CRASH RESISTANCE OF THE UH–1Y AND AH–1Z ATTACK HELICOPTERS FOR THE U.S. MARINE CORPS

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ABSTRACT

The USMC H–1 Upgrade Program has the objective of enhancing the mission capabilities of the utility (UH–1N) and attack (AH–1W) helicopters by incorporating state-of-the-art technologies throughout both platforms. When the USMC utility and attack helicopters started service there was a significant amount of commonality in the dynamic components. However, the attack helicopter has undergone a series of upgrades, primarily in the rotor, engine, and drive systems, while the utility aircraft remained unchanged. With increasing emphasis on cost of ownership, the H–1 Upgrade Program was initiated to upgrade the rotor and drive systems for the attack helicopter and install these same systems on the utility helicopter. In addition, a common integrated advanced state-of-the-art avionics system is being developed for both helicopters. The result of this design effort will be modern utility (UH–1Y) and attack (AH–1Z) helicopters. This paper will describe the design features of both configurations that are being incorporated to enhance the crash survivability.

Occupant crash survivability is accomplished by strong surrounding structure and energy-attenuating seats. The structure is designed to retain all large masses to 20*g* accelerations, maintain occupancy volume after crash and rollover loads, support the energy-attenuating seats under crash loads, and contain the fuel cells with full head pressure at 20*g*. The fuel cell containment is the highest ever achieved for a rotary-wing aircraft. The flight crew energy-attenuating seats for both the AH–1Z and UH–1Y are based on proven seats fielded on another USMC helicopter. Static and dynamic test of the unique integration aspects for each seat has been performed to verify the installations. The UH–1Y troops seats are the Common Crash Resistant Troop Seat System newly developed by the U.S. Navy.

INTRODUCTION

The AH–1W (a twin T-700 engine upgrade from the AH–1T) and the UH–1N (the Pratt & Whitney T-400 twin version of the Huey) are currently a mainstay of USMC rotary-wing operations, filling all requirements for attack and utility helicopters. While currently capable of performing these missions, the AH–1W design is more than fifteen years old, with the UH–1N more than twenty. As these aircraft moved into the 21st Century, it was readily recognized that the incremental improvements through the years to the H–1 line were in need of a major upgrade, one that addressed both the basic air vehicle (performance and service life) and its mission equipment subsystems (integration and modernization). While new replacement aircraft were considered as an alternative to major upgrades of the H–1 fleets, extensive study by the Marine Corps showed that an upgrade was the most affordable, most supportable, and most effective solution for the USMC attack and utility helicopter mission. Thus, the USMC H–1 Upgrade Program was born.

The USMC H–1 Upgrade Program is the most significant step in the continuing evolution of the power plant, dynamic systems, armaments, and avionics of the H–1 series helicopter. The H–1 Upgrade air vehicles and their systems upgrades are depicted in Figs. 1 and 2. Major upgrades address the dynamics (rotors, drive, and propulsion), weapon subsystems, and integrated avionics and cockpit. The AH–1Z has a maximum gross weight of 8,391 kg (18,500 lb). Its drive system rating is 1957 kW (2,625 horsepower) and the internal fuel system capacity is 1,540 L (407 gal). These are all significant increases over that of the current AH–1W helicopter. For the UH–1Y, the maximum gross weight and drive system rating are increased to 8,391 kg (18,500 lb) and 1957 kW (2625 horsepower), respectively, which provides significant performance enhancements. Although the H–1 Upgrade program is a remanufacture of baseline aircraft, the design requirements are the most stringent applied to a helicopter to date. These requirements include the latest standards for

1. Crashworthy fuel cells.
2. Large mass crash retention.
3. Fire protection with dry bay protection vapor inerting.
4. High sink rate landing gears.
5. Flaw tolerance (reduced materials properties due to material flaws).

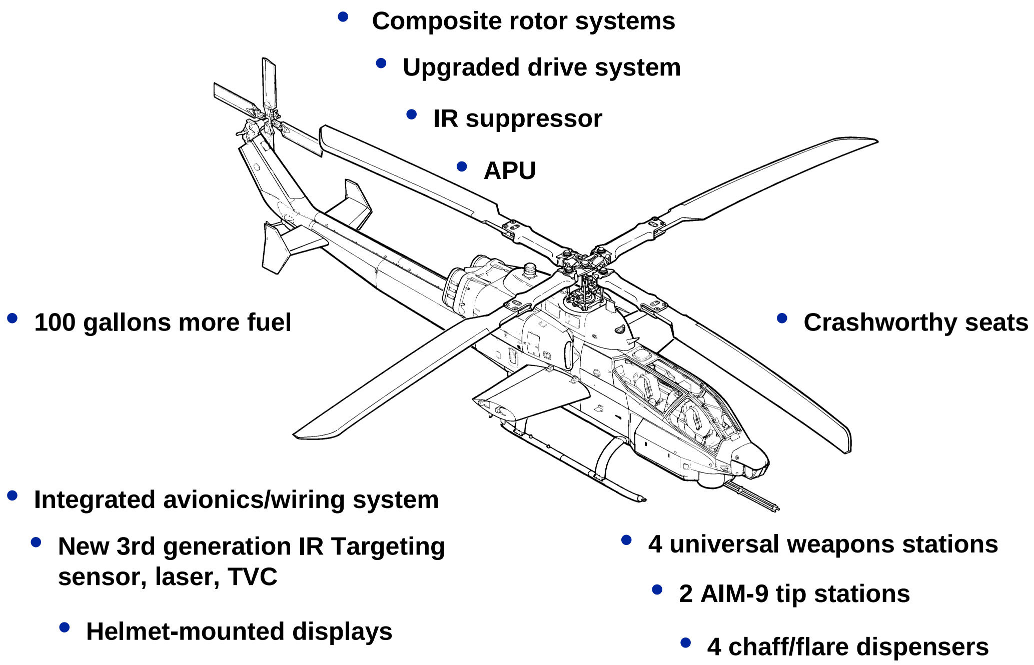


Fig. 1. AH–1Z configuration upgrades.

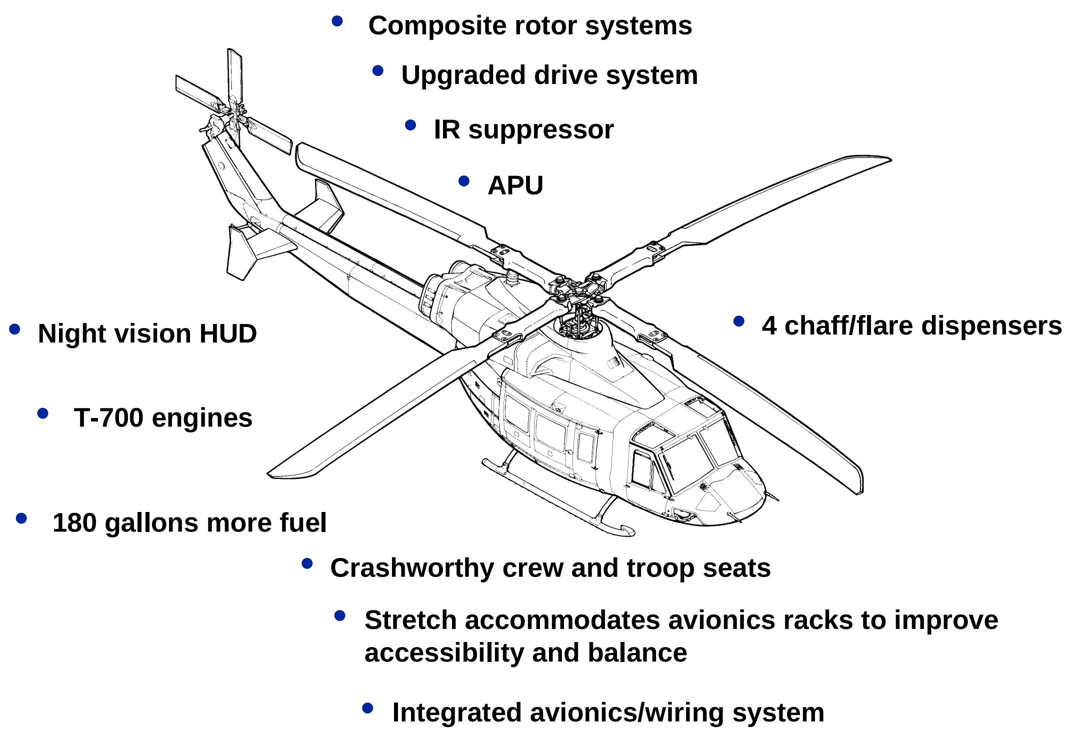


Fig. 2. UH–1Y configuration upgrades.

6. Ballistic tolerance.

7. Structural redundancies.

8. Fail safe designs.

9. 10,000 hour fatigue lives for severe spectrums for ground-air-ground, low cycle maneuver, and high-frequency vibratory loads.

10. Crashworthy seats for crew and troops.

While these requirements tend to add weight and nonrecurring and recurring cost to the aircraft they also, however, provide additional robustness, long service lives, reduced maintenance, and less induced damage resulting in overall life-cycle cost reductions.

AIRFRAME DESIGN

For the USMC, the most significant advantage of this upgrade approach is the commonality aspects for the dynamic components. Since both helicopters are being upgraded concurrently, the commonality can be further exploited. The significant air vehicle components that are common to both helicopters are shown in Fig. 3. The H–1 aircraft are 55% common by weight. The commonality in the avionics and cockpit are summarized in Fig. 4. Commonality is made possible by the structural architecture of the AH–1W and UH–1N airframes. Two structural main beams that extend from the nose of each airframe to the tailboom attachment bulkhead. These main beams are located at Buttline 14, right and left, and they provide the foundation for the cockpit, main transmission support, fuels cell structure, and engine decks. The main beams are not common between the aircraft because they are tailored for each application. On the AH–1Z, the main beams support the gun turret and the targeting sight. For the UH–1Y, the main beams (along with other outboard beams and a series of connecting bulkheads) support the cabin and additional fuel cells. The design approach for crashworthiness of the airframes is to provide

1. Survivable occupant volume

2. High mass retention strength (20*g* up, down, and forward, and 10*g* lateral)

3. Crashworthy seat retention

4. Occupant environment protection by the simplified glass cockpit arrangement

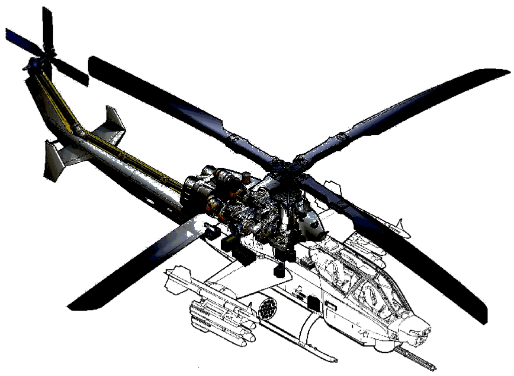
5. Post hazard protection with fuel cell containment structure designed to the same criteria as the high mass retention with maximum head pressure

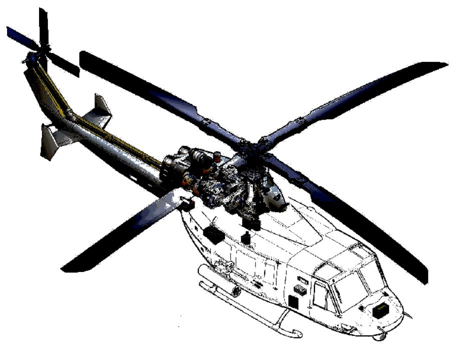
6. Emergency egress

7. High sink rate skid landing gears to accommodate variety of impact surfaces

AH–1Z Airframe

Inherent to the AH–1Z airframe design is the wing structure that helps prevent rollover and provide side rest during a crash. The strength of the forward bulkhead (designed to retain the targeting





AH–1Z **UH–1Y**

Identical components

Main rotor hub and blades	**Hydraulic system**
Blade fold system	**Oil cooling system**
Rotating controls	**Flight control servoactuators**
Main transmission	**SCAS**
Combining gearbox	**Electrical generation and distribution system**
Engines	**Countermeasures**
Drive train	**Cockpit/avionics**
42-degree gearbox	**Fire extinguishing system**
90-degree gearbox	**Pylon structure**
Tail rotor hub and blades	**Battery**
Rotating controls	**APU**

85% of maintenance-significant items are common to both aircraft.
This reduces the logistics tail, training, footprint, and cost.

Fig. 3. AH–1Z and UH–1Y air vehicle commonality.

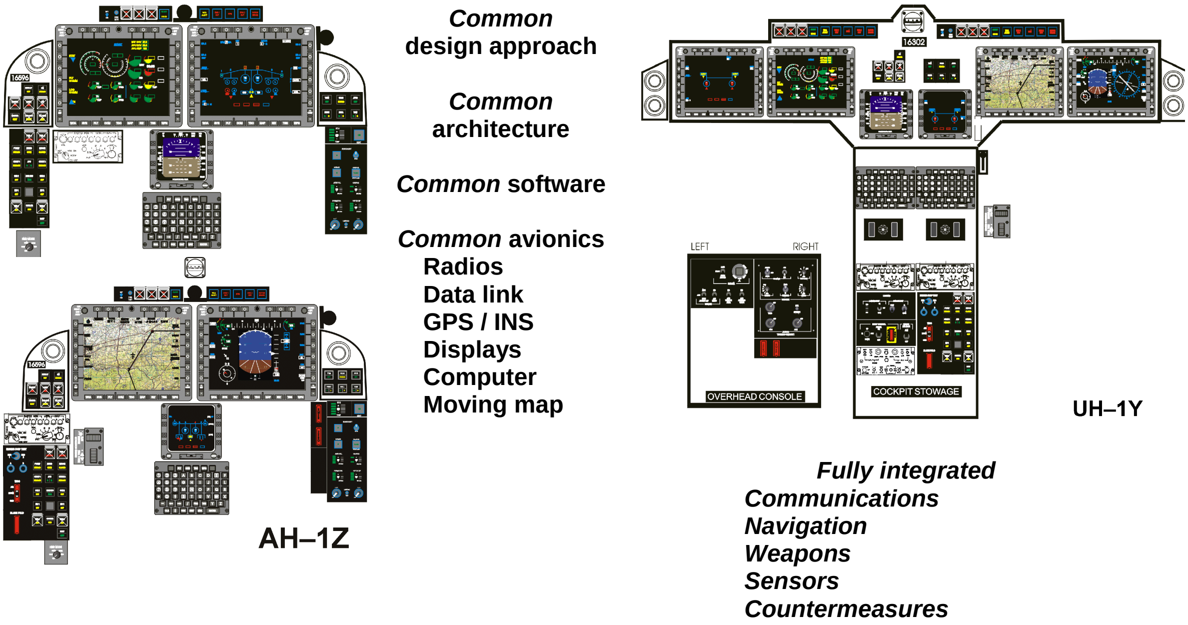


Fig. 4. AH–1Z and UH–1Y cockpit commonality.

system) and the geometry relative to the rotor mast provide cockpit volume integrity in the event of a rollover. The side beam structure in the cockpit area provides crew protection. The main airframe structure, as designed using the three dimensional (3D) Unigraphic design system, is shown in Fig. 5. The cockpit structure is shown in Fig. 6. The fittings that support energy-attenuating seats are designed to 20*g* forward, 12*g* aft, 10*g* lateral, 25g down, and 8*g* up. A frangible cover (that prevents ammo fumes from entering the cockpit) is incorporated below the forward seat to provide more seat stroking distance. Another feature in the AH–1Z is the use of side cyclic control sticks that minimize the occupant environment hazard. An explosion canopy removal system is incorporated along with breakaway knives for emergency egress.

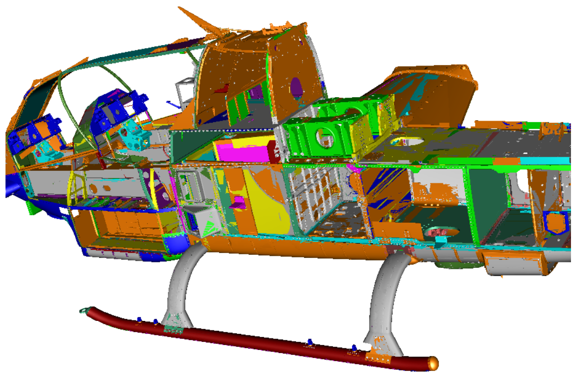


Fig. 5. AH–1Z airframe structure.

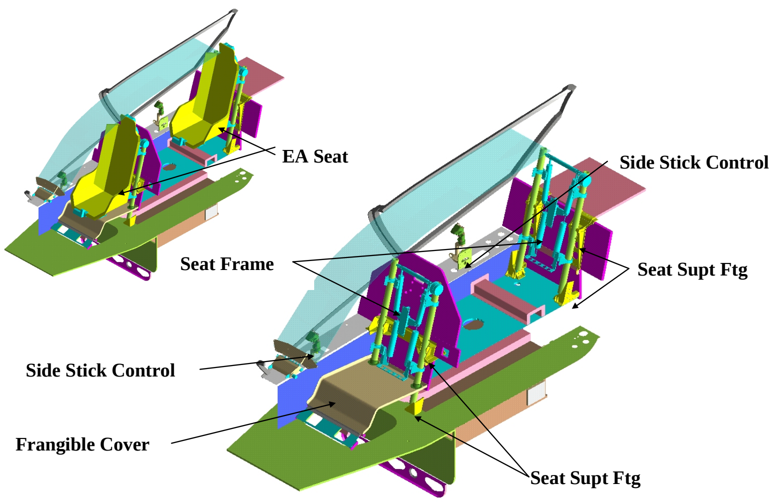


Fig. 6. AH–1Z cockpit structure.

The AH–1Z and UH–1Y have a new upgraded main rotor and transmission system common to both aircraft. The retention of these components required new structure referred to as the pylon supports. The pylon supports are attached to machined bulkheads that mate to the main beams that form the primary structure of the airframes. The pylon support arrangement for the AH–1Z is shown in Fig. 7. The new machined bulkheads provide the support for the internal fuel cells (aft support for the forward fuel cell and forward support for the aft fuel cell). The bulkheads also provide the attachments for the weapons pylon, which are sized for retaining fuel cells inside of the weapons pylons to 20*g* forward.

The landing gear to cross tube interfaces for the airframe were sized to react the limit loads for the sink rate of 3.56 m/s (12 ft/s) at 7575 kg (16,700 lb) vertical impact as well as the appropriate lateral component for side load reaction as defined by the NAVAIR AR-56 specification. This imposes significant loads at these local interfaces as well as high inertia loads throughout the airframe. Satisfying this requirement offers a significant level of protection to the aircraft against damage during a minor crash.

UH–1Y Airframe

The UH–1Y airframe is derived from the UH–1N helicopter. Some of the significant structural differences of the UH–1Y relative to the UH–1N are as follows:

1. The maximum gross weight is increased from 4,763 kg to 8391 kg (10,500 lb to 18,500 lb).

2. A 0.53 m (21.0 inch) fuselage extension is added forward of the crew bulkhead.

3. Troop seats are changed from floor-mounted to bulkhead-mounted.

4. The fuselage rollover strength is increased to 4*g*.

5. The major mass item retention strength is increased from 8-8-8*g* to 20-20-10*g*.

A thorough analytical and test correlation study was conducted for the UH–1Y. Based on measured UH–1 crash testing, this contracted study concluded that the UH–1Y airframe crash resistance capability in terms of both peak acceleration and crash impact velocity can be estimated as shown in Table 1.

The primary fuselage structure of the UH–1Y, shown in Fig. 8, retains the UH–1N configuration with strong main beams at BL ±14.0 that extend from the nose under the floor, as keel beams, all the way to the tailboom junction. The new main beam assemblies used in the UH–1Y (Fig. 9) are constructed from a single high–speed machined 7050-T73 aluminum billet. Web thickness varies from 0.127 cm to 0.152 cm (0.050 inch to 0.060 inch) with intermittent vertical stiffeners between

Table 1. Estimate of UH–1Y airframe crash resistance capability.

Crash pulse parameter	Vertical	Longitudinal	Lateral
Change in velocity, ΔV	12.19 m/s (40 ft/s)	9.75 m/s (32 ft/s)	6.09 m/s (20 ft/s)
Peak accerlation, G_m	39*g*	16*g*	12.5*g*

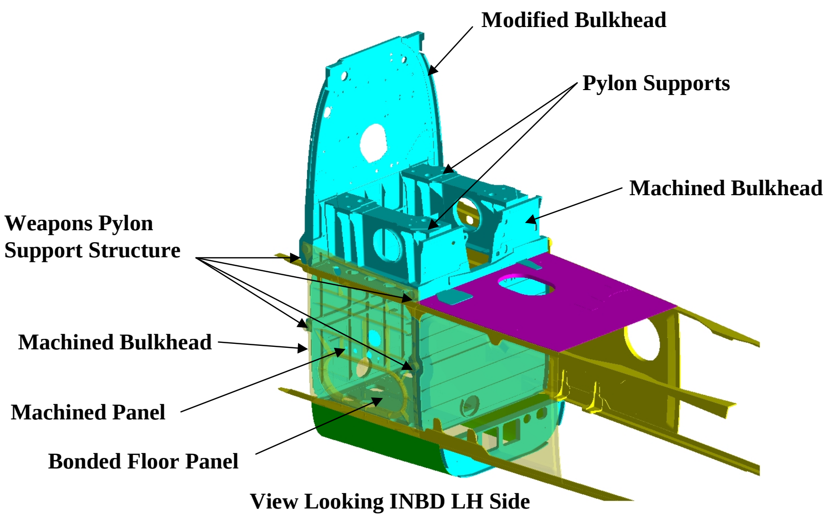


Fig. 7. AH–1Z pylon support structure.

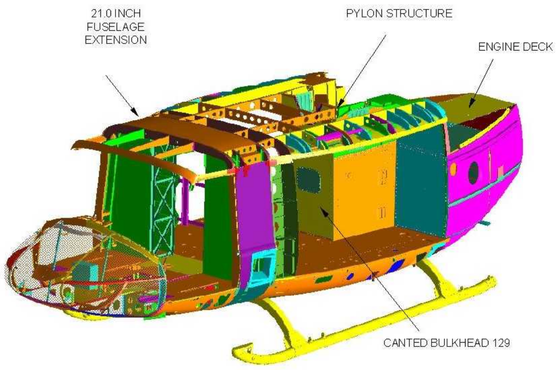


Fig. 8. UH–1Y airframe structure.

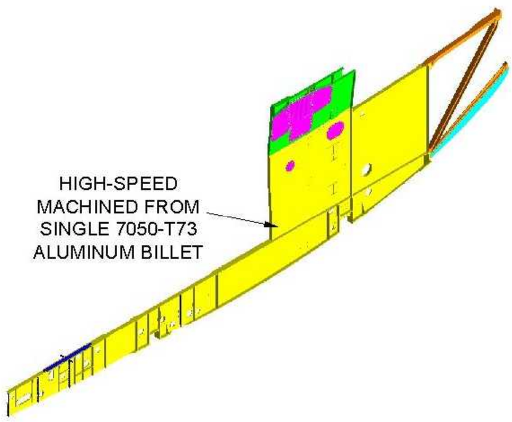


Fig. 9. UH–1Y main beam.

bulkheads. Keel beams provide outboard support for the floor mounted crew seats. The cap areas and web thickness of the keel beams are approximately the same as the BL 14.0 beams. The fittings and backup structure that support the crew seats are sized to 20*g* forward, 12*g* aft, 10*g* lateral, 25*g* down, and 8*g* up (the same values as used on the AH–1Z).

The subfloor structure at the cross tube interfaces was also sized to react the landing loads due to high sink rate impact of 3.56 m/s (12 ft/s) in the same manner as that of the AH–1Z. However, due to the geometry of the wider but shorter landing gear cross tubes, the side loads introduced into the UH–1Y airframe are very large. Meeting this requirement provides the aircraft with significant crash side load capability that will offer better protection to the occupants as well as aircraft damage due to a minor side impact crash.

The main rotor transmission support is provided in the same manner as that of the AH–1Z and uses the same criteria. The pylon support is shown in Fig. 10. The pylon supports are made from the same forging as those of the AH–1Z, but have different interfacing to the bulkheads, due to the geometry of the different aircraft. New machined bulkheads are incorporated. The forward bulkhead provides the load path to the new main beams and supports the attachments for the crashworthy troop seats. Fig. 11 shows the structure in more detail. All of the longitudinal beams and intercostals and more of the bulkheads are new high–speed machined structures. This structural arrangement provides the support for retaining all of the fuel cells to 20-20-10*g* with full fuel and head pressure form the aft fuel cells imposed on the sub-floor structure surrounding the lower fuel cells. The figure also shows the stanchions and interface structure for the energy-attenuating troops seats. There are four troop seating sections on the UH–1Y. They include three aft-facing seats, three forward-facing seats on the canted bulkhead, and two pairs of side-facing seats at BL 14.0. The stanchions are vertical beams made from 7075-T3 aluminum with rectangular cross section. Each stanchion connects with the floor and roof structure at BL 30.0. The stanchion-to-floor fitting is designed to allow up to 15 degrees of misalignment in any axis and still maintain structural integrity. Each stanchion is also attached to the roof with a pivoting-sliding fitting

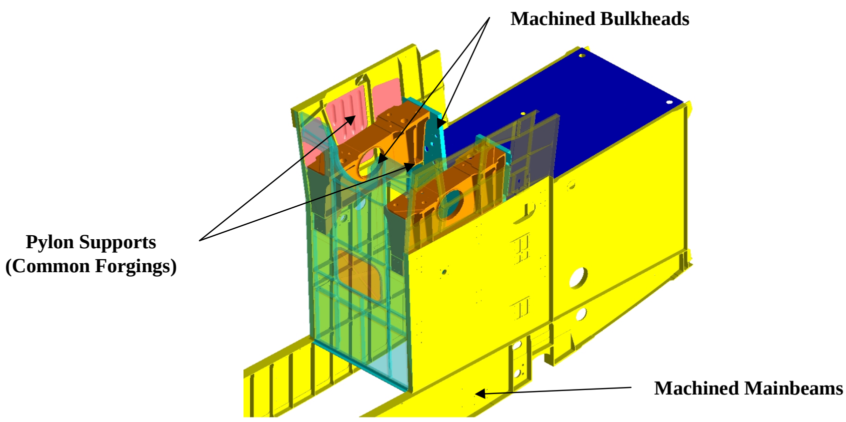


Fig. 10. UH–1Y pylon support structure.

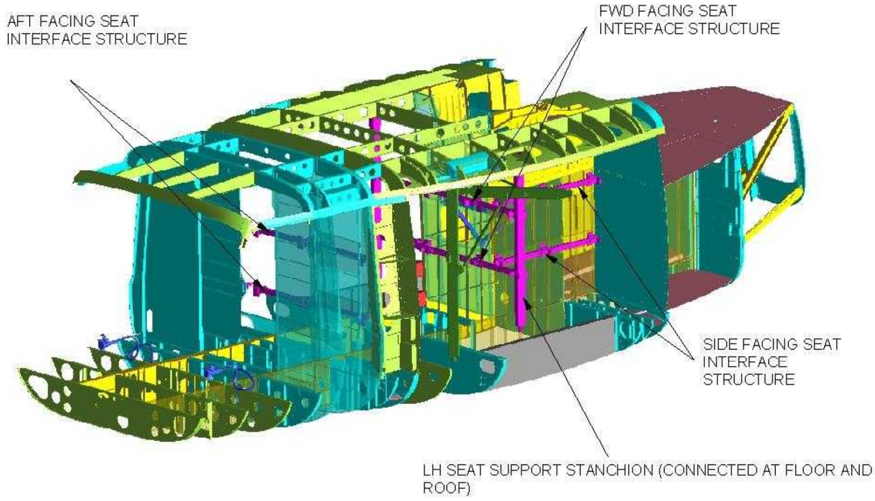


Fig. 11. UH–1Y airframe internal structure.

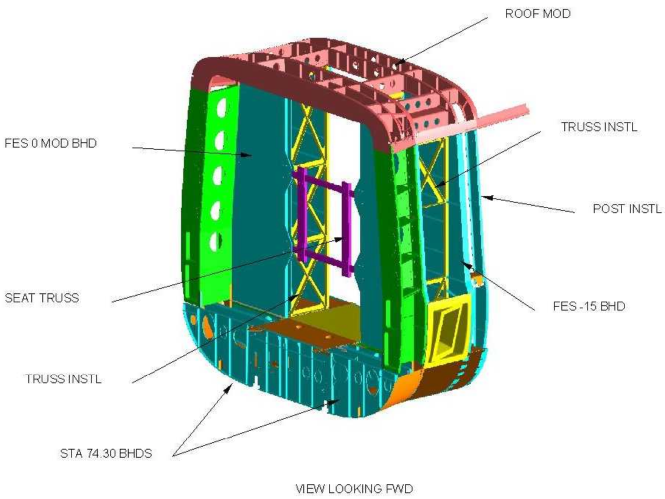


Fig. 12. UH–1Y fuselage splice structure.

that in normal operation transmits horizontal loads only. During a crash, the roof fitting can slide approximately 0.5 inch prior to bottoming and initiating vertical load transfer into the roof structure. UH–1Y design criterion uses a 122 kg (269 lb)/95th percentile male equipped with an ALICE pack.

On the UH–1Y, a 0.53-m (21.0-inch) splice, shown in Fig. 12, is integrated behind the crew station and forward of the cabin. Avionics racks are incorporated within the splice. All of the components mounted on the racks are retained to the high mass retention criteria. This splice, which contains a strong double bulkhead that is integrated with the floor and roof structure, helps meet the combined-axis rollover strength requirement as well as providing support for the aft-facing troop seats. The roll over requirement is 4*g* at the design gross weight of 7,575 kg (16,700 lb).

Troop Seats

The UH–1Y incorporates energy-attenuating (EA) bulkhead-mounted troop seats developed by Skyline Industries through a NAVAIR-funded program referred to as the Common Crash Resistant Troop Seat System (CCRTSS), shown in Fig. 13. The CCRTSS seats provide protection for an expanded troop population weight range of 50 to 110 kg (110 to 240 lb). The CCRTSS is the first troop seat to passively accommodate such a large occupant weight range, from an unequipped female representing the 5tH–percentile of body mass to a fully equipped male at the 95tH–percentile. The seat passively accommodates different occupant weights without requiring adjustments or complex active adjustment systems. The seat's EA system absorbs the high acceleration forces and transfers them to the seat occupant at levels below injury thresholds. As

Fig. 13. CCRTSS energy-attenuating troop seat.

the seat strokes downward during an impact, sets of offset metal rollers deform the two straight metal bars behind the seat, dissipating crash energy.

The seats were statically tested to 20-20-10*g* for any orientation and subsequently dynamically tested to NAVAIR-tailored specifications shown in Fig. 14. The specification was tailored to provide compatibility between the respective capabilities of the seat and UH–1Y airframe (discussed previously). Providing compatible crash capabilities results in an optimum seating system weight. The CCRTSS provides 11 m/s (36 ft/s) vertical impact velocity capability.

When deployed aboard fleet aircraft, the seats will be subjected to vibration, salt water, sea, air, dust, and extreme temperatures. To ensure the seats would function properly under those conditions, two seats were subjected to the full-spectrum of environmental testing and subsequently tested on Naval Aviation Systems' horizontal accelerator at the Naval Air Station, Patuxent River, MD.

To ensure the occupant is properly restrained throughout the entire crash sequence, an easy-to-use five-point restraint system with a rotary buckle is used. The seat configuration for the UH–1Y is shown in Fig. 15 (fifth strap not shown) and a Unigraphics operational depiction is shown in Fig. 16.

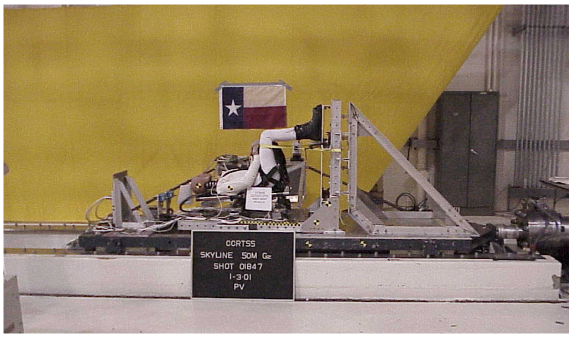


Fig. 14. CCRTSS acceleration test.

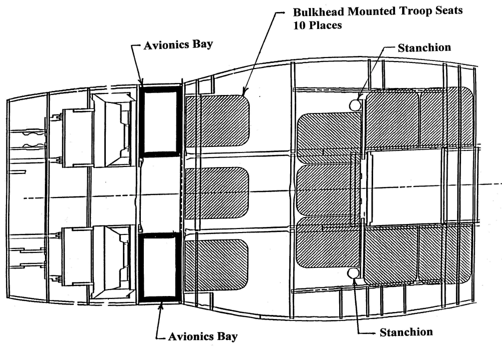


Fig. 15. UH–1Y cabin arrangement.

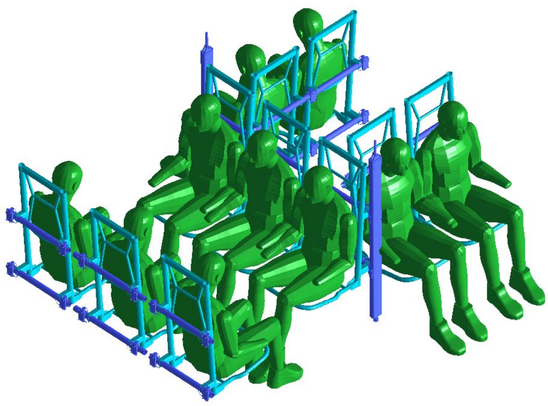


Fig. 16. UH–1Y troop seat arrangement.

Crew Seats

The AH–1Z and UH–1Y employ a common armored energy-attenuating crew seat, shown in Fig. 17, for all of the crew seat locations. This seat, developed and built by Simula Technologies Inc., was previously developed for another platform. Additional static and dynamic tests were conducted for the specific applications for the AH–1Z and UH–1Y. Fig. 18 shows one of the dynamic tests for 30-deg vertical and 10-deg roll condition.

As with the troop seat, the EA specification was tailored to provide compatibility between the respective seat and airframe structure capabilities. Due to the available stroke space, the vertical velocity capability for the UH–1Y is 12.5 m/s (41.1 ft/s), while the AH–1Z application provides 11.6 m/s (38.0 ft/s) for the aft seat and 10 m/s (32.8 ft/s) for the forward seat.

The crew seats provide variable load energy attenuators (VLEA) that can be adjusted by the crewmember to ensure the proper protection based on the occupant’s weight. In addition, a 5-point restraint system that incorporates MA-16 inertia reels enhances occupant survivability in a crash.

While the AH–1Z seats are bulkhead-mounted, the UH–1Y crew seats are floor-mounted. Overturning pitch moments from the seat to the floor structure are controlled by load-limiters. The “vertical” guide tube on each side of the seat is pivoted at the floor base member. Invert-tube attenuators control the forward motion of the seat to simultaneously limit the loads transmitted to the floor while still preventing occupant head strike.

Landing Gears

The AH–1Z and UH–1Y have skid landing gears design to 3.56 m/s (12 ft/s) at 7575 kg (16,700 lb) limit drop condition (where the airframe would not make contact to the ground and there would be no airframe damage). The landing gears also have a reserve energy capability of 4.5 m/s (14.7 ft/s) where they would continue to absorb energy as the airframe structure crushes due to ground impact. Rectangular cross sections instead of traditional circular cross sections were used for the cross tubes to better meet the structural requirements without a large weight impact. The skid landing gears have different heights and widths for the two aircraft, so each one had to be tailored to different load and geometric criteria. To support this effort, a number of drop tests were conducted. The drop tests included level landing, level landing with drag, rolled landing, and landing with one side obstructed, skid restricted laterally. Figs. 19 and 20 show drop tests for the AH–1Z and UH–1Y, respectively. The test results satisfied the requirements and correlated with the analyses, which were prerequisites for flight testing.

Fuel Systems

The UH–1Y has an all-new fuel system, shown in Fig. 21. The fuel system consists of five new fuel cells with 1,438 L (380 gal) of useable fuel. There is also the capability to install auxiliary fuel tanks on external mounts. These auxiliary fuel tanks can be jettisoned in the case of an emergency. Each fuel cell incorporates features for ballistic self-sealing

Fig. 17. Common crew energy-attenuating seat.

Fig. 18. Crew seat vertical dynamic test.

Fig. 19. AH–1Z landing gear drop test.

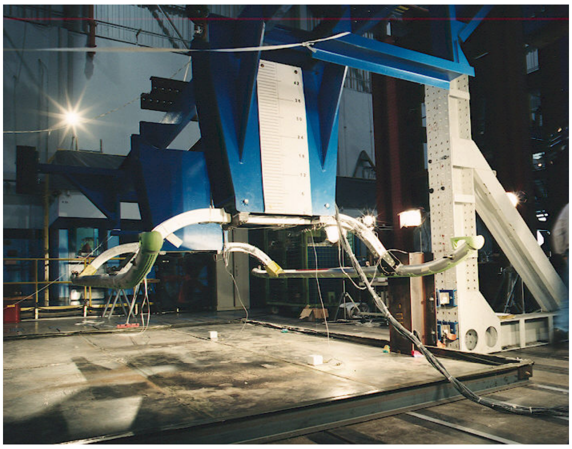


Fig. 20. UH–1Y landing gear drop test.

and each one has to satisfy the military standard drop test. The drop test requirement is for each separate cell to be filled with water, and dropped from a height of 20 m (65 ft) without any external support and for no part of the basic cell or metallic fittings to rupture. This requirement imposes a significant amount of weight for the fuel cells, but research by the Military has shown that this does provide greater post-crash hazard protection for survivable crashes. The fuel system also has a vapor inerting system, OBIGGS, that reduces the amount of oxygen in the fuel cells that would aid in reducing the likelihood of a post crash fire. The structure around the fuel cells is not only sized for the crash retention as mentioned earlier, it also incorporated features that offer dry bay fire protection in the event of a leak due to a ballistic round.

The fuel system for the AH–1Z, shown in Fig. 22, retains the two internal fuel cells (originally designed for the AH–1W aircraft) that meet the military standards. Two additional fuel cells are incorporated inside of the weapons pylon. This provides a fuel system with 1,540 L (407 gal) of usable fuel in addition to external auxiliary fuel tanks that can be jettisoned. The new fuel cells inside of the weapons pylon have also undergone the

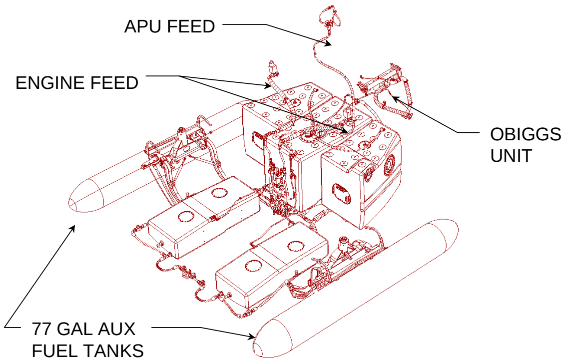


Fig. 21. UH–1Y fuel system.

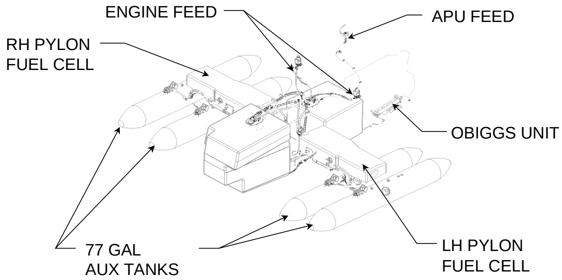


Fig. 22. AH–1Z fuel system.

required qualification testing and have meet the requirements. The OBIGGS system and dry bay fire protection features are also incorporated on the AH–1Z.

Both aircraft have a new fire suppression system for the engines and auxiliary propulsion unit. The fire suppression system uses a non-ozone-depleting agent. The system can be activated by a flight crew member in the event of a post-crash fire.

SUMMARY

The AH–1Z and UH–1Y are derivatives of aircraft designed over twenty years ago, but they meet the latest standards for crashworthiness for military aircraft. The overall crashworthiness approach is to provide a complete crash survivable system for

1. Protective shell for the occupants for rollover
2. High mass retention
3. Occupant acceleration with energy attenuating seats
4. Occupant environmental hazard protection
5. Enhanced landing gear capability
6. Post hazard fire protection

7. Occupant egress capability

The Bell and NAVAIR team has incorporated the features that will provide the USMC with aircraft that not only offer operational effectiveness, mission suitability, and life cycle cost improvements, but also will also provide improved crash survivability for the users.