Saucier, MODELING BALLISTIC LIVE-FIRE EVENTS, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, http://web.arl.mil/reports/modeling/tacom.7.html.

Appendix A

CCTT Model Data Sheets

Listed by Section and Model Name

REFERENCE ONLY

Volume	Section Name	Lot	Model No.	Model Name	Model Description
1	U.S. Vehicles	MM 13	224	M1025	M1025 HMMWV Armament Carrier
1	U.S. Vehicles	MM 13	225	M1043	M1043 HMMWV Armament Carrier
1	U.S. Vehicles	MM 13	226	M1044	M1044 HMMWV Armament Carrier
1	U.S. Vehicles	MM 7	179	M1064	M1064 Mortar Carrier
1	U.S. Vehicles	MM 8	180	M1078	M1078 LMTV Cargo Truck
1	U.S. Vehicles	MM 8	181	M1079	M1079 LMTV Van
1	U.S. Vehicles	MM 8	182	M1083	M1083 MTV Cargo Truck
1	U.S. Vehicles	MM 8	183	M1083 Volcano	M1083 MTV Cargo Truck w/ Volcano
1	U.S. Vehicles	MM 8	184	M1089	M1089 MTV Wrecker
1	U.S. Vehicles	MM 8	185	M1091	M1091 MTV Tanker
1	U.S. Vehicles	MM 7	178	M109A6	M109A6, Self-Propelled Howitzer
1	U.S. Vehicles	MM 4	163	M113	M113A3 Armored Personnel Carrier
1	U.S. Vehicles	MM 4	160	M1A1	M1A1 Abrams Main Battle Tank
1	U.S. Vehicles	MM 4	161	M1A2	M1A2 Abrams Main Battle Tank
1	U.S. Vehicles	MM 7	176	M270	M270 MLRS
1	U.S. Vehicles	MM 4	162	M2A2	M2A2 Bradley Fighting Vehicle
1	U.S. Vehicles	MM 4	164	M577	M577A1/A2 APC Command Post
1	U.S. Vehicles	MM 5	168	M58A3	M58A3 Mine Clearing Line Charge
1	U.S. Vehicles	MM 5	165	M60 AVLB	M60 Armored Vehicle Launched Bridge
1	U.S. Vehicles	MM 5	166	M728	M728 Combat Engineer Vehicle
1	U.S. Vehicles	MM 6	175	M88A2	M88A2 Recovery Vehicle
1	U.S. Vehicles	MM 5	167	M9	M9 Armored Combat Earthmover
1	U.S. Vehicles	MM 13	227	M93	M93 NBC Reconnaissance Vehicle
1	U.S. Vehicles	MM 13	222	M966	M966 HMMWV TOW Missile Carrier
1	U.S. Vehicles	MM 6	171	M977	M977 HEMTT Cargo
1	U.S. Vehicles	MM 6	172	M978	M978 HEMTT Fuel Servicing
1	U.S. Vehicles	MM 7	177	M981	M981 FIST-V
1	U.S. Vehicles	MM 6	173	M984E1	M984E1 HEMTT Wrecker
1	U.S. Vehicles	MM 6	174	M985	M985 HEMTT Cargo
1	U.S. Vehicles	MM 7	136	M992	M992 FAASV
1	U.S. Vehicles	MM 13	223	M998	M998 HMMWV Cargo/Troop Carrier
1	U.S. Vehicles	MM5	169	Mine Plow	Mine Plow for M1 /M1A1
1	U.S. Vehicles	MM5	170	Mine Roller	Mine Roller for M1 /M1A2
1	U.S. Aircraft	MM 1	137	A-10A	A-10A Thunderbolt II Attack Aircraft
1	U.S. Aircraft	MM 1	135	AH-1S	AH-1S Cobra Attack Helicopter
1	U.S. Aircraft	MM 1	139	AH-64	AH-64 Apache Attack Helicopter
1	U.S. Aircraft	MM 2	144	F-16B	F-16B Fighting Falcon Multirole Fighter
1	U.S. Aircraft	MM 1	140	OH-58D	OH-58D Kiowa Warrior Attack Helicopter
1	U.S. Aircraft	MM 2	148	UH-60A	UH-60A Blackhawk Utility Helicopter
1	U.K. Vehicles	MM 3	150	Challenger 2	Challenger 2 Main Battle Tank
1	U.K. Vehicles	MM 3	151	Chieftain	Chieftain Main Battle Tank
1	U.K. Vehicles	MM 3	152	Warrior	Warrior Armored Fighting Vehicle
1	French Vehicles	MM 3	153	AMX-10P	AMX-10P IFV
1	French Vehicles	MM 3	154	AMX-10RC	AMX-10 RC Armored Car
1	French Vehicles	MM 3	155	AMX-30	AMX-30 Main Battle Tank
1	French Vehicles	MM 3	156	AMX-40	AMX-40 LeClerc Main Battle Tank
1	German Vehicles	MM 3	157	Leopard 1A4	Leopard 1A4 Main Battle Tank
1	German Vehicles	MM 3	158	Leopard 2	Leopard 2 Main Battle Tank
1	German Vehicles	MM 3	159	Marder 2	Marder 2 Armored Fighting Vehicle
1	Missiles/Rockets	MM 14	228	TOW II	TOW II missile

CCTT Model Data Sheets

Listed by Section and Model Name

Volume	Section Name	Lot	Model No.	Model Name	Model Description
2	C.I.S. Vehicles	MM 9	186	2S1	2S1 122mm Self-Propelled Howitzer
2	C.I.S. Vehicles	MM 11	204	2S12	2S12 120mm Mortar
2	C.I.S. Vehicles	MM 9	189	2S19	2S19 152mm Self-Propelled Howitzer
2	C.I.S. Vehicles	MM 11	205	2S23	2S23 120mm Howitzer/Mortar
2	C.I.S. Vehicles	MM 9	187	2S3	2S3 152mm Self-Propelled Gun
2	C.I.S. Vehicles	MM 10	195	2S31	2S31 120mm Combination Gun
2	C.I.S. Vehicles	MM 9	188	2S6	2S6 Air Defense System
2	C.I.S. Vehicles	MM 9	190	ACRV	ACRV (MT-LB 1V12)
2	C.I.S. Vehicles	MM 12	212	BAT-2	BAT-2 Combat Engineer Vehicle
2	C.I.S. Vehicles	MM 10	198	BMP II	BMP II
2	C.I.S. Vehicles	MM 10	199	BMP III	BMP III SIFV
2	C.I.S. Vehicles	MM 10	196	BMP1Ksh	BMP IKshM Command Vehicle
2	C.I.S. Vehicles	MM 10	197	BMP1P	BMP IP w/ AT-4 ATGW
2	C.I.S. Vehicles	MM 10	200	BRDM2 ATGM	BRDM 2 w/ AT5 ATGM
2	C.I.S. Vehicles	MM 10	201	BRDM2 RC	BRDM 2 Reconnaissance Vehicle
2	C.I.S. Vehicles	MM 12	213	BREM-1	BREM-1 Recovery & Repair Vehicle
2	C.I.S. Vehicles	MM 11	206	BTR60PB	BTR60PB Armored Fighting Vehicle
2	C.I.S. Vehicles	MM 11	207	BTR80	BTR80 Armored Fighting Vehicle
2	C.I.S. Vehicles	MM 11	208	D30	D30 122mm Howitzer
2	C.I.S. Vehicles	MM 12	218	GAZ-66	GAZ-66 4x4 Truck
2	C.I.S. Vehicles	MM 12	214	GMZ	GMZ Tracked Mine Layer
2	C.I.S. Vehicles	MM-12	215	KMT-5M	KMT-5M Mine Clearing Roller/Plow
2	C.I.S. Vehicles	MM 12	221	KrAZ-255B Cargo	KrAZ-255B 6x6 Truck
2	C.I.S. Vehicles	MM 12	220	KrAZ-255B Fuel	KrAZ-255B Fuel Service Truck
2	C.I.S. Vehicles	MM 12	216	MT-12	MT-12 100mm Anti-tank Gun
2	C.I.S. Vehicles	MM 12	217	MTU-20 AVLB	MTU-20 Armored Bridgelayer
2	C.I.S. Vehicles	MM 10	202	SA13	SA-13 SAM
2	C.I.S. Vehicles	MM 10	203	SA15	SA-15 Gauntlet SAM
2	C.I.S. Vehicles	MM 11	209	T62	T62 without Reactive Armor
2	C.I.S. Vehicles	MM 11	210	T64BV	T64BV with Reactive Armor
2	C.I.S. Vehicles	MM 9	191	T72Bv	T72Bv w/ Reactive Armor
2	C.I.S. Vehicles	MM 9	192	T72M	T72M Main Battle Tank
2	C.I.S. Vehicles	MM 9	193	T80	T80 without Reactive Armor
2	C.I.S. Vehicles	MM 9	194	T80Uv	T80Uv with Reactive Armor
2	C.I.S. Vehicles	MM 12	219	UAZ-469B	UAZ-469B 4x4 Light Vehicle
2	C.I.S. Vehicles	MM 11	211	ZSU-23/4	ZSU-23/4 Quad 23mm AAA
2	C.I.S. Aircraft	MM 2	149	Ka-50	Ka-50 Hokum A Attack Helicopter
2	C.I.S. Aircraft	MM 1	141	Mi-24W	Mi-24W Hind E Helicopter Gunship
2	C.I.S. Aircraft	MM 1	142	Mi-28	Mi-28 Havoc Combat Helicopter
2	C.I.S. Aircraft	MM 1	143	Mi-8TBK	Mi-8TBK Hip Utility Helicopter
2	C.I.S. Aircraft	MM 2	145	MiG-27D	MiG-27D Flogger J Attack Aircraft
2	C.I.S. Aircraft	MM 2	146	Su-17R	Su-17R Fitter C Attack Aircraft
2	C.I.S. Aircraft	MM 2	147	Su-24	Su-24 Fencer C Attack Aircraft
2	C.I.S. Aircraft	MM 1	138	Su-25	Su-25 Frogfoot Attack Aircraft

Appendix B

CCTT

Model Documentation Sheet

7 August 1996 v1

Model Name:	M1A1	**Model Inspection Date:**	2/7/95
Model Number:	160	**Entity Type:**	1.1.225.1.1.2.0
Model Description:	M1A1 Abrams Main Battle Tank	**Database:**	Central U.S.

1 RESOURCE INFORMATION

1.1 Source Data

The following validated source data was used in the generation of this model. These materials are located in Orlando, Florida at the PMCATT Data Repository.

Type of Source	*Title*	*Media/Area*	*ID #*
1.1.1 Geometry	General Dynamics Blue Prints	5 aperture cards	002.025.002
1.1.2 Texture	US/GE Standardized Camouflage Pattern Painting	6 drawings	059.046.001
1.1.3 Color	Federal Standard 595B Color, Marking and Camouflage TB 43-0209	pgs 16,31,46 pgs 1-27	093.079.001 088.097.001
1.1.4 Thermal (IR)	Center for Night Vision and Electro-Optics USA-AMSEL-NV-TR/0076	pgs A22-A28	081.006.001
1.1.5 Light Amplified (NVG)	Miscellaneous Software Data (Color to B&W conversion for light intensified simulation)	document	500.310.008
1.1.6 Vehicle Markings	Tactical Vehicle Combat-Operational Markings	document	088.192.001
1.1.7 Identification Features	FKSM 17-224 Armor Fighting Vehicle Identification	pgs 88, 89	082.188.001
1.1.8 Origin	DIS Standards IEEE 1278-1993	document	086.114.004
1.1.9 SME	CPT Allen - Ft Knox SFC Henry - Orlando IDT SFC Sawyer - Ft Knox Steve Burzlaff		

1.2 Polygon Allocation

The total visible out-the-window polygons are shown below at various ranges from the eyepoint. At each range a best/worst case polygon count is shown. Best case represents the model at a 90° angle to the eyepoint (side view). Worst case represents the model at a 225° inclined angle to the eyepoint (top-front-left view)

Model State	*50 meters*	*250 meters*	*500 meters*	*1000 meters*	*1900 meters*
Undamaged	72/88 polygons	42/60 polygons	30/41 polygons	11/12 polygons	5/7 polygons
Damaged Hull	75/88 polygons	33/60 polygons	25/45 polygons	15/16 polygons	9/11 polygons
Damaged Turret	63/79 polygons	20/48 polygons	18/38 polygons	13/14 polygons	7/9 polygons
Destroyed	37/50 polygons	30/45 polygons	14/24 polygons	6/8 polygons	6/8 polygons

1.3 Material Codes

The material code numbers listed below are the material reference numbers used in this model and are found in the CCTT Central U.S. Database Infrared File (.if file). A description of the reference number and location on the model are provided.

Material Code	*Description*	*Location*
537	variable temperature painted steel	hull, turret
34	glass	cupola, doghouse
38	warm glass	lights
515	variable temperature painted engine	engine
533	variable temperature warm exhaust	exhaust
513	variable temperature painted gun barrel	main gun barrel
12	hot painted steel	wind sensor tube
536	variable temperature bare steel	machine gun barrels
7	painted steel	antennas

1.4 Model & Submodels

A model (primary model and/or submodel[s]) are a collection of polygons which move as a group (articulate). The "Degrees of Freedom" represent the direction and orientation each articulated part is free to move within, in its coordinate space. "Chained to" represents the coordinate space of an articulated part with respect to it's parent articulated part.

Model/Submodel	*#*	*Description*	*Model Name*	*Degrees of Freedom*	*Chained to*
Primary Model	0	hull	pmm1a1	x, y, z, h, p, r	ground
Submodel 1	1	turret	sm1m1a1	heading	0
Submodel 2	2	120mm gun	sm2m1a1	pitch	1
Submodel 3	3	cupola & .50 cal	sm3m1a1	heading	1

1.5 Color & Texture

The color numbers listed below are the color reference numbers used in this model and are found in the CCTT Central U.S. Database Color File (.cf file). RGB values and symbolic names are provided. The texture images are the image reference names used in this model and are found in the CCTT Central U.S. Database Texture Container File (.tcf file).

Color #	*Red*	*Green*	*Blue*	*Name*
7	255	0	0	RED
8	0	255	0	GREEN
9	0	0	255	BLUE
10	255	255	0	YELLOW
14	255	255	255	WHITE
392	150	150	150	m1a1_p
393	0	0	0	m1a1_s

Texture Images
m1a1imb
lot_mm4IR
invhole

2 INTERACTIVE INFORMATION

2.1 Model State

The state of this model is controllable using the select numbers as described below.

2.1.1 Primary Model

Select #	*Model description for primary model*
0	Vehicle off
1	Undamaged hull
2	Damaged hull (thrown tracks)
10	Destroyed vehicle (simplified geometry, blackened areas)

2.1.2 Submodel 1

Select #	*Model description for submodel 1*
0	Submodel off
1	Undamaged turret
2	Damaged turret (burned areas)

2.1.3 Submodel 2

Select #	*Model description for submodel 2*
0	Submodel off
1	Undamaged main gun

2.1.4 Submodel 3

Select #	*Model description for submodel 3*
0	Submodel off
1	Undamaged commander's cupola and machine gun

2.2 Model Initialization

To initialize this model the primary model and submodels should be positioned with the following x, y, z, heading, pitch and roll settings.

Model/Submodel	*Origin & Axis*	*Initial Position (dm, deg)*
Primary Model	Midpoint of hull bounding volume	x=0,y=0,z=0,h=0,p=0,r=0
Submodel 1	Base & centerpoint of turret	x=0,y=0,z=0,h=0,p=0,r=0
Submodel 2	Base & origin point of main gun	x=0,y=0,z=0,h=0,p=0,r=0
Submodel 3	Base & centerpoint of cupola	x=0,y=0,z=0,h=0,p=0,r=0

2.3 Model Animation

The internally attached animation sequence numbers for this model are listed below and are found in the CCTT Central U.S. Database Support File (.sf file). The submodel number is the articulated part the animation sequence is chained to.

Sequence #	*Description*	*Attached to*	*Submodel #*	*Type of Sequence*
21	Main gun muzzle flash	Main gun	2	Single
25	MG muzzle flash	Machine gun	3	Single
26	MG muzzle flash	Machine gun	3	Continuous
25	Coax MG flash	Main gun	2	Single
26	Coax MG flash	Main gun	2	Continuous
35	Smoke & fire	Hull	0	Continuous
36	Smoke	Hull	0	Continuous

2.4 Model Polygon Switches

The following polygon switches have been implemented within this model. Those marked IR will only be visible in a Thermal Viewport. Any combination of switches may be activated but not all combinations are realistic. When activated, these switches are unique within each instantiation of this model and will not affect any other. A few polygons transition to light points at a specific range from the eyepoint. These polygons have polygon switches which map to light switches. As an example, polygon switch #6 and #7 map to light switch #1 and #3.

Switch #	*Switch Description*
0	Small dust, vehicle moving forward
1	Medium dust, vehicle moving forward
2	Large dust, vehicle moving forward
3	Small dust, vehicle moving backward
4	Medium dust, vehicle moving backward
5	Large dust, vehicle moving backward
6	Headlights
7	Taillights & Brakelights
8	*Spotlight reserved*
9	*Unused*
10	IR - Main gun
11	IR - Entire tank body
12	IR - Exhaust plume
13	IR - Turret ring
14	IR - Engine
15	IR - Tracks

2.5 Model Light Switches

The following light switches have been implemented within this model. Any combination of switches may be activated but not all combinations are realistic. When activated, these switches are unique within each instantiation of this model and will not affect any other. A few light points transition to polygons at a specific range from the eyepoint. These light points have light switches which map to polygon switches. As an example, light switch #1 and #3 map to polygon switch #6 and #7.

Switch #	*Switch Description*
0	Blackout brakelight
1	Headlights
2	Blackout lights
3	Tail & Brakelights
4	Green chemlight - located on the back top of the turret
5	Red chemlight - located on the back top of the turret
6	Blue chemlight - located on the back top of the turret
7	Yellow chemlight - located on the back top of the turret
8	*Spotlight reserved*
9	*Unused*
10	OTW - Main gun tracer
11	*OTW - medium-small weapon tracer reserved*
12	*OTW - small weapon tracer reserved*
13	OTW - commander's and coaxial machine gun tracer
14	*Unused*
15	*Unused*

2.6 DIS Mapping

This section details the mapping of the Standard for Distributed Interactive Simulation -- Application Protocols, Entity State and Fire Protocol Data Unit (PDU) to the image generator and database.

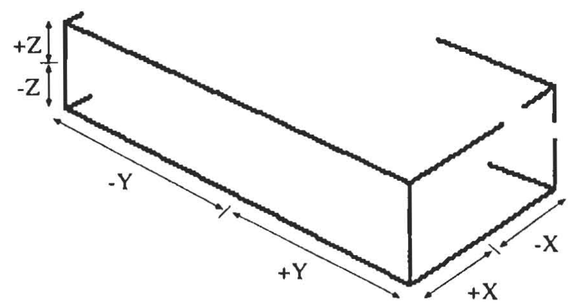
2.6.1 Entity State PDU, Entity Type Record

Kind	1	Platform
Domain	1	Land
Country	225	USA
Category	1	Tank
Subcatagory	1	M1 Abrams
Specific	2	M1A1
Extra	0	n/a

1.1.225.1.1.2.0

2.6.2 Bounding Volume

The bounding volume of the primary part (excluding the articulated and attached parts) of the land vehicle model:



+X = 17.399dm
-X = -17.399dm
+Y = 37.531dm
-Y = -37.648dm
+Z = 8.622dm
-Z = -8.650dm

2.6.3 Entity State PDU, Articulation Parameter Record

The following table maps the articulated part parameter record to the image generator and database moving model primary model and submodels. In the database the submodels are pre-attached to the primary model with correct offsets. Only the variable of rotation or translation need be set.

Entity State PDU, Articulation Parameter Record					Image Generator / Database				
Part Name	*Part #*	*Attached to*	*Parameter Type*	*Offset (dm)*	*Model Name*	*Submodel #*	*Chained to*	*Parameter*	*Value (dm)*
Hull	0	n/a	n/a	n/a	Hull	0	Ground	n/a	n/a
Primary Turret 1	1	0	X	0.000	Turret	1	0	X	0.000
			Y	3.500				Y	0.000
			Z	6.600				Z	0.000
			Azimuth	variable				Heading	variable
			Elevation	0				Pitch	0
			Rotation	0				Roll	0
Primary Gun 1	2	1	X	0.000	Main Gun	2	1	X	0.000
			Y	11.875				Y	0.000
			Z	3.683				Z	0.000
			Azimuth	0				Heading	0
			Elevation	variable				Pitch	variable
			Rotation	0				Roll	0
Secondary Turret 1	3	1	X	5.018	Cupola	3	1	X	0.000
			Y	-5.800				Y	0.000
			Z	8.509				Z	0.000
			Azimuth	variable				Heading	variable
			Elevation	0				Pitch	0
			Rotation	0				Roll	0

2.6.4 Entity Appearance, Entity State PDU

The bits of the Entity Appearance field for land platforms are mapped to the CCTT image generator and visual database as follows:

2.6.4.1 Camouflage

The models in the database are built with a fixed paint and camouflage scheme. The network information will reflect the fixed paint and camouflage scheme.

2.6.4.2 Damage and Destroyed

The kill and damage bits are mapped to database model selects. Not all combinations of bits are implemented but are defined for completeness.

Entity State PDU, Entity Appearance Field				Image Generator / Database
Name	*Bits*	*Value*	*Value Description*	*Submodel Select Mapping*
Mobility Kill	1	0	No mobility kill	See table below
		1	Mobility kill	" "
Fire Power Kill	2	0	No fire power kill	" "
		1	Fire power kill	" "
Damage Level	3-4	0	No damage	" "
		1	Slight damage	" "
		2	Moderate damage	" "
		3	Destroyed	" "

Entity Appearance Field			Submodel Selects			
Mobility Kill	*Fire Power Kill*	*Damage Level*	*Hull*	*Turret*	*Main Gun*	*Cupola*
0	0	0	1	1	1	1
1	0	0	1	1	1	1
0	1	0	1	1	1	1
1	1	0	1	1	1	1
0	0	1	1	1	1	1
1	0	1	1	1	1	1
0	1	1	1	1	1	1
1	1	1	1	1	1	1
0	0	2	1	1	1	1
1	0	2	2	1	1	1
0	1	2	1	2	1	1
1	1	2	2	2	1	1
0	0	3	10	0	0	0
1	0	3	10	0	0	0
0	1	3	10	0	0	0
1	1	3	10	0	0	0

2.6.4.3 Smoke and Flame

The flame is not present without smoke. The smoke, and fire and smoke animations are built-in (attached) to the model. The engine smoke animation is not built-in to the model, but must be placed at run-time. Information on the attached animations is contained in the table below.

Entity State PDU, Entity Appearance Field				Image Generator / Database	
Name	*Bits*	*Value*	*Value Description*	Animation	Attached to
Smoke	5-6	0	Not smoking	none	-
		1	Smoke plume	Smoke	Hull
		2	Engine Smoke	none	-
		3	Plume/Smoke	Smoke	Hull
Flaming	15	0	None	none	-
		1	Flames present	Smoke & Fire	Hull

2.6.4.4 Dust

The dust is constructed as a set of polygons on polygon switches attached to the front and rear of the model. Only one dust polygon switch should be on at any time. The forward or reverse determination must be made based of the vehicle motion. For example, a "Rear" location implies the vehicle is moving forward with the dust at the rear of the vehicle.

Entity State PDU, Entity Appearance Field				Image Generator / Database				
Name	*Bits*	*Value*	*Value Description*	*Model Polygon/Light Switch*				
				Location	*Type*	*Mask*	*Number*	*Value*
Trailing Effects	7-8	0	None	none	poly	0x0000	0-5	-
		1	Small Dust	Rear	poly	0x0001	0	3
				Front	poly	0x0008	3	3
		2	Medium Dust	Rear	poly	0x0002	1	3
				Front	poly	0x0010	4	3
		3	Large Dust	Rear	poly	0x0004	2	3
				Front	poly	0x0020	5	3

2.6.4.5 Hatch/Ramp/Tent

This model does not have a hatch, ramp or tent.

2.6.4.6 Lights

The lights on the model are represented with both polygon switches and light switches in the image generator. When a light is indicated both the polygon and light switch will be turned on. If the light is multistate, the states are documented.

Entity State PDU, Entity Appearance Field				Image Generator / Database			
Name	*Bits*	*Value*	*Value Description*	*Model Polygon/Light Switch* *Type*	*Mask*	*Number*	*Value*
Head Lights	12	0	Off	poly	0x0000	6	-
				light	0x0000	1	-
		1	On	poly	0x0040	6	3
				light	0x0002	1	3
Tail Lights	13	0	Off	poly	0x0000	7	-
				light	0x0000	3	-
		1	On (brake lights off)	poly	0x0080	7	3
				light	0x0008	3	3
		1	On (brake lights on)	poly	0x0080	7	5
				light	0x0008	3	5
Brake Lights	14	0	Off	poly	Taillights	7	Taillights
				light	Taillights	3	Taillights
		1	On	poly	0x0080	7	5
				light	0x0008	3	5
Blackout Lights	26	0	Off	light	0x0000	2	-
		1	On	light	0x0004	2	3
Blackout Brake	27	0	Off	light	0x0000	0	-
		1	On	light	0x0001	0	3
Spot Lights	28	0	Off	-	- -	-	-
		1	On	-	- -	-	-
Interior Lights	29	0	Off	-	- -	-	-
		1	On	-	- -	-	-

2.6.4.7 Launcher

There is no launcher on this model.

2.6.4.8 State and Status

The frozen status and entity state have no visual unique condition.

2.6.4.9 Concealment

When the vehicle is in a prepared position this bit may be set. Otherwise there is no visual unique correlation.

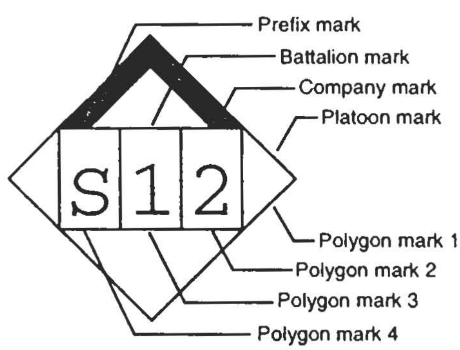
2.6.4.10 Thermal

The power plant status is currently used to activate the heated thermal switches on the model.

Entity State PDU, Entity Appearance Field				Image Generator / Database			
Name	*Bits*	*Value*	*Value Description*	*Model Polygon/Light Switch* *Type*	*Mask*	*Number*	*Value*
Power-Plant status	22	0	Off	poly	0x0400	10	0.0
				poly	0x0800	11	0.0
				poly	0x1000	12	0.0
				poly	0x2000	13	0.0
				poly	0x4000	14	0.0
				poly	0x8000	15	0.0
		1	On	poly	0x0400	10	2.0
				poly	0x0800	11	2.0
				poly	0x1000	12	0.5
				poly	0x2000	13	2.0
				poly	0x4000	14	0.6
				poly	0x8000	15	1.0

2.6.5 Entity State PDU, Entity Marking Record

The Entity Marking Record is used to provide unique vehicle marking for each vehicle.



Entity State PDU, Entity Marking Record			
Name	Value	Name	Polygon Mark
Character Set	2	-	-
1st Character	n/a	-	-
2nd Character	n/a	-	-
3rd Character	n/a	-	-
4th Character	n/a	-	-
5th Character	n/a	-	-
6th Character	n/a	-	-
7th Character	n/a	-	-
8th Character	See Character set	Platoon	1
9th Character	" "	Company	2
10th Character	" "	Battalion	3
11th Character	" "	Prefix	4

2.6.6 Weapons Fire & Tracers

This model has been built to support attached weapon fire effects. The Fire PDU is used on the DIS network to describe these events. This section provides a mapping from the Fire PDU to the built-in models.

2.6.6.1 Main Gun

All main gun weapons fire is mapped to this animation. If tracers are indicated in the Fire PDU Entity Type Record, the appropriate light switch must be turned on.

Fire PDU, Burst Descriptor		Image Generator / Database		
Quantity	Rate	Animation	Attached to	Offset (dm)
1	0	Main Gun Muzz Flash	Gun	X= 0.930 Y= 42.291 Z= -0.220

Tracer switches are mapped accordingly.

Fire PDU, Burst Descriptor		Image Generator / Database			
Name	*Description*	*Model Light Switch*			
		Type	*Mask*	*Number*	*Value*
Tracer	Off	light	0x0000	10	-
	On	light	0x0400	10	3.0

2.6.6.2 Commander's Machine Gun

All commander's machine gun weapons fire is mapped to this animation. If tracers are indicated in the Fire PDU Entity Type Record, the appropriate light switch must be turned on.

Fire PDU, Burst Descriptor		Image Generator / Database		
Quantity	Rate	Animation	Attached to	Offset (dm)
1	0	MG Muzzle Flash Single	Cupola	X= 0.000 Y= 19.400 Z= 4.257
Vari	Vari	MG Muzzle Flash Continuous	Cupola	X= 0.000 Y= 19.400 Z= 4.257

Tracer switches are mapped accordingly.

Fire PDU, Burst Descriptor		Image Generator / Database			
Name	*Description*	*Model Light Switch*			
		Type	*Mask*	*Number*	*Value*
Tracer	Off	light	0x0000	13	-
	On	light	0x2000	13	3.0

2.6.6.3 Coaxial Machine Gun

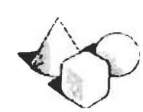
All coaxial machine gun weapons fire is mapped to this animation. If tracers are indicated in the Fire PDU Entity Type Record, the appropriate light switch must be turned on.

Fire PDU, Burst Descriptor		Image Generator / Database		
Quantity	Rate	Animation	Attached to	Offset (dm)
1	0	MG Muzzle Flash Single	Gun	X= 3.064 Y= 11.000 Z= -0.150
Vari	Vari	MG Muzzle Flash Continuous	Gun	X= 3.064 Y= 11.000 Z= -0.150

Tracer switches are mapped accordingly.

Fire PDU, Burst Descriptor		Image Generator / Database			
Name	*Description*	*Model Light Switch*			
		Type	*Mask*	*Number*	*Value*
Tracer	Off	light	0x0000	13	-
	On	light	0x2000	13	3.0

3 ENGINEERING NOTES



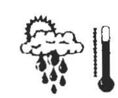
3.1 Geometric Information

3.1.1 Undamaged State

A 7.62 loader's machine gun is present but does not fire nor have any special effects.

3.1.2 Damaged & Destroyed States

If the turret is damaged the vehicle can still maneuver. The definition of a damaged hull is a thrown track. If the hull is damaged the turret can still move and fire. If the vehicle is destroyed it has no articulated parts. The host should turn off submodel 1 (turret) when the vehicle is in the destroyed state.



3.2 Thermal Information

Vehicle hot spots are controllable by polygon switches. Polygon switch #11 is used to control the thermal intensity of the vehicle body. This has been made available to provide the host with the ability to better control relative contrast levels. All other IR polygon switches have been implemented according to the heat signatures of a main battle tank.

3.3 Light Intensified Information

No vehicle unique blooming effects have been modeled. A grey-scale color palette has been provided for use with the light intensified (NVG) viewport. This color palette uses high intensity RGB values for all lights, firing effects, tracers and detonations.

3.4 Model Effects Information

Switchable trailing dust effects are represented by motion texture.

Firing effects are provided for the main gun, .50 Cal and coaxial machine gun.

In the OTW and NVG viewports, the tracer effect is represented by a light string animation controlled by a light switch as part of the firing effect. In the IR viewport, the tracer effect is represented by a polygonal animation which is non-switchable and is part of the firing effect.

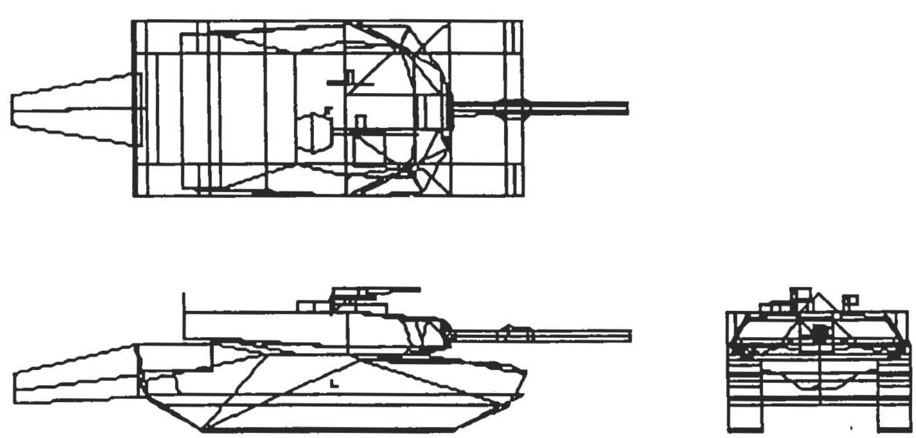
3.5 Combat Vehicle Markings

The vehicle marking system on this vehicle is represented on both sides of the tank on the track skirts and on the back of the turret. The vehicle marking system utilizes table driven texture.

3.6 Fade Range

The fade range of this vehicle is 24000 decimeters (48000 under zoom). Any active animations internal to this vehicle will also fade at this range.

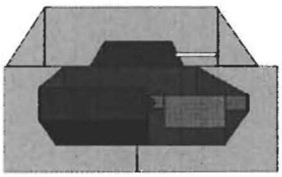
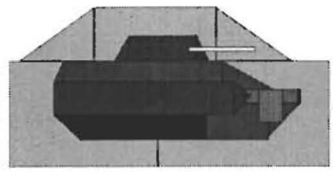
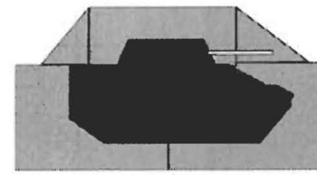
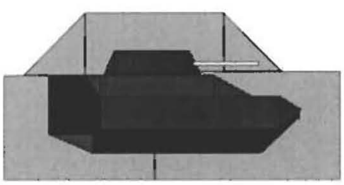
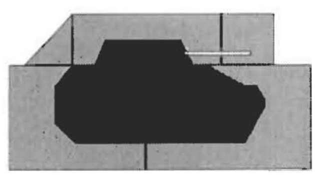
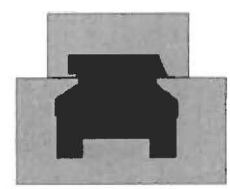
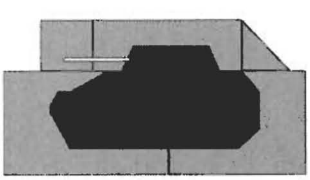
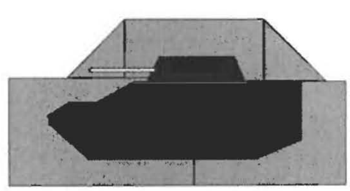
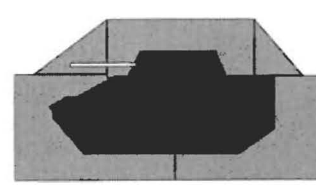
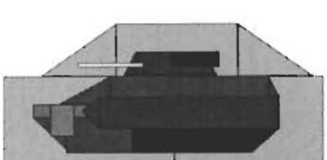
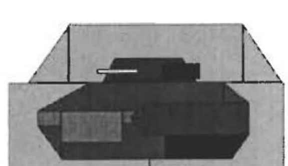
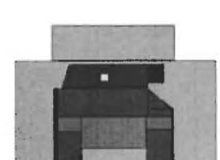
4 3-D PLOTS



Polygons: 182

Appendix C

M2

Sight
Back door
Skirt
Track front/back
Skirt front
Lower hull front
Turret ring
Upper hull
Turret
Gun
Tow
Near_miss_area
Track side