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AH-64 FLIGHT AND WEAPONS SIMULATOR CONCEPT FORMULATION STUDY. V--ETC(U)

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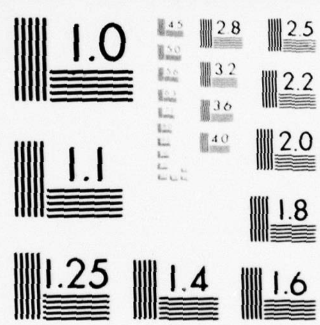

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AH-64

FLIGHT AND WEAPONS SIMULATOR

CONCEPT FORMULATION STUDY

Volume I

Final Report

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The purpose of the study was to formulate the major elements of the design of a simulator for the AH-64 Advanced Attack Helicopter (AAH). The AAH pilot/gunner training requirements were analyzed, and alternative approaches to satisfying these → next page

cont. requirements were considered. Technological areas examined included cockpit configuration, motion and visual system options, computer system requirements, weapon delivery systems, aerodynamic and engine simulation, and instructional system capabilities. The six development objectives of AR 71-1 were adhered to; and specific recommendations were made, proposing a training system composed of a full-mission trainer and a part-task trainer.

PREFACE

This report presents the analysis, conclusions, and recommendations of the preparing activity, Sperry SECOR, regarding the optimum design of a flight and weapons simulator for the AH-64, the Advanced Attack Helicopter.

The report details the results of a study conducted for the Naval Training Equipment Center, Orlando, Florida, under Contract Number N61339-77-C-0048, dated 14 February 1977.

Sperry SECOR wishes to acknowledge the assistance provided by the many military and contractor personnel who generously gave their time in interviews and discussions, and often provided extensive reference material. Of particular note was the assistance provided by PM TRADE, the U. S. Army Aviation Center, and the U. S. Army Armor Center.

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SECTION I

INTRODUCTION AND SUMMARY

PURPOSE OF THE STUDY

The purpose of this study is to determine the optimum design features of an Advanced Attack Helicopter Trainer. The study has been prepared for the Naval Training Equipment Center, Orlando, Florida, in accordance with the specification entitled "AH-63/64 Flight and Weapons Simulator Concept Formulation Study", dated 12 July 1976, as amended by the Computer Section Study Outline appended to the contract. Since publication of the specification, the Hughes AH-64 has been selected to be the Advanced Attack Helicopter; and the terms Advanced Attack Helicopter Trainer (AAHT) and AH-64 Flight and Weapons Simulator (FWS) are used synonymously in the study.

METHODOLOGY

The study was conducted by a project group composed of analysts, engineers, and training specialists, each individual having qualifications in one or more of the various areas of investigation. Under direction by the Director of Engineering, Sperry SECOR, the group consisted of several members of Sperry SECOR, Fairfax, Virginia; a member from Sperry System Management, Great Neck, New York; and, as a consultant, a member from Seville Research Corporation, Pensacola, Florida. Each member contributed directly to the study, by writing sections related to his area of expertise.

The study was prepared in three phases: a data-gathering phase, an approach-definition phase, and a report-writing phase. As predicted in the Sperry SECOR proposal, the phases tended to overlap each other.

Data was obtained by a number of methods. Initially, discussions were held with persons directly interested in the study, at PM TRADE, Naval Training Equipment Center, Orlando, Florida; the U. S. Army Armor Center, Ft. Knox, Kentucky; and the U. S. Army Aviation Center, Ft. Rucker, Alabama. Later, those contacts were broadened to include interviews with training supervisors, helicopter pilots, and simulator instructors. Helicopter flights were made at Ft. Rucker, Alabama and Ft. Bragg, North Carolina, to observe techniques of nap-of-the-earth flying, acquisition and identification of typical targets, and other aspects of attack helicopter training. For the latest data on the Hellfire missile system, program managers and engineers were interviewed at the Hellfire Project Manager office, Redstone Arsenal, Alabama; and at Rockwell International, Columbus, Ohio. Visits were also made to the U. S. Army Night Vision Laboratory, Alexandria, Virginia, and the U. S. Air Force Human Resources Laboratory at Williams AFB, Arizona. To obtain information on visual system technology, visits were made to Singer Link Division, Sunnyvale, California; and Evans and Sutherland, Salt Lake City, Utah. Perhaps the most important source of information was the large volume of reports and specifications generously provided by PM TRADE.

Visits, interviews, and helicopter flights were performed by a limited number of study group members. Their observations and all published data were made available to all members as required.

SUMMARY ANALYSIS OF TRAINING REQUIREMENTS

The mission of the Advanced Attack Helicopter, the AH-64, will be to perform air cavalry and aerial escort roles, and to conduct direct aerial fire against enemy armor and other mechanized targets. Manned by a crew of two - a pilot and a copilot/gunner, the AH-64 will be armed with Hellfire laser-guided missiles, 2.75-inch rockets, and a 30-mm gun. Visionic equipment will consist of the Target Acquisition and Designation System (TADS), the

Pilot Night Vision System (PNVS), and the Integrated Helmet and Display Sight System (IHADSS). In general, the copilot/gunner, who occupies the front seat, will perform navigation and operate the weapon systems, and the pilot, in the rear seat, will fly the helicopter, although all weapons and most visionic equipment can be operated from either position.

The AAH will conduct tactical operations in day or night, and will be capable of IFR navigation. Normally, the helicopter will approach target areas by terrain flight tactics (low level, contour, and nap-of-the-earth); and will engage targets either autonomously or by using designator aircraft or ground personnel. If a hostile ground or air threat is encountered, the AAH will take appropriate evasive or defensive action.

Deliveries of the AH-64 to U. S. Army field units are expected to commence in the 1980-1982 period. The AH-64 FWS should be available in the same period.

A simulator (or simulator system) to conduct pilot and gunner training for the AH-64 will be required to have a broad range of capabilities. The following requirements are basic:

Realistic depiction of the scenes that the pilot and gunner will see during terrain flight navigation.

Depiction of targets, with sufficient resolution to permit identification and acquisition, at ranges appropriate to the AH-64 weapons.

Simulation of the AH-64 visionic equipment.

Simulation of all modes of fire of the missile, rocket, and gun systems.

Simulation of the flight characteristics of the AH-64 helicopter.

Simulation of instruments and controls at the pilot and gunner positions.

Simulation of intercom and radio systems, including their use in air traffic and tactical modes.

Simulation of threats to the airborne AH-64.

In addition, the simulator will be required to enable an instructor to initiate and control training exercises, and observe and evaluate student performance.

These requirements can also be viewed functionally. Training in the AH-64 can be categorized as either "institutional" or "operational". Institutional training is that familiarization and initial qualification instruction given at Ft. Rucker, Alabama; and operational training would be the more advanced, continuation training conducted at units located worldwide. The AH-64 FWS must be capable of meeting both types of training requirements.

Institutional training (in the AH-64 FWS) would include:

- Aircraft handling
- Normal and emergency procedures
- Instrument flight and navigation
- Terrain flight and navigation
- Weapon indoctrination

Operational training would consist of:

- Maintenance of proficiency in emergency procedures, instrument flight and terrain navigation
- Maintenance of proficiency in operating all weapons and visionic systems (by both crewmen)
- Crew coordination, in connection with NOE navigation, target acquisition, and weapon delivery
- Tactical decision-making
- Simultaneous engagement of multiple targets
- Response to hostile actions (small arms, radar, AAA, enemy aircraft)
- Coordination with scout helicopters, ground personnel, forward air controllers, etc.

CONCLUSIONS AND RECOMMENDATIONS

In consideration of the training requirements summarized above, the Sperry SECOR study group visualizes the AH-64 FWS primarily as a full-mission trainer capable of providing a broad range of both institutional and operational training, and enabling integrated pilot and copilot/gunner training in those areas where crew coordination is important.

The cockpit would replicate the tandem seating of the AH-64 and would be mounted on a six-degree-of-freedom motion base with reduced excursions (see Figure 1). Proposed is a visual system using computer-generated imagery (CGI) projected on a wide-angle (180-degree), fixed-base, cylindrical screen by five Hughes liquid crystal light valve projectors.

The instructor station, which would be situated remote from the cockpit, would be normally manned by one instructor, or two on occasions when simultaneous training demands on the pilot and copilot/gunner require, and would accommodate a number of observers if desired.

The instructor station would contain three 21-inch CRT's for problem control and student monitoring, two 5-inch CRT's for monitoring the pilot and copilot-gunner's visionic displays, and five 7-inch CRT's that would reproduce the visual system displays.

A variety of displays and instructional programs would enable the instructor to enter malfunctions by several methods and to monitor the student's procedures; to play back a student's maneuvers in order to show him his mistakes; to show demonstrations of correctly performed maneuvers; to evaluate student precision-flying ability on both instrument and visual flight profiles; to evaluate student proficiency in weapon delivery; and to print out CRT displays for critique purposes. Graphic displays would enable the instructor to monitor training in instrument navigation and approaches. Included would be a combat situation display by which the instructor could control targets, threats, and friendly elements that would be depicted on the visual display and require decisions and responses by both the pilot and copilot/gunner.

The study group considers that a need will exist for specialized training in NOE navigation, target detection and identification, and operation of visionic and armament equipment, and recommends that a part-task trainer be included in the AAH simulator system to accomplish training in these areas. This trainer would represent the gunner's cockpit and would use a wide-angle (120-degree) cinematic system with either a flat or curved screen to produce the visual display, and a seat-shaker system to provide disturbance motion cues. The instructor station would be located immediately to the right rear of the student. (See Figure 1a).

A cinematic visual system is recommended because NOE navigation and target detection and identification require lifelike detail and resolution that are beyond the capabilities of CGI or terrain model board systems. Films of NOE flight routes would enable the student to correlate map symbols with observed scenes and thus practice navigation, and films of armored vehicles and other targets in various degrees of concealment would enable training in target detection and identification. Computer-generated displays, correlated with the through-the-windscreen scene, would be shown on the student's visionic systems and would enable training in target acquisition and engagement and in operating procedures of the visionic and armament equipment. Spot projectors focussed on the cinematic scene would simulate missile and rocket plumes and the flash of detonations, and miss distances would be calculated from the CGI displays.

Thus, the study group recommends that the AAH simulator system consist of two trainers, one possessing a full-mission training capability within the limitations of current interactive visual systems, and the other providing part-task training where a high degree of visual resolution and realism are necessary. These two trainers would be designated the AAH Mission Trainer (MT) and the AAH Navigation and Weapon System Trainer (NWST).

The study group has arrived at many peripheral conclusions regarding the components of the simulator; supporting areas, including logistical; aerodynamic and engine simulation; and instructional systems. These conclusions and corresponding recommendations are contained in the various sections, following, in this report.

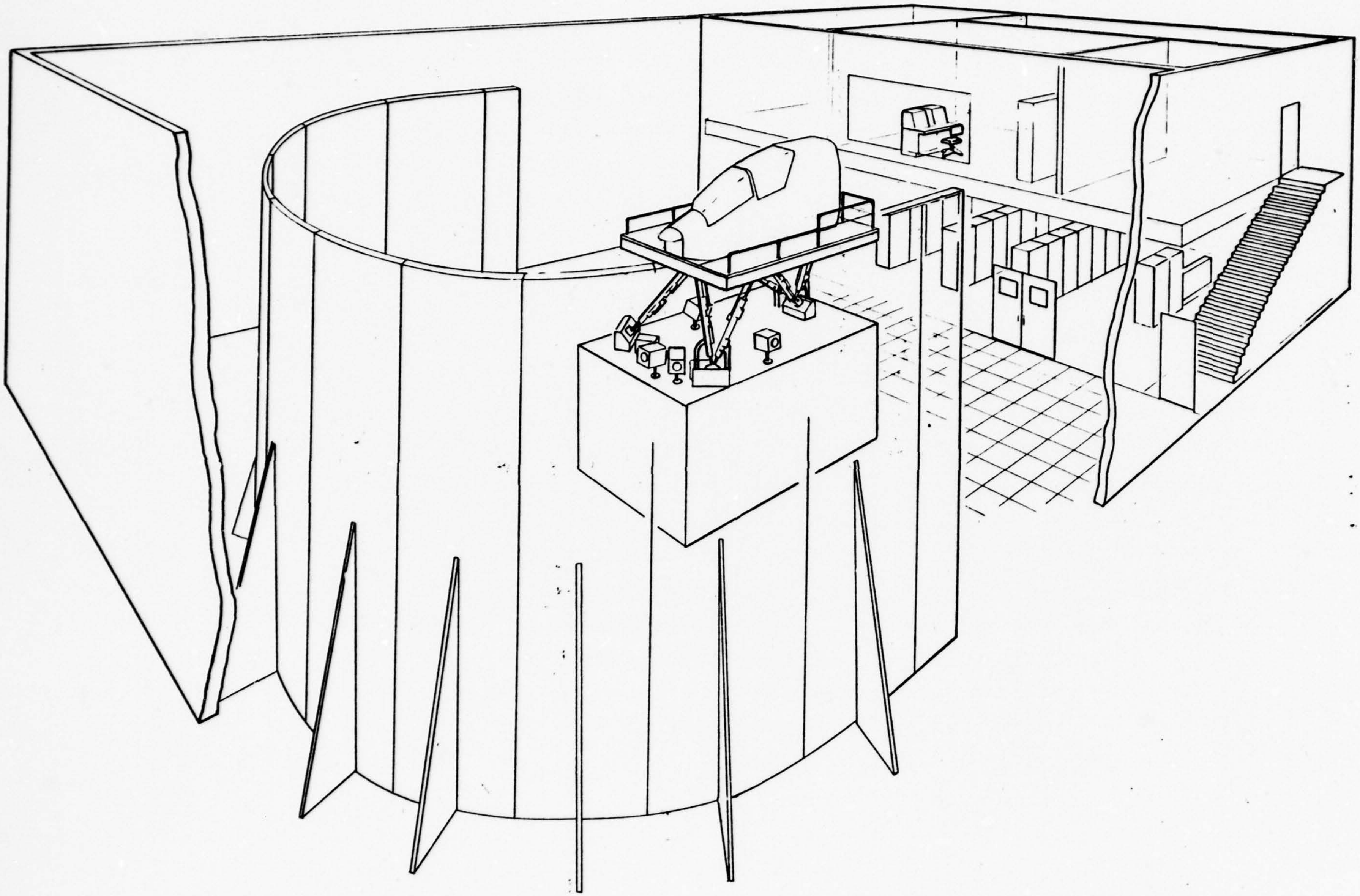

Figure 1. Artist's Concept of the AH-64 FWS Mission Trainer

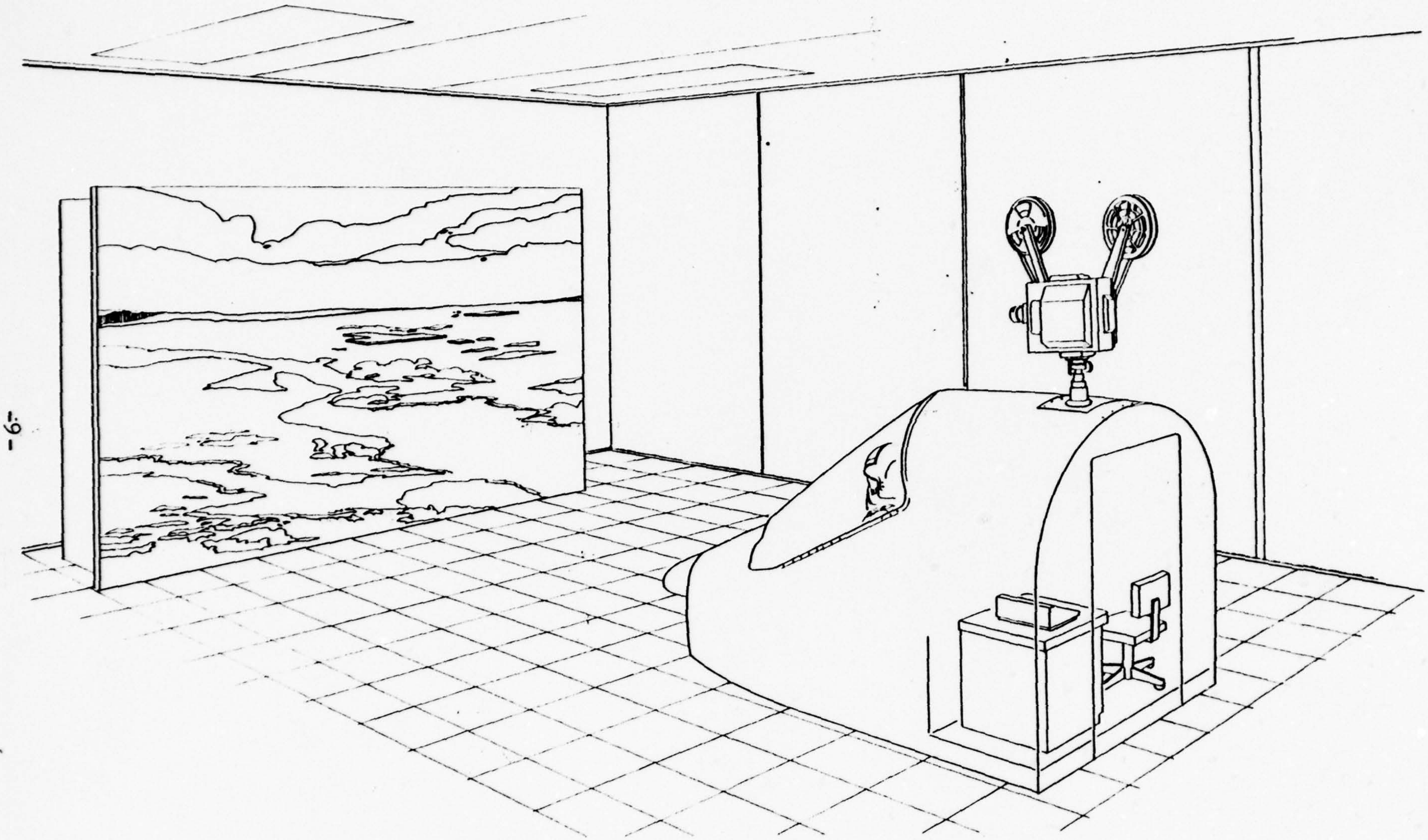

Figure 1a. Artist's Concept of the AH-64 FWS Navigation and Weapon System Trainer

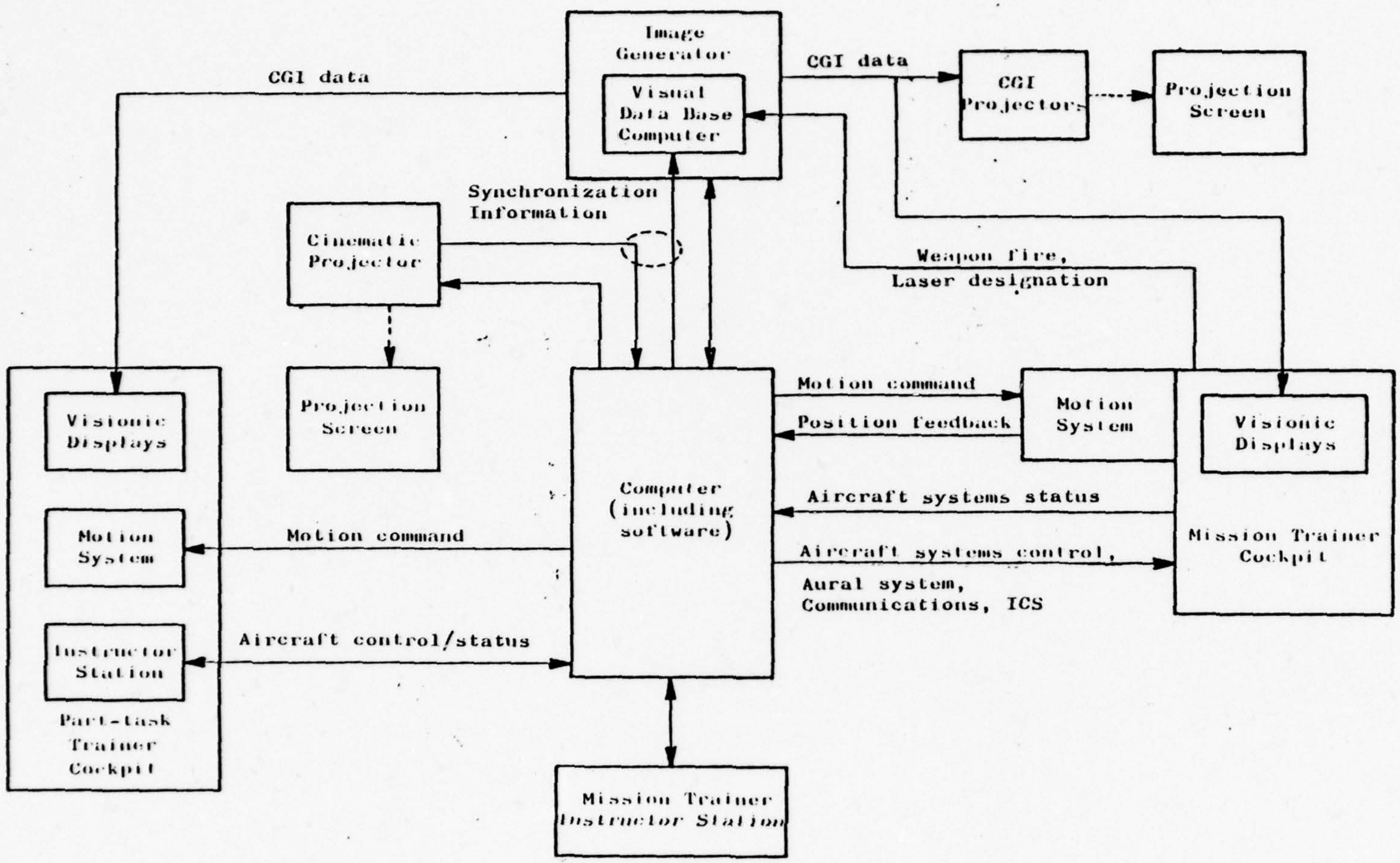

Figure 2. AH-64 Flight and Weapons Simulator Block Diagram

SECTION II

ANALYSIS OF AAH TRAINING REQUIREMENTS

As a part of the AH-64 Flight and Weapons Simulator Concept Formulation Study undertaken by Sperry SECOR, a review was conducted of the performance requirements associated with the AAH pilot and gunner as those requirements are understood at the present time. The review included extensive interviews with Army aviators who expect to participate in future AAH training activities, aviators who have flown a wide variety of missions in Army aircraft (with an emphasis upon those who have had operational experience with the AH-1 Cobra), and aviators who participated in the operational testing of the AAH itself. In addition, pertinent Army aviation training programs were reviewed, design documents describing the AAH and its various on-board systems were analyzed to identify operator requirements, and reports of earlier studies in which Army aircrew task analyses have been conducted and training objectives derived were studied. From these efforts an understanding of the roles of the AAH pilot and gunner has evolved, and, from that understanding, training requirements have been organized in a manner that can be related to AAH simulator design and training concepts. The present section of this report describes those relationships so that the reader will have a better appreciation for some of the concepts embodied in the simulator design described elsewhere.

AAH PILOT/GUNNER TRAINING REQUIREMENTS

The AAH is being developed by the Army to perform a mission similar to that currently being performed by the AH-1 Cobra. While the AAH may replace the AH-1 at some indefinite future time, due to attrition or other factors, current plans are that the two vehicles will perform, together, virtually the same operational mission. There are some differences in the battlefield performance capabilities of these vehicles, and the survivability of the AAH is expected to be greater. From the pilot and gunner training standpoint, however, the requirements associated with the AAH are expected to parallel in all significant respects the requirements associated with the AH-1. These requirements are discussed below:

Pilot Training Requirements

The pilot will be responsible for the overall conduct of the AAH mission. Although he may elect under some circumstances to assign certain tasks he normally performs to his gunner, e.g., mission planning and conducting radio communications, he will retain responsibility for their performance, so such tasks are viewed here as pilot tasks rather than gunner tasks. Likewise, there are tasks that can be performed in the AAH by either the pilot or the gunner by virtue of the fact that duplicate displays/controls are located at each position. These tasks also are viewed here as pilot training tasks. It should be noted that it is firm Army policy that all AAH gunners will be fully qualified AAH pilots, although conceivably this policy could change.

Mission and Flight Planning. Tasks associated with AAH mission and flight planning include reviewing the tactical situation and the capabilities of the enemy threat, planning flight routes and attack positions, obtaining maps, utilizing appropriate aircraft and air traffic control reference sources, and filing the appropriate flight planning documents. Verifying the readiness for flight and for the mission of the assigned aircraft are also tasks that can be considered to be within this category. The training related to the AAH required for the pilot with respect to these tasks consists of those activities involving preflight of the aircraft itself and assuring that its stores/fuel loadings are within required operational limits. Preflighting tasks involving portions of the aircraft external to the simulated cockpit areas are not of concern to a simulator training requirement, of course. Other mission and flight planning tasks can also be a part of a training activity involving an AAH simulator, but they constitute training program design considerations, i.e., how the simulator is used, rather than simulator design considerations. Therefore mission and flight planning tasks have no significant implications for AAH simulator design.

Aircraft Operation and Control. Tasks associated with AAH operation and control consist of performance of all cockpit checklist items and tasks that involve aircraft handling, i.e., controlling the position, attitude, and movement of the AAH with respect to external objectives and features of the environment. Examples of aircraft handling tasks include taxi, hover, takeoff, enroute flight, approach to an operational or landing area, and landing. All basic aircraft maneuvers are included in these tasks, and skill at them is prerequisite to performance of operational missions in the AAH. However, skill at the performance of aircraft operation and control tasks does not assure that the pilot will be able to perform an operational mission or any tactical element of such a mission. The performance of mission-related tasks is discussed in subsequent sections.

The most common use of modern aircraft simulators is in the conduct of pilot training related to aircraft operation and control tasks, and it should be planned that the AAH simulator will be the primary locus of such training for the AAH pilot. The basic simulator design implications of the requirements for such training are for a device that closely resembles in appearance and size the interior of the cockpit (pilot position) of the AAH with controls and displays that correspond in function to the same items in the aircraft's cockpit. All on-board systems with which the pilot interacts must also be simulated with respect to both normal and abnormal or emergency conditions. Additional requirements relate to simulation of the atmospheric and electronic environment in which the simulated aircraft operates, and simulation of motion, visual and sound cues essential to the tasks being performed. A more comprehensive and precise specification of the features and characteristics of an AAH simulator is presented elsewhere.

Instrument Flight Missions. The instrument flying tasks associated with AAH training are virtually identical to those associated with instrument flying in other instrument-equipped Army aircraft, except to the extent that the cockpit displays themselves may differ among aircraft. Instrument flight training has historically been a primary function of aircraft simulators, and the technology with respect to both simulator design and training program design needed to support such training is readily available. A simulator in which AAH operation and control tasks can be performed and that contains simulation of the instrument navigation environment would be suitable for conduct of AAH instrument training. Virtually all (i.e., 95%+) AAH instrument training can be provided in such a device.

Terrain Flight Missions. Terrain flight consists of flying at speeds varying from 0 to 80 knots at altitudes varying from below treetops and other masking features of the terrain to an altitude high enough to clear the highest obstacle in the flight path. The tasks involved in terrain flight include hovering in and out of ground effect; contour, low-level and NOE flight; all aircraft operation and control flight tasks; masking and unmasking; performing quick-stop maneuvers without unmasking; determining obstacle clearances; and performing evasive maneuvers. Terrain flight requires a high degree of skill on the part of the pilot because of the constant danger of blade strikes and collisions with objects and with the terrain itself. Terrain flight operations occur within a very restricted and cluttered airspace, and as a consequence, a much higher aircraft control skil level is required than for operations in more open airspaces.

It should be noted, however, that it is not necessary to develop all of the necessary aircraft control skills in such a threatening environment. A high degree of skill in maintaining precise control over the position and movement of the AAH can be developed in another more open environment and transferred to the cluttered terrain flight environment, thus reducing the magnitude of the terrain flight training requirement. For example, a pilot who learns to fly "on instruments" to a high skill level, particularly if the instrument displays permit him to maintain very close tolerances on all attitude, position and rate parameters, likely will develop terrain flight aircraft control skills much more rapidly than will a pilot trained to less precise instrument flight standards.

Because of the potential dangers of conducting flight training in the terrain flight environment, the AAH simulator is a highly desirable locus for such training. The extent to which terrain flight mission training activities can be accomplished in a high fidelity simulator such as would be required for conduct of the other simulator training discussed above will be limited by the device's visual display and motion system. Visual display and motion system requirements related to terrain flight mission training are discussed below.

Terrain Flight Navigation. Navigation consists of maintaining continuous, accurate geographic orientation. Gainer and Sullivan (1976a, 1976b) have pointed out that the navigation skills required at high altitude in a benign environment are virtually irrelevant in a terrain flight environment. Instead, the pilot must acquire skills involving accurate terrain analysis, precise piloting in a highly restricted visual field, and valid and rapid map interpretation. Even for the highly skilled and experienced Army aviator, terrain flight navigation is extremely difficult, particularly when operating in relatively unfamiliar terrain.

Factors which must be considered in the specification of training requirements for terrain flight navigation include a greatly restricted geographic area of view, terrain and vegetation masking, a sharply oblique view of the terrain, a highly dynamic visual scene, a high angular velocity of objects in the visual field, and a distorted relationship between visually observed features of the environment with respect to their representations on maps. In addition to these factors, the pilot engaged in the terrain navigation task must simultaneously perform a variety of aircraft control tasks, monitor the cockpit displays, make tactical decisions, and manage the weapons and avionics systems (he may assign some of these tasks to the gunner). The requirement under most terrain flight mission conditions to make frequent changes in airspeed makes dead-reckoning navigation techniques useless, and there are virtually no navigation aids reliably available.

Terrain navigation training is a formidable task for the AAH pilot. Because of safety restrictions as well as resource limitations, the conduct of this training in the AAH itself must be restricted. This is an important area where a simulator may be employed. Because of the severe visual cue requirements associated with terrain navigation and the need to correlate observed features with their cartographic counterparts, however, present state-of-the-art simulators do not provide the full-mission terrain navigation training potential that may be desired. Simulator visual display considerations related to terrain flight navigation are discussed elsewhere. While simulators will undoubtedly prove indispensible in AAH terrain navigation training, it is likely that the AAH itself will also play a significant role in that training.

Target Detection and Identification. Target detection and identification in the AAH is a task that is primarily performed visually by the pilot. He frequently will be aided by having a particular target called to his attention by the gunner, by the crew of another aircraft, or by a ground observer. The task involves skills such as analysis of the terrain and the tactics and capabilities of the threat in order to identify potential target locations, approaches, and types; detection of target signatures such as sun reflection, movement, dust trails, and weapons flash; and recognition of familiar target shapes, patterns and colors. While, in the past, aircraft have sometimes been used as platforms from which target detection and identification training have been conducted, the more successful training related to these tasks has been conducted in non-flight environments such as classrooms. Simulation offers some potential for the conduct of such training, since many of the successful classroom training techniques probably can be adapted to the simulator environment. Target detection and identification training and the associated AAH simulator visual display requirements are discussed elsewhere.

Target Engagement. The target engagement task for the pilot consists of four principal elements: (1) maneuvering the aircraft into and maintaining (as required) an attack or weapons release envelope; (2) weapons selection/preparation; (3) weapons release; and (4) damage assessment. The first element is basically that of controlling the aircraft and has been discussed above. An added component of the task involves time sharing aircraft control with cognitive activities associated with threat analysis, evaluating tactical alternatives, and planning the attack. The second element involves the execution of procedural tasks and checklists, and it too must be time shared with cognitive activities as well as with aircraft control. Weapons release for the pilot, assuming the two earlier task elements have been performed correctly, is a relatively simple task for some weapons, e.g., rockets, and involves only maintaining the aircraft in a steady, in-trim state for a relatively brief time interval. For weapons such as the mini-gun or cannon, the pilot must respond to visual cues derived from weapons tracers or impact to adjust his aim as may be required. The pilot normally will not fire the AAH's flexible aim weapons or the missile, and his only task associated with their use by the gunner involves positioning the aircraft and remaining within a prescribed envelope until the gunner's task is completed. For damage assessment, the pilot may be aided by the gunner who will employ the optical sighting device available to him to obtain a magnified view of the target.

Use of the AAH simulator for target engagement training of the pilot is highly desirable due to the high cost of such training in the aircraft. Except to the extent that visual display technology imposes limits upon the visual detectability of appropriate targets, the AAH simulator will provide an excellent vehicle for most target engagement training activities. Because of visual display limitations, however, it is likely that the aircraft will continue to be necessary for a portion of such training and to provide confirmation of the effectiveness of training conducted in the device. Visual display considerations related to the use of simulators for target engagement training are discussed elsewhere.

<u>Night Missions</u>. It is projected that the AAH may be required to engage in a significant amount of night, restricted visibility, or low light level operations. These operations will potentially include the full range of day operations discussed herein, each of which will be made more difficult to perform by virtue of the poor visibility associated with night operations. In the tactical environment, security requirements will dictate that there be little or no cultural lighting to provide navigation and

orientation cues at night, and the illumination from fire, flares, and weapons flashes will be of only limited help because of the necessity to fly at NOE altitudes where they may be visible only infrequently. To avoid detection and to maintain dark adaptation, the AAH's landing and search lighting equipment will seldom be used except in the secured stagefield environment.

Operation of the AAH under night and dusk conditions in a tactical environment without electronic viewing aids will be a formidable task for which training can provide only limited relief. The best preparation for such a requirement will be to develop high levels of skills at the tasks required for operation under daylight levels of illumination so that less attention will be required for their performance at night and more attention can be directed to seeing hard-to-distinguish objectives and features of the environment. Such high skill levels can be developed in a simulator without a night simulation capability, although a "night visual" simulator might be useful to train pilots to recognize specific light patterns.

Operation of the night viewing aids available to the AAH pilot will require training. While use of light enhancement goggles is not a demanding task per se, the pilot will be required to practice using them, primarily to adapt to the reduced field of view they permit. The infra-red and LLLTV displays, when viewed through the pilot's helmet visor, will present training problems associated with display interpretation, i.e, recognition of objects and features of the environment under various conditions of illumination and heat retention. The technology is available to provide such training in an AAH simulator, although it is likely that a portion of the flight training will continue to be conducted in the AAH in order to build pilot confidence as well as to assure the validity of the overall training program.

Communication and Coordination. The AAH pilot does not operate alone. He must function as an integral part of the crew of the aircraft and, often, of an attack unit involving other aircraft and ground elements. Primarily, the pilot must employ his radio and intercom system to effect the necessary communication and coordination, but to a lesser extent, he may employ visual cues such as hand signals, smoke, flares, and the maneuvering of his own or other aircraft. Provision of the appropriate communication capability in a AAH simulator is straightforward and requires no design features not required to support almost any other training likely to be conducted in it. Provision of the desired visual cues in dynamic (i.e., not canned, pre-programmed) fashion, however, is a formidable task and may not be fully achievable with present-day technology. For this latter reason, the communication and coordination training requirement associated with the AAH and its missions received particular attention during the present study.

With respect to communication and coordination between the pilot and the gunner in his own ship, personnel experienced with the AH-1 Cobra and the AAH equate the two so far as these task requirements are concerned. Primary coordination in the Cobra takes place via intercom during all mission activities from the time power is applied prior to flight until the aircraft is shut down at the conclusion of a mission. A secondary but important means of cumminication and coordination involves the use by the pilot of his helmet sight to point out targets to the gunner by slaving the gunner's TADS and optical sighting devices to it. This technique, which is available in the pilot-to-gunner direction only, has virtually no training requirement associated with it. In addition, the gunner, on rare occasions, may employ hand signals to communicate with the pilot, but, because of the configuration of the vehicle, this channel cannot easily be reversed. Here again, however, hand signals are employed to indicate direction only, and training needs associated with them are minimal.

Communication and coordination with elements outside the AAH present somewhat more of a training problem. To the extent that that problem can be met through use of the aircraft's communications equipment, training in a simulator is likely to be as effective as training in the AAH itself and can be conducted more efficiently. To the extent that visual contact must be maintained with other attack units, whether on the ground or in the air, the probable value of simulator training is more limited. Both visual communication and coordination of attack activities require closed-loop interaction between participating elements. While the construction of a simulator that would involve multiple unit interaction is technically possible, its cost would likely far exceed its value for training. In that regard it should be noted that AH-1 pilots who were questioned concerning the manner in which they communicated non-verbally with other attack elements and the effectivenss of that communication reported consistently that they experienced no problem in achieving effective coordination. While these reports can be questioned, they do suggest that the techniques involved either were adequately supplemented by available verbal communication channels or that the techniques required were available without specific training.

Comments by Gainer and Sullivan (1976a) concerning verbal communication requirements during NOE flight are generally applicable to all missions that will involve the AAH. These researchers point out that effective communication involves formulation and transmission of relevant, accurate, and intelligent messages as well as the ability to understand and follow specified communication procedures. They suggest that simulators provide an efficient medium for the development and maintenance of the procedural skills involved in effective communication. Training related to cognitive functions, such as decision making, verbalization, enunciation, vigilance, audition, attention sharing, memory and judgement, present more of a challenge. Developing these latter skills in an AAH simulator will require imaginative planning to provide a meaningful and stressful situational context that will permit training to deal with such problems as failure to communicate timely messages, untimely communications, garbled syntax, unintelligible speech, misunderstandings and misattributions.

Reconnaissance, Indirect Fire Control, and Intelligence. The AAH pilot must be trained to perform a wide variety of higher order activities involving use of his aircraft as an aerial vehicle. Many of these activities require that he be intelligent, innovative, adaptable to the environment and the threat at hand, and responsive to a highly dynamic situation. These activities are dependent upon the prior development of skills previously discussed. For example, the effective conduct of a reconnaissance or fire control mission requires that the pilot be able to control his aircraft, navigate effectively, and maintain precise geographic orientation. Once these underlying skills are developed, many of the required higher order skills can be developed with relative ease, and special training in the aircraft or a simulator may not be required. Other higher order activities, such as those associated with intelligence (e.g., deceiving the enemy as to his unit's tactics and collecting information of potential intelligence value), while also dependent upon the same underlying skills, are not so easily developed.

The extent to which useful higher order skills such as those discussed above can be trained in a simulator--or, for that matter, the extent to which they can be trained in the AAH itself--is not known at the present time. Important though they are, activities employing some of these skills have not been subjected to the kinds of job analysis that would permit their precise definition. While it is likely that s simulator could be designed that would provide practice at tasks involving reporting what is seen along a flight route, estimating distances and directions of simulated weapons impact to targets, and employing circuitous flight routes, the value of such training in a simulator with limited cue possibilities would be questionable. Training objectives involving such higher order skills specified in the absence of an adequate job analysis are viewed as possible "high risk" objectives so far as AAH simulator training is concerned.

Tactics Training

The ultimate goal of any aircrew training is effective employment of a weapon system in combat. Thus, tactics training for the AAH aviator involves training encompassing each of the areas discussed above. In addition, the pilot must exhibit sound judgement, effective decision making, ingenuity and a host of other high-order skills. Since these skills are difficult to define, it is even more difficult to define training requirements and simulator features appropriate to their development.

It is possible, however, to cite examples of aviator behavior that illustrate some of these higher order skills and to design simulator and training programs around them. In the case of the AAH, for example, behavior can be identified that will increase battlefield survivability and therefore make effective weapons system employment more likely. Such behaviors include limiting exposure to possible anti-aircraft fire by avoiding flying through clearings, down highways and rivers, and along ridge lines; effective use of the terrain for concealment; altering attack routes and positions; and employing a variety of types of evasive maneuvers when under fire. Relatively simple algorithms can be devised that will permit an AAH simulator to be used effectively for such training.

Tactics training that involves dynamic interaction with an enemy force in a realistically simulated tactical environment presents more difficult training and simulator design problems. A principal characteristic of the battlefield is the use of the terrain and its cultural and natural cover for concealment. Designing a simulator in which visual presentations are appropriate to the training of aviators to interact with an enemy in such a visual environment, while possible with current simulation technology, is hampered by the absence of tactical doctrine and relevant training objectives. Currently available task analysis methodologies are inadequate to the determination of these objectives. Therefore, the best that the simulation designer can do at the present time is to point out the need for better definitions of the relevant tactics and related training requirements and to design simulators that can be adapted to those requirements when they are developed.

Gunner Training Requirements

In the case of the AH-1 Cobra, the bulk of the aircraft qualification training takes place while the trainee occupies the aircraft's pilot position. The trainee receives training in the gunner position approximately 10% of the time. This ratio accurately reflects the facts that (1) most AH-1 aircrew tasks can be performed and learned from the pilot position; (2) transfer of training from the pilot position to the gunner position is virtually 100% for all tasks that can be performed from both positions; and (3) the few tasks that can be performed only from the gunner position are relatively simple and easy to master by anyone who has previously mastered the aircraft pilot's tasks. Front seat training in the AH-1 concentrates primarily upon operation of the target acquisition and weapon systems that must be operated from that position.

The tasks of the gunner in the AAH are comparable in most respects to the tasks of the gunner in the AH-1, and the training considerations applicable to one of these aircraft are also applicable to the other. Personnel who are familiar with both vehicles indicate that the virtual identity of aircraft controls and associated displays between the two AAH crew positions (as contrasted with dissimilar controls in the AH-1) will facilitate the transfer of aircraft operation and control skills from the pilot to the gunner position even beyond that between comparable positions in the AH-1. In fact, it appears likely that tasks which can be performed from either cockpit (e.g., aircraft operation and control, navigation, and reconnaissance) need be trained only in one of the two crew positions. In the present discussion, preference is given to the conduct of such training in the pilot position, although the alternate options would be equally viable in most cases.

During unit training exercises not involving an instructor pilot, the gunner practices tasks associated with mission accomplishment from the front seat, of course. This training undoubtedly is helpful in increasing/maintaining gunner skills, although there are few tasks that are practiced during the flight that are not being practiced equally effectively by the pilot in the rear seat. Except to the extent that these flights provide an opportunity for the gunner to increase/maintain his skills in the relatively simple tasks unique to the front position in the AAH, the chief advantage they provide is the opportunity to practice, along with the pilot, higher order tasks such as navigation, target identification, night missions, communications, etc.

There are important tasks that are primarily or exclusively gunner tasks and for which training must be provided while the trainee occupies the front cockpit position. These tasks are discussed below.

Aircraft System Operation. There are tasks involving operation of aircraft systems that can be performed only from the gunner position. Execution of aircraft start-up and other checklists requires completion of certain steps by the gunner in coordination with the pilot, and these procedural tasks must be learned. In addition, there are weapons selection, target designation, and electronic countermeasures panels that must be operated by the gunner during certain missions because they are not available to the pilot. These gunner tasks are primarily procedural in nature and can be trained in a simulator.

Target Acquisition and Designation. The gunner in the AAH has primary responsibility for acquiring targets through viewing aids located in the front cockpit. These aids provide both image enhancement through infrared and TV sensors and magnification through optical viewing devices. They are very well engineered from the standpoint of operator tasks, and the development of skills in their use is neither difficult nor time consuming. The design of the equipment virtually eliminates the need to develop complex psychomotor tracking skills, and there are no significant requirements for cognitive skills associated with their use. The procedural tasks involve a relatively small number of steps, and virtually all training requirements can be met in a simulator. Designating a target, i.e., illuminating it with a laser, is associated with these sighting aids. Procedural steps associated with target designation also are amenable to accomplishment in a simulator. Cognitive learning demands upon the gunner are limited essentially to considerations related to safe use of the laser. Once the procedural skills are acquired, minimum continuation training will be needed to insure successful operation of these systems in the operational environment. Must of this training can be conducted in a simulator, although a simulator is not viewed as necessary to such training. However, because of the potential injuries to personnel and livestock that could be inflicted through unrestricted use of the laser designator, it would be difficult if not impossible to conduct such training exclusively in aircraft.

Target Engagement. The target engagement task of the AAH gunner will involve firing the flexible weapons and the missiles. Firing the flexible weapons is a task that requires practice to develop psychomotor skills in order to maintain fire on a target.

Since the gunner is not required to pilot the aircraft while engaging in the target engagement task, he has a relatively light time-sharing requirement while firing, and simultaneous cognitive demands also are minimal. To the extent that the targets of interest can be represented on its visual display, the simulator is an appropriate locus for the development of the skills underlying employment by the gunner of the AAH flexible weapons.

Firing the missile, when that task is separated from the target designation task (which may or may not be performed by the gunner is any specific instance), is essentially a procedural task involving final preparation of the missile through discrete controls on a gunner cockpit panel, verifying that the orientation of the aircraft is within the required launch envelope, and missile release. If the gunner is also designating the target, he must time-share that task with missile firing, but both these tasks are sufficiently well engineered that the acquisition of acceptable levels of skill and the maintenance of proficiency will not require great amounts of training in a simulator or in an aircraft. The major portion of the procedures associated with missile preparation will be performed on the ground prior to takeoff, normally will not be subject to critical time pressures, will not have to be time shared with other tasks, and will make few cognitive demands on the gunner. It is believed that a simulator with an appropriately designed visual display will be an acceptable medium for the bulk of the training that will be required. The visual display requirements for the gunner that are related to target engagement are discussed below.

Night Missions. In addition to the night mission skills that the gunner will acquire during his training as an AAH pilot, he will be required to learn to operate the infrared equipment from the controls located at the gunner position. The task will involve operating the panel controls to obtain useable images on the display scope or on his visor and the interpretation of the images obtained. This training can be provided in a simulator, or even in a part task trainer, in which a range of displayed images could be provided so that the gunner can practice adjusting the sensitivity of the equipment and interpreting the IR signatures of the objects involved.

Communications and Coordination. Although skills necessary to tasks associated with communications and coordination will be developed by the gunner largely during his training as an AAH pilot, the requirements for his coordinated participation in all AAH operational missions is such that additional comment is appropriate here. During a tactical mission, particularly in the terrain flight environment, the gunner will perform most of the visual navigation tasks, leaving the pilot relatively free to attend to aircraft control and obstacle avoidance. Most of the controls associated with employment of the missiles and with use of the IR and TV sensors are located in the front cockpit, so extensive verbal communication is required between crew members where use of this equipment by the pilot is concerned. The gunner and pilot share the tasks of observation, target detection and identification, intelligence collection, and many other tasks that are involved in an operational mission. In practice, they often function together on such tasks, either alternating the conduct of a given task between each other or duplicating each other's efforts such as occurs when both crewmen look for targets in an area of interest.

The sharing of or alternating between tasks makes frequent but brief verbal communication between crewmembers a characteristic feature of AH-1 operational missions, and the same characteristic is expected to hold for AAH missions. However, since communications skills tend to break down under task overloads, effective crew coordination is dependent on each crewman's being highly proficient at the non-communication as well as the communication tasks he must perform. To the extent that a meaningful situational context and stress or tasks overload can be provided, the simulator is a suitable environment in which pilot-gunner procedural and cognitive communications skills can be developed under controlled, tutorial conditions.

<u>Conclusions Concerning Pilot and Gunner Training Requirements</u>

Analysis of the AAH pilot and gunner training requirements identified during the current study reinforces the view that an AAH simulator can play a major role in meeting those requirements. A suitably designed simulator, used in conjunction with an appropriate training program within a well-managed training system, can provide a better qualified aircrew at a significantly lower cost than could be obtained through training exclusively in the AAH itself. In addition, training in such a simulator will increase flight safety, reduce the use of expensive missiles and other weapons, reduce environmental pollution, and free terrain and other training resources for other uses.

<u>Qualification Training</u>. A major portion of projected AAH aircrew qualification training can be conducted in simulators. Based upon the review during this study of AH-1 training currently conducted at Fort Rucker, Alabama, it is estimated (subject to empirical validation when appropriate resources are available) that at least two-thirds and possibly three-quarters of the expected AAH transition training can be conducted in simulator training equipment such as that described in subsequent sections of this report. Such simulator training would emphasis the following training areas, with subsequent practice in the aircraft required only to build aircrew confidence and to verify that the necessary skill levels have been achieved:

- emergency procedures
- aircraft characteristics
- aircraft limitations
- cockpit procedures
- takeoff to a hover

hovering flight
landing from a hover
normal takeoff
high speed flight
normal approach
maximum performance takeoff
traffic pattern
steep approach
autorotation to touchdown (all airspeeds, altitudes)
maximum gross weight operations
quick-stop/deceleration maneuvers
instrument flight
radio communication
coordinated crew activities
all procedural tasks associated with navigation, weapons and target acquisition systems

In addition to the above, it is expected that such a simulator will be suitable for the aircrew's initial training in the following activities with additional training to be required in the AAH itself to assure that all associated training objectives have been fully met:

night missions
terrain navigation
terrain flight takeoff
terrain flight traffic patterns
terrain flight approaches
introduction to weapons use
range safety procedures
masking and unmasking techniques

Gunnery Training. Because of the high cost of gunnery practice, particularly where the expensive Hellfire missile is concerned, the use of a simulator for gunnery training is highly desirable. It is expected that the proposed AAH simulator can be used for the conduct of a significant portion of that training. It will be fully suitable for the introduction of the pilot and the gunner to the operational procedures associated with each on-board weapons system, and it is expected that relatively high proficiency levels can be reached through training in the simulator for each of them. Because of the inherent simplicity and accuracy of the Hellfire missile system, virtually full proficiency at its employment will be obtainable in the simulator, and firing live missiles from the aircraft will be required only to build confidence in the aircrews involved. For the other weapons systems, practice firing from the aircraft likely will be required in order to hone skills to combat proficiency levels, but practice in the simulator will greatly reduce the need for such inflight training.

Instructor Pilot Training. Because of its configuration and flexibility, the AAH simulator will be an appropriate vehicle in which to conduct major portions of AAH instructor pilot training, and will permit a greater degree of standardization of instructor performance than would be possible in the aircraft where instructors could not be observed directly. The aircraft itself will be required for the conduct of portions of the AAH instructor pilot's training, however.

Unit Training. The use of AAH simulators at Army aviation units will contribute significantly to aircrew proficiency at all of the tasks described above and can be expected to eliminate completely the need for Unit aviators to fly the aircraft solely for the purpose of developing, re-acquiring or maintaining such proficiency. The simulators will be less useful, however, for training that would involve performance in conjunction with other combat elements. Therefore, the AAH aircraft will play a significant role in the training of Army aviators. It is expected, however, that the use of the AAH in support of ground unit training, plus the flying essential to exercise the aviation maintenance support system, will be fully sufficient to provide the training necessary to the maintenance of AAH pilot and gunner skills not amenable to maintenance in the proposed simulators.

VISUAL DISPLAY TRAINING CONSIDERATIONS

The preceding review of the training requirements associated with an AAH simulator indicates a clear need that the simulator have an extra-cockpit visual display. The need for such a display derives principally from the requirement to conduct simulator training related to four kinds or groups of tasks: (1) tasks related to aircraft handling; (2) tasks related to terrain flight navigation ; (3) tasks related to target detection and identification; and (4) tasks related to target engagement. The following discussion examines each of these kinds of training tasks and the suitability of model board, CGI, and film-based visual display systems with respect to each. It should be noted that this discussion is limited to training considerations. Other kinds of considerations affecting simulator visual display system design are addressed in Section IV.

Task 1: Aircraft Handling Tasks

This training requirement consists of the development of precise skill in controlling the position, attitude and movement of the AAH with respect to external objects and features of the environment. Most aircraft handling skills can be developed using the information available inside the cockpit, i.e., the instrument displays. The need for an extra-cockpit visual display arises when the tasks to be learned involved approaching stagefields, confined areas or other potential landing areas; maneuvering around or near natural or cultural objects or features such as occurs when hovering and during NOE flight; using environmental features for concealment or masking; and flying in formation with other helicopters. In all such cases, critical visual cues are those that permit the pilot trainee to determine distances to objects, clearances between objects, and closure rates. A wide variety of visual scenes is not a requirement for such training, e.g., a single stagefield and a relatively small NOE maneuver area would be sufficient for the full development of such skills. Since recognition of specific features of the environment and objects involved would not be a significant part of aircraft handling training, it would be feasible to conduct such training in a familiar visual environment.

Model Board Considerations. A model terrain board can provide the visual cue information needed for the conduct of aircraft handling training. A board of modest size, e.g., representing a geographic area of from 15 to 25 square miles, would be sufficient and might include simulation of a stagefield or heliport with its associated visual cues with a surrounding area consisting of a variety of natural and cultural features in which NOE aircraft control tasks could be practiced. An important feature of such a model board display would be its information content, i.e., the amount of detail in which its features and objects were represented. A high level of detail would be required, and this would dictate a requirement for a relatively large model scale, e.g., probably greater than 1000:1, depending upon the techniques employed in board construction.

CGI Considerations. In concept, CGI visual displays can provide the information content and detail necessary to the conduct of aircraft handling training in a simulator, although the specific information to be programmed for display may not always be clear. In general, a CGI display modeled after the model board display described above would offer the kinds of training opportunities required. The amount of detail that would have to be displayed in a CGI scene of a simulated NOE maneuver area is not known and probably would have to be determined experimentally.

Present state-of-the-art CGI displays are believed to be capable of displaying the required detail, however.

Film Considerations. Film is not considered to be a suitable medium for the generation of a visual display for use in the conduct of aircraft handling training. Because of the fixed nature of film, a film-based display would not be sufficiently responsive to changes in the aircraft position and attitude resulting from pilot control input.

Conclusion. Aircraft handling training requirements can be met using either model board or CGI visual display technology.

Task 2: Terrain Flight Navigation Tasks

The navigation tasks of concern to the AAH pilot consist of relating map symbols and features to objects and features of the visual world as seen by the pilot at contour and NOE flight levels. Therefore, a realistic presentation of those features, in sufficient variety, is a basic requirement of a simulator that is to be used for navigation training.

Model Board Consideration. The adequacy of a model terrain board visual display for the presentation of environmental features suitable for navigation training is limited by the size and scale of the geographic area simulated, the information content of the board, and the depth of field of the optical system employed. The present state-of-the-art will permit, at least in concept, the development of a board of adequate size, scale and information content for realistic navigation training. As a practical matter, since the very nature of the navigation task necessitates a considerable variety of training situations, the cost of building, housing, and operating a board large enough to provide sufficient variety of the features needed for navigational training, and to provide those features at a reasonable scale, may well be prohibitive. Using present day optics, depth of field limitations pose an additional and serious problem for navigation training, since navigation at terrain flight levels is dependent upon the identification of geographic features in both near and far fields. Because of these considerations, the navigation training value to be derived from model board visual simulation is limited.

CGI Considerations. Present day CGI displays, as well as those forecast for the next 2-3 years, offer very little training potential for terrain flight navigation. Since present CGI technology permits only gross and/or symbolic representation of visual scenes, such a display could not be used to provide the necessary training. The navigation task as presented in a simulator with a CGI display would consist of relating map symbols to visual display symbols rather than to features of the visual world. Training to identify such relationships in the simulator would not be expected to transfer to the task required to navigate in the operational environment, because the task of relating CGI display symbols to terrain features as seen from low altitudes would remain to be trained. Except possibly for minor procedural elements, such as map manipulation and orientation, CGI technology expected to be available within the next few years would appear to hold little promise to terrain flight navigation training.

Film Considerations. The use of cinematic methods to teach navigation skills and geographic orientation has been thoroughly explored and has been found to be a satisfactory method for training terrain navigation (McGrath, 1973). Its chief limitation lies in the fact that it does not permit closed-loop exploration of a geographic area, and therefore does not permit practice of navigation per se. Gainer and Sullivan (1976a) have noted, however, that this is not a serious deficiency in the use of film-based media for NOE navigation training, since the fundamental skills and knowledge needed for performance of the terrain navigation task involve detecting and identifying various types of preselected navigational checkpoints, interpreting terrain forms, relating sighted features to those portrayed on a map, and making navigational decisions. These skills and knowledges can be developed using still and motion pictures.

Conclusion. The visual training necessary for successful terrain flight navigation in the operational environment can best be provided using a library of wide-angle films in conjunction with appropriate instructional procedures and practical exercises, followed with limited confirmatory practice in a non-simulated environment. Navigation training of much more limited scope would be possible in a simulator with a relatively large model board display. Training involving a CGI display would be of little, if any, value.

Task 3: Target Detection and Identification Tasks

The tasks of detecting and identifying targets is dependent upon being able to see those targets and their distinguishing characteristics. Further, they must be seen at ranges that equal or exceed the ranges at which they are to be engaged. The principal characteristics of a visual display suitable for such training relate to the clarity of images of targets at simulated engagement ranges.

Model Board Considerations. The principal limitations of model board visual simulation with respect to target detection and identification are the resolution of the display and depth of field. Depth of field, or focus, is a problem in a simulated tactical environment where near focus is required in order to avoid striking objects used for concealment or masking, while at the same time, far focus is needed to view distant objects. With respect to resolution, examination of existing model board displays indicates that, regardless of overall model board scale or the number of display TV line pairs, identification of targets, even large targets such as tanks, at ranges appropriate for their tactical engagement is not possible. Even detection of the presence of such objects at appropriate ranges is impossible, and the use of oversized models which would aid detection is not desirable where close approaches to such targets would occur during other training exercises. Therefore, adequate training for tasks involving target detection and identification in a simulated tactical context cannot be provided using the model board approach.

<u>CGI Considerations</u>. With compromised (enhanced) scale, color, contrast and/or brightness of targets when they appear at far ranges, it is possible to assure target detection with a CGI display. There is a danger in this approach, however, inasmuch as many of the cues to detection employed in a non-simulated tactical environment cannot be represented appropriately, given the present state-of-the-art of CGI technology. Training aviators to pick out targets from among the background clutter at specified engagement ranges using detection cues that must be employed tactically (e.g., shapes, relative size, light dust and smoke trails, small movements) cannot be done well if at all. Instead, detection would have to be made a very easy task through distortion and exaggeration of these target signatures and characteristics so that the detection task would become basically unlike that required operationally. Sufficient target detail to be used for target identification training could be provided by CGI, but if appropriate scale were maintained, the resolution of the display would limit the value of such training.

<u>Film Considerations</u>. Film media can provide scene content and image quality appropriate to target detection and identification training, but at the sacrifice of closed-loop maneuverability of the simulated flight vehicle. This approach becomes feasible in a part-task training device where the flight path can be fixed and filmed in advance, or in a classroom situation where a wide range of still and motion picture views of targets in tactical situations can be presented inexpensively in conjunction with appropriate training procedures and techniques.

Conclusion. The model board has little merit as a medium for target detection and identification training in the AAH simulator. CGI is preferable to a model board for this training requirement, but the deficiencies are still such that the value of the training provided would be suspect. Film is the best available simulation medium for this training. Target detection and identification training should be provided in part-task trainers not providing closed-loop control over the simulated aircraft's flight path or in a classroom environment.

Task 4: Target Engagement Tasks

The visual elements of the target engagement task consist of maneuvering the AAH into an attack position, acquiring the target, tracking the target during the period of weapon release or missile flight, making adjustments in aim based upon weapons impact point, and assessing target damage. Those elements of the task related to aircraft handling, maneuvering with respect to mask and cover in the NOE environment, and target detection and identification are discussed above.

Model Board Considerations. The use of a terrain board visual display for target engagement training would be constrained primarily by three factors: (1) target variety would be limited to a relatively small set in fixed locations on the board, and target movement would be severely restricted; (2) engagement ranges would be restricted to ranges at which the targets could be detected, and these ranges typically would be less than the ranges suitable for engagements in an operational situation; and (3) there would be little or no capability to provide feedback to the pilot concerning the accuracy and effectiveness of his weapons except through artificial means, e.g., numerical scores, and the visual effects of weapons firing would have to be generated electronically for superimposition upon the model board display. An additional constraint would be the need to relate visual display information with cockpit displays depicting radar and infrared views of the same areas and magnification of those views.

CGI Considerations. CGI technology could provide a visual display suitable for the conduct of target engagement training activities and would not share many of the constraints of the model board approach. Targets could be engaged at realistic ranges, and a considerable variety of target types and positions could be simulated. Weapons effectiveness could be represented, at least symbolically, and weapons signatures could be provided without additional hardware. CGI displays would be constrained, however, by the artificality of appearance of current state-of-the-art CGI display scenes, and the limitation discussed elsewhere concerning target detection and identification would be of concern.

Film Considerations. There are three primary constraints with respect to the use of film as a visual display medium in target engagement training: (1) training involving closed-loop control of the simulated flight path would be precluded because of the fixed nature of the display; (2) feedback concerning weapons accuracy and effectiveness would be restricted much as it would using a model board display; and (3) correlation of film displays with visionic displays in the trainer cockpit would present a complex technical problem. The first of these considerations, the fixed flight path, is not a major problem, since most target engagement activities can be performed while flying a pre-selected flight path. The latter two problems can be solved by displaying CGI depictions of the film scene on the visionic displays in the cockpit. This approach will necessitate accepting stylized images on the visionic display, but it is presumed that the need for realsim and detail will have been satisfied by the film scene during a preceding target detection and identification phase. From the CGI displays weapon accuracy and effectiveness can be calculated.

Conclusion. Except in training situations in which closed loop maneuverability is required, a cinematic visual display is the display of choice. The second choice overall and the first choice for target engagement training where the simultaneous task of maintaining control over the flight of the aircraft is desired is the CGI display. Use of a model board display would impose severe constraints upon target engagement training, primarily because of the unrealistic engagement ranges that would be necessary for some weapons systems.

Summary of Display Type Considerations

There is no clear choice of a visual display system for the AAH simulator. In fact, none of the display types considered is even minimally suitable for all the required training. Instead, the advantages and disadvantages of each type with respect to the training discussed above suggest that a simulator with a mix of visual displays would possibly be the best solution. Even then, however, it is clear that the present state of the visual simulation art will not permit the full range of training for AAH visual flight tasks to be conducted in a simulator. At best, the AAH simulator will be a part-task training device with respect to visual training requirements. A significant portion of AAH training will have to be conducted in flight where real-world visual cues can be employed.

Since no single solution is available, it would be well to consider multiple solutions, each optimized, so far as the state-of-the-art will permit, to particular training requirements. Such an approach would lead to design of a system of simulators or training devices rather than to a single, all-purpose, full-mission simulator in which only those training activities suitable to the visual display system selected could be conducted. Such an approach would permit a greater proportion of AAH training to be conducted in simulation, and, as a consequence, would reduce the total requirement for use of the AAH itself for such training.

There are advantages to the use of cinematic visual displays in meeting some of the AAH visual training requirements. In fact, film can be the medium of choice for two or three of the four kinds of training tasks discussed above, i.e., terrain navigation, target detection and identification, and possibly target engagement. Therefore, consideration must be given to a simulator in which training in these tasks could be conducted. At the same time, however, a film-based display would be totally unsuitable for the conduct of aircraft handling training, so a simulator with a model board or CGI display would be required for it.

The design of an AAH pilot and gunner simulator system that would meet the diverse visual display requirements discussed above is described in Sections IV and V.

MOTION SYSTEM TRAINING CONSIDERATIONS

The Role of Motion in Simulator Training

It is recognized that the AAH is capable of movement in three rotational (pitch, roll, yaw) and three translational (vertical, lateral, longitudinal) axes, and that it is possible for an experienced pilot to distinguish movement associated with each axis under optimum conditions. These facts do not necessarily dictate the motion system design necessary for effective simulator training, however. Direct and indirect costs associated with procuring and operating simulators with large excursion, six-axis motion systems are very high, and economy in motion system procurement is desirable. One large user of flight simulator has recently decided to forego platform motion systems on its newer simulators in order to reduce the cost and complexity of required visual systems. While the elimination of motion in an AAH simulator would not seem productive, it is certainly desirable to examine the need for AAH simulator motion and to make sure that the simulator's motion systems are appropriate to the training requirements. Otherwise, there is a danger that a simulator motion system might be procured that is modeled after aircraft motion without regard to training needs per se. The fact that the AAH moves in a certain manner is insufficient reason to design a training simulator that moves the same way. The effects of movement upon pilot and gunner performance are the critical factors. Investigation of the influence of motion upon transfer of simulator training to operational aircraft has been largely ignored. There were a number of studies of simulator motion in relation to aircraft handling qualities and control during the 1950's and 1960's, but most of them addressed transfer of training only indirectly. The first significant published transfer of training study of the effectiveness of simulator motion upon subsequent performance in flight was reported in 1975 by Jacobs and Roscoe.

Jacobs and Roscoe reported that pilot performance in the aircraft did not benefit from the presence of normal washout cockpit motion in the simulator. In that study, training received in the GAT-2 in a two-axis (pitch and roll) normal washout motion condition, compared with training in the same device without motion, resulted in non-significant differences in amount of transfer to the aircraft for those two conditions. There was, however, significant positive transfer for both motion and no-motion conditions. Similar results have been obtained in a U. S. Air Force undergraduate pilot training study involving the more sophisticated six-axis motion system associated with the Advanced Simulator for Pilot Training (ASPT) (Wood ruff, 1976).

The finding in these two recent studies that the presence of motion did not increase simulator training effectiveness is of considerable interest, since there are other studies showing that, at least under some circumstances, motion does influence simulator training. For example, Fedderson (1962) reported a slight advantage in favor of a motion simulator trained group over a no-motion group during brief transfer trials hovering a helicopter. More importantly, perhaps, the motion group in his study reached asymptotic performance in the simulator more rapidly, suggesting that simulators with motion may provide more efficient training. A recent U. S. Air Force study of pilot responses to engine failure in a simulated transport-type aircraft found that training is more effective when motion is added to a simulator with a visual display than when the same simulator and visual are used without motion (DeBerg, McFarland & Showalter, 1976).

Further, there is evidence that pilot performance in the simulator differs as a function of the presence or absence of motion. For example, Perry and Naish (1964) found the pilots respond to external forcing functions such as side gusts more rapidly, with more authority, and in a more precise manner in a simulator with motion and visual cues than when only visual cues are present. NASA researchers (Rathert, Creer & Sadoff, 1961) found that the correlation between pilot performance in an aircraft and in a simulator increased with the addition of simulator motion cues where such cues help the pilot in coping with a highly damped or unstable vehicle or a sluggish control system, or under some circumstances, where the control system is too sensitive. Where the aircraft is easy to fly, however, as is the case with the aircraft used in the Jacobs and Roscoe study (Piper Cherokee) and in the Air Force ASPT study (T-37), motion may have no effect. In another NASA study (Douvillier, Turner, McLean & Heinle, 1960) of the effects of simulator motion on pilot's performance of flight tracking tasks, the results from a moving base flight simulator resembled the results from flight much more than did those from a motionless simulator. In a British study, Huddleston and Rolfe (1971) reported that the presence of a simulator motion produced patterns of control response more closely related to those employed in flight. That is, using simulators without motion, experienced pilots were able to achieve acceptable levels of performance, but their patterns of control response showed that their performance was achieved using a strategy different from that used in a dynamic training environment. Research at the University of Illinois related to instrument display design responses to display types differentially, with inappropriate banking motions interferring with command flight path tracking (Ince, Williges, & Roscoe, 1975).

Thus, numerous studies provide evidence that the presence of motion, i.e., movement of the platform upon which the simulator cockpit rests, does affect performance in the simulator. Not only can motion affect learning rates, but the performance of the pilot in the presence of motion may be different than it would be in the absence of motion. With motion, his simulator control responses to external forcing functions appear to be more rapid and accurate and more like responses used to control the aircraft in flight. While it cannot be concluded from these studies that simulator motion during training will enhance subsequent performance in the aircraft, they do suggest that simulator motion can affect the acquisition of skills in the simulator. These effects of motion upon performance in the simulator have been demonstrated under controlled experimental conditions that tend to make it unlikely that the noted differences in performance could be attributed solely to factors other than the presence of motion during simulator training.

The influence of platform motion is not necessarily always beneficial, however. Excessive or inappropriate motion, e.g., high levels of simulated turbulence, could make learning less rapid if it were a factor in making the simulator more difficult to control. Likewise, motion that is out of synchronization with visual or other cues could interfere with simulator control if it made trainees ill or presented misinformation to them. For example, it has been reported that the simulator used in the Air Force ASPT study cited above has time lags in the motion system that make the performance of some maneuvers difficult (Hutton, Burke, Englehard, Wilson, Romaglia, & Schneider, 1976).

Maneuver vs. Disturbance Motion

In discussing the influence of motion upon pilot performance in simulators, Gundry (1976a, 1976b) distinguishes between two kinds of motion cues and suggests that they might affect performance differentially. Maneuver motion is that motion that arises within the control loop and results from a pilot-initiated change in the motion of the aircraft in order to change its heading, altitude, or attitude. Disturbance motion, on the other hand, arises outside the control loop and results from turbulence or from failure of a component of the airframe, equipment or engines that causes an unexpected (to the pilot) motion of the aircraft. Matheny (1976) made a similar distinction in a study in which he identified aircraft motion as resulting from external forcing functions or from input into the aircraft controls.

The reason that platform motion can result in quicker, more accurate simulator control probably is that the disturbance component of that motion resulting from simulated turbulence or equipment failure can provide more rapid and relevant alerting cues about forces acting upon the aircraft than can be obtained from other cue sources. Maneuver motion does not fulfill an alerting function, because it results from pilot-initiated control movements. Research involving maneuver motion, Gundry states, indicates that this component of platform motion has little effect upon the control of an aircraft whose flight dynamics are stable. For unstable vehicles, however, the presence of maneuver motion will allow the pilot to maintain control even in flight regions where control by visual cues alone would be impossible. Thus, disturbance motion permits more rapid and accurate aircraft control under all flight conditions in which such motion is appropriate. Maneuver motion, however, improves aircraft control only when the aircraft is unstable.

In both the Jacobs and Roscoe and the Air Force ASPT studies cited above, emphasis was upon simulation of maneuver rather than disturbance motion. Since maneuver motion is pilot induced and the aircraft involved in these studies were quite stable, the most likely role of motion was to provide confirmatory feedback to the pilot. If sufficient feedback were available from other sources such as the aircraft instruments or an extra-cockpit visual display, as likely was the case, the maneuver motion provided in these two studies could not be expected to have a large effect upon simulator training effectiveness, and probably would be ignored altogether by the trainees. Had these two studies examined the influence of disturbance motion resulting from factors outside the control loop, e.g., malfunctions, the results probably would have been different. The evidence that disturbance motion may have a large effect upon pilot performance in the aircraft should not be overlooked in the design of an AAH simulator.

The influence of platform motion upon transfer of simulator training has not been clearly established by the data available at the present time. It has been demonstrated that motion can affect pilot performance in the simulator in ways that may make his performance in the simulator more like his performance in the aircraft, but it has not been shown that simulator motion enhances his subsequent performance in the aircraft. The two studies that have addressed the question of transfer directly did not support a conclusion that motion is needed. Likewise, there is no consensus among pilots as to the need for motion in simulator training.

More attention has been paid in the design of existing simulators to maneuver motion than to disturbance motion. Emphasis has been upon providing in a simulator the motion cues associated with well-coordinated pilot control inputs, scaled down to the limits of travel and accelerations of the motion platform. Since most training and operational aircraft are relatively stable, this kind of motion simulation may be of very little potential value in training. It would be more beneficial from the training standpoint to provide the motion cues associated with disturbance to the aircraft not originated by the pilot, and then only at initial suprathreshold onset values, so that he could learn to respond specifically to motion cues rather than learning to respond to visual or other cues that occur later in time.

The distinction between maneuver and disturbance motion is useful in attempting to understand both the prior research on motion and the reactions of pilots to the motion component of aircraft simulators. In the transfer of training studies in which motion did not appear to influence subsequent pilot performance, the motion involved was predominantly, if not exclusively, of the maneuver variety. On the other hand, disturbance motion was the predominant type of motion in studies in which changes in pilot performance were related to motion simulation. Thus, the results of both sets of studies can be accepted and attributed to the nature of the motion simulation involved in each. Disturbance motion is important, at least in training situations where disturbance cues can be related to specific training objectives and when the aircraft simulated is unstable or is particularly responsive to control input. Maneuver motion may be important also under some circumstances, but the evidence available at this time has not shown that it contributes to transfer of training in easy-to-fly aircraft.

Motion Characteristics of the AAH

In considering the need for and performance characteristics of motion systems for an AAH simulator to be used for training, it is helpful to distinguish between the two kinds of motion discussed above, i.e., maneuver motion and disturbance motion, and to identify the training needs associated with each.

AAH Maneuver Motion. During flight at airspeeds above translational lift, the AAH is a stable, easy to control aircraft. The handling characteristics of the AAH, as reported by pilots who participated in the YAH-64 operational tests, are comparable to other helicopters. The aircraft reportedly handles very much like the AH-1 Cobra, and the pilot's workload is comparable. An initial pilot reaction is that it is more of a challenge to fly, but this apparently is due to its greater size. Possibly because of its size, the AAH tends to be somewhat more stable in flight than the AH-1. There is a pitch up in attitude during normal takeoff that occurs at about 40K, but the primary cue to this change is visual rather than motion since it does not occur abruptly, and correcting for it presents no particular training problem. Attitude changes that occur during pilot induced maneuvers, such as rapid deceleration, steep turns, and autorotation, are directly responsive to pilot inputs and present no unusual control problems.

Although the AAH has freedom of movement with respect to each of the six motion axes during such flight, the cues associated with this motion do no more than confirm to the pilot what he already knows, i.e., that the aircraft has responded to his control input. Consequently, these cues are not necessary to precise control of the aircraft and have no demonstrated training value. It is likely that the pilot would frequently even be unaware of the presence (or absence) of maneuver motion cues during flight at airspeeds above translational lift, since those cues would be compatible with information he already has. In fact, there have been numerous anecdotal reports of pilots not knowing whether the simulator's platform motion was on or off during training periods when only maneuver motion was simulated.

When taxiing and operating in ground effect, on the other hand, the AAH is relatively unstable. In order to taxi, power must be applied to lighten pressure on the wheels. When this is done, the aircraft tends to "fishtail" (yaw) and roll due to torque and to the fact that the tail rotor is located above the CG. The roll is most pronounced during turns and is of magnitude of approximately 3° to 4°. The roll is felt by the pilot, since it occurs rapidly, and a rapid correcting response is required in order to maintain directional control.

In the hover mode of operation, the pilot must use motion cues as the primary or initial source of information about changes in the position, movement, and attitude of the aircraft. Visual cues that would reflect these small but rapidly occurring changes tend to be noted by the pilot later than motion cues and thus would be inadequate for aircraft control. In fact, the pilot would be very likely to be unable to learn to hover the AAH in a simulator that lacked maneuver motion cues simulated through a platform motion system. Such a learning task would be comparable to learning to balance on a unicycle without being able to feel the onset of an imbalance condition. Visual cues alone would be insufficient for efficient learning to take place.

When taxiing and operating within ground effect, the sensitivity of the AAH to control input is such that the onset of motion resulting from pilot control input is prompt, and motion acceleration is rapid, particularly with respect to rotational movements. The magnitude of motion tends to be small, however, because large movements must be prevented to preclude contact with external objects and/or the terrain. Consequently, in simulating maneuver motions of the AAH, particular attention should be directed to rapid motion onset and acceleration, but large displacement would not appear required. (Large displacements with respect to maneuver motion occur in flight above translational lift, but the research literature, as described above, does not indicate a need for such motion in a training simulator).

It must be concluded that the magnitude of excursion of motion in an AAH simulator is less important that the promptness of such motion. Time lags between pilot control input and vehicle response that exceed corresponding lags in the AAH when operating in ground effect would have an adverse effect upon pilot performance, since the consequence would be loss of the early alert to the pilot that the cues associated with such vehicle motion provide. In that regard, it should be noted that the human body cannot perceive motion directly; it is sensitive only to higher order derivatives such as acceleration and jolt (Kinkade & Wheaton, 1972).

It is not possible, on the basis of available behavioral and training research data, to quantify precisely the excursions required in each degree of freedom in order to provide the maneuver motion cues appropriate to training pilots to taxi and hover the AAH. It is clear that time lags between control input and the onset of vehicle motion must approximate those of the aircraft itself. The rate of motion onset must be sufficient to alert the pilot, but greater rates probably add nothing to a simulator's training value. Rotational and translational displacements are unimportant in themselves. Displacement sufficient to permit the required alerting, plus provision for washout effects, is believed appropriate and sufficient. Quantitative specification of the relevant onset lags, rates, and displacements appropriate to the proposed AAH simulator are presented elsewhere.

Although designed to withstand 3 to 3.5 g's, the mission of the AAH will seldom subject it to these forces. During abrupt maneuvers at high airspeeds, it is possible for sustained g-forces to increase to the point that they are quite noticeable to the pilot. Since they occur as a function of pilot control input, they must be considered to be maneuver motions. Sustained g-forces cannot be simulated through available simulator motion platforms systems.

G-seats that can redistribute pressures on the pilot's body (within limits) have been used in simulators for high performance aircraft and generally have been endorsed by pilots as providing useable cues <u>in the simulator</u> to control of g-forces. They report that g-forces simulated in this manner provide cues that alert them to attend to the g-meter to avoid overstressing the aircraft. Even pilots who "like" g-seats for simulator training question their value with respect to transfer of training to the aircraft, however. Research by the Air Force involving the ASPT, in which the cue-value of a g-seat was examined, found no evidence that simulated g's affected pilot performance. NASA research involving simulation of g-forces with a centrifuge concluded that there was little need to simulate sustained g-forces in a simulator unless levels of acceleration stress greater than about 4g are anticipated (Rathert, et al., 1961).

In view of the lack of evidence that available and feasible kinds of g-simulation devices will contribute to the training effectiveness of an AAH simulator, no provision for sustained g-force simulation is included in the proposed simulator.

AAH Disturbance Motion. There are a number of events outside the pilot's control loop, or external forcing functions, that result in motion of the AAH that is unexpected by the pilot. These motions provide a degree of realism to helicopter simulation (e.g., the shakes and vibrations that characterize helicopter flight under normal conditions and that experience has shown to be necessary to the maintenance of pilot vigilance), provide prompt cues to the need for action to overcome the effects of equipment failure (e.g., the sudden yaw that accompanies failure of the tail rotor pitch control system), and influence training problem difficulty (e.g., simulated turbulence makes precise aircraft control more difficult).

There are two kinds of disturbance motion that should be provided in an AAH simulator. Uncorrelated disturbance motion, the first kind, is low frequency motion that is not correlated with pilot control movements or visual displays and appears to the aircrew to be either irregular in occurrence and essentially random in frequency, direction, and amplitude; or to be of a relatively fixed frequency, direction, and amplitude but to be virtually always present. Turbulence and oscillatory shakes are examples of correlated disturbance motion. These motions do not present a cue that the pilot must learn to discriminate from other similar cues in order to initiate a particular control input. For this reason, simulation of uncorrelated motion can be relatively gross with respect to corresponding motion in the aircraft but should be present in the simulator under circumstances which characterize its presence in the aircraft.

Correlated motion, the second kind of disturbance motion of concern in AAH simulation, is motion that is a consequence of events that are of immediate interest to the pilot and require his prompt attention. The pilot must be trained to discriminate among correlated disturbance motion cues in order to make an appropriate response. Accurate simulation of disturbance motion cues within the limits of the pilot to make the necessary discrimination is important to effective simulator training.

Motion that results from an equipment failure or sudden (and unintended) change in configuration of the aircraft, such as damper failure or asymmetrical external stores hangup or jettison, is illustrative of a correlated disturbance motion. Its characteristic is a rapid onset or jolt that has a characteristic and predictable effect on the performance of the aircraft. The pilot must learn to respond to such motion by rapidly identifying its probable cause in order to initiate an appropriate emergency procedure, and must rapidly make an input to the aircraft's controls that will allow him to maintain control over the vehicle's flight.

Correlated disturbance motion cues that should be provided in an AAH training simulator include motion cues that result from each of the aircraft failures and malfunctions that will be identified in the AAH flight manual when that document is prepared. Since the final configuration and flight characteristics of the aircraft are not known at the present time, these malfunctions cannot be listed here. In addition, motion cues correlated with the following disturbing events should be provided in the AAH simulator: buffets, blade stall, blade imbalance, blades out of track, touchdown impact, stores release, weapons firing, blade strikes, tail assembly strikes, wheel strikes, and projectile impacts on the airframe and blades. Motion cues uncorrelated with specific events that should be included in the AAH simulator include turbulence and the general vibrations and oscillations associated with routine helicopter operation.

For the same reasons discussed above related to maneuver motion cues, disturbance cues in the simulator that are correlated with specific events should faithfully reproduce, with respect to time and onset rates, the cues that are caused by similar events in the aircraft. Likewise, unless magnitude of excursion is a significant cue that enables the pilot to determine the event with which the disturbance is correlated, these cues can be of relatively low magnitude, since it is the accleration or jolt that provides information to the pilot that is useful in training. Quantitative specification of the relevant onset lags, rates, and displacements appropriate to the proposed AAH simulator are presented elsewhere.

<u>Motion Requirements for AAH Gunner Training</u>

The preceding discussion of AAH motion simulation has emphasized the requirements related to pilot tasks and the discriminations that pilots must be trained to make among motion cues. The gunner is not in the pilot's control loop, so some motions that are confirmatory to the pilot may be unexpected to the gunner. It is therefore desirable to examine the influence of motion upon the performance of the gunner during operational missions in the AAH.

There are few aircraft motions that could be considered maneuver motions so far as the gunner is concerned. The only change in movement of the aircraft through space attributable to gunner activity results from a weapons recoil effect upon the airframe.

This effect is a jolt that confirms that the weapon has fired, but it has no other training value, since the gunner is not required to learn to distinguish it from other motions. The chief advantage of providing motion associated with weapons release is to add a degree of realism that could contribute to the perceived worth of the device.

The gunner can be expected to experience all of the disturbance cues experienced by the pilot. Those that are correlated with specific events related to equipment malfunctions or emergency situations will be of little training value to the gunner, except to the extent that he must take corrective action himself or that they may enable him to assist the pilot in their discrimination and identification. The gunner will have been trained to discriminate and identify these latter motions during his training as an AAH pilot, however. Uncorrelated distrubance cues, i.e., representative helicopter vibrations and oscillations and the effects of turbulence, will contribute to the realism and influence the difficulty of the gunner's task, but they will not provide cues he must learn to discriminate.

The amount of physical displacement of his cockpit can affect the gunner's operation of his weapons, sensing, and target detection systems. Tuning his IR or TV display, for example, will be more difficult in heavy turbulence than in smooth air. Heavy turbulence can also affect the difficulty of the tasks involved in operation of the TADS and aiming and firing the flexible fire weapons and missiles, although these systems are shock mounted and optimally designed to permit their smooth and effective operation from a moving platform. Normal operation of the helicopter at an altitude of several hundred feet involving steep bank and pitch angles would have little effect upon the effective use of these well established systems, and gunner training in their effective use does not require a device in which large excursions are simulated.

The motion requirements for effective training of the AAH gunner are to provide the shakes, vibrations and oscillations associated with normal helicopter operation, light to moderate levels of turbulence appropriate to the operational environment of the AAH, jolts associated with weapons firing, and the disturbance motion cues correlated with any equipment failure or malfunction to which the gunner must learn to respond in concert with the AAH pilot. Excursions can be small, and motion onset times are important only with respect to jolts associated with weapons firing and the few motions that must be correlated with equipment failure that involve direct action by the gunner. Motion onset rates adequate to simulation of uncorrelated disturbance motion and jolts will be required. Quantitative specifications of the requirements for motion simulation for AAH gunner training are presented elsewhere.

SECTION III

A RECOMMENDED AAH SIMULATOR TRAINING SYSTEM

This section of the report describes the AAH training system that has been conceptualized during the conduct of the AH-64 Flight and Weapons Simulator Concept Formulation Study. The training system is responsive to the training requirements described above. At the same time, constraints upon system design imposed by non-training factors have been taken into consideration. In some instances, it has been necessary to adopt concepts that might be judged less than optimum from the training standpoint in order to avoid much more costly alternative concepts. Overall, it is believed that the simulator training system described below will provide optimum school and unit level training for AAH pilots and gunners in conjunction with other Army training resources.

It is important to note that the AAH itself is a principal resource that will play a large role in AAH aircrew training. In selecting simulator design concepts, the unique value of training in the aircraft in an operational or simulated tactical environment was taken into account. No attempt has been made to design simulators that would eliminate completely the need for the aircraft, although the system described below can reduce the role of the aircraft in training virtually to that of building the confidence of pilots and gunners with respect to their simulator-acquired skills, integrating those skills with others that have been acquired elsewhere, and broadening the base of experience in the performance of tasks for which only limited variety can be provided economically through simulation.

The principal deficiencies in the training that can be provided through simulation, and that therefore should be the subject of further practice in the aircraft, are related to operationally oriented visual skills. These include visually acquiring, identifying, and engaging targets at maximum weapons ranges, damage assessment, assessment of and interaction with a dynamic tactical situation, coordinated attacks involving visual reference to other (friendly) attacking units, and operations at night under battlefield illumination. While the basic skills underlying these kinds of operationally oriented tasks can be developed to criterion levels of proficiency in the proposed AAH simulator, and the operational tasks themselves can be introduced and practiced in the device, use of the aircraft for the integration and refinement of these skills is believed to represent a cost effective use of the aircraft in conjunction with other training resources.

OVERVIEW OF THE RECOMMENDED AAH SIMULATOR TRAINING SYSTEM

The AAH simulator training system that has been conceptualized during the present study consists of two simulators with unique characteristics designed to provide training that is minimally constrained by limitations in current simulator technology while at the same time providing the maximum amount of effective training that technology will permit at an acceptable cost. The two simulators are: (1) an AAH Mission Trainer (MT); and (2) an AAH Navigation and Weapon System Trainer (NWST). These two simulators are illustrated in Figures 1 and 1a and described schematically in Figure 2.

The MT and the NWST consist of the principal components described below. A full description of each component and its functional capabilities is presented in subsequent sections of this report.

AAH Mission Trainer (MT)

- A pilot and gunner trainee station that replicates the cockpit configuration interior, displays, and controls associated with these two cockpit positions in the aircraft.

• An instructor station located remotely but in proximity to the cockpit module. The instructor will be provided displays and controls that permit him to monitor performance of both the pilot and copilot/gunner, including displays of the TADS, PNVS, and IHADSS presentations that are visible to both crewmen. In addition, controls will be provided to enable the instructor to control the training program, and also to operate the Mission Trainer when gunner-only training is in progress.

• An additional instructor position and two observer positions adjacent to the instructor position. From this position, the observers will be able to see the instructor's displays and controls and will be able to monitor the training activities underway.

• A motion system that will provide the maneuver and disturbance cues necessary to the training underway.

• A separate vibration or "shaker" motion system mounted on the motion platform. This shaker motion system will provide disturbance cues through the pilot and gunner seats and controls that are of inappropriate frequencies for efficient operation of the primary motion system.

• A wide-angle visual system that will project computer generated visual scenes on a cylindrical direct viewing screen located off of the motion system.

• A computer and its associated peripheral and interface equipment needed to operate the MT in real time.

AAH Navigation and Weapon System Trainer (NWST)

• A gunner trainee station that replicates the cockpit interior, displays, and controls associated with the forward cockpit in the aircraft. Only those displays and controls used in navigation and target detection, identification, and engagement will be operationally simulated.

• An instructor station located immediately to the right-rear of the gunner. From his position, the instructor will have a direct view of the gunner and his controls and cockpit displays and of the extra-cockpit visual display. Controls and associated displays that will permit the instructor to operate the NWST and to control the training program will be conveniently located for his use.

• An observer or instructor trainee position adjacent to the instructor station. From this position, an observer will be able to monitor the instructor displays and controls and will be able to observe the training underway.

• A vibration or "shaker" motion system that will provide disturbance cues through the gunner's seats and controls.

• A wide-angle visual system that will project a cinematic visual scene on a flat or curved direct viewing screen.

• A computer and its associated peripheral and interface equipment needed to operate the NWST in real time.

SCOPE OF MT AND NWST TRAINING

The training that will be required for AAH aircrews has been discussed in Section II of this report. It consists of aircraft qualification training, gunnery training, and training in the operational employment of the AAH as a weapons system. The concepts of employment of the MT and the NWST in the conduct of the required training are described below.

Two concepts of employment are conceivable. One is based on the premise, believed to be currently in effect, that the pilot and gunner will be fully rated pilots and generally proficient in the functions of either cockpit of the helicopter, although not necessarily equally so. The other, understood to be a future possibility, envisions that the gunner will be specialized in front cockpit functions and will receive pilot training only sufficient to enable him to safely return and land the helicopter if the pilot is incapacitated.

Under the first concept, all trainees would receive the same AAH qualification training. At the unit level each AAH air-crewman would be required to maintain full proficiency as both a pilot and a gunner. Consequently, the simulator training of an AAH crewman would consist of his training as both a pilot and a gunner. While the following discussion distinguishes between pilot training and gunner training, each trainee would be trained to function effectively in both roles, and both pilots and gunners would receive training in both the MT and the NWST.

Under the second concept, both the pilot and gunner would receive training in the MT, concentrating on their rear and front cockpit roles respectively. The gunner's training in aircraft handling would be accomplished in the front cockpit. Considerable attention would be paid to training in crew coordination, because of the different backgrounds and skills of the two crewmen. In addition, the gunner would receive training in the NWST in navigation and gunnery.

<u>Training in the Mission Trainer</u>

As its name suggests, the MT will be used for the full mission training of an AAH pilot and gunner. All AAH systems operated by the two crewmen from their respective cockpits will be simulated, and the proficient operation of these systems will be the goal of training in the device. In addition, MT training will encompass those areas in which the crew must function in coordination with each other and with other simulated friendly units.

The MT will be comparable to other high fidelity, visually equipped flight simulators with respect to pilot training. In it, the pilot will be able to develop the full range of skills required for his basic qualification in the aircraft, including execution of normal and emergency procedures, and aircraft operation and control during taxi, hover and flight under instrument and visual conditions. In addition, the device will be used for instrument flight training and retraining for AAH-qualified aviators and for the maintenance of high levels of proficiency of all aircraft operation and control skills associated with maintenance of combat readiness.

The principal limitation of the MT with respect to pilot training will relate to the visual display. The CGI display will not permit the full range of visual task training that will be required of the AAH pilot in a tactical environment. (Limitations of the CGI type of visual display are described in Section II of this report). Consequently, visual tasks involving terrain flight navigation and target detection and identification will not be trained in the MT. Pilots will receive training related to these visual tasks, as will the gunner, in the NWST.

Much of the training of the AAH pilot in the MT, particularly during his initial qualification in the aircraft, can be conducted more efficiently on an individual basis. For example, developing skill in aircraft control does not require the active participation of the gunner under normal conditions. Therefore, while the pilot is undergoing such training in the MT, the gunner will be undergoing separate training in the NWST.

Prior to his training in the front or gunner seat of the MT, each gunner trainee will have undergone training in the back seat of the device (this applies to the current concept of dual qualification). In addition, he will have undergone training in the NWST that will make him familiar with the operation of the controls and displays associated with the gunner's position in the AAH. Therefore, emphasis in the MT training of the gunner will be upon his functions as a member of an integrated AAH crew. Training will include the use of all weapons and visionic systems in both primary and back-up modes, and all aspects of crew coordination including verbal and other interaction with the pilot under a variety of tactical situations. Gunner training in aircraft handling will also be accomplished in the front seat of the MT if a concept of specialization of gunners is adopted in the future.

Training in the Navigation and Weapon System Trainer

The NWST will be the primary training equipment with respect to the training of AAH aircrewmen to perform all terrain flight navigation tasks and target detection and identification tasks that are amenable to training in an open-loop situation, i.e., where maneuvering of the aircraft is not a requirement. A front cockpit simulator is an appropriate device for the conduct of such training, since its occupant, the gunner, normally does not control directly the flight of the aircraft. In addition, the NWST will be used to conduct training in use of the gunner's visionic and armament systems. The training tasks will include performance of aircraft checklist front cockpit procedures; set-up and operation of the indirect viewing, target designation, missile coding, and other equipment; and launching or firing weapons and assessing results.

Because of the advantages discussed in Section II of the NWST's cinematic visual display for certain visual task training, this simulator will be the primary locus for the training of visual skills that must be developed by the pilot and gunner but that are inappropriate to training in the MT because that device's CGI visual display system has been optimized for other tasks. Terrain flight navigation training and target detection and identification will be the principal training activities dependent upon the NWST's cinematic visual presentation. Gunnery training, which will also be accomplished on a closed-loop, integrated crew basis in the MT, will be accomplished in the NWST as a follow-on to the target detection and identification tasks.

Effective navigation training in this device will require a library of wide-angle films prepared during actual flights in simulated tactical environments. For terrain navigation, the films will depict a variety of natural and cultural features including different types of vegetation. Emphasis in this training will be upon maintaining geographical orientation and identifying preselected checkpoints by correlating information from tactical maps with features observed on the visual display. Some training in the verbal functions of the gunner during a terrain flight mission - verbal identification of checkpoints and alerts to the pilot concerning upcoming terrain features, obstacles and targets - will be conducted in the NWST with the instructor simulating the role of the pilot, but the development of crew coordination and skill in verbal interaction will be accomplished in the MT.

In addition to terrain navigation, the NWST's film library will contain films that provide tactical scenes in which the gunner can practice target detection and identification and subsequent engagement. A variety of targets will be presented, both single and multiple, and in various forms of concealment.