COMBAT MISSION SIMULATION: THE "ATTRACTIVE ALTERNATIVE"

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ABSTRACT

The AH-64 Apache--the Army's most advanced and lethal attack helicopter--is a highly complex and formidable weapons system designed to fly nap-of-the-earth at night and in adverse weather and to defeat a sophisticated array of enemy tanks and air defense weapons. The complexity of the weapon system coupled with its operational environment and mission presents a formidable challenge to the training community. The challenge has been met through the development of a suite of system training devices designed to off-load training from the actual aircraft. The Apache program further challenges collectively the user community, the materiel developer, and industry to develop and deliver as part of this training system a means to attain and maintain tactical decision-making skills necessary to fight and survive in a high threat environment. This paper describes the general capabilities of the AH-64 Apache helicopter and its training system from both institutional and unit perspectives. The capstone of the training system, the Combat Mission Simulator, is introduced with detailed explanations of design approaches and tradeoffs made to attain the highly sought combat skills training capability--the attractive alternative.

INTRODUCTION

The objective of the Army's new AH-64 Apache helicopter is to provide front line commanders with a means of quickly concentrating antitank and suppressive firepower on targets in day, night, and adverse weather conditions. In meeting this objective, Apache equipped units, when fielded, must be trained and ready for action in order to provide the commander with the combat multiplier required for victory. The preparedness of each unit to enter combat immediately at the time of activation is influenced mostly by the characteristics and capabilities of the Apache weapon system; each crewmember's knowledge of the weapon systems and established tactics and doctrine; and the availability of a training system that permits the employment of the weapon system in a simulated, hostile threat environment.

THE WEAPON SYSTEM

The AH-64 Apache (Figure 1) is a quick-reacting, airborne antitank weapon system with superior combat capabilities. Due to terrain limitations and an unfavorable balance in armor forces, the Army's newest attack helicopter has been designed to react quickly to the heaviest enemy penetration and destroy, disrupt, or delay the attack long enough for friendly armor and ground forces to reach the scene.

The destruction of the enemy armor forces is accomplished by the primary antitank weapon of the Apache--the HELLFIRE laser--guided missile. It acquires and homes on laser-designated targets with devastating accuracy. The missile's laser seeker and large, shaped charge warhead enable the attack helicopter to destroy a stationary or moving target with a single round. The helicopter is also armed with a 30mm automatic cannon and 70mm (2.75 inches) folding-fin rockets with high explosive, submunition, smoke, and illumination warheads. All of the onboard weapons can be slaved to the helmet sights of either crewmember.

The AH-64 also has a superior acquisition and weapon delivery capability provided by the Target Acquisition and Designation Sight/Pilot Night Vision Sensor (TADS/PNVS) system. The TADS/PNVS system allows the Apache to fly nap-of-the-earth (NOE) at night and in adverse weather

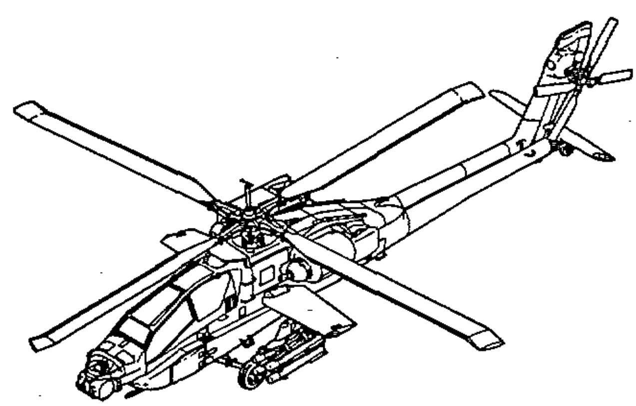

Figure 1

and to deliver HELLFIRE missiles with laser-guided, lethal precision.

The TADS is a multisensor, mission-flexible standoff fire control system with direct view optics (DVO), day television (DTV), and forward looking infrared (FLIR) sensors. These high resolution, multiple field of view sensors allow target detection and destruction through dust, smoke, haze, rain, sleet, and snow at ranges far beyond the reach of enemy defenses. All TADS sensors can be operated with the system's automatic, manual, and laser spot trackers and can be boresighted with the touch of a button.

The PNVS FLIR sensor provides real-time imagery of the terrain for NOE night flight and penetration of obscurants such as rain, fog, dust, and smoke. The PNVS is slaved to the pilot's helmet mounted display system, and the TADS is slaved to the copilot/gunner's controls. But either crewmember can view the video from either system and slave the TADS to his controls to strike at targets. Both TADS and PNVS units provide full flight envelope and targeting symbology with fingertip control.

The AH-64 Apache is a truly formidable system with awesome capabilities!

THE TRAINING SYSTEM

The AH-64 helicopter presents a genuine challenge for the training community, the materiel developer, and industry to prepare an effective and affordable training system. To be economical, the system must substitute training devices for actual aircraft flight time and at the same time deliver training devices which are an attractive alternative to the crewmembers who work with them--crews at the institution and in the combat aviation units. Compounding the complexity of the Apache aircrew training program is the requirement to graduate combat skills qualified crews ready to fight and survive on the modern battlefield.

The dual objectives of aircraft qualification and combat skills qualification are met through a training system heavily reliant on a suite of training devices. The fourteen week institutional course of instruction is multi-phased and one of the most comprehensive in Army aviation. It consists of approximately 135 hours of academic instruction, 65 hours of aircraft flight training, and more than 60 hours of formal instruction on the training device system.

During the first phase of the institutional training program, each new attack pilot begins academics and is simultaneously introduced to the most demanding task in the course--flying a helicopter at nap-of-the-earth with the sole reference to the terrain being PNVS FLIR imagery presented on a monocular, helmet mounted display. This critical 24 flight hour block of instruction is accomplished in the AH-1S Cobra helicopter equipped with the Apache PNVS--sometimes called the PNVS Surrogate Trainer. The academic curriculum is supported by the Classroom Systems Trainer (CST) which replicates the aircraft and mission systems in both normal and degraded operations. Near the end of this phase, the attack pilot begins ten hours of instruction in the Cockpit, Weapons, and Emergency Procedures Trainer (CWEPT) where Apache specific start, runup, shutdown, and associated emergency procedures are learned.

The second phase of training is the beginning of aircraft flight certification and is accomplished in the Apache helicopter. Each trainee during this phase receives 21 flight hours of instruction at the pilot's station--12 hours learning basic flight procedures followed by nine hours of flight training on the Apache's PNVS. Also used in this phase are the HELLFIRE Dummy Missile (HDM) which permits pilot familiarization with the handling characteristics of a fully loaded Apache, seven hours in the Combat Mission Simulator (used as an operational flight trainer) to review normal and degraded flight operations, and ten hours on the TADS Selected Task Trainer (TSTT) which introduces basic copilot/gunner gunnery and navigation tasks in preparation for the next phase.

The TADS/Gunnery phase is the next block of institutional training. This phase is accomplished through 20 flight hours of instruction at the copilot/gunner's station in the Apache helicopter and is supplemented by a second ten hour block of instruction in the CWEPT. The HELLFIRE Training Missile (HTM) is also used during this phase to replicate the prelaunch and launch environments. This reusable (not fired) training missile allows the training of most HELLFIRE tasks while in flight. The primary purpose of the TADS/Gunnery phase is to teach the gunner how to fire the three weapons systems onboard the AH-64 from the copilot/gunner's station.

On completion of the first three phases of training, the attack pilot has completed the transition into the aircraft and is now helicopter and systems qualified. The last phase of the institutional program is combat skills training and is accomplished solely in the AH-64 Combat Mission Simulator (CMS)--the apex of the training device hierarchy (Figure 2). Each pilot receives 15 hours in the CMS to accomplish ten prescribed tactical missions against a progressively lethal threat force. Five missions (7.5 hours) are flown in each of the aircraft crewstations with three missions at each station flown under night conditions. An Aircraft Survivability Equipment Trainer (ASET) is also available with the CMS to reinforce learning of radar warning receiver tasks. On completion of this simulator phase of instruction, the Apache

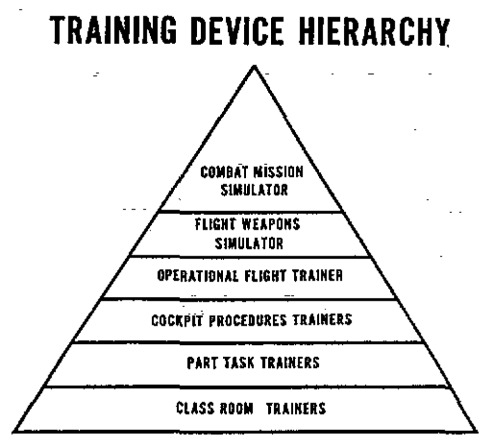

Figure 2

pilot is certified as combat skills qualified and is ready to join his assigned unit.

The Apache pilots in the field will continue to use training devices for the maintenance of individual skills and as part of the unit training program. At each Apache helicopter field site, pilots will have access to a Combat Mission Simulator, HELLFIRE Dummy Missiles, HELLFIRE Training Missiles, and Aircraft Survivability Equipment Trainers. A Cockpit, Weapons, Emergency Procedures Trainer has been proposed to be located with each attack unit which will complete the suite of training devices for field use.

This Apache training system is producing the best attack helicopter pilots in the world who are not only proficient in the aircraft and mission systems but are also tactically and doctrinally ready to fight if necessary. This preparedness for combat is only possible because of the system training devices of which the capstone is the Combat Mission Simulator--the attractive alternative to actual combat as the best teacher.

THE ATTRACTIVE ALTERNATIVE

General Description

The objective of the AH-64 Combat Mission Simulator (CMS) is to provide a ground based means to obtain and maintain tactical decision-making skills required to fight and survive on the modern battlefield. To meet this objective, the CMS has been designed to provide a training capability for flight and weapons delivery, normal and emergency procedures, and sensor system operations required in the Apache helicopter. The simulator consists of pilot and copilot/gunner (CPG) trainee modules, two instructor modules, two motion subsystems, two visual subsystems, and a shared computer complex (Figure 3). The pilot and CPG trainee modules are replicas of the design basis helicopter cockpit and each is mounted on a six degree-of-freedom, synergistic motion platform. The visual subsystems are comprised of digital image generators and wide-angle, collimated displays which provide a state-of-the-art terrain scene and sensor imagery to each of the appropriate crewmember video displays. Simulated imagery in the CMS includes forward-looking infrared (FLIR), day television (DTV), and direct view optics (DVO). Pilot displays provided in the simulator consist of the integrated helmet and display sight system helmet display unit (IHADSS HDU) and a panel mounted video display unit (VDU). Gunner displays include the IHADSS HDU, a Target Acquisition and Designation Sight heads down display (TADS HDD) and a TADS heads out display (HOD). The simulator will be operated from the instructor's station located directly behind each trainee module and through the computer complex which will fulfill subsystem interface requirements and tactical algorithm processing.

In summary and from another perspective, the CMS has been designed to permit high-fidelity interplay between the ownship and a lethal threat array on a common piece of terrain, with common meteorological conditions, under the mediation of an unbiased tactical algorithm (Figure 4).

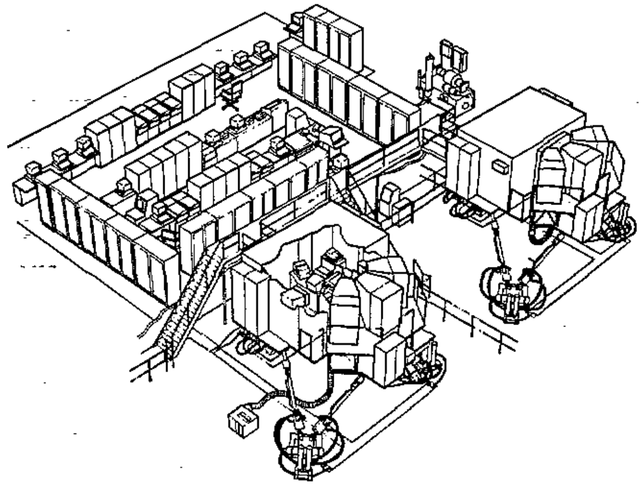

Figure 3 - AH-64 Combat Mission Simulator

The Ownship

Aero and Flight Systems

AH64CMS computer programs provide a high fidelity simulation of the flight dynamics of the AH-64A aircraft, aircraft systems and weapons/sensor systems. Aerodynamically, AH64CMS performance in most flight and operational regimes is generally in accord with TM-55-1520-238-10 and closely approximates that of the AH-64 APACHE. When engineering design was complete, an air vehicle manufacturer test pilot flew, evaluated, critiqued, and contributed ideas to tailor the aerodynamic performance, engine, and systems operation of the simulator. Following four quarterly test pilot sessions, the CMS was judged to be better than 80% acceptable during government pilot review. Army attack pilots completed the remaining 20 percent of work and tailored, with the contractor, stabilator performance and engine responsiveness in addition to completing other unfinished business.

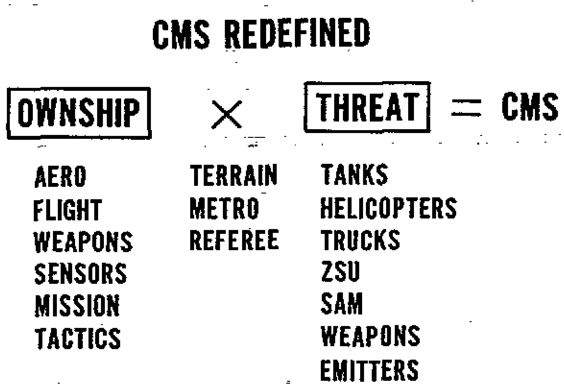

Figure 4

Today there are few aero, engine, or systems-peculiar complaints. If anything, some pilots claim the aero is over-responsive to lateral cyclic control inputs, most notably at a hover. Very responsive cyclic authority is not uncharacteristic of the actual aircraft, however, and experienced CMS evaluation pilots who understand limitations in visual scene edge density and field-of-view are insisting a control problem doesn't exist.

As measured by user satisfaction, performance of CMS systems such as engines, auxiliary power unit (APU), and heading and attitude reference system (HARS) represent the most satisfactory simulation of aircraft systems performance of all systems used by the Army. Nevertheless, future aero performance can still be improved by reducing total control input-to-output transport delay time.

Tactics

After accomplishing the aero performance goal early-on, the program then advanced into the high fidelity ownship weapons and tactics simulation. The integration of all tactical systems such as TADS, IHADSS, and PNVS went well. Image Autotracker performance, a concern early in the program whether it would be able to track a perfect CGI scene, turned out to be a non-issue. Tracker performance, including offset track and breaklock, is very realistic in all sensors.

Doppler and Heading and Attitude Reference System (HARS) navigation simulation is aircraft-accurate. The Doppler will put HARS into free inertial mode when the ownship overflies water thus requiring the crew to correct Doppler position error as often as they do in the APACHE.

The government-furnished Fire Control Computer has been integrated to the CMS main computational system and operates at the same fidelity level as it does in the aircraft. The FCC has already undergone upgrade in the CMS as we attempt to keep pace with aircraft and FCC engineering changes.

Weapons

There are 15 selectable ownship weapons loads mixing various 30mm cannon, 2.75 inch FFAR, and HELLFIRE missile configurations. Nap-of-the-earth movement and judicious use of terrain masking, however, can lead to HELLFIRE launches where the missile does not clear the mask or impacts on some obstruction close to the launching helicopter. Because crews training in the actual aircraft will rarely launch a HELLFIRE missile and experience such situations prior to actual combat, the CMS must provide the training community with a completely realistic missile model, interactive with the simulated terrain. In this requirement, the simulator has been more than satisfactory.

Because the accuracy of the HELLFIRE is also dependent on how the laser designator is used, smooth tracking of the target vehicle is necessary, especially in the final few seconds of missile flight. CMS trained gunners are learning to track smoothly in addition to learning tracking techniques that provide minimal warning to the threat crew while maximizing the probability of a kill. These gunners are learning for example that ripple launches of several missiles inflight simultaneously demand precise designation control as the gunner moves the aim point from target to target. When firing rockets and 30mm cannon, crews are learning that aiming relies, in part, on pilot or CPG applied corrections based on observed impact points. The ability to train gunners to perform these tasks while the pilot is trying to avoid being shot down differentiates CMS from Weapons Systems Simulators of the past.

All these considerations led to the decision to simulate actual in-flight ballistics for the three weapon types with sufficient precision to match the operational accuracies of the weapons.

Missile Ballistics

The HELLFIRE missile ballistics are simulated using a five degree-of-freedom (DOF) model, roll control being assumed to be perfect. The software is made up of three major sections: the ballistics, the seeker, and the autopilot. Aerodynamic data from wind tunnel tests is used to compute forces on the missile; these lead, by way of standard calculations, to missile attitude and position. In order to obtain the fidelity required (especially along the initial flight path) the ballistics and autopilot modules are iterated at 100Hz, while the seeker runs at 25Hz.

The seeker module includes detection sensitivity analysis, angular and angular rate limits, and field-of-view considerations in addition to seeker search modeling.

The autopilot module emulates the real missile transfer functions with the exception of the roll channel. Missile position and attitude are used to provide a visual scene of the missile departing from the aircraft, from the appropriate side, and eventually descending on target (assuming the gunner has designated correctly) with the resulting explosion and kill.

HELLFIRE fidelity is the difference between just another simulator and "the attractive alternative." Indeed, more is being learned about missile performance in simulation than could ever be realized in the aircraft. Gunners will be ready for combat and fewer missiles will be lost due to crew error, thanks to the training levels achieved in the CMS.

Rocket Ballistics

The rocket ballistics use the same 5 DOF model as the HELLFIRE missile except that no seeker or autopilot is required. Elimination of the autopilot allows the iteration rate to be reduced to 50Hz while still maintaining sufficient fidelity for the flight path. A single rocket, a pair, or a quad of rockets (i.e. up to four launched together) are treated as a single flight path calculation (offsets being applied to give the individual rocket positions where necessary).

Rotor downwash has a major effect on rocket dynamics, because they pass through the downwash region while still moving relatively slowly (the missile is not affected to the same extent). In order to correctly model downwash effects on the rocket, calculations of average downwash based on flight conditions are incorporated into the simulation.

During early testing of the CMS, the rocket model revealed discrepancies in the actual aircraft fire control computer software aiming algorithms. These discrepancies were subsequently corrected following actual weapons trials.

Five rocket types are modeled, each with unique data. The types are the MK40/M151/M423 high explosive round, the MK40/M151/M433 high explosive round, the MK66/M257 illumination round, the MK66/M264/M439 smoke round, and the MK66/M261/M439 multipurpose round. Aerodynamic data were provided for these types by US Army Missile Command (MICOM) and the Ballistics Research Lab (BRL).

Visual cues for rocket position are limited to a light point representing the rocket motor (for the duration of the motor burntime) and the appropriate warhead impact effect.

Rocket system performance is very realistic, as accurate as the Fire Control Computer software load used.

Gun Ballistics

The 30mm gun round positions are computed using a simple three DOF point model. Gyroscopic effects due to the rapidly spinning bullet tend to curve the flight path in the horizontal plane. This curvature is computed using actual weapon test data. Comparisons with actual aircraft data reveal that this technique is sufficiently accurate for the training required.

Up to 5 rounds are treated as a single flight path calculation in order to bring the amount of computation down to a reasonable size; use of the simplified equations allow iteration at 10Hz. Downwash is not a factor with the gun round since it is traveling at maximum velocity while in the downwash region.

The gun is used in training to destroy light armor and aircraft as well as for self-defense. Gunners and pilots alike are learning to fire without tracers, a task veteran pilots are unaccustomed to. Accuracy of the gun under various conditions is learned, enabling crews to achieve a higher ratio of hits over the course of training.

Scoring

Missile, rocket, and gun round positions are computed until it is determined that impact has occurred with some object in the visual database. At weapon launch time, data is collected which describes the position at which the crewman is aiming, including the sighting directions (TADS, IHADSS). The aim position is used to find the target nearest to the sighted point, the assumption being that this is the target at which the weapon was launched. For HELLFIRE remote designation launches, the instructor-selected remotely designated target is assumed to be the target of interest. Scoring then compares the weapon impact point with the selected target position and provides miss/hit data to the instructor, a hit being scored if the impact is within a pre-determined range from the target. Given a hit, a check of target type versus weapon type will decide if a "kill" has occurred.

Data is presented to the instructor (by way of a CRT page) which show the launch parameters, target miss distance, miss/hit/kill, and identifies the crewmember who fired the weapon. For autonomous HELLFIRE launches the crewman's designation performance is also measured and displayed. In the event of a HELLFIRE miss, scoring page messages indicate why.

Where two or more rockets are launched simultaneously, rocket scoring requires the calculation of the individual rocket impact points based on pylon positions and ownship attitude at launch time.

Gun scoring, where a single impact calculation may represent from one to five rounds, takes gun dispersion effects into account.

Once a miss/hit/kill decision has been made, the appropriate weapon effect is cued on the visual system displays.

Instructor/Operator Station

While fidelity of simulation is an important factor in the training effectiveness of the AH64CMS, the simulator has a variety of instructional and design features that have nothing to do with fidelity and are provided solely to enhance the effectiveness and efficiency with which training can be given. Some of these features (the ability to "freeze" the action in mid-sequence is an example) provide training capabilities that simply do not exist in a real aircraft. These capabilities make the CMS, in effect, a learning laboratory, an environment more conducive to learning than the aircraft itself. They provide the means whereby the instructor can actively manage the learning process more efficiently than in the aircraft.

Instructor/operator (I/O) stations are onboard the motion platform and rear of each of the two crew stations. The gunner I/O was specified as master instructor station but in hindsight should probably not have been. Instead, equal control should be given to both instructors enabling them to share duties and reduce the master instructor's workload. They could then coordinate their individual duties over the intercom system during integrated mode operation.

During gunner independent mode training, a feature called "Auto Fly" is available. When activated, it commands the computer to fly the aircraft along a predetermined route of flight to multiple battle positions. Upon arrival at the battle positions, the computer brings the aircraft to a hover, unmasks, and affords the gunner the opportunity to engage targets before automatically remasking and continuing along to the next preprogrammed battle position. When necessary to extend time at programmed firing positions to accomodate training, the instructor can choose to override the automatic flight program by selecting manual mode. Manual mode selection will command the computer to maintain aircraft position over the hover point or, if enroute to a firing position, maintain aircraft position upon arrival at the next programmed hover point. At that time the instructor, using a control stick located at his console, can take aircraft heading and altitude control away from the computer. This enables the instructor to control ownship exposure time and to align the aircraft in launch constraints along the gunner-selected target line-of-sight. Needless to say, during independent gunner training modes, "auto-fly" is regarded as essential.

User instructors are generally pleased with the hardware and software design of the I/O station which currently has only one data-graphics display for problem control. Indications are that they would prefer an additional data-graphics display because two graphics pages are often required simultaneously for them to do their job efficiently. A TADS/PNVS steering and field of view indicator should be removed and an additional sensor monitor installed in its place so each IP can monitor both the pilot's and gunner's sensor operation simultaneously rather than having to switch the one display provided back and forth. A requirement to mount IHADSS hardware at the I/O station may prove worthwhile but as of this writing instructors have gotten along without it, opting instead to view the hard-mounted repeater displays and leaving their Helmet Display Unit in it's holster.

The Threat

The Army's SFTS program includes several types of helicopter simulators. They include instrument simulators, operational flight trainers, and flight and weapon systems simulators. Only the AH64CMS is a Combat Mission Simulator. What distinguishes it from all other simulators is the inclusion of an intelligent, interactive threat. The threat permits crews to develop and maintain the proficiency to fight and survive on the modern battlefield.

The threat is more than a few moving, firing targets. It is a complex, sophisticated array of systems that will defeat a poorly trained APACHE crew. When hostility is enabled, the threat weapons are able to acquire the ownship optically or via radar acquisition and when the requisite criteria is satisfied, they will fire at the ownship.

Threat targets include T8Ø and T62 tanks; SA4, SA6, SA8, and SA9 Surface-to-Air-Missile systems; ZSU23/4 and BMP anti-aircraft gun systems; and a FLAPWHEEL radar acquisition system. Threat vehicles that do not shoot at the ownship include light and heavy trucks, BTR6ØPA personnel carriers, and Mi2 and Mi24D helicopters. Non-threat vehicles include U.S. Army M1 tanks.

Threats are activated with a basic load of ammunition manually by the instructor or automatically by the computer. Physical characteristics of the threat that are simulated include their aim rate, weapon firing angles, sensor height, radar angles, and doppler versus non-doppler radar characteristics. The radar simulation also addresses pulse repetition interval, beamwidth, low band signal characteristics, power characteristics, and radar jammer characteristics. Radar jammer characteristics are further simulated with azimuth and elevation limits, number of simultaneous threats, and signal threshold.

Hostility ON/OFF conditions are instructor controlled or automatically activated during target engagement exercises (TEE's). TEE's are pre-canned threat arrays with up to ten target types, ten firing positions or target pathways, and preselected (yet adjustable) target speed settings for any of 15 preprogrammed scenarios. The IP may manually build scenarios by placing up to ten targets on any of 99 available target sites. Ground targets move up to 4Ø km/hr and air targets as much as 2ØØ km/hr.

When a threat engages the ownship, the threat turret or launcher articulates and aims (if the target was moving, it will first be commanded to stop). When the threat fires its weapon, a visual cue of weapon launch can be seen both out the window and in the selected sensor field-of-view of the ownship. When witnessing this process, attack crews just can't seem to move fast enough to satisfy their anxious desire to get out of the way.

Threat models are accurately designed at a level-of-detail that allows them to be identified. More importantly, they are also coded with FLIR signatures which provide crews with the capability to learn threat system identification using TADS/PNVS sensors at night.

The Common Ground

Visual Terrain Database

A computer generated data base provides a tactical gaming area and an airfield area (Figure 5) of approximately 1,2ØØ square kilometers (32km x 4Økm). The gaming area is a generic terrain representation that was specifically designed to meet the diverse training requirements related to attack helicopter operations. Design was engineered to meet the immediate need for CMS and to reduce the effort required to build future visual data base designs throughout the Army's Synthetic Flight Training System (SFTS) program. Blackhawk, Chinook, and Cobra helicopter simulators, which use the same CGI visual system as APACHE, have different terrain requirements based upon their unique missions. Utility and cargo helicopter crews practice sling-loading heavy equipment long distances to and from confined landing areas and pinnacles. On the other hand, Cobra crews fight the same threat as APACHE crews but from closer battle positions that better accomodate TOW missile engagement ranges. Rather than build four totally different data bases from the ground up, the Army wanted to limit design of these other data bases to construction of small areas of terrain that could be interspersed with existing AH64CMS terrain and

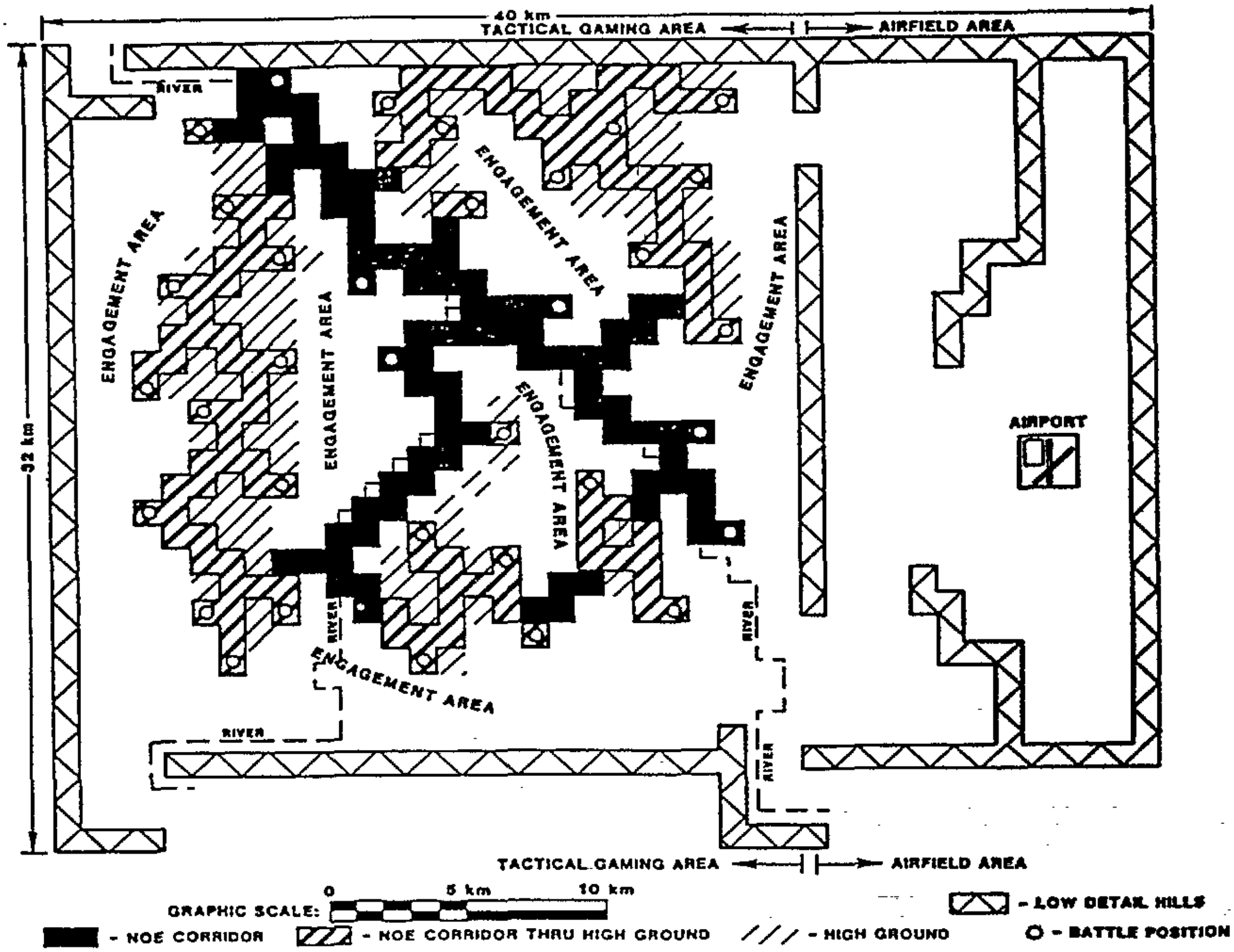

Figure 5 - 32 x 40 km Visual Database

also shuffling terrain layout slightly to move battle positions closer to the threat. The ultimate goal was to build a data base in excess of 8,000 square kilometers using fewer than 300 one-kilometer blocks of modeled terrain—a mere 100 more than what the APACHE CMS required.

To meet the overall SFTS terrain data base design goal, development began on modular one kilometer square terrain pieces called area blocks. A library of interconnectable, rotateable area block 'puzzle pieces' was amassed using eight categories of terrain (Figure 6) with unique characteristics that define the terrain appearance and the training requirements its design accomodates. Edge budgets were established based on the block category and the training task envisioned as being most often performed with that block. This enabled us to economize computer resources, increase the scene density in the ownship NOE maneuver blocks, and decrease the density in the threat maneuver blocks. In order to satisfy the attack pilots, edge density budgeting for NOE supportive area blocks was enhanced with four times the edge density the image generator could accomodate in an average one kilometer area. However, the non-NOE supportive area blocks only required half as much density as the image generators could handle and there were four times as many non-NOE blocks needed as there were NOE blocks. Quantitative and qualitative management of scene edge density enabled us to put the high detail in the NOE areas where it was needed. Great care was taken to blend NOE corridors with the entire terrain layout and to avoid the appearance of channelized NOE mazes commonly used on research data bases. NOE blocks attract pilots because they afford the crew the means to traverse the threat-infested data base and remain masked in the process. Other non-NOE area blocks do not provide the same security. The crews travel over these blocks quickly, if at all, using contour or low-level flight techniques, therefore eliminating the requirement to enrich these blocks with unneeded edge detail. The modular area block approach lends itself to getting 100% out of the terrain design while pushing the state-of-the-art.

The tactical utility of terrain design has

AH-64 CMS VISUAL DATA BASE

AREA BLOCK CHARACTERISTICS

CHARACTERISTIC \ BLOCK	A	B	C	D	E	F	G	CONNECT		
	MANEUVER	RIVER	MANEUVER	WAY POINT	FIGHTING	ENGAGE	BORDER	C	D	F
NOE FLIGHT	X	X	X		X			X		
FLAT CORRIDOR	X	X								
ROLLING CORRIDOR					X			X		
LOW HILLS	X	X	X			X		X		X
HIGH HILLS			X	X	X				X	
MOUNTAINOUS			X				X			
THREAT OPNS	X					X				
VALLEY FLOOR	X	X		X	X	X				
PLATEAU			X	X	X					
RIDGELINE								X	X	X
AIRFIELD						X	X			
TACTICAL	X	X	X	X	X	X	X	X	X	X

Figure 6

been very favorably received. The design demands very low and slow NOE flight when mask is necessary. Although the crew may elect to fight from any location, specific elevated battle positions are provided to enable overwatch extended-range intervisibility with targets along threat avenues of approach. Circuitous NOE routes meander up from the valley or plateau floors to the elevated battle positions 200 to 600 feet above threat elevation, challenging the crew's navigation skills and demanding that flight be performed low and slow to avoid detection. Trees and low hills populate the threat valley areas requiring the gunner to time his missile launches to insure impact when there is a clear field-of-fire for the ownship laser. Route of flight planning is accomplished with an actual 1:50,000 scale tactical map of the data base exactly as it is in the real-world. Changes to the route are made during flight following spot reports from aero scouts (the instructors) and the supported ground units (instructors) played in each tactical scenario. Instructor pilot creativity has further enhanced CMS utility as instructors fill the role of many other players in a typical mission and conduct combat scenarios limited only by the scope of their own imaginations. The remarkably successful modular terrain design approach has really paid off. It has already enabled the Army to build bigger and better data bases on other SFTS programs in one tenth the time at a much reduced cost.

Even though training is progressing well with the current tactical terrain design assets, in hindsight, valleys and plateaus could probably have been given more definition had the slope of connector blocks been increased and the base height of the plateaus doubled. In the near future, hardware textured terrain will enhance low-level NOE visual flight cues.

The CMS visual system provides the user with scenes that may be mathematically correct; however, subjective distance estimates by crews are, for the most part, not without considerable error. Recent studies have attempted to identify the causes for this anomaly but only suggest that more research is necessary. This anomaly, presently tolerated because industry has not yet provided a solution, must be solved for simulations requiring slow flight close to the earth — the future of Army simulation.

Tactical Algorithm

The referee for combat skills training is the tactical threat algorithm. The threat in the CMS is as intelligent as their real world counterparts. His acquisition and hit capability, engagement and acquisition range performance, rate of fire, accuracy, and impact effect have been simulated realistically. A high speed computer manages line-of-sight information and determines occultation between ownship and as many as ten threat targets simultaneously. Threat intelligence is provided by a complex algorithm that looks at a series of real time variables whenever a threat has intervisibility with the ownship. The algorithm considers threat variables, ownship variables, target engagement exercise contingencies, and several simulator unique controls (i.e. Lethality Level) prior to firing at the ownship. The threat scoring algorithm then records results of threat events and actions. A threat event is defined as a threat engagement or potential engagement of the ownship. An event starts when ownship has been exposed (may be non-continuous) for more than ten seconds in mask zone one (predetermined height above mask defined for each threat at every range) or higher. The twelve most recent threat events or engagements against ownship are summarized on the threat scoring page at the instructor station. The scoring page displays exposure time; range; hover height of ownship above mask; and acquisition and hit probability (P_A, P_H) maximum, mean, and final for each event. Should acquisition probability be satisfied, the threat will engage ownship (if it is within weapons range). Probability of hit determines the outcome. Whether it be a hit or near miss, a visual effect, a motion cue, and an associated aural cue are simulated at a magnitude appropriate to the threat weapon. The outcome of threat engagements never fails to get the crew's attention and always discourages members from making a similar mistake that will cause them to be engaged again.

The threats' actions and weapon effectiveness are governed by mathematical equations for the probability of acquisition (P_A) and the probability of hit (P_H). Mean P_A/P_H threat performance was determined for the parameters which make up the equation and the resultant level of performance categorized as threat lethality level five. This lethality level is the default value the CMS initializes for typical training missions. The instructor may vary the lethality level in order to increase or decrease threat proficiency to a level equal to the ownship crew's level of performance. There are ten selectable levels of lethality available to the instructor. As attack crew proficiency increases with training, so too can the lethality level be increased to continue challenging the crew. When P_A exceeds the threshold value appropriate to the selected lethality level, the threat may acquire the ownship. When P_H exceeds the same threshold value, hostility is enabled, and the ownship is within weapons range of the threat, the threat will fire on the ownship. Threshold is related to the selected Lethality Level (L) as follows:

$$\text{Threshold} = \frac{1}{10}(10 - L)$$

The equation for determining Probability of Acquisition (P_A) is as follows:

$$P_A = (P_{R\ ACQ})(P_{EXP})(P_{MSK})(P_{IR})(P_{BD})(P_{RDR})(P_{CHF})(P_{NT})(P_{VIS})$$

where
$P_{R\ ACQ}$ = Acquisition Range Factor
P_{EXP} = Exposure Time Factor
P_{MSK} = Mask Factor
P_{BD} = Backdrop decay
P_{IR} = IR jammer decay
P_{RDR} = Radar jammer decay
P_{CHF} = Chaff decay
P_{NT} = Night time decay
P_{VIS} = Visibility Decay

The equation for determining Probability of Hit (P_H) is as follows:

$$P_H = (P_{H\ WPN})(P_{H\ MSK})(P_{H\ IR})(P_{H\ RDR})(P_{H\ CHF})$$

where
$P_{H\ WPN}$ = Hit weapon release range factor
$P_{H\ MSK}$ = Hit mask factor
$P_{H\ IR}$ = Hit IR jammer decay
$P_{H\ RDR}$ = Hit radar jammer decay
$P_{H\ CHF}$ = Hit Chaff Decay

Threat search, acquisition, and track range; minimum and maximum weapon range; ownship hover height above mask; backdrop utilization; and aircraft survivability equipment (ASE) effectivity which includes the use of Chaff, the IR jammer and the radar jammer are all parameters contributing to the equations for acquisition and hit (Figure 7 and Figure 8). Night and reduced visibility will limit optical-only threat acquisition performance. There is also a computer limitation of eight kilometers range beyond which threats currently are limited to search mode operations.

The CMS threat teaches crews to fight from extended ranges, to remain as low as possible, and to reduce their exposure time. Battle positions which provide the crew extended range

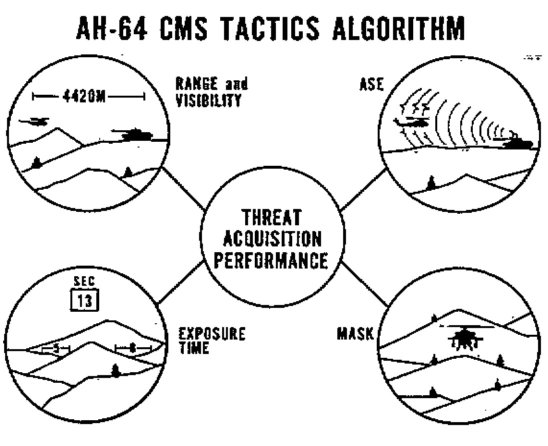

Figure 7

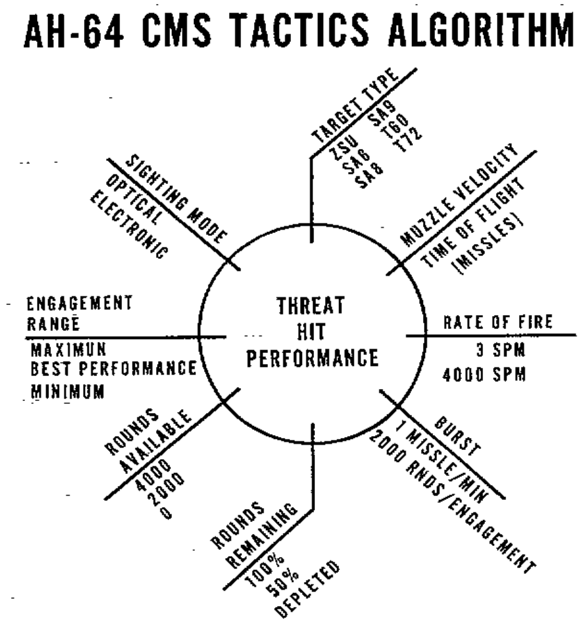

Figure 8

intervisibility and backdrop are actively pursued. Crews learn which ASE equipment is effective against specific threats. They learn to recognize APR-39 radar warning receiver detection audio and strobe information and more importantly how and when to react to it. At night, crews extinguish external aircraft lighting when it is potentially visible to the threat so as to avoid detection. Under varying weather conditions, crews learn what visibility conditions are sensor penetratable but not necessarily laser accomodative.

The threat algorithm is a training tool. It delivers a high-fidelity quasi-intelligent threat aggressor into the training arena for the very first time. A threat against which attack helicopter crews can apply and practice basic combat engagement rules. Rules predicated on common sense.

CONCLUSION

In the CMS, pilots can learn and practice the tactical decision making skills required to survive on the modern battlefield. Although nothing can replace the training effectiveness of fighting in actual combat, there is one alternative to achieving combat skills proficiency without the casualties. It is the attractive alternative. It is the Combat Mission Simulator.

ABOUT THE AUTHORS

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