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ADP010302

TITLE: The H-1 Update Program: Affordable War  
Fighting Capability for the U.S. Marines

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# THE H-1 UPGRADE PROGRAM: AFFORDABLE WAR FIGHTING CAPABILITY FOR THE U.S. MARINES

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## ABSTRACT

In late 1996, Bell Helicopter Textron Inc. was awarded a contract from the United States Marine Corps for the H-1 Upgrade Program. The program award was preceded by studies of all aircraft and approaches available to provide helicopter war fighting capability for the Marine Air Ground Task Force through the first quarter of the 21st century and beyond. Upgrades were defined for both the UH-1N utility helicopter and the AH-1W attack helicopter to integrate the following enhancements:

- Improved mission capability
- Increased performance and maneuverability
- Additional survivability features
- Reduced pilot workload
- Potential for growth

These enhancements give the Marine Corps the equivalent of new, state-of-the-art, zero-time aircraft, with 10,000-hour service lives.

Total ownership cost affordability was, of course, a major requirement. Commonality, improvements in reliability and maintainability, the use of COTS/NDI equipment, and the reuse of existing equipment were encouraged to enhance squadron operability and supportability and help reduce recurring and O&S costs. Cost As An Independent Variable (CAIV) studies were also required to continuously evaluate potential cost reduction elements in trade against program and technical requirements.

Bell and NAVAIR formed Integrated Product Teams (IPT) with representatives from all functional disciplines, to improve communication and to ensure the configuration designs were not only adequate technically but were also cost-effective to manufacture and to operate and support in the fleet. This IPT process has been instrumental in improving the contractor/customer approval process during design reviews.

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This paper summarizes the H-1 Upgrade Program. The Marine Corps modernization plan is described and the role of the H-1 is defined. The resulting configurations are described, as is the process of optimizing configuration details within program constraints.

## INTRODUCTION

The current U.S. Marine Corps (USMC) utility helicopter, the UH-1N Huey, was fielded initially in 1970. The versatile Huey has been modified over the years with added systems that have increased its roles and mission utility, as summarized in Fig. 1. These modifications have also resulted in weight increases that have adversely impacted its payload and power-available



UH-1N "HUEY"  
 Airframe: Bell Helicopter  
 Engines: T400-PW-400  
 105 Aircraft Inventory  
 Last Produced 1979

### Mission Tasks

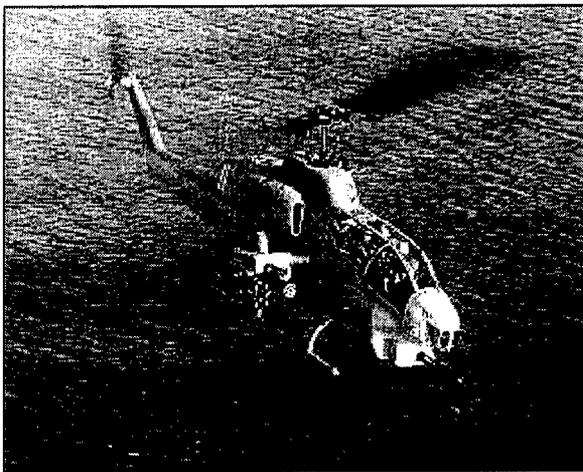
- Airborne command & control
- Combat assault support
- Control of supporting arms
- Special operations support
- Search & rescue augmentation
- Medical evacuation
- Shipboard & austere base ops
- Night & adverse weather ops
- Visual reconnaissance

Fig. 1. Marine light helicopter today, the UH-1N

margin. Additionally, the fielded aircraft are approaching the end of their service life, and have become an increasing logistic and maintenance burden to the fleet.

The AH-1W Super Cobra, the current USMC attack helicopter, was initially fielded in 1986. The AH-1W is a modification of the AH-1T that incorporated the GE-T700-401 engines. Like the Huey, the Cobra has been upgraded incrementally with advanced avionics and weapons systems to maintain a viable capability against evolving threats. These sequential upgrades, without optimal integration, have come at the cost of increased aircrew workload that impacts mission effectiveness. Mission tasks are shown in Fig. 2.

The Marine Corps attack and utility helicopters are uniquely consolidated into the same squadron for training, maintenance, and deployment. Over the years, the divergence of the AH-1W and UH-1N configurations has resulted in increased support costs for maintenance,



AH-1W "SUPER COBRA"  
Airframe: Bell Helicopter  
Engines: T700-GE-401  
201 Aircraft Inventory  
Final Deliveries 1998

#### Mission Tasks

- Transport helo support
- Ground force fire support
- Control of supporting arms
- Search & rescue augmentation
- Visual & armed reconnaissance
- Shipboard & austere base ops
- Night & adverse weather ops
- Anti-armor operations
- Anti-helicopter operations
- Enemy fixed wing defense

**Fig. 2. Marine attack helicopter today, the AH-1W.**

training requirements, procurement of spares, support equipment, and publications. Therefore, the Marine Corps desired an upgrade approach that would increase commonality between the aircraft.

In addition to correcting existing deficiencies to the current aircraft, the Marine Corps recognized the need to modernize their attack and utility helicopters to meet emerging and future mission needs. These requirements include

- Operations at greater ranges and with larger payloads.
- Command, control, and communications interoperability.
- Expanded night and reduced visibility operations.
- Improved targeting sensors and weapons.
- Survivability enhancements.

A high degree of growth potential was desired that would allow efficient reaction to rapidly evolving future threats, technologies, and mission requirements.

This modernization would occur in a period of austere budgets driven by simultaneous modernization of multiple major weapon systems. A series of trade studies were conducted to determine the most cost-effective way to provide utility and attack helicopter warfighting capability for the Marine Air Ground Task Force through the first quarter of the 21st Century. In late 1996, as a result of these trade studies, Bell Helicopter was awarded a contract for the H-1 Upgrade Program, which will remanufacture the AH-1W and UH-1N into the AH-1Z and UH-1Y. The Upgrade Program is a part of the Marine's "neckdown plan" for VTOL aircraft, as shown in Fig. 3. This paper describes the H-1 Program with emphasis on the team approach and metrics, the resulting configurations, and the improved mission effectiveness of the aircraft.

#### REQUIREMENTS

To ensure that the design of the aircraft addressed current operational shortfalls, the team of government and contractor personnel reviewed all identified deficiencies from past developmental and operational testing and from 20 years of fleet experience. In addition, to maximize reliability and maintainability in the new design, the team analyzed major maintenance and logistic cost drivers. The analyses included reviewing current mission readiness degraders, maintenance man-hour drivers, and logistic action chits. Site interviews were also conducted at all levels of maintenance—organizational

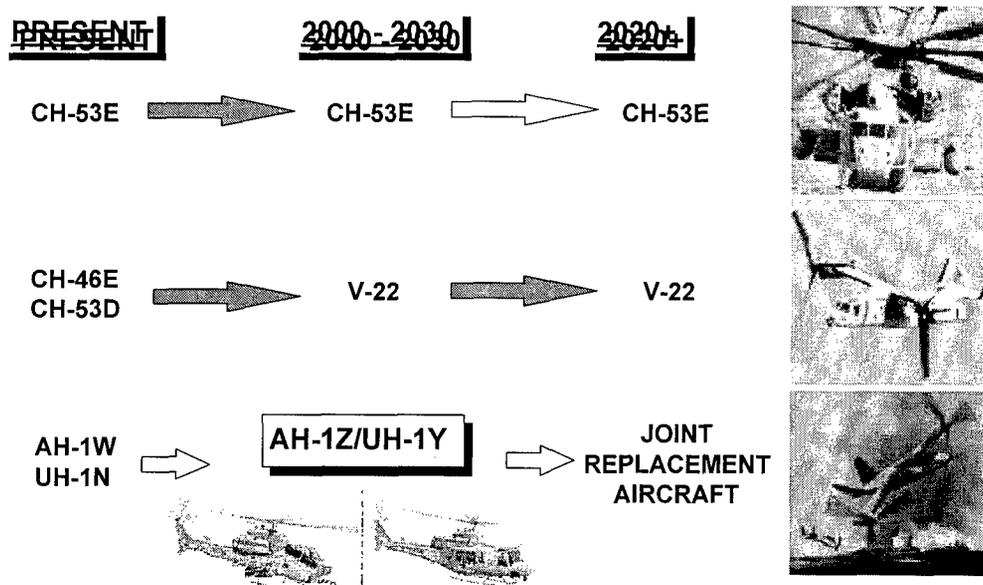


Fig. 3. The USMC VTOL neckdown plan.

through depot—to identify other unreported areas of concern.

Total ownership cost affordability was, of course, a major design driver. Maximum commonality between the aircraft and other DOD assets, combined with improvements in reliability and maintainability, were required to reduce recurring costs, qualification and flyaway costs, and all operating and support costs. Commonality was not limited solely to the aircraft components, but also included spares, maintenance, training, support equipment, and publications. The use of commercial off-the-shelf/nondevelopmental items (COTS/NDI) equipment and reuse of existing equipment were also encouraged, to reduce costs.

In addition to the more obvious operational capability enhancements, the design teams had to be cognizant of the other factors that make the aircraft deployable “in every clime and place.” Design specifications were provided that defined the Marine shipboard and ground operating environments, namely:

- Material and manufacturing techniques to resist the harsh and corrosive environment.
- Hardening of avionics and electrical distribution systems to operate in the electromagnetic environment.
- Additional structure to react high sink-rate landings.
- Tiedowns for extreme winds and ship motions.
- Minimum space required for aircraft, support equipment, and spares stowage.

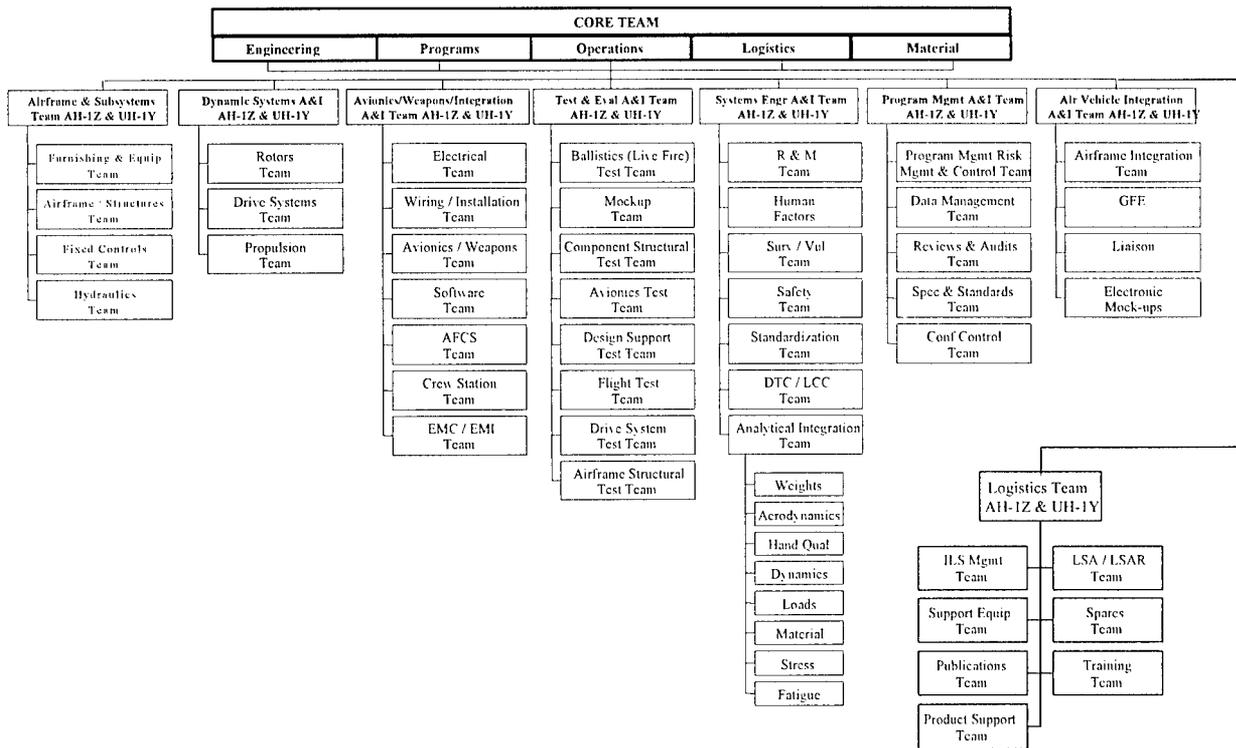
- Extreme operating temperature range from  $-65^{\circ}\text{F}$  through  $+125^{\circ}\text{F}$ .
- Survivable occupied space when subjected to accelerations of 20g longitudinal, 20g vertical or 10g lateral.
- Crash-attenuating crew and troop seating.
- Redundant load paths, with damage and flaw tolerant structural design criteria to ensure safe operations.
- Extension of dynamic component lives to 10,000 flight hours, and gearboxes with a design objective of 5,000 hours between overhauls.

In addition, the Marines required heavy emphasis on design concepts to minimize intermediate level maintenance with a desire for either unit level (O) or original equipment manufacturer (OEM) repairs.

With these requirements, the Bell/NAVAIR/Marine Corps teams began the design process.

#### THE DESIGN PROCESS

Bell, the Naval Air Systems Command (NAVAIR), and the Marines recognized the advantages of working in Integrated Product Teams (IPT), and all entities had previous experience using such teams. Recent experience included the Bell/Boeing V-22 program. To manage the H-1 Upgrades program, an organization was defined (Fig. 4) using the Program’s work breakdown structure elements (WBSE). A Core Team, with members from Engineering (the authors), Program



**Fig. 4. H-1 upgrade program team organization.**

Management, Operations (Tooling and Manufacturing), Materiel (including Procurement), and Logistics was given the responsibility to execute the Program within budget and Statement of Work constraints. Major subcontractors also participated on the Core Team.

The next level of management was the Analysis and Integration (A&I) Teams, which were responsible for several IPT elements and were organized in the same manner as the Core Team, with representatives from all functional disciplines.

The Integrated Product Teams were responsible for the discrete "Products" of the H-1 configurations. Although the accounting for the two helicopter configurations was kept separate for tracking purposes, the IPTs generally had responsibility for both aircraft (the Airframe IPT had both the AH-1Z and UH-1Y airframes, for example). Technical leaders from Bell, NAVAIR, and the Marine Corps were resident as IPT members with responsibilities initially for defining requirements and then for creating design concepts to satisfy these requirements. The Marine Corps had Resident Integrated Logistics Support Detachment (RILSD) members who brought fleet experience to the design process.

The IPT process is illustrated in Fig. 5, with many factors that had to be balanced to provide the optimum

solution. The IPTs developed cost, weight, and reliability and maintainability goals to support program requirements; these goals, together with budget and schedule constraints, were used to help balance the design through trade studies.

The Marines encouraged the use of the Cost As An Independent Variable (CAIV) process during design trades and interactions, where the IPTs could address any variable—configuration or program—to keep costs down. Through Critical Design Review (CDR), nearly 250 of these studies had been conducted and 57 were incorporated, saving over \$800,000 in aircraft recurring costs.

Technical Interchange Meetings (TIM) were used and found to be very beneficial in encouraging communication between all IPT members. These TIMs were held frequently, as shown in Fig. 6. The success of the process is summarized in Table 1, where the program technical status relative to targets is summarized at the time of the Preliminary Design Review (PDR) and at the CDR. The teams did an excellent job of meeting or exceeding targets and also made significant progress in most areas in the 14 months between PDR and CDR. The CDR was especially successful, with the Chairman, Mr. John McKeown, Naval Aviation Systems Command, commenting that "the CDR was an exceptionally fine one."

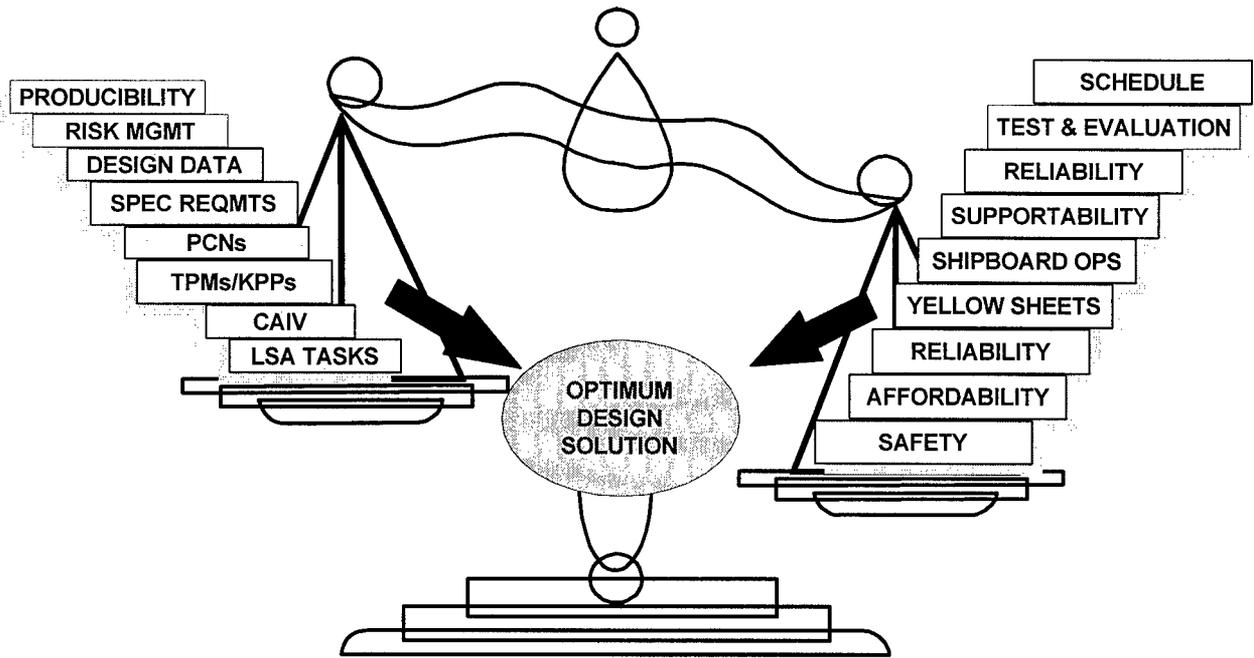


Fig.5. Balancing requirements to meet program needs.

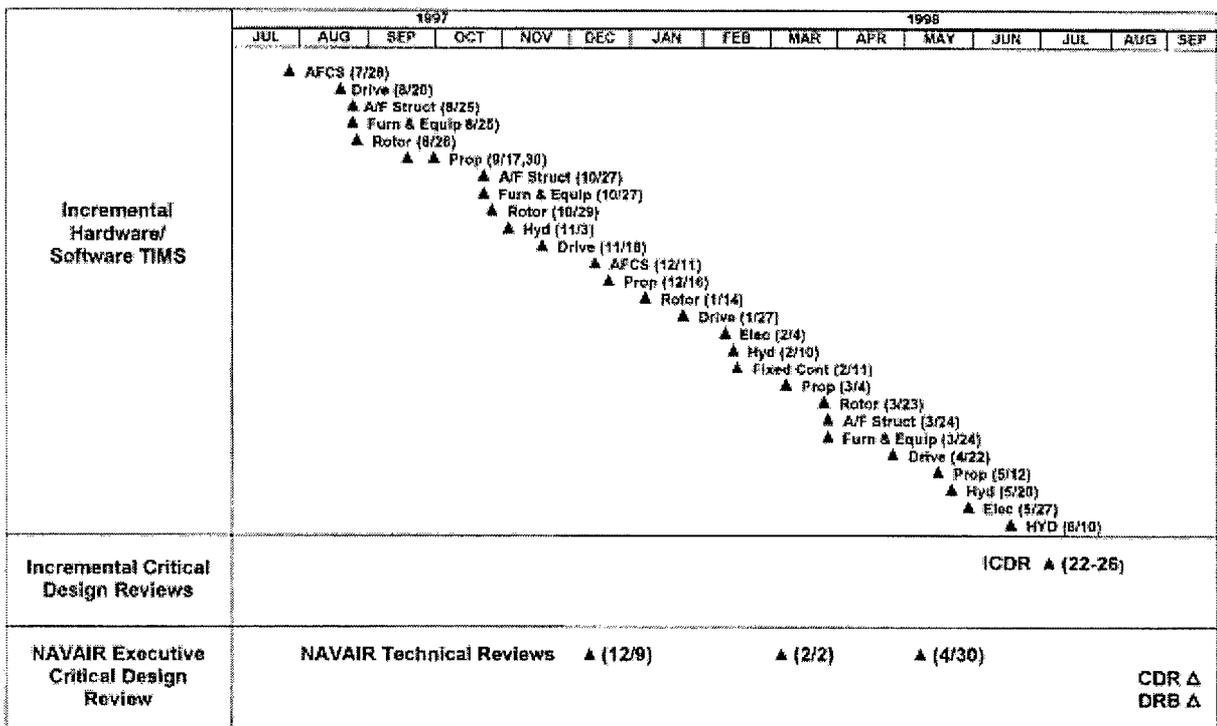


Fig. 6. The roadmap to CDR using TIMS.

**Table 1. Tracking technical status.**

	Performance ratio at PDR (June 97)		Performance ratio at CDR (Sep 98)		Desired direction
	UH-1Y	AH-1Z	UH-1Y	AH-1Z	
Weight*	1.003	0.998	0.985	0.977	↓
Recurring costs*	1.012	1.002	1.035	0.979	↓
Unscheduled maintenance costs*	1.083	1.022	0.984	0.944	↓
Reliability*	1.061	1.161	1.309	1.381	↑
Maintainability*	0.740	0.700	0.696	0.640	↓
Key performance parameters**					
Payload	1.074	1.100	1.092	1.121	↑
Maximum continuous speed	1.110	1.029	1.114	1.043	↑

\* Relative to Plan to Perform.

\*\* Relative to requirement at delivery.

### Commonality as a Strategy

The H-1 Upgrades Program presented a unique opportunity for the IPTs to maximize commonality between the AH-1Z and the UH-1Y. Commonality was recognized by all team members as being beneficial to the Program; however each of the disciplines within the IPTs viewed it as being important for different reasons. For example,

- The designers and planners saw it as a way to minimize the number of drawings that had to be created and, hence, a way to reduce budget and schedule requirements.
- The cost analysts viewed it as a way to reduce recurring costs because of the increased quantities of common items.
- The tool designers saw commonality as a way to reduce the number of tools.
- The logistician saw it as a way to minimize LSA tasks, manuals, and training.
- The Customer viewed commonality as a way to reduce costs and real estate needs aboard U.S. Navy ships (because of fewer spares and less support equipment).

This emphasis on commonality resulted in a significant number of components on the two aircraft being identical — hence the term “identity” was used to describe them. As illustrated in Fig. 7, the AH-1Z and UH-1Y are over 50% common by weight and cost; perhaps even more importantly, about 85% of the maintenance-significant components are identical. This reduces the logistics tail, training, foot-print, and cost.

### IMPROVED MISSION EFFECTIVENESS

The purpose of the H-1 Upgrades Program is to improve the mission effectiveness of the AH-1Z and UH-1Y in

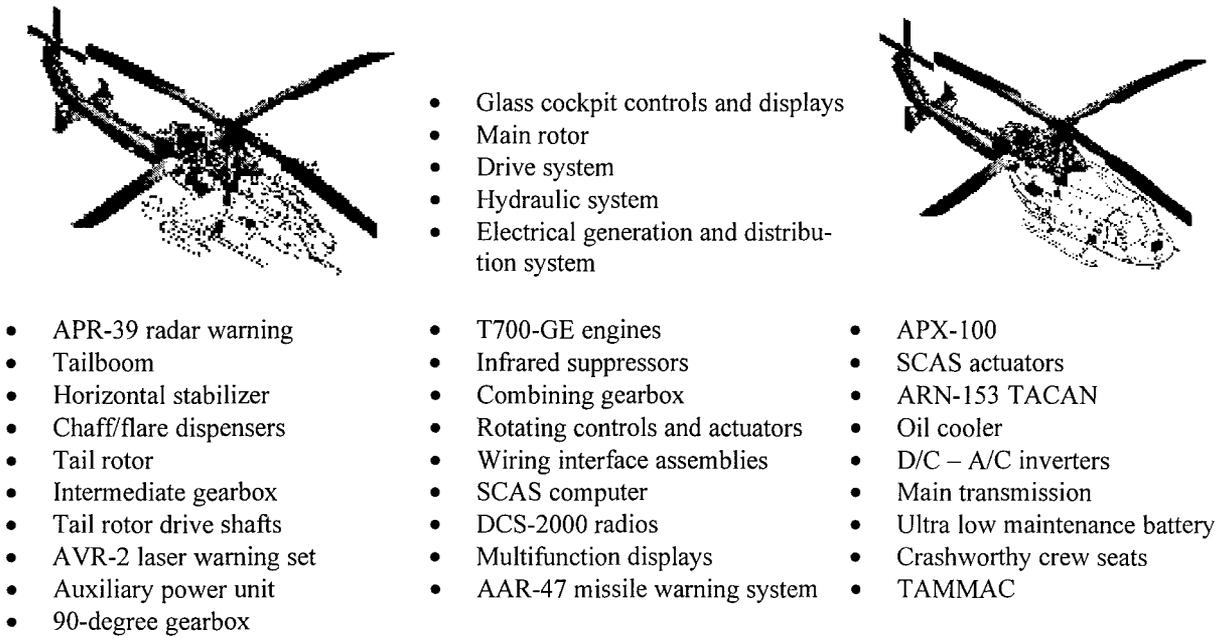
ways that are cost effective over the life cycle of the aircraft. This enhanced effectiveness is the result of improvements in five major areas—propulsion, integrated cockpit, survivability features, improved weapons capability, and the targeting sight system. Improvements are summarized in Fig. 8. The “upgraded” helicopters are new with “zero-time” airframes and the following new components:

- Main and tail rotors.
- Main transmission and 90-degree gearboxes.
- Landing gear.
- Transmission support structure.
- Airframe stretch with new primary structure (UH-1Y).
- Crew and troop seats.
- Integrated avionics.
- Auxiliary power unit.
- Fuel system (UH-1Y).
- Engine digital electronic control unit.
- Weapons pylons with internal fuel (AH-1Z).
- Hydraulic system.
- Electrical system.
- State-of-the-art integrated wiring.
- Target sight system (AH-1Z).

In this section, these improvements and their impact on the effectiveness of the aircraft are described. Features to marinize both aircraft for the U.S. Navy shipboard environment are also discussed.

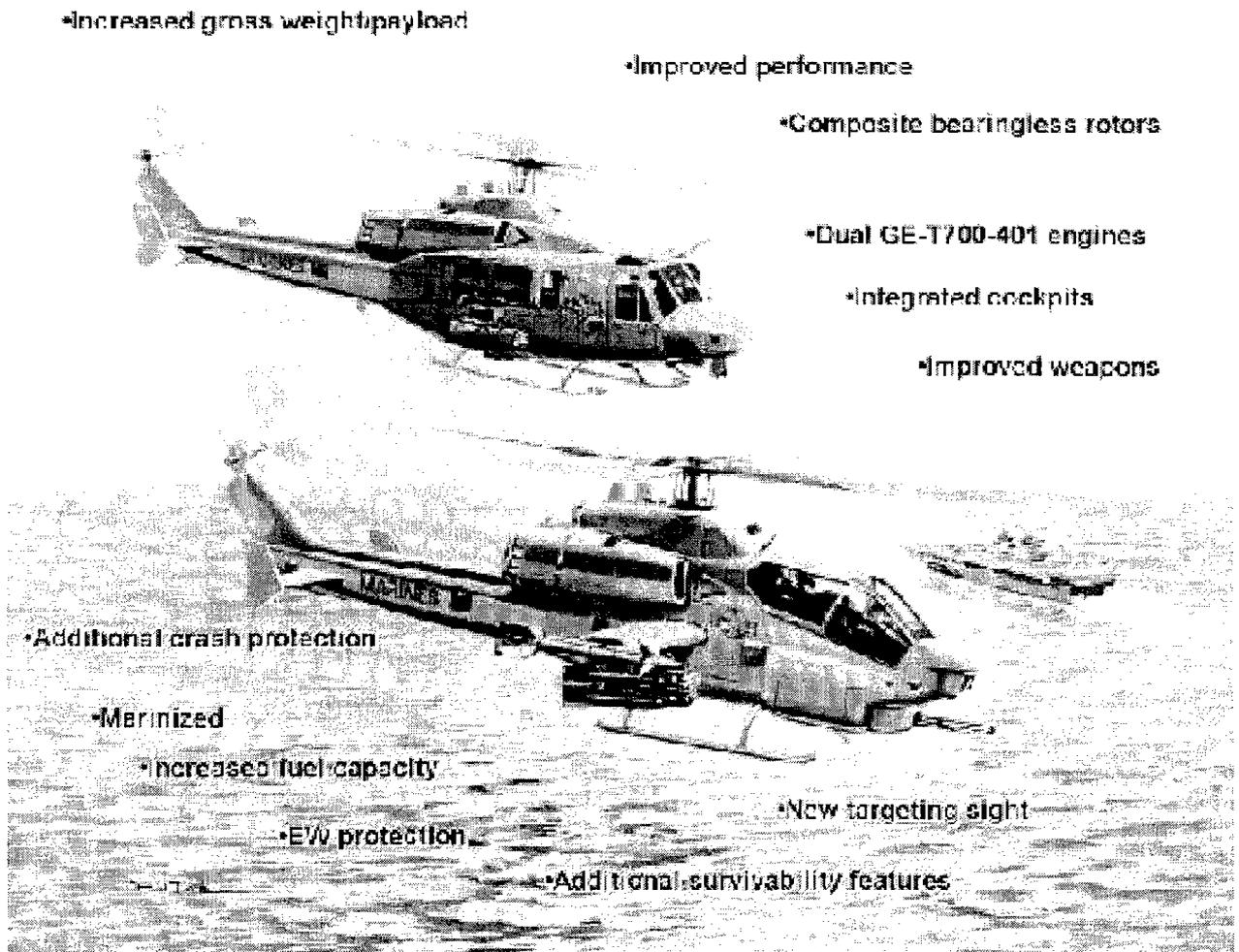
### Propulsion System

The propulsion system, as discussed on the following pages, includes the rotors, drive system, engines, fuel systems, and auxiliary power unit. Improvements in hydraulics, controls, and other subsystems also increased effectiveness because of simplifications that reduce weight and cost and improve reliability; but these are not discussed in detail here because of space limitations. The propulsion system is identical on both the AH-1Z and the UH-1Y. The propulsion system design incorporates



- APR-39 radar warning
- Tailboom
- Horizontal stabilizer
- Chaff/flare dispensers
- Tail rotor
- Intermediate gearbox
- Tail rotor drive shafts
- AVR-2 laser warning set
- Auxiliary power unit
- 90-degree gearbox
- Glass cockpit controls and displays
- Main rotor
- Drive system
- Hydraulic system
- Electrical generation and distribution system
- T700-GE engines
- Infrared suppressors
- Combining gearbox
- Rotating controls and actuators
- Wiring interface assemblies
- SCAS computer
- DCS-2000 radios
- Multifunction displays
- AAR-47 missile warning system
- APX-100
- SCAS actuators
- ARN-153 TACAN
- Oil cooler
- D/C – A/C inverters
- Main transmission
- Ultra low maintenance battery
- Crashworthy crew seats
- TAMMAC

Fig. 7. List of identical components for AH-1Z and UH-1Y.



•Increased gross weight/payload

•Improved performance

•Composite bearingless rotors

•Dual GE-T700-401 engines

•Integrated cockpits

•Improved weapons

•Additional crash protection

•Marinized

•Increased fuel capacity

•EW protection

•New targeting sight

•Additional survivability features

Fig. 8. Summary of improvements for enhanced mission effectiveness.

the latest technology in materials and design concepts while balancing these with weight and cost constraints.

**Rotor**

The main and tail rotors are shown in Fig. 9. Both rely on advanced composites to provide durable, damage-tolerant designs where the flexing of composite members, not bearings, is used to accommodate blade pitch change requirements. The main rotor is derived from the proven Model 680 rotor concept used on the 4BW (AH-1Z prototype) and on the production Bell Model 430.

The main rotor has reduced part count, is easily removable, and requires no lubrication. It is ballistically tolerant, flaw tolerant, and designed for 10,000-hour fatigue life. The blades are folded for Navy shipboard operation. The tail rotor has four blades with an integral tension-torsion strap that attaches to a fail-safe titanium hub. An elastomeric bearing is integral to the hub to provide for rotor flapping. Lubrication is not required.

**Drive**

The H-1 drive system is shown in Fig. 10. The main transmission and tail rotor gearbox are new for the H-1 Upgrade. The main transmission is rated at 30% more power to improve the performance of both the AH-1Z and UH-1Y. On the new cases, magnesium has been replaced with aluminum to reduce corrosion. The new gearboxes are designed with 30-minute run dry capability to reduce vulnerability to ballistic damage; they are also designed for a 5000-hour time-between-overhaul (TBO) to reduce the O&S costs to the Marines.

**Engines/Auxiliary Power Unit**

The H-1 engine and auxiliary power unit is shown in Fig. 11. The APU, provided by Sunstrand, is currently in the DOD inventory. This unit provides electrical power for system checkout, hydraulics to permit control movements for ground check and blade fold, and compressed air for starting the GE-T700-401 engines. The engines are used currently in the AH-1W and are modified slightly with a digital electronic control unit (DECU) for improved rotor speed control. The GE-supplied IR suppressor is also modified slightly to give better interface to the aircraft and to reduce exhaust gas temperatures.

**Fuel**

The fuel systems (Fig. 12) are improved on both aircraft—with increased capacity for additional range, ballistic protection, fuel cell inerting, and improved crash-worthiness for enhanced survivability, as discussed later. One benefit of the propulsion system improvements is an increase in maximum hover gross weight and hence payload, so that additional fuel, ordnance, and speed is available. This means the aircraft can operate at extended ranges, get there quicker, have more time on station, and carry more weapons or payload for the Marines they support.

**Integrated Cockpit**

The heart of the H-1 Upgrade integrated cockpits is the Integrated Avionics System (IAS), supplied by Litton Guidance & Control Systems. The IAS uses powerful technology with large growth margins and open architecture combined with commercial base components to

- Bearingless
- Advanced airfoils
- 10,000 hr fatigue lives

- No lubrication
- Ballistically tolerant
- Simple, reduced parts count

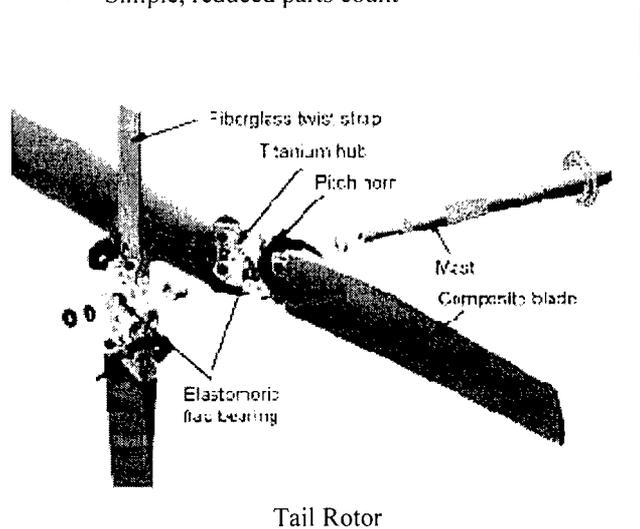
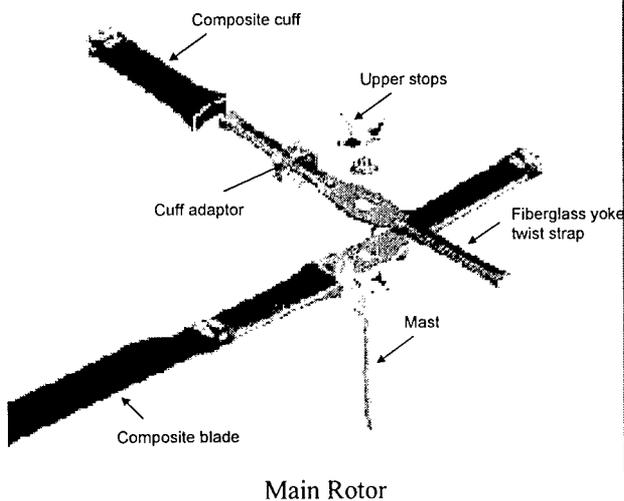


Fig. 9. H-1 main and tail rotors.

For new components

- Run dry
- 5000 hr TBO

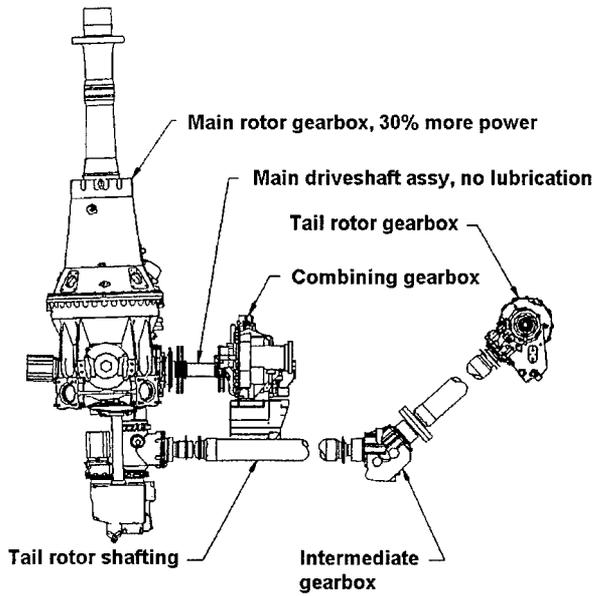
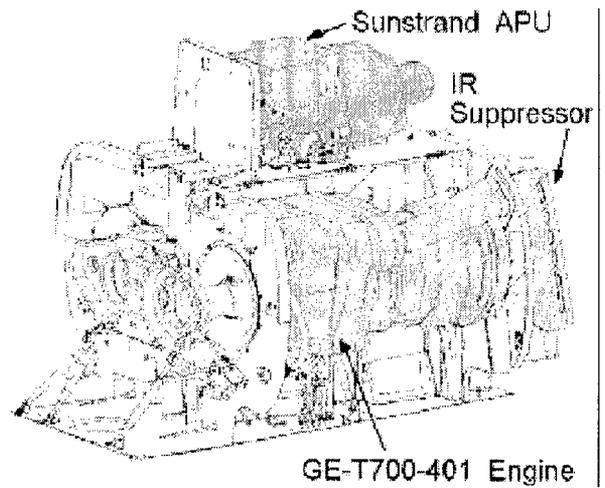
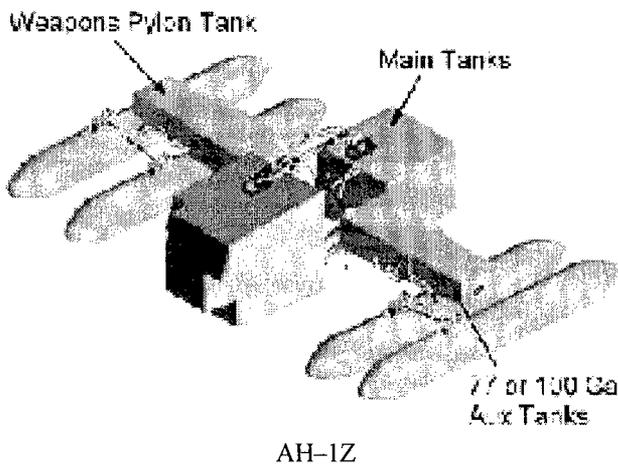


Fig. 10. H-1 drive system.



- Integral particle separation
- Fully marinized
- Self-contained lubrication

Fig. 11. H-1 engine/APU install.



- Self-sealing
- Crashworthy, break away fittings
- OBIGGS inerting
- Zero G capability
- Pressure refueling

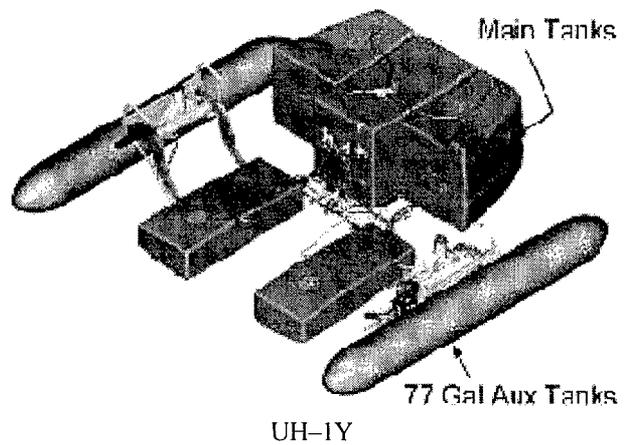


Fig. 12. H-1 Fuel Systems.

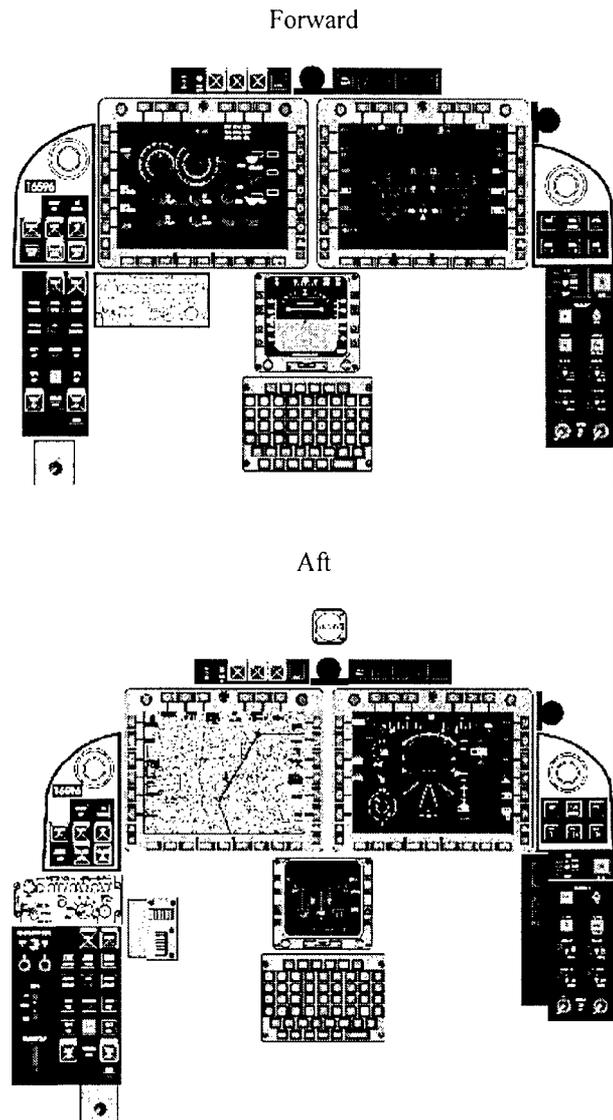
give the H-1 a cost-effective state-of-the-art system. Building on nondevelopmental items (NDI), the IAS is designed to accommodate upgrades in countermeasures and other systems, as they become available without expensive redesign.

The cockpit integration is a culmination of the efforts of multiple design teams. From aircraft subsystem sensors and controls, which are processed by Wiring Interface Remote Terminal (WIRT) computers, to advanced avionics systems integrated in the mission/weapon computers, the many sources of information required to fly and fight the aircraft effectively are made available to the aircrew in the functionally identical cockpits. Extensive design efforts were conducted to ensure the information and capabilities available to the pilots are presented in an intuitive and unambiguous format. The designers were faced with the task of making it all happen within the available cockpit space, and with the additional challenge of improving the pilot's exterior field of view.

The cockpits were designed to reduce pilot workload by (1) allowing easy access to information required and (2) automation of routine procedures. The cockpits are virtually identical, allowing the pilots to fully fight and fly from either station. The reduced crew workload permits the pilots a "heads out of the cockpit" level of situational awareness that allows enhanced safe operation of the aircraft, decreased vulnerability of the aircraft to threats, and more rapid, lethal responses to requests for close air support.

One example of automation is the execution of an immediate close air support mission. The mission brief is received digitally over the radio and is decoded and stored for retrieval in the mission computer. Once the pilot accepts the mission, the computer will provide steering to the assigned attack position that will have the aircraft in place with sufficient time to acquire the target and fire. As the aircraft is maneuvering into the attack position, the targeting sensor will be pre-pointed to the target coordinates and elevation. The computer will also use the range to target and selected weapon system to calculate stores time of flight and cue the pilot when to fire, allowing fire support "on target, on time."

The crew interface architecture is centered around the "all-glass" cockpits, shown in Fig. 13 for the AH-1Z, consisting of two multifunction displays (MFD), one dual function display (DFD), keyboard, Integrated Helmet Display Subsystem (IHDSS), mission grips, and hands-on collective and stick (HOCAS) controls. The glass cockpit allows the pilots' access to all tactical, flight, aircraft system, weapons, and targeting sensor information required. The crew vehicle interface design was based on the premise of not requiring the pilot to change his primary display setup to access flight and



**Fig. 13. The AH-1Z Cockpit Instrument Layouts**

mission critical information or conduct routine in-flight tasks such as changing communication frequencies or changing nav aids.

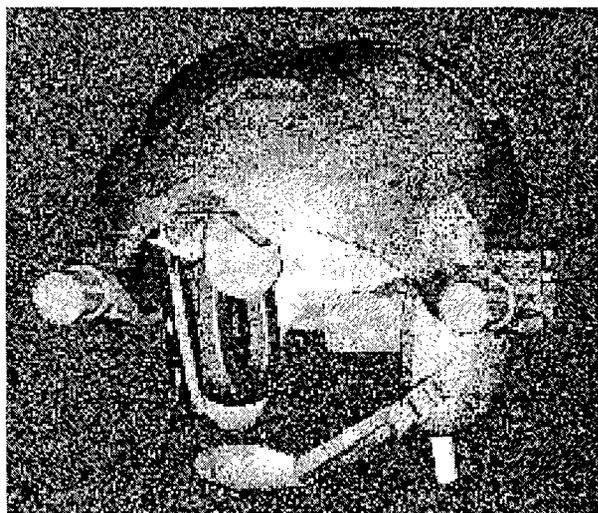
The primary displays depicted in Fig. 13 are the map/nav page, flight page, weapons page and the targeting page. The map/nav page is the primary navigation and steering cueing to the aircrew and provides overlays of the tactical situation. The flight page provides all attitude, airspeed, and altitude information to the pilot as well as the critical aircraft systems information of rotor speed, drive torque, and engine power available. The flight page essentially replaces the instrument panel gauges of a traditional cockpit. The weapons page allows rapid selection and intuitive viewing of the current state of the weapon selections and remaining stores. The targeting page allows selection of the Target Sight System (TSS) modes and viewing of either the color TV video or forward looking infrared (FLIR) imagery for detection

and selection of targets. The other primary MFD pages provide detailed access for electronic warfare, detailed system information, communication, warnings/cautions/advisories, and tactical data communications (TDC).

The IHDSS (Fig. 14) provides the aircrew day and night heads up, heads out text and graphical symbols of critical flight, navigation steering, and weapons aiming information. The visor-projected information provided to the pilot allows normal operation of the aircraft without having to continually scan inside the cockpit for critical information. The integrated helmet tracker allows the helmet display to provide line-of-sight referenced displays that provide a "virtual heads up display" (HUD) for aircraft datum launched weapons and attitude display, off-axis weapon and sight cueing, and navigation steering cues overlaid on the real world.

The night vision cameras coupled into the IHDSS provide a high-resolution scene display to the pilot that is unequalled by any other HMD currently being developed. The cameras equal, and in some cases exceed, the performance of even the latest fielded direct view night vision goggles (NVG) at low ambient levels, particularly in urban environments.

The intuitive, easily accessed system controls and displays are further enhanced by the mission grips and HOCAS controls. These are presented in Fig. 15. The HOCAS controls allow the aircrew traditional flight control switch functions augmented by the new capability to control the MFD pages, select modes, and change

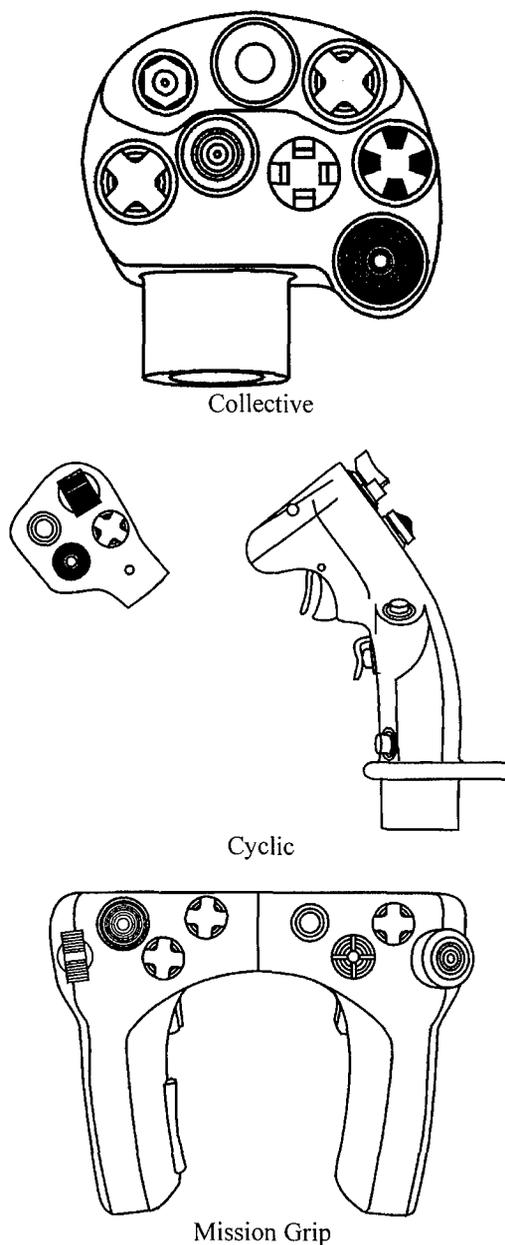


- 1<sup>st</sup> helo with night capable HMD
  - Dual image intensifier (I2) cameras
- Metal tolerant head tracker
- Dual CRT visor projects day or night symbology
- Provisions for FLIR/TV video on HMD
- Heads-up-display information overlaid on HMD image

**Fig. 14. The AH-1Z Integrated Helmet System.**

radios and frequencies without having to release the flight controls. The following highlight some of the HOCAS features:

- Selection of any weapon system.
- Selection of systems, caution/warning/advisory, electronic warfare, and sensor pages for display, as well as return to the primary display.
- Selection of radio and changing preset communication frequencies.
- Selection and adjustment of automatic flight control system (AFCS) "autopilot" modes.



**Fig. 15. H-1 HOCAS and mission grips.**

The mission grips allow either pilot to fully operate the TSS and control weapon selection and delivery “hands on.”

This description has focused on the AH-1Z configuration; however, most of the cockpit instruments and their functionality are identical on the UH-1Y, as shown in Fig. 16. The UH-1Y uses the same cyclic and collective grips as the AH-1Z, but a different targeting sensor and control grip. The grip is integrated into the avionics system and has identical control and display features when identical functions are selected. Currently, the UH-1Y does not incorporate the IHDSS, but a NVG-HUD is provided to display critical flight and navigation

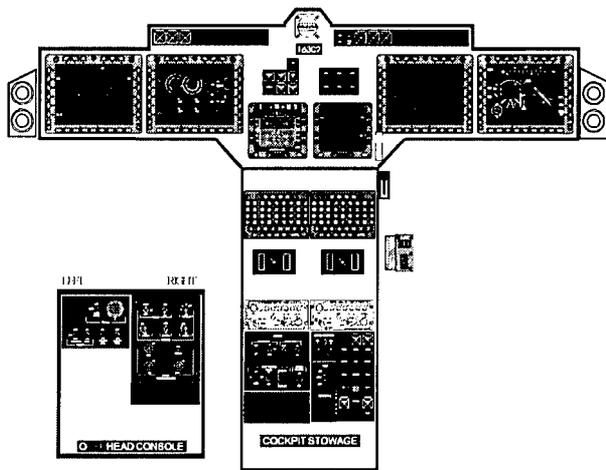


Fig. 16. The UH-1Y cockpit instrument layout.

information “Heads out” during the more hazardous operating environment present at night.

**SURVIVABILITY FEATURES**

Mission effectiveness of the AH-1Z and UH-1Y has also been increased with design features to improve survivability in the battlefield (Fig. 17). Vulnerability to ballistic threats has been reduced with a number of improvements:

- The diameter of control tubes has increased to reduce vulnerable areas.
- The rotor systems have been designed for continued flight after penetration by rounds as lethal as 23mm HEI. Redundant load paths in the main and tail rotors enhance this feature.
- Self-sealing fuel tanks with powder panels are used to preclude fires after penetration by incendiary rounds.
- New gearboxes are designed with 30-minute run dry capability to prevent forced landing after loss of lubricant from ballistic penetration.
- Redundant load paths are provided in highly loaded airframe components, and redundancy in control actuators and other subsystems is used to provide for fly-home capability.

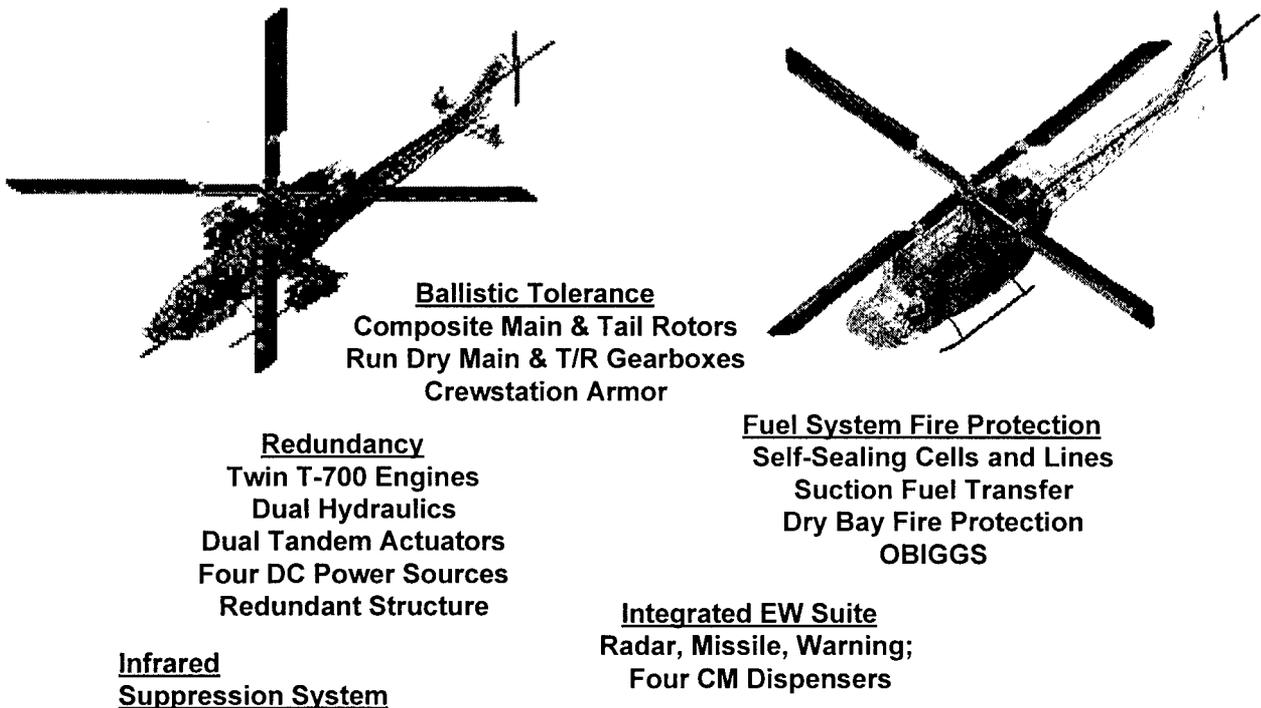


Fig. 17. H-1 survivability features.

The reduction in vulnerable area as a result of these design features is presented in Fig. 18.

The infrared signature of the aircraft has also been reduced, primarily with the improved IR suppression and exhaust shielding on the GE-T700-401 engines. The effectiveness of these improvements in reducing the signature of the aircraft below the specification requirement is presented in Fig. 19.

Active countermeasures are also included on both aircraft, and they are integrated into the avionics systems to improve their effectiveness. The number of chaff/flare dispensers has been increased to four on both aircraft, and placed strategically on the airframes to increase their effectiveness in all quadrants. Dispensing of these countermeasures can be manual or automatic with the integrated avionics package, since they are coupled with the radar/missile/laser warning systems.

Additional design features, shown in Fig. 20, protect the aircraft, passengers, and crew in the event of a hard landing. The AH-1Z and UH-1Y landing gears are

designed for landings up to 12 ft/s without damage to the aircraft. In addition, large mass items, including fuel cells, are designed to remain attached to basic aircraft structure for crashes up to 20g fore-and-aft or vertical or 10g lateral. In the event of a crash, stroking seats provide extra crew and passenger safety on both aircraft.

All of these improvements help the Marines stay in the fight while ensuring that damaged aircraft make it home and can be repaired for follow-on missions.

## MARINIZATION

Features to protect aircraft operating in the maritime environment experienced by the Navy and Marines are expensive to incorporate if they are not included as a part of the basic design process. Both the UH-1Y and the AH-1Z are designed to operate effectively in this environment. Features incorporated in both aircraft, shown in Fig. 21, include corrosion resistant composite main and tail rotor systems; aluminum cases on all the new or modified gearboxes; elimination of many aircraft structure joints through the use of high-speed machined

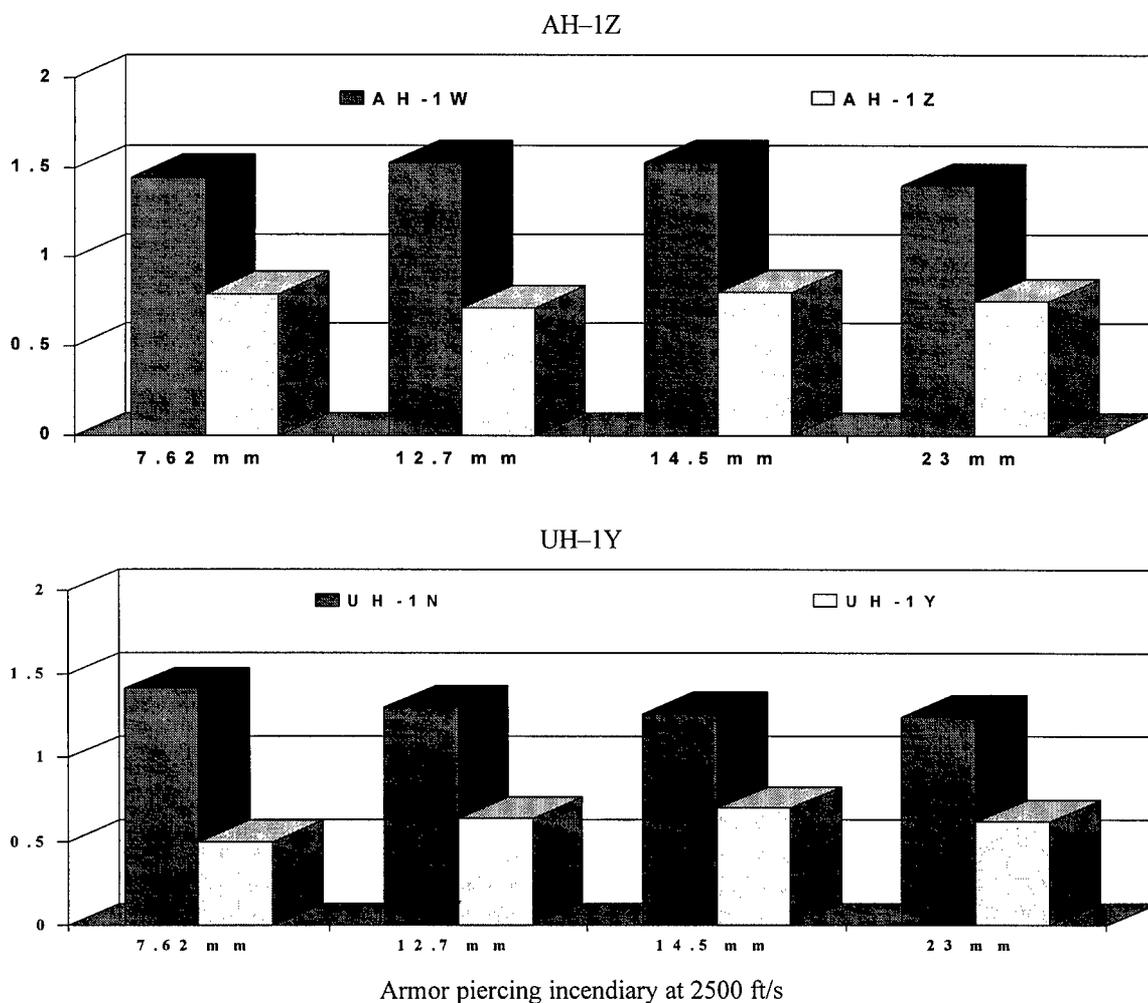


Fig. 18. AH-1Z and UH-1Y ballistic vulnerable area improvement.

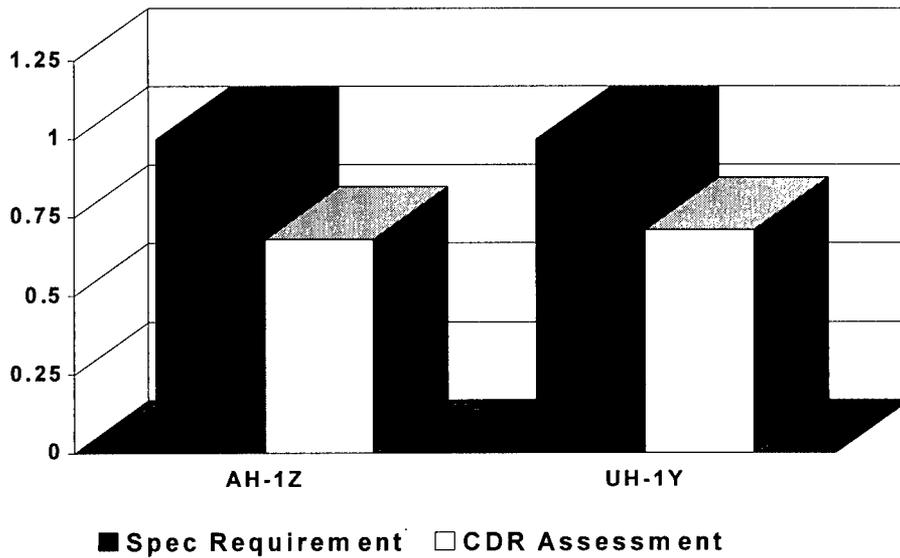


Fig. 19. Improved IR signature of H-1 aircraft.

• IMPROVED LANDING GEAR

- 20, 20, 10G RETENTION

- CRASHWORTHY FUEL CELLS, BREAK-AWAY FITTINGS

- ENERGY ATTENUATING CREW SEATS

- ENERGY ATTENUATING TROOP SEATS

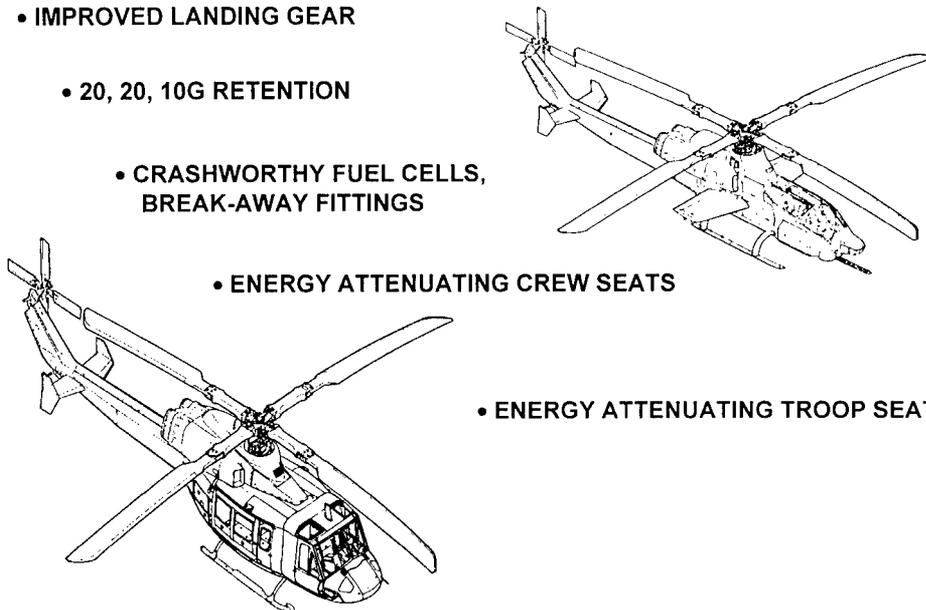


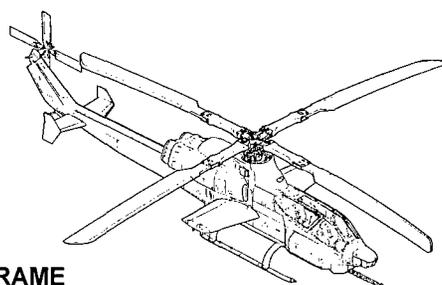
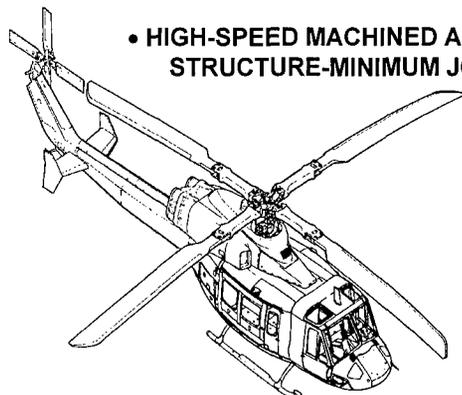
Fig. 20. Improved crashworthiness features

components and treatment of the remaining joints to resist corrosion; marinized engines; and electronic components designed to operate and survive in the high energy electromagnetic fields found near Navy ships. In addition, other aircraft design features, such as blade fold, 30-degree turnover angle, and tiedown provisions for high wind and rough sea conditions, enhance the operation of the H-1 aircraft in this environment. These features not only extend the life of the aircraft, they reduce the amount of time the Marines must spend maintaining the aircraft.

**IMPROVED WEAPON SYSTEM**

The new AH-1Z weapons/ordnance array is the greatest of any helicopter in the world today. These ordnance options are illustrated in Fig. 22. The existing 20-mm gun with 750 rounds of ammunition is being retained, but the accuracy is improved with the Litton integrated avionics package combined with a low-air-speed system from Marconi Electronic Systems. The gun is controlled by either crewmember, using either the helmet mounted display or the mission grip.

- ELECTROMAGNETIC SHIELDING
- MARINIZED ENGINES
- ALUMINUM GEARBOX CASES
- HIGH-SPEED MACHINED AIRFRAME  
STRUCTURE-MINIMUM JOINTS



- SEALANT ON AIRFRAME JOINTS
- FOLDING MAIN ROTOR BLADES
- DECK TIE-DOWN PROVISIONS

Fig. 21. Marinization/shipboard operating enhancements.

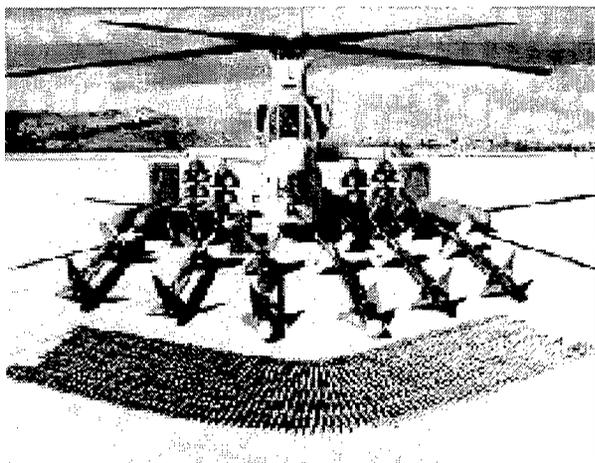


Fig. 22. The AH-1Z weapon suite.

On the AH-1Z, four new universal weapons stations can accept the following ordnance types:

- Sidewinder
- Sidearm
- Stinger
- HELLFIRE
- Rockets
- Longbow HELLFIRE and Maverick

The four stations can also be used for auxiliary fuel to provide long-range ferry capability. In addition to the four universal stations, two additional stations are incorporated into the weapons pylon tips to accept either the Sidewinder, Sidearm, or Stinger.

On the UH-1N, provisions are made to mount the Marine's DAS mount, which has the capability to accept 50-caliber or 7.62mm machine guns and the 2.75-inch rocket pod.

#### Targeting Sight System

One major element of the improved mission effectiveness of the AH-1Z is the new targeting sight system (TSS), provided by Lockheed Martin. The TSS brings state-of-the-art, third-generation FLIR targeting for the Marine Corps. When combined with the Integrated Avionics System from Litton, the TSS gives the AH-1Z unsurpassed capability to fight and survive in the battlefield of the 21st century.

The TSS, shown in Fig. 23, mounts to the nose of the AH-1Z through an interface structure that supports the turret assembly. A five-axis gimbal provides the motion required. The payload is supported on this gimbal and isolated from helicopter and gunfire vibrations. An integral boresight module attaches to the rear of the interface structure.

The turret assembly, made by WESCAM, and the payload details are shown in Fig. 24. The gimbal is designed to accommodate each of the major components as modules so that future upgrades can be implemented without major redesign.

The heart of the TSS is a third-generation, mid-wave infrared, staring-focal-plane-array FLIR. This FLIR has an 8.55-inch diameter aperture and enhanced image processing that result in increased identification,

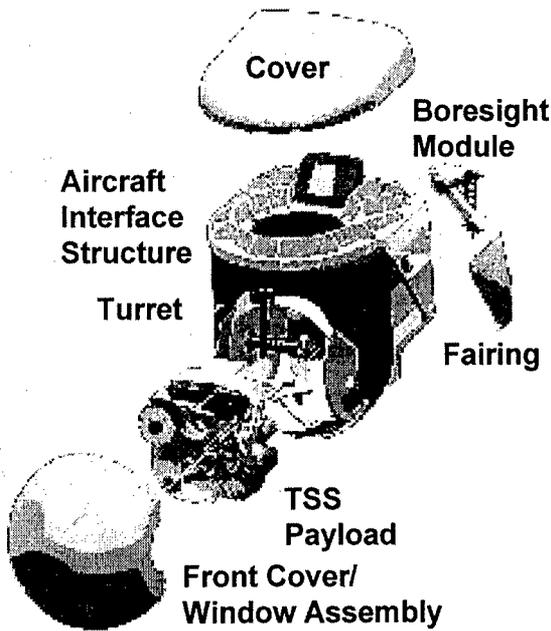


Fig. 23. The AH-1Z targeting sight system (TSS).

recognition, and detection range with sharper image resolution and less sensitivity to weather. Four fields of view are provided to aid in detecting, identifying, and tracking potential targets.

The TSS also has a color TV made by Sony to aid in target detection. The TV has continuous optical zoom, which gives magnifications up to 21x, selectable from

the mission grip. Performance filters for glare reduction and haze penetration can be selected by either crew-member.

A Litton laser, used on the F-16 LANTIRN pod as well as the TSS, is installed on the gimbal for designation and for rangefinding. The laser has an integral eye-safe mode that can be used for enhanced safety during training. A laser spot tracker is also included to enhance the capability of the AH-1Z to track or designate targets during high-workload, battlefield environments. A Litton LN200 Inertial Measuring Unit (IMU) is also mounted on the gimbal to give precise inertial coordinates for interface with the Integrated Avionics System and geopositioning of aimpoints for GPS guided weapons.

Operationally, the TSS can be controlled by either crewmember, either manually or automatically, through the heads-up-display (HUD) on the helmet. It also interfaces with the TAMMAC (digital map) for pre-pointing to selected targets. In addition to the laser spot tracking mentioned above, the TSS also performs scene tracking in both the FLIR and TV modes and is capable of prioritizing and tracking up to 4 targets simultaneously.

The third-generation FLIR and the laser give the AH-1Z unparalleled capability to detect, recognize, identify, and designate targets. A comparison to existing systems is presented in Fig. 25. The capability of the TSS to address targets at the maximum range of several missiles is

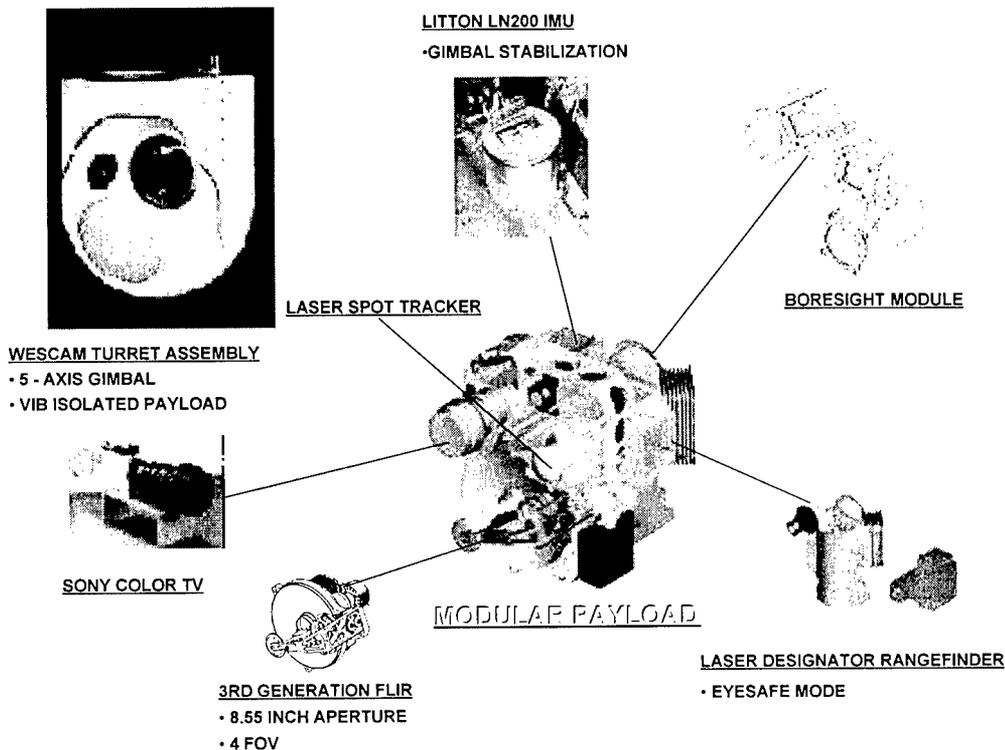
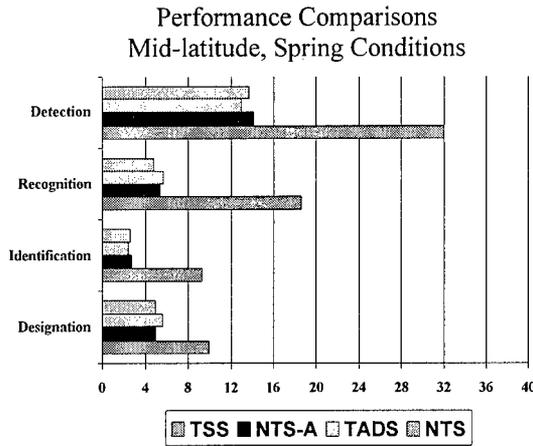


Fig. 24. TSS details.



**Fig. 25. Range comparison for targeting sight systems.**

shown in Fig. 26 and compared to first- and second-generation systems. The increased performance of the TSS at these ranges gives the AH-1Z and the Marines the ability to make maximum use of the capability of these systems. The TSS allows the Marines to rapidly identify and engage targets at extended ranges, increasing their lethality over a greater area while reducing the vulnerability of the aircraft to engagement by the threat.

**SUMMARY AND CONCLUDING REMARKS**

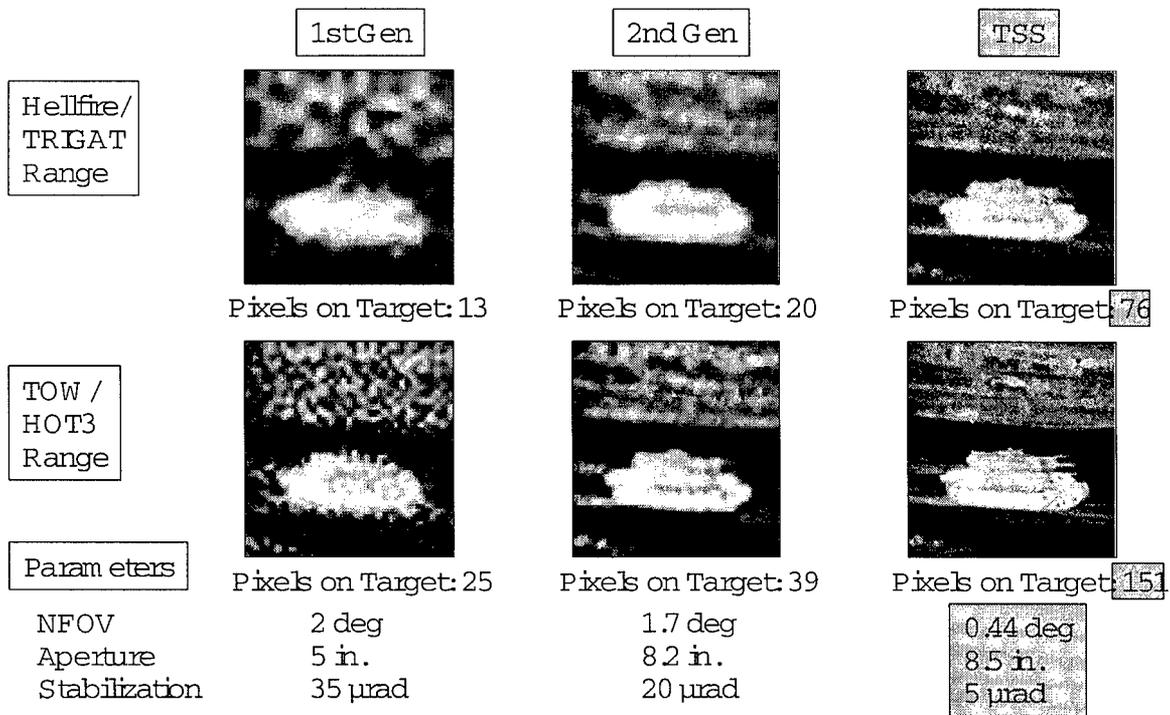
As a part of the Marine Corps strategy to provide war-fighting capability through the first quarter of the 21st

century, Bell Helicopter and the Marines are using Integrated Product Teams to upgrade the UH-1N utility aircraft and the AH-1W gunship to new configurations—the UH-1Y and AH-1Z.

The upgrade program is structured to give the maximum capability achievable within constraints of development and life-cycle costs, and CAIV studies are used to address potential savings against program requirements.

The resulting H-1 configurations have significant improvements compared to the current aircraft. Both aircraft have been designed to operate in the harsh maritime environment required for the Navy and Marine Corps missions. New dynamic components, combined with increased power in the main transmission, increase the performance of both aircraft to improve both speed and payload. The increased power also accommodates improvements to reduce vulnerability to ballistic and infrared threats. Crashworthiness is also improved with large mass retention at higher crash load factors and energy-absorbing seats and landing gears.

New integrated cockpits for both aircraft have state-of-the-art displays, and the Bell/Government/Litton cockpit team has defined cockpit functionality and man/machine interface to drastically reduce pilot workload and improve situational awareness. On the AH-1Z, an integrated helmet display subsystem with night-vision cameras provides day and night heads-up pilotage capability to improve the effectiveness of the aircraft.



**Fig. 26. The impact of FLIR technology on performance.**

The AH-1Z also has a new target sight system with third-generation FLIR, color TV, and both tactical and eye-safe laser. With the sight, the AH-1Z identifies and designates targets out to the maximum kinetic range of the weapons it carries.

The H-1 Upgrade designs presented a unique opportunity to incorporate common components in the two configurations and in the final design, about 85% of the components that require maintenance are identical. Over the life cycle of the aircraft, this identity has a tremendous paypack in reduced costs to maintain and support the aircraft.

The new AH-1Z and UH-1Y are modern, zero-time aircraft designed to operate effectively the next 30 years. The UH-1Y is the most capable light, multi-role helicopter in military service. The AH-1Z is the premier attack helicopter on the battlefield, carrying the widest array of weapons and equipped with the most capable target sight system in the world. The AH-1Z and UH-1Y provide the most potent and cost effective attack and utility combination for the 21st century warfighters. Both aircraft are currently being fabricated, with many components in test to support first flight next year. Production deliveries begin in 2003 with 180 AH-1Z and 100 UH-1Y scheduled to be delivered to the Marine Corps.