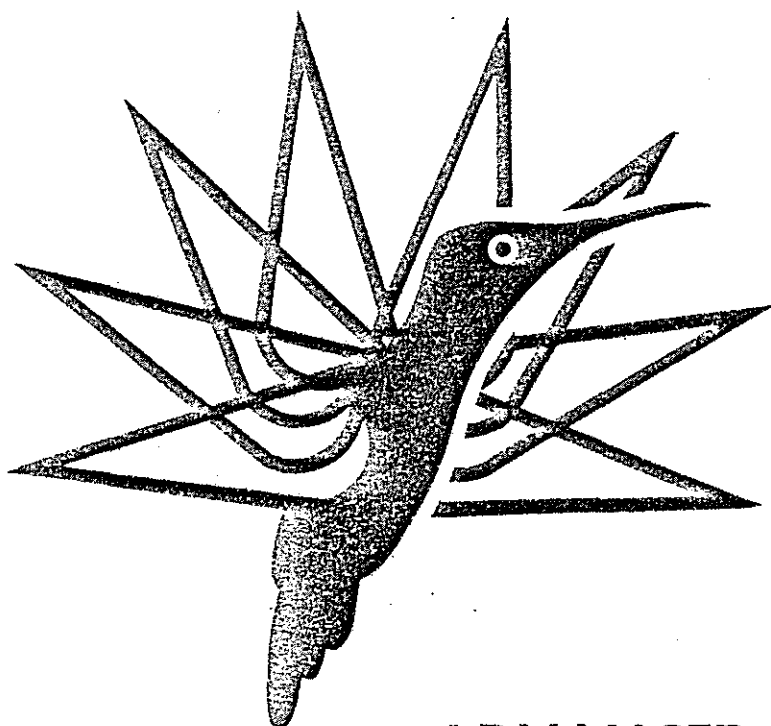


PAPER Nr. : 6



ADVANCED ATTACK HELICOPTER

WEAPON CONTROL SYSTEM

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ADVANCED ATTACK HELICOPTER WEAPON CONTROL SYSTEM

ABSTRACT

The Advanced Attack Helicopter (AAH) is a major new US Army weapon system for anti-armor operations. This twin-engine, two-man highly agile weapon platform carries up to 16 missiles or 76 rockets at four external stores stations plus 1200 rounds of 30mm ammunition. The aircraft has been designed for high survivability against hits from projectiles up through 23mm.

The AAH primary armament system consists of the 7-inch diameter HELLFIRE missile and the gunner's Target Acquisition and Designation System (TADS). The HELLFIRE is a modular guided missile that can accommodate either a laser, imaging infrared or an air defense suppression seeker. The gunner uses the TADS to acquire and engage armor and other types of targets, day and night, at long stand-off ranges.

Secondary armament, which consists of the XM230, 30mm gun and the 2.75 inch Rocket System is intended for engaging light armor and area targets. The gun has been designed to interoperably fire British ADEN, French DEFA and US XM789 HEDP ammunition. The 2.75 inch Rocket System provides the main area target capability and delivers both high explosive and multi-purpose submunition warheads. The gunner's TADS is used for precision delivery of gun and rocket ordnance. An Integrated Helmet and Display Sighting System (IHADSS) provides a backup capability.

The AAH armament subsystems are integrated through a dual redundant multi-plexed digital fire control system. Fire control subsystems include the TADS and IHADSS for sighting and weapon control, a high-speed hybridized fire control computer, a Doppler navigator, a strap-down inertial heading and attitude reference unit, a three-axis air data sensor and mode control electronics for the HELLFIRE missile. Kalman algorithms have been developed to improve accuracy. A captive boresight fixture is used to measure boresight error components which are registered in the fire control computer.

I. Introduction

The Advanced Attack Helicopter is a major new US Army weapon system for anti-armor operations. The system is intended to provide the firepower, mobility, advanced fire control and sensor capabilities and survivability necessary to fight outnumbered and win on the battlefield of the future.

In June 1973, the Deputy Secretary of Defense authorized the Army to initiate a two-phase development of the Advanced Attack Helicopter. Phase I was a competitive development for selecting the best helicopter airframe to enter Phase II, full scale engineering development. Phase II focuses on completing subsystems (missile, cannon, rocket, target acquisition and night vision) development and their integration.

In July 1973, Bell Helicopter Company and Hughes Helicopters were each awarded contracts for two flying prototypes to be evaluated in a competitive fly-off. Military development test pilots and operational pilots from user commands participated in the evaluation. The Source Selection results were presented to the Secretary of the Army on 10 December 1976. He selected the Hughes YAH-64 as the winner (Figure 1). On the same day, the Deputy Secretary of Defense authorized the Army to proceed with the YAH-64 full scale engineering development program which includes the fabrication of three (3) additional flying prototypes.

This paper addresses the weapon control system of the YAH-64, its supporting armament and visionics sighting systems and pertinent features of the aircraft design which enhance weapon system effectiveness and survivability.

II. Aircraft Design and Performance

The two-man aircraft is a twin-engine, four bladed main rotor weapon platform that has been designed for mixed ordnance payload weights of approximately 3300 pounds. Sixteen anti-tank missiles or 76 rockets and 1200 rounds of 30mm cannon ammunition can be carried. The aircraft has demonstrated a vertical rate of climb in excess of 450 ft/minute and a cruise speed of 145 knots. Fuel capacity provides 2.5 hours endurance in the European standard day condition (2000'/70°F).

Aircraft design performance characteristics are shown in Figure 2 and payload options are shown in Figure 3.

The dynamic system of the YAH-64 comprises two General Electric T700-GE-700 turboshaft engines, driving the main rotor by way of nose gear boxes and the tail rotor through intermediate and tail rotor gear boxes. Redundant flight control systems are carried for both main and tail rotors. The four-blade main rotor is fully articulated. The blades incorporate five aluminum spars and each blade has a separate skin plate with a composite layer, so that cracks in one part will not propagate through the blade. All main blades are interchangeable, and attached to the hub by a laminated strap retention system.

Survivability is one of the major aircraft design features and is depicted in Figures 4 and 5. All components of the drive system are designed to operate for at least 20 minutes after taking a 12.7mm hit; in actual tests most have operated much longer. The main rotor is designed to operate after a hit from a 23mm projectile. In a laboratory test one rotor blade operated for 5 hours after such a hit. Fuel tanks are being designed to survive 23mm projectiles. The YAH-64 crew is encased in a shell of Kevlar backed boron carbide tiles. An acrylic laminate clear armor shield has been placed between gunner and pilot which is capable of stopping 23mm fragmentation particles.

An infrared suppressor is being developed that will significantly reduce engine exhaust gas temperature; in tests the Hughes designed "BHO" (Black Hole Ocarina) has achieved results 20% better than the Army's requirement. The aircraft is also provided with an add-on counter-countermeasure kit that includes a radar jammer and chaff and IR flare dispensers.

The Advanced Attack Helicopter is being designed to be self-deployed between the US and Europe (Figure 6) or to be transported by C-141 and C-5A loadings (Figure 7) where a more rapid deployment is needed. Self-deployability is achieved by carrying four 1250 pound external fuel tanks. This provides sufficient fuel for a ferry range in excess of 800 nautical miles with a 20 knot headwind and 45 minute fuel reserve.

Hughes Helicopters YAH-64

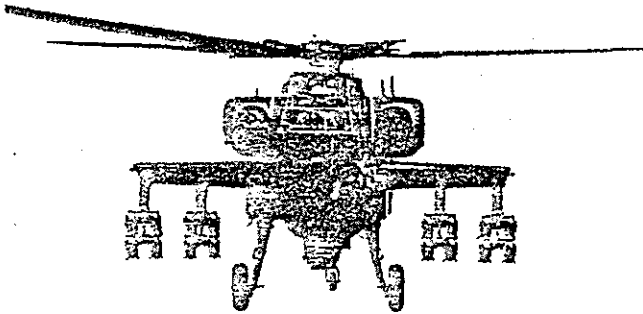


Figure 1

AAH ARMAMENT OPTIONS = MISSION FLEXIBILITY

MISSION	PERFORMANCE					
	4 HF	320 RDS	4 HF	700 FPM	148 KTS	1.83 HRS
ANTI-ARMOR (DEFENSE) MID-EAST PRIMARY MISSION 4000/95°F	4 HF	320 RDS	4 HF	700 FPM	148 KTS	1.83 HRS
EUROPE ALTERNATE 2000/70°F	8 HF	1200 RDS	8 HF	600 FPM	145 KTS	2.5 HRS
COVERING FORCE (AIR CAV) MID-EAST ALTERNATE 4000/95°F	4 HF	777 RDS	4 HF	450 FPM	148 KTS	1.83 HRS
EUROPE ALTERNATE 2000/70°F	4 HF 19 RKTS	1148 RDS	4 HF 19 RKTS	450 FPM	145 KTS	2.5 HRS
AIRMOBILE ESCORT MID-EAST ALTERNATE (4000/95°F)	19 RKTS	418 RDS	19 RKTS	450 FPM	145 KTS	1.83 HRS
EUROPE ALTERNATE (2000/70°F)	38 RKTS	788 RDS	38 RKTS	450 FPM	145 KTS	2.5 HRS

Figure 3

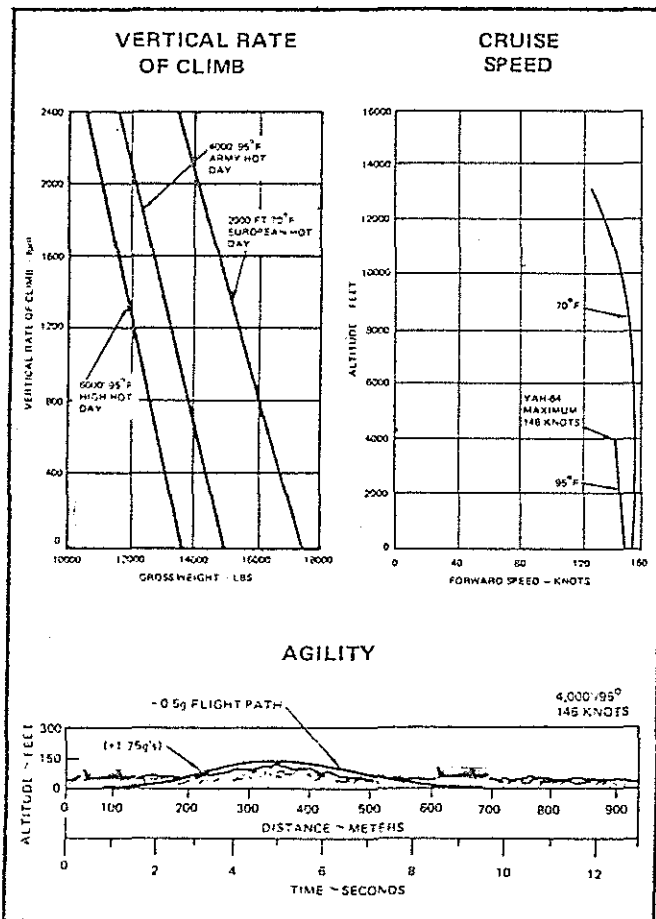


Figure 2

DETECTABILITY - AURAL, VISUAL, RADAR, IR

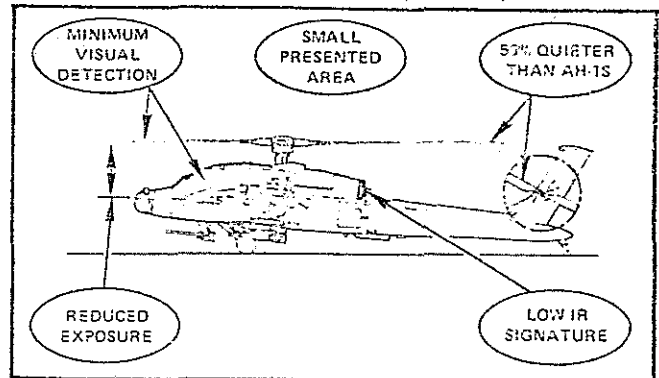


Figure 4

CRASHWORTHY

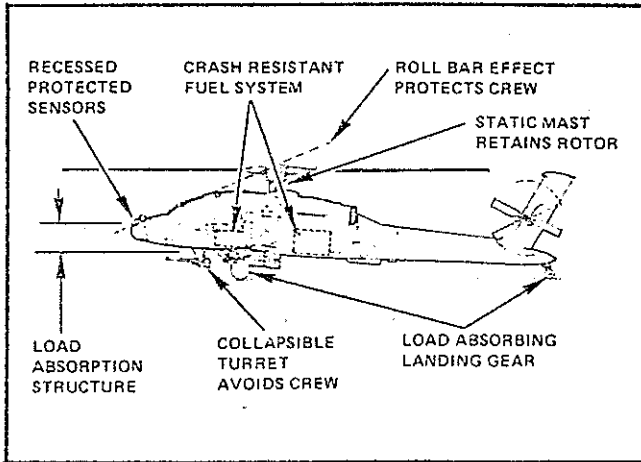


Figure 5

SELF-DEPLOYABLE (800NM FERRY RANGE)

YAH-64 TRANSATLANTIC FERRY MISSION

GOOSEBAY, CANADA	
TO FROBISHER BAY	700 NMI
FROBISHER BAY	
TO SONDERSTROM, GREENLAND.	440 NMI
SONDERSTROM, GREENLAND	
TO REYKJAVIK, ICELAND	760 NMI
REYKJAVIK, ICELAND	
TO PRESTWICK, SCOTLAND.	790 NMI



Figure 6

AIR TRANSPORTABLE

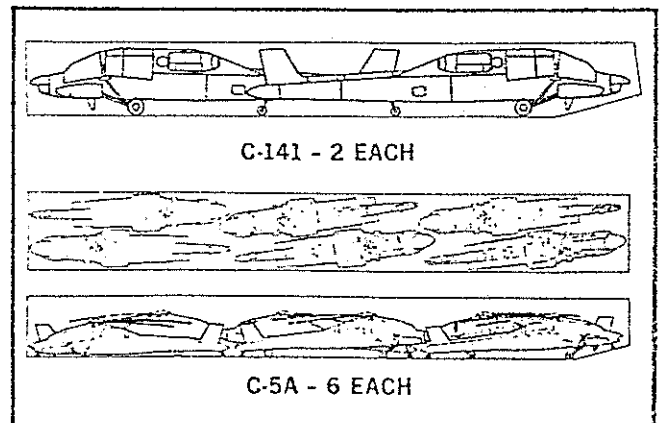


Figure 7

III. Armament

The armament system consists of the HELLFIRE anti-tank missile, a 30mm cannon which provides a highly responsive area weapon capability for defeating personnel and lightly armored vehicles and 2.75 inch rockets which are capable of delivering a wide variety of payloads.

The HELLFIRE terminally guided missile provides the primary anti-tank armament for the YAH-64. The missile as shown in Figure 8 is based on a modular design to facilitate a variety of homing seeker heads. The first missiles to be fielded will be equipped with a laser semi-actively guided seeker. Planned follow-on seekers include a true fire-and-forget seeker that guides on the inherent contrast of the target and an air defense suppression seeker for use against radiating air defense targets.

The 90-pound missile is 64 inches long and 7 inches in diameter, with a 20-pound shaped charged warhead. Lethality tradeoff studies dictated a 7-inch diameter warhead based on latest intelligence about the evolving armor threat.

The YAH-64 can carry up to 16 missiles which are fired from four-rail launchers. The missile offers higher rate of fire, shorter flight times and increased range relative to the current TOW missile. Techniques are single, rapid and ripple fire. In the ripple mode, 16 missiles can be fired in 1 minute.

The guidance scheme requires that a laser beam be positioned accurately on the target during the terminal phase of the flight path. The laser designation can be accomplished autonomously by the YAH-64 gunner using his TADS or remotely by another ground or airborne laser designator system.

The principle virtue of laser semi-active guidance is the versatility provided by a multiplicity of firing modes which permit engagements by direct, indirect and psuedo-direct fire. Direct fire is operationally similar to command line-of-sight guidance schemes. The gunner requires line-of-sight to the target. The seeker can be locked on to the target before launch which provides the greatest latitude in the helicopter launch envelope. Alternatively, the seeker can be locked-on after launch, which provides extended stand-off range in degraded weather and improved performance under certain types of countermeasure environments.

Indirect fire does not require line-of-sight, enabling the helicopter to fire from concealed, defiladed positions. The laser guidance signal is provided by a remotely located designator. Target information required to launch the missile is handed-off to the helicopter from the remotely located designator. Shortly after launch, the missile climbs to an elevated trajectory. As the missile proceeds down range, it picks up the laser signal reflected by the target and enters a guided flight mode.

Pseudo-direct fire is a hybrid of the direct and indirect modes. The missile is launched on a ballistic flight path prior to exposing the aircraft. Shortly after launch, the pilot maneuvers the aircraft to establish line-of-sight to the target. The gunner, whose TADS is precisely directed at the known target coordinates by the YAH-64 navigation system, rapidly acquires and designates the target putting the missile into a guided mode. The pseudo-direct mode reduces aircraft exposure time, but requires timely, accurate target hand-off and close coordination between pilot and gunner.

The initial phase of the missile test firing program has been completed with highly favorable results. Ballistic missiles were successfully fired from the YAH-64 early in 1979 to check out blast and debris. Guided missile test firings are scheduled to begin in September 1979 from the YAH-64 to demonstrate compatibility of the missile with the aircraft fire control system.

Secondary armament consists of the XM230, 30mm gun and a 2.75 inch rocket system. The XM-230, which is being developed by Hughes Helicopters, is a lightweight, externally powered single barrel gun that emphasizes simplicity and reliability. The chain operated bolt simplifies the design by eliminating declutching feeders, chargers or other special devices to insure firing all rounds. The gun is mounted in a flexible turret underneath the aircraft providing a field of fire of ± 110 degrees azimuth and $+10$ degrees to -60 degrees elevation. Total weight of gun, turret, drive motors and control electronics is 110 pounds.

The aluminum cased 30mm ammunition is stored in a 1180 round rotating magazine and fed to the gun over an endless conveyor. The gun is designed to fire US and foreign ADEN/DEFA class ammunition. High explosive incendiary and armor piercing rounds are in development.

The principal fire control mode for the gun is through the gunner's TADS. This provides highly accurate gun positioning. All gun pointing corrections are handled automatically by the fire control computer. The gun can be fired in a backup, degraded accuracy mode by the pilot using his helmet sight. This enables the pilot to deliver suppressive fire when the gunner is occupied or disabled.

The YAH-64 carries a payload of seventy-six 2.75 inch rockets. The rockets are carried in a four 19-tube lightweight launchers equipped with precision mounting lugs. Elevatable pylons, controlled by the YAH-64 fire control computer, permit highly accurate firing without pitch trimming the helicopter. Two modes of rocket delivery have been incorporated. A precision mode using the TADS and a backup mode in which the pilot can fire using his helmet sight. The rocket control system has been designed to accommodate seven different warhead options including the multi-purpose submunition warhead currently in development. Rockets can be fired in quantities of 1, 2, 4, 8, 12, 24 or All. Fuze setting is automatically controlled through the fire control computer.

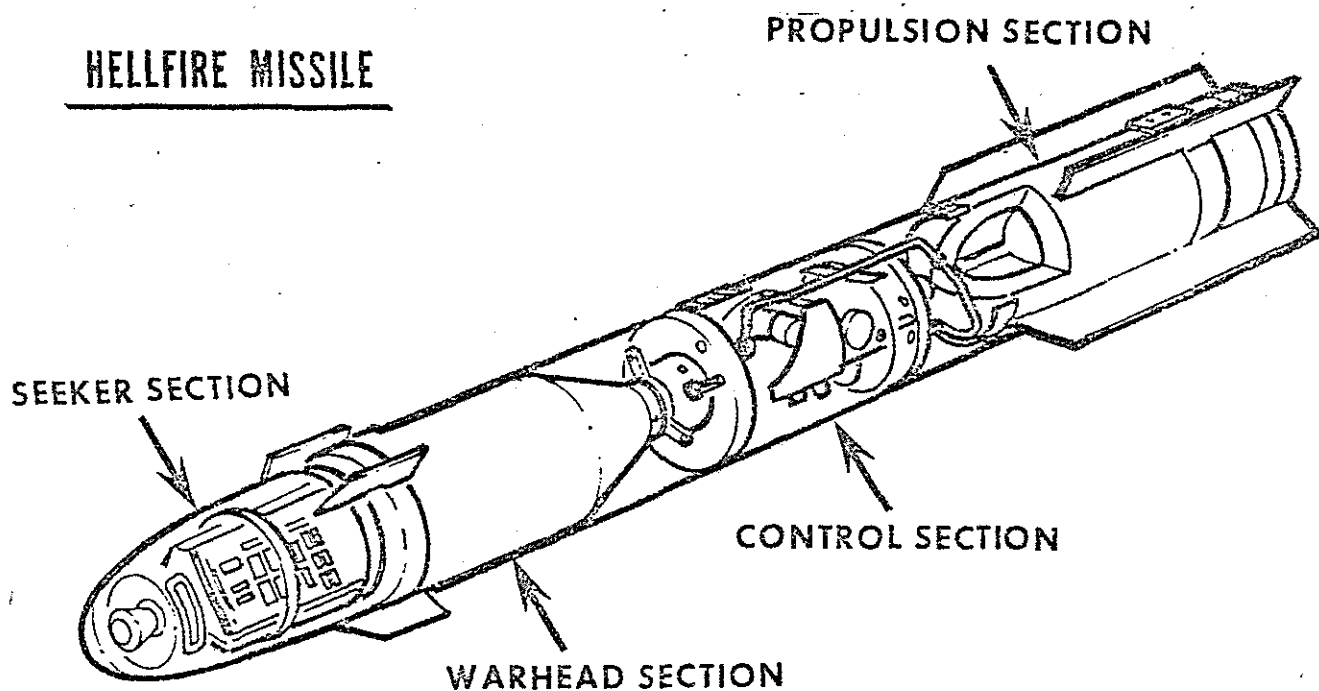


Figure 8

IV. Visionics

Three complementary electro-optical systems are being developed which will provide the AAH with the most advanced visionics capability of any known tactical aircraft. The Target Acquisition and Designation System (TADS) will enable the gunner to acquire targets, day or night, at long stand-off ranges. The Pilot's Night Vision System (PNVS) will permit the aircraft to be flown nap-of-earth in darkness and adverse weather. The Integrated Helmet and Display Sighting System (IHADSS) provides both crew members with a heads up display for viewing PNVS and TADS sensors and for presenting stores status and flight symbology information.

The TADS is a stabilized multisensor sighting and fire control platform which contains direct view optics, silicon vidicon television and Forward Looking Infrared (FLIR) imaging sensors. Integrated into the platform and boresighted to the sensor line-of-sight is a precision laser designator/rangefinder and a laser spot tracker which provides rapid acquisition of remotely designated targets.

The imaging sensors provide at least two fields-of-view and magnifications to separately optimize target detection and recognition functions. The FLIR incorporates automatic gain and level control to minimize gunner workload. The imaging sensors are viewed by the gunner through an optical relay tube (ORT). In the case of direct view optics, this provides a magnified optical image. A cathode ray tube, also located inside the ORT optical chain, provides the gunner with a highly magnified image of the TV and FLIR sensors. Pertinent weapon stores status and other fire control information is displayed in alpha numeric format at bottom of the gunners display. All relevant TADS and weapon control functions are located on hand grips which mount on the side of the ORT. These features enable the gunner to go through a complete acquisition and engagement sequence in the heads down mode.

The TADS turret mounts on the nose of the YAH-64. The system is currently in a competitive development between Northrop Corporation and Martin-Marietta. The two prototypes are shown in front of the YAH-64 in Figure 9. The winning TADS will be selected for maturity phase development following the competition of the TADS/PNVS flyoff which will be conducted between December 1979 and March 1980.

The PNVS is also a competitive development by the same two subcontractors in conjunction with the TADS. The heart of the PNVS is a FLIR sensor integrated into a highly flexible turret that also mounts on the nose of the aircraft adjacent to TADS. Whereas the TADS emphasizes high magnification, narrow field of view optics, PNVS sensor provides wide

field-of-view (30 degrees by 40 degrees) and low magnification to provide the pilot with the closest possible thermal image replication of normal daytime "out-the-cockpit" viewing. The PNVIS has been developed to enable the pilot to fly the aircraft in total darkness and adverse weather under nap-of-earth flight conditions. Both Northrop and Martin systems have been undergoing flight tests since April 1979 with favorable results.

The IHADSS is a companion visionics subsystem to the PNVIS. Its main purpose is to display the PNVIS image to the pilot. This is accomplished by integrating a miniature cathode ray tube display and monocular optical relay chain into the helmet (Figure 10). An array of infrared emitters located in the helmet optically couple to detectors mounted in the cockpit to monitor the rotational coordinates of the pilot's head position. These coordinates are fed to the PNVIS turret sensors to keep the PNVIS sight line parallel to the pilot's normal visual sight line. Through the display and servo system, the PNVIS provides the pilot with a FLIR image of the outside world that corresponds to the terrain features that would be seen under normal daylight conditions.

To compensate for the loss of depth perception and limited peripheral field, alpha numeric and graphic flight symbology is superimposed on the IHADSS display. The symbology is preformatted in a number of sets depending on the particular flight and weapon delivery mode. Basic symbol formats are generated in symbology generator. Symbology dynamics for graphical symbols are controlled by the fire control computer.

The IHADSS also enables the pilot to quickly handoff targets to the gunner. This is accomplished by incorporating mode logic to slave TADS to IHADSS line-of-sight. The pilot can also call up TADS target imagery on his helmet display. Both gunner and pilot are equipped with IHADSS to enable the gunner to fly the helicopter in darkness in the event the pilot is disabled.

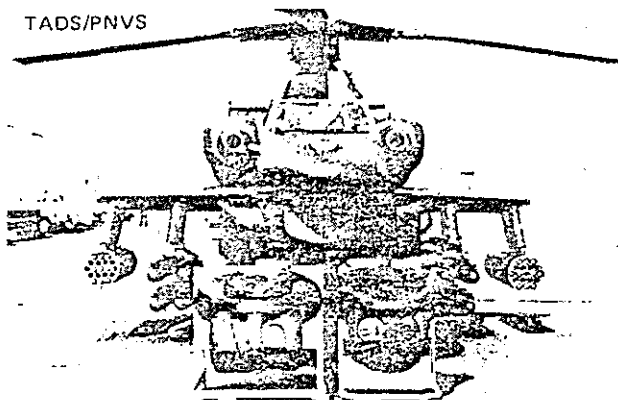


Figure 9

CRT DISPLAY

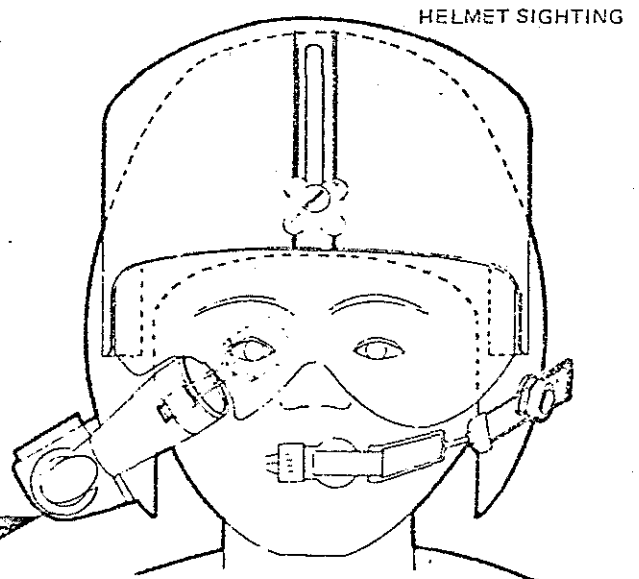


Figure 10

V. Weapon Control System

The AAH will feature an all-digital integrated fire control system. A network of subsystem imbedded mini/microcomputers are interconnected through a closed loop multiplex system to take advantage of the cost and simplicity benefits achieved from a distribution of digital capacity and to exploit the latest state-of-art advances in computer technology. The Fire Control Computer, which is the heart of the fire control network, is the executive controller of all other imbedded microcomputers. This approach allows each subsystem developer maximum software and interface flexibility by only requiring rigid software interface specification controls for the higher order interface message traffic which must flow between subsystems.

The YAH-64 multiplex system, which ties together the computer network, is a distributed time division multiplex system consisting of 13 units, interfacing directly to redundant data busses. Nine of the units are Remote Terminals specifically designed to adapt off-bus subsystems to the multiplex data bus. Functionally, the YAH-64 multiplex system replaces much of the signal and control wire and relay logic required in conventional aircraft configurations. The system can be expanded to include 32 units in order to meet future requirements.

Figure 11 is the block diagram of the present YAH-64 multiplex system. The primary data bus and controller is on the left side of the aircraft, while the secondary data bus and controller is on the right side. This isolation between the busses increases survivability. Critical signals can be routed into remote terminal units by providing separate signal paths, precluding the loss of that function with a remote terminal failure. The active bus controller collects data from all boxes on the bus (via transmit commands), performs the required logic processing and computations, and outputs the revised data to all boxes on the data bus (via receive commands). During normal operation, sole control of information transmission on the bus resides with the active bus controller, within the Fire Control Computer (FCC) while backup control resides in the Backup Bus Controller (BBC) located in the avionics bay.

The fire control computer is the executive controller of all other on-board computers. It integrates the AAH operations associated with delivery of all weapons as well as performing certain specific computational functions such as gun and rocket ballistics, navigation updating and Kalman filtering (see Figure 12). In addition to controlling the multiplex bus, the computer performs a Fault Detection/Location System (FD/LS) housekeeping function. The BBC also is capable of performing some of the computational and housekeeping functions of the FCC when it has control of the bus.

The fire control contains a 16-bit general purpose processor with memory, power supply and input/output electronics all housed in a single enclosure. The computer is microprogrammed, digital parallel,

synchronous machine containing 16K by 16 bits of Random Access Memory (RAM). When the design reaches production, it is planned to convert most of the memory to Read Only Memory (ROM) leaving only about 2K words RAM for scratch pad functions.

The AAH navigation system plays a major role in fire control and weapon delivery. It is used to precisely prepoint TADS to known target locations for rapid acquisition and weapon engagement. It is also tied into the fire control system for indirect launches of the HELLFIRE missile and can be used to fire the gun.

The principal elements of the navigation system are the AN/ASN-128 Doppler, a strapped down inertial heading and attitude reference system (HARS) and an air data sensor. Aircraft and target position are provided in both universal transverse mercator (UTM) and latitude longitude coordinates. Output signals are provided for magnetic bearing, helicopter pitch, roll and heading, ground speed and drift corrected steering data.

Since the basic Doppler system is a "dead reckoning" navigator, it is necessary to periodically update the system by inputting position fixes at known geographic points in order to truncate the growth in system error. This can be accomplished either by overflying a known reference point stored in the fire control computer or alternatively using the TADS to get range and angular coordinates to the reference point. This latter mode is referred to as offset updating since the updating can be performed from a distance eliminating the need to overfly the reference point.

A three axis air data sensor mounted at the top of the rotor mast provides vertical, lateral and longitudinal airspeed, side-slip and air density ratios. This information is utilized by the fire control computer in the solution of both navigation and weapon's delivery equations. A gun muzzle velocity sensor measures muzzle velocity which is used in the gun fire control equations. The HARS is used to determine the gravity vector for drop compensation in correcting weapon aimpoint. Linear motion compensation is used to correct gun aim and TADS target tracking by automatically producing a line-of-sight rate proportional to helicopter velocity.

A complete onboard Fault Detection/Location System (FD/LS) capability has been integrated into the YAH-64 multiplex system to detect and isolate electrical and electronic failures. Fault processing, control and data storage are performed by the active bus controller while the remote terminals are used for signal conditioning and data transfer. By means of keyboard entries, flight or maintenance personnel can command a particular subsystem checkout or run a complete end-to-end aircraft checkout. Failed units are identified alpha numerically on the TADS display. The present system fault detects and isolates 69 aircraft replaceable units.

The distributed digital control system has several advantages over the single (or central) computer approach. It allows subsystems contractors maximum flexibility to autonomously work out individual organic software design. In a system where numerous different companies provide hardware, this approach presents a lower risk development by alleviating significant scheduling problems emanating from the rigid software design interfaces which must be established at the outset of development when all subsystems share one central computer.

During development, many of the embedded computers are in a programmable state in order to maintain the flexibility for design updating. In production they will be converted to ROM to eliminate field management of software tapes.

To assure that the hardware and software design and integration is accomplished with a minimum of risk, the prime system contractor has developed a Mission Equipment Development Laboratory (MEDL) which is dedicated to hardware and software integration, test, and evaluation prior to air vehicle integration and flight tests. The MEDL includes a complement of bench test capabilities and a Mission System Simulator (MSS) which is, in essence, a hot mock-up of the AAH used to exercise total system capabilities. The major features of the MEDL include: non-real time data generation, real-time data simulation, scenario programs and sensor models employed through a host computer system and computer generated imagery. All subsystems are evaluated and software interfaces resolved in the MEDL prior to integration into the prototype aircraft.

Summary

The AAH armament subsystems are integrated through a full solution digital fire control system. The design philosophy is predicated on distribution of digital capacity with imbedded subsystem microcomputers to simplify system integration and provide maximum flexibility for future growth. The principal subsystems contributing to the fire control system include the TADS and IHADSS for sighting and weapon control, a high-speed hybridized fire control computer, a lightweight Doppler navigator, a strap-down inertial heading and attitude reference unit, a three-axis air data sensor and mode control electronics for the HELLFIRE missile. These subsystems communicate through a dual redundant multiplex bus. Kalman algorithms have been developed to improve accuracy of ballistic weapons, to reduce navigation errors and to improve targeting response times.

These design features along with the aircraft's performance, survivability mission flexibility and growth capability will provide the US Army with a total weapon system designed for the 80's and beyond.

YAH-64 MULTIPLEX SYSTEM BLOCK DIAGRAM

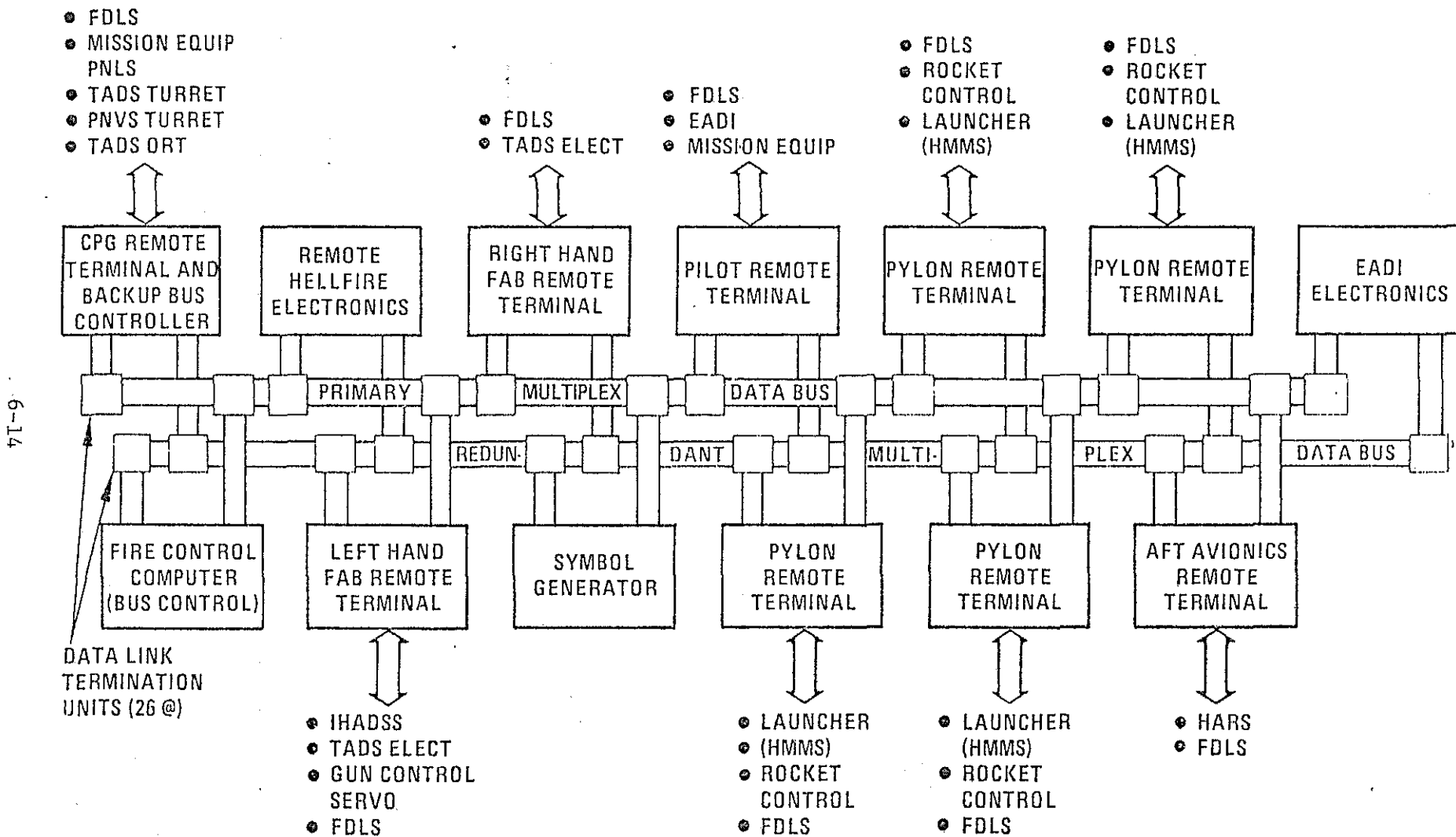


Figure 11

