Joint Replacement Aircraft: The Case For A Single Multi-Mission HMLA Platform

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EXECUTIVE SUMMARY

Title: Joint Replacement Aircraft: The Case For A Single Multi-Mission HMLA Platform

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Thesis: The proposed introduction of the Joint Replacement Aircraft, as a follow-on for the UH-1Y/AH-1Z program, is an ideal opportunity to build a single platform that performs both the rotary-wing attack and utility missions for the Marine Corps.

Background: Historically, the Marine Light/Attack Helicopter missions have been flown by two different aircraft. The AH-1 Cobra performs the attack mission, while the UH-1 Huey handles various "utility" tasks. Originally assigned in equal numbers, each squadron is now equipped with 18 AH-1W Cobras and 9 UH-1N Hueys.

The two-to-one ratio is indicative of a trend. Over the years, the UH-1N's performance has been eroded by the increased weight of new systems. This reduced capability has left many questioning the worth of a "utility" platform. The poor capability of the UH-1N is mistakenly viewed as a reflection on the poor value of multi-purpose helicopters in general.

Although the Huey and Cobra are both Bell products that originally shared many components, the Cobra has received extensive upgrades since its introduction. As a result, the two helicopters now share very few parts and require specialized maintenance training. In an effort to correct these deficiencies, the four bladed UH-1Y/AH-1Z program was initiated to improve performance and dramatically increase commonality. When these new helicopters begin arriving in 2003, they will share 85% in common components.

While the UH-1Y/AH-1Z program an important step in the right direction, an opportunity for even greater benefits lies ahead. An undeveloped concept program, the Joint Replacement Aircraft, is slated for introduction in the 2015 to 2020 time frame. Although the design is still open, many involved with the acquisition process believe that a tilt-rotor or futuristic canard rotary wing concept is favored over a conventional helicopter. In fact, since the introduction of the MV-22, many officers in the Pentagon believe that helicopters are reaching the end of their military usefulness.

Although determining future requirements is difficult, two factors will serve to define the Joint Replacement Aircraft. The first is the changing nature of conflict for the Marine Corps. These are the volatile humanitarian, peace-keeping and peace-making operations that General Krulak has termed the "three block war." The second is the looming defense budget shortfalls, as the services continue to push for expensive programs with no clear vision of funding sources. These factors should encourage the Marine Corps to pursue a Joint Replacement Aircraft that offers the benefits of a multi-mission platform.

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Recommendation: The Marine Corps should continue the trend it started with the UH-1Y/AH-1Z program. The Joint Replacement Aircraft should be developed as a single multi-mission *advanced concept helicopter*. This will offer an affordable, viable and capable platform that can be tailored to any mission. The resulting versatility and responsiveness will improve firepower, while serving as an effective "force multiplier" for the Marine Corps.

LIST OF ILLUSTRATIONS

Preface

This study investigates the feasibility of designing a single multi-purpose aircraft as a replacement for the AH-1Z and the UH-1Y in the 2015 to 2020 time frame. The Marine Corps has labeled this generation-after-next aircraft the Joint Replacement Aircraft, but little else has been done. This subject was undertaken to provide a starting point for debate on the roles and missions of the Joint Replacement Aircraft, as well as an evaluation of recent technology advances that may prove suitable.

I wish to thank several people at the Command and Staff College, who have provided the help and support needed to complete this project. First, to Lieutenant Colonel James J. Cooney, who brought a Cobra Pilot's perspective to the project. His analytical thinking and grasp of core issues proved invaluable in framing key arguments. Second, to Dr. John B. Matthews, whose combat experience as a Marine Corps Officer, provided the much needed "infantry" perspective to the paper. Finally, to Colonel Eugene H. Grayson, Jr., USA Retired, whose enthusiasm and personal knowledge of military helicopter development was indispensable.

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CHAPTER 1

INTRODUCTION

The Joint Replacement Aircraft (JRA) is scheduled to replace the AH-1Z and the UH-1Y in the 2015 time frame. In terms of design, capabilities and requirements, little has been done other than acknowledge that a replacement will be needed. The purpose of this study is to investigate whether a single JRA platform can be developed to perform both the attack and "utility" helicopter missions for the Marine Corps. Given the current neck-down strategy in the Department of Defense, the search for a versatile multi-mission platform that performs both roles is appropriate.

Currently, the rotary-wing attack and "utility" missions are both functions of the Marine Light/Attack Helicopter Squadrons (HMLA). The AH-1W Cobra, a formidable attack helicopter, has received numerous upgrades since its introduction in the mid sixties. The UH-1N "Huey", a perennial workhorse, has lost much of its performance capability over the years, but continues to be heavily tasked by the Ground Combat Element because of its versatility.

In spite of their common ancestry, the Huey and Cobra have become increasingly divergent, as the attack platform has required periodic performance improvements to remain viable. As a result, these two aircraft share very few interchangeable parts and require specialized training for maintaining each, though both are found in the same squadron. In an effort to correct this deficiency, as well as bring another round of improvements to both aircraft, the four bladed UH-1Y/AH-1Z program was initiated. This program, scheduled for introduction in 2003,

promises to bring back a measure of commonality. Both aircraft will share 85% in common components, including engines, drive train, rotors, tailboom and selected avionics.

A natural question results from this commonality. What is so critical about the remaining 15%, that a unique aircraft is required to perform each mission? Or restated, can one design perform both functions? This paper takes the view that a single multi-mission platform could be designed to performs all HMLA functions. It attempts to dispel the common belief that a multi-mission aircraft cannot perform the attack mission as well as a "dedicated" attack design.

Furthermore, this paper proposes that an *advanced concept helicopter* design is superior to pursuing a "leap-ahead" technology for the JRA. While this idea runs counter to prevalent Pentagon thinking, looming defense budget concerns must not be ignored. This paper will show that by combining several advanced concepts, the Joint Replacement Aircraft can offer numerous capability advantages over a conventional helicopter, while keeping costs at an acceptable level.

In building a case for a single multi-mission Joint Replacement Aircraft, this paper will:

1. Explore the development of the dedicated attack helicopter, to show that many design features, such as fore and aft seating, were adopted to increase airspeed rather than improve weapons employment.

2. Look at the global perspective, with an emphasis on the debate over dedicated attack helicopter designs versus "utility" models with "add-on" weapons systems.

3. Investigate the historical change in threat and missions, resulting in a trend towards precision guided weapons, which can be delivered effectively from multi-mission helicopters.

4. Delve into the Army's efforts to define its future aviation needs, to show that a "leap-ahead" technology is neither available, affordable, nor warranted.

5. Probe the expeditionary nature of the Marine Corps' roles and missions, to highlight how a single multi-mission Joint Replacement Aircraft will improve capabilities.

6. Research current and future design options, in order to offer an *advanced concept helicopter* proposal for the JRA that optimizes multi-mission performance.

Dedicated attack helicopters have their place. They are a valuable addition to a large service like the United States Army, where mission specialization among 5,000 helicopters is not a pressing concern. In the Marine Corps, however, where the Joint Staff is predicting fleet of 447 helicopters in 2015, this type of mission specialization does not optimize capability.

The Marine Corps is unique among the armed services. It is the smallest branch of the military, yet it is the only one to contain both fixed and rotary wing aviation assets to support its ground forces. This dichotomy is necessary in a "911 force" tailored for a "first to fight" mission. The wide spectrum of potential Marine Corps missions in 2015 and beyond, makes a compelling case for a single multi-mission Joint Replacement Aircraft. The versatility, flexibility and responsiveness of such an aircraft, would be a valuable "force multiplier" for the Marine Corps.

CHAPTER 2

BACKGROUND

I. Development of the Dedicated Attack Helicopter

Serious attempts to develop an armed helicopter date back to World War II, when German engineers produced the Focke-Achgelis 223 Drache in 1944. Although this helicopter never progressed beyond a prototype, it validated the concept when equipped with two MG-15 7.62 mm machine guns.[1]

Helicopters gained limited acceptance during the Korean War when they proved more suitable for a variety of missions in the rough, mountainous terrain. The OH-13, a small two seat design with a bubble canopy and a wire-framed tailboom, saw widespread action as a medical evacuation platform and often delivered small quantities of desperately needed supplies to troops near the front lines. The Marine Corps relied heavily on the much larger Sikorski CH-19 to efficiently move equipment and supplies forward. In the later stages of the war, the United States Army procured the CH-19 and added troop movements to its list of accomplishments.[2]

During the period between the Korean War and Vietnam, many progressive thinkers in the Army began to push the idea of "air mobility" and theorized about the helicopter's role in this

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1 Bamberger, Mark H., MAJ. *Are Non-Precision Munitions a Viable Weapon for Attack Helicopters?* Fort Leavenworth, KS: MMAS Thesis, U.S. Army Command and General Staff College, 1992 5.

2 Allen, Matthew. *Military Helicopter Doctrines of the Major Powers, 1945-1992: Making Decisions About Air-Land Warfare*. Westport, CT: Greenwood Press, 1993 4.

concept. Most of these proponents were former paratroopers, which made it easy for them to envision the tactical successes a helicopterborne force could achieve.[3]

In addition, as early as 1955 the Army began taking steps towards arming some of its helicopters in an anti-tank role. Project ABLE BUSTER was undertaken by the Army Aviation School to evaluate firing small arms, rockets and chemicals from helicopters. The results were poor, due in large measure to the firing of aerial rockets that were designed for much greater airspeeds than the helicopters could provide.[4]

Following project ABLE BUSTER, the Army Aviation School continued experimenting on a smaller scale, with many tests conducted on weekends with volunteer pilots. This culminated in the creation of a Sky Cavalry Platoon (provisional) at Fort Rucker in 1957, which conducted a series of exercises that generated great interest in armed helicopters. In spite of these progressive steps, the biggest hurdle remained convincing a conservative Army hierarchy of this radical proposal.[5]

The new Kennedy administration provided the impetus for change in April of 1962. Secretary of Defense, Robert S. McNamara directed army leadership, in no uncertain terms, to examine future tactical mobility requirements in an "open and free atmosphere".[6] McNamara made it clear he wanted fresh, bold ideas.

The army responded by assembling a board led by Lieutenant General Hamilton Howze in May of 1962. The Army Tactical Mobility Requirements Board, or "Howze Board" as it was

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3 Allen, 7, 8.

4 Weinert, Richard P. *A History of Army Aviation - 1950-1962*. Fort Monroe: United States Army Training and Doctrine Command, 1991. 160

5 Weinert, 165.

6 Braden, James W. *From Hot Air to Hellfire: The History of Army Attack Aviation*. Novato, CA: Presidio Press, 1994 108.

commonly called, conducted an exhaustive investigation of the subject and encouraged input from throughout the Army. In three months time the board concluded its work and recommended sweeping changes in pursuit of air mobility. Had all the proposals been acted upon, Army Aviation would have more than double in size before 1967. Needless to say, this report raised the eyebrows of many in the Air Force, who soon voiced their opposition. Of particular concern was the Army's plan to arm the OV-1 Mohawk for Close Air Support missions.[7]

Fortunately for the Air Force proponents, McNamara was supportive of the Howze board recommendations, but was wary of its costs. Many of the ideas were worthy of further testing however. One of these ideas was buried deep in the report. As an offshoot of its study of the French SS-11 antitank missile, the Howze board recommended development of a specially designed armed helicopter. Though the SS-11 was considered a marginal weapon system at the time of the report, improvements to antitank missiles were ongoing and the board felt the time for an armed helicopter was close at hand.[8]

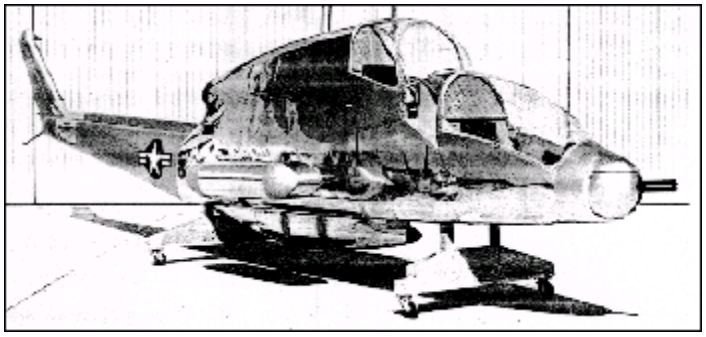

Fig. 1

Concurrent with the work of the Howze board, Bell Helicopter revealed to Army officials a radical new helicopter design at their Fort Worth facility in June, 1962. On their own initiative, Bell engineers had designed a mock-up for a dedicated attack helicopter, the Bell Model D255 "Iroquois Warrior" (Figure 1). Designed more along the lines of a jet fighter than a helicopter,

7 Allen, 9, 10.

8 Braden, 110.

the D225 featured a fore and aft cockpit layout, small stub-wings and a nose-mounted gun turret. Though the Army showed some interest, the conventional wisdom favored multi-purpose machines like the UH-1, which provided much more utility than a dedicated attack platform.[9] Events in Vietnam soon changed this way of thinking.

Vietnam is often described as the "helicopter war." Helicopters were particularly well suited in overcoming the many challenges of terrain and limited infrastructure. As the conflict developed, the airmobile concept "came of age." The UH-1 utility helicopter formed the backbone for troop movements of infantry, while the CH-47 provided lift for artillery and supplies. Along with these capabilities came a need. An armed helicopter was required to escort troop lifts and provide fire support to the infantry once on the ground.[10]

The initial answer was found in arming the UH-1. This platform was effective enough for delivering rockets and suppressive fire, but it had no real "dash" capability. The ability to push ahead of the transports and sweep the landing zone prior to troop insertions was deemed critical during escort missions. The time for a dedicated attack helicopter had arrived and the emphasis was on getting it to the fight quickly.

Bell Helicopter had continued its attack helicopter development as a company-sponsored effort, since its mock-up D255 had not resulted in any government contracts. Now the effort kicked into high gear. The Army issued requirements for its Advanced Aerial Fire Support System (AAFSS) in 1964, but Bell management realized this program represented a rather tardy solution to an immediate need. Since the Bell effort, which had now reached prototype stage,

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9 Peoples, Kenneth. *Bell AH-1 Cobra Variants*. Arlington, TX: Aerofax, Inc., 1988, 2.

10 Allen, 13.

was never intended to meet this long-range vision, the company pressed on with development of what was described as an "interim" effort.[11]

While the Army continued to pursue its advanced concept, through the trials of the ill-fated Cheyenne and the eventual success of the Apache, Bell Helicopter continued to refine its attack helicopter concept to meet the rigors of combat in Vietnam. The resulting design would shape the future of the dedicated attack helicopter for the next 40 years.

II. Design Principles for Attack Helicopters

The dedicated attack helicopter designed by Bell engineers was put together quickly to meet a pressing need in Vietnam. Time was not the only constraint. Many other factors shaped the design as well. An evaluation of these factors explains why certain design features were incorporated. Since many of these characteristics have become the "standard" for attack helicopters, such as fore and aft seating, analyzing the original design criteria will help determine their necessity in future attack platforms.

The premise for the design of the HueyCobra was the need for an escort platform with more speed than the Huey could provide. The constraints to the design were twofold. First, the aircraft would have to use "off the shelf" technology to speed production. Second, commonality with the existing UH-1 was highly desired. Bell went so far as to promote the HueyCobra as a modified version of the UH-1, which could be introduced to units flying Huey's in Vietnam with minimal degradation. From both an operational and support standpoint, the HueyCobra was an easy sell.[12]

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11 Peoples, 3.

12 Peoples, 4.

For Bell engineers the task soon became clear. Using "donkey" technology, they were to create a thoroughbred. As the project developed, Army specifications called for a 150 knot airspeed. Internal Bell design goals were seeking 175 knots in a clean (without carrying ordnance) configuration. As the design team turned the mock-up into a flying prototype, the quest for speed drove the external design.[13]

The "off the shelf" concept meant that engineers had to "find" increased performance in the design. Though a new, stronger engine, the Lycoming T-53-L-13 was on the way, it would be connected to the UH-1C's Bell 540 transmission. This meant the L-13's shaft horsepower had to be reduced from 1400 to 1100, because the transmission could not accept the horsepower produced by the engines. Speed would have to come from a reduction in drag and engineers worked diligently to minimize it. Aerodynamic cowls were added to the upper transmission and mast area. Even flush mounted screws and rivets were used to remove seemingly insignificant sources of drag.[14]

The most striking aspect of the design was the fore and aft seating arrangement. This layout was necessary in order to dramatically reduce drag by making the entire fuselage much narrower than previously possible. This had the added benefit of presenting a smaller target area when viewed from the front. The pilot seat was located behind and slightly above the copilots seat. The pilot's controls were conventional, utilizing a cyclic stick and collective lever. In the front seat, a floor-mounted sight prevented conventional controls, so a side-stick arrangement was devised that allowed the gunner to take control of the aircraft.[15]

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13 Braden, 120.

14 Braden, 120

15 Peoples, 4.

The pilot's visibility directly to the front and below was hindered by the fore and aft seating arrangement, but visibility to either side was excellent. Additionally, the low threat, high altitude tactics of the period made this seating arrangement ideal. Orbiting above the zone, safely beyond the range of small arms fire, both the pilot and copilot/gunner could orient on the ground threat by looking out the "wing down" side. When a target was identified, the aircraft simply "rolled in" further and commenced a diving attack, minimizing aiming errors from the unguided rockets and guns.

The decision on where to put the pilot-in-command was essentially decided by fitting the gunner's pantograph sight in the front seat, which minimized engineering requirements. This hand-held, floor-mounted sight was slaved to the turreted gun and allowed accurate fire, both on and off axis.[16] While the AH-1 Cobra, as the production aircraft was soon named, put the pilot in the back seat, this was by no means the final word on the matter. Nearly ten years later, Bell's entry in the Army's Advanced Attack Helicopter competition, the YAH-63A, was designed with the pilot in the front seat and the gunner in back. This change involved running a complicated optical sighting system from the nose of the aircraft to the gunner in the rear seat.[17] Obviously, the design team at Bell felt the added weight and complexity was justified.

The original armament available for the Cobra was modest. The helicopters primary weapon system was a single 7.62 mm electric minigun mounted to a hydraulic turret below the nose. It could be directed up to 115 degrees off axis by the gunner in the front seat and provided 21 degrees of elevation and 50 degrees of depression. On some models a 40mm grenade launcher was added to the turret, and later still, other models replaced the small mini-gun with a 20mm

16 Peoples, 6

17 Braden, 149.

unit. In addition, the Cobra carried an impressive assortment of 2.75" forward firing aerial rockets.[18]

Early on, Marine units in Vietnam received the Army's single engine version of the Cobra, the AH-1G, while Bell put the finishing touches on the twin-engine design. Both the AH-1G and the twin-engine version, the AH-1J, were to serve the Marines in Vietnam well. The new gunships were faster and much better armed than the modified UH-1E gunships. Once they arrived on station in adequate numbers, they freed up the Hueys to perform their original light helicopter missions.[19]

III. The Global Perspective

The United States was not the only country working to develop an attack helicopter during this period. Several other countries were progressing down a similar path. Each had its own motivation for pursuing armed helicopters and confronted similar obstacles to their development.

France was pushed headlong into helicopter development by the mobility requirements of the Algerian War. After this conflict was over, the French military found themselves equipped with over 600 helicopters, but without the doctrine needed to employ these assets in conventional warfare. By the mid-1960's, the introduction of anti-tank helicopters started the slow shift towards employing helicopters as an independent maneuver force.[20]

The United Kingdom experimented with armed helicopters prior to deploying to Cyprus in 1958. Throughout the 1960's, counterinsurgency operations in Borneo and the Near East

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18 Peoples, 8.

19 Peoples, 8.

20 Allen, 179.

advanced the notion that an armed helicopter capability was needed. As operations in Borneo ended in 1968, Britain shifted her focus towards the developing NATO commitment. Simultaneously, improvements in anti-tank guided weapons made this option increasingly viable, but progress was slow.[21]

Of considerable debate during this period were arguments for a dedicated attack helicopter versus a utility design with an "add on" armament system. The RAF and many in the British Army were in favor of a utility design, primarily because the pure attack aircraft would have little value in areas such as Northern Ireland. While it was acknowledged that specialized designs had merit, the cost and limited utility made it difficult to purchase them in large numbers. In the end the Army chose multi-mission platforms, fitting TOW missiles to both the Lynx and Gazelle.[22]

The Soviet Union took a similar track with discussions on the merits of armed helicopters predominant in the 1960's. The first tentative step was the development of the MI-24 Hind-A in 1968. The Hind was originally developed as an armed transport, which acted as the lead element for a larger flight of MI-8 Hips. Its mission was to clear the zone by fire, then drop a small force to secure the zone for follow-on waves. It was only after the Soviet's analysis of the 1973 Arab-Israeli War that the subsequent versions were "optimized" for the attack role, though decidedly handicapped by the initial design.[23]

IV. Changing Threat and Missions

Towards the latter stages of Vietnam, the increased proliferation of lethal anti-helicopter systems brought about a dramatic change in tactics. Until then, the primary threat of small arms

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21 Allen, 134.

22 Allen, 141

23 Allen, 91

and Anti-Aircraft Artillery (AAA) systems allowed helicopters to fly 1,500 feet above ground level or higher with relative impunity. The North Vietnamese used the 1972 Easter Offensive as an opportunity to introduce radar guided systems, such as the ZSU-23-4 to theater.[24] In addition, sophisticated (for their time) shoulder-launched heat seeking missiles, such as the SA-7 Grail, demanded an alteration to the high-altitude tactics employed in the past.[25]

The impact of these modern weapons was also becoming a major concern in the European theater. In addition to the SA-7 and ZSU-23-4, NATO aviators were potentially facing many other deadly Soviet systems. Both the SA-8 Gecko, a radar-guided Surface to Air Missile (SAM) mounted on a tracked vehicle, and the SA-9 Gaskin, a heat-seeking SAM launched from a wheeled vehicle, posed a significant threat to helicopters. Increasingly, senior leaders in the United States Army began voicing the opinion that helicopters, specifically attack helicopters, were no longer viable due to the threat. In an effort the evaluate some of these claims on a scientific basis, the Ansbach Trials were held in Germany during the spring of 1972.[26]

The trials were conducted in an area of rolling farmland, with some villages and areas of thick forests. The experiment was joint in nature, with aircraft from many NATO countries involved.[27] Aircraft and ground vehicles were instrumented with a laser hit-kill system for accurate scoring. The results proved that armed helicopters were an effective, survivable weapon system. Using Nap-of-the-Earth (NOE) flight profiles, helicopters destroyed armored fighting vehicles at a ratio of nearly 19 to 1.[28]

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24 Grayson, Eugene H. Jr., *Helicopter Support to Infantry: Dusting Off the Lessons of the Past.* Infantry, January-February 1996. 19.

25 Allen, 20

26 Braden, 125

27 Braden, 129.

28 Allen, 24-25.

The results of these trials were devastating to the development of the Cheyenne helicopter. By establishing the proven low-altitude tactics required to meet the threat, the trials were effectively a death-knell to the Cheyenne's development. The Cheyenne (see Figure 2) was the result of the Army's Advanced Aerial Fire Support System Competition, which Bell had lost to Sikorsky and Lockheed in 1965. Development of the Cheyenne had continued since then, all the while emphasizing the speed, or enroute portion of the attack mission. By virtue of its stub wings and pusher prop arrangement, this "compound" helicopter was able to attain top speeds of 254 miles per hour. To attain this tremendous speed, design measures were incorporated which made low speed performance and handling suffer. In tests conducted after the Ansbach Trials, the Cheyenne proved unable to safely hover out of ground effect (where air is compressed between the rotors and the ground) and was unable to perform mission tasks below 120 knots.[29] Within a year the program was canceled altogether.

Fig. 2

The other lesson to be drawn from the Ansbach trials was the need for long-range precision guided munitions. As the attack helicopter role shifted towards an anti-armor mission, experiments were conducted to develop precision weapons capable of destroying a tank.

29 Braden, 130

Anti-armor missiles like the TOW (tube-launched, optically tracked, wire guided) and later the laser-guided Hellfire missile, fulfilled this role in the years to come.

The irony of the development of these Anti-Tank Guided Missiles (ATGMs) was their impact on attack helicopter design. This was reflected in the Army's early Material Need (MN) requirements for the Advanced Attack Helicopter (AAH). The aircraft would be a twin-engine design, using the existing UH-60 Blackhawk engines. It would use the Weapons Command's 30mm chain gun. It needed a range of 800 nautical miles so it could self-deploy to Europe and the ability to hover at 4,000 feet pressure altitude on a 95 degree day. Lastly, it needed a cruising speed of between 145 and 175 knots. In the end, the Apache became a rather large attack helicopter, with a width of 17 feet from wingtip to wingtip and an empty weight of over 10,000 pounds.[30] The ability of an attack helicopter to carry large amounts of anti-armor missiles was judged to be more important than agility on the modern battlefield.

In many respects, the Apache is a legacy of the Cold War. Designed expressly for the anticipated battles with thousands of Soviet-built tanks on the plains of Europe, it seems somewhat out of place in the current strategic environment. During its first combat use, OPERATION JUST CAUSE in Panama, Apache crews found themselves flying over people on one block waving American flags, only to receive ground fire from the next block. In this situation, many pilot's felt the Apache's 30mm cannon was just too large for use in an urban environment They described having to search for a large clear area into which they could fire a few rounds as a show of force.[31]

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30 Geddes, J. Philip. *Apache*. Washington D.C.: International Defense Images, 1988, 64

31 Braden, 171

Operations in Panama and more recently, Somalia, have become the "standard" for military operations in the foreseeable future. This has led to the Army's push for development of a smaller helicopter to replace much of the existing inventory and complement the AH-64.

V. Into the Future - United States Army

The number one priority for Army aviation is the development and acquisition of the Light Helicopter (LH). The Comanche program was begun in the early 1980's with the intention of acquiring nearly 5,000 aircraft. When the numbers were cut by more than half, the Army decided to drop the utility version of the LH and concentrate exclusively on a scout-attack platform. Therefore, the current plan is to replace 3,200 AH-1 Cobra's, OH-6 Cayuse and OH-58 Kiowa aircraft with 1,875 Comanche scout-attack aircraft (Figure 3). The utility mission was set aside, to be addressed "at some later time."[32]

Fig. 3

In terms of roles and missions, from the Marine Corps' perspective, the Army approach seems too narrow in its focus. The Army is touting the Comanche as a very versatile helicopter, which may be true as a scout-attack platform when compared to Army Cobras. This argument

32 Ludvigsen, Eric C. *Fielding a Light Helicopter Is Vital to Future Army*. Army (August 1990) 27-38

loses its logic, however, when comparing the versatility of the Comanche with that of the OH-6 or OH-58. Both OH aircraft are truly multi-role platforms, with the ability to perform scout, light-attack and helicopter assault missions. While the Department of Defense, particularly fixed-wing aviation, is moving towards multi-role aircraft, the Army continues down a path of increased specialization. They are turning a blind-eye towards losing the utility capabilities of their OH helicopters, when recent experience in Somalia has shown these platforms to be absolutely critical to success in confined urban areas.

The structure and requirements of the Army do not directly correspond to those of the Marine Corps. The roles and missions of the two services are so different in philosophy and scope, that any comparison quickly loses its meaning. But if we compare an Army Special Operations unit, such as 160th Special Operations Aviation Regiment (SOAR), certain key points emerge. Like the Marine Corps, the 160th SOAR is charged with a wide variety of small-scale operations. It is interesting to note the helicopter mix the 160th SOAR has selected for its mission accomplishment. They employ the AH-60L Blackhawk (Figure 4), arguably the best

Fig. 4

multi-mission platform in the Army's inventory. This aircraft can be armed with a 30mm cannon, 7.62 minigun, Hellfire, AIM 92A Stinger Missiles and rocket pods in the attack role, or can be

stripped down for troop transport in an assault role.[33] Other aviation assets include the AH and MH-6, multi-mission platforms for attack and troop inserts, and the MH-47D for heavy lift.[34] The 160th SOAR has no dedicated attack aircraft, such as the Cobra or Apache. The unit's mission requirements and size do not allow that degree of aircraft specialization.

33 Francillion, Rene J. *The Naval Institute: World Military Aviation 1997-1998*. Annapolis: Naval Institute Press, 1997. 234.

34 Posture Statement 1994. *U.S. Special Operations Forces*. B-2.

CHAPTER 3

MARINE CORPS ROLES AND MISSIONS

As described by General Krulak, the United States Marine Corps is America's force in readiness. Because it is much smaller than the Army, both in personnel and equipment, the doctrine of the Marine Corps is to fight as a Marine Air/Ground Task Force (MAGTF), in order to use its organic aviation assets as an effective supporting arm.

I. Marine Expeditionary Units

A key component of the Marine Corps' mission is the world-wide deployment of a Marine Expeditionary Unit, Special Operations Capable [MEU(SOC)] embarked aboard a Navy Amphibious Ready Group (ARG). Three MEUs are always active, deployed from the East Coast, West Coast and Okinawa, in order to maintain a forward presence.

The Marine Expeditionary Unit is made up of a Ground Combat Element, a Force Service Support Element and an Aviation Combat Element. In keeping with the MAGTF concept, the ACE tries to deliver all six functions of Marine aviation to the ground element. These functions include: reconnaissance, assault support, offensive air support, anti-aircraft warfare, electronic warfare and control of aircraft and missiles.

Given the limited deck space aboard an LHA or LHD, the results are often a compromise. The current aviation mix for a MEU's is contained in a composite squadron composed of (12)

CH-46Es, (4) CH-53E's, (6) AV-8B's and the HMLA detachment. The goal is to provide the most versatile, yet capable aircraft mix to meet a wide variety of contingency operations.

An analysis of "real-world" missions conducted by the East Coast MEU's since 1990, shows an interesting trend. The use of armed helicopters is few and far between. In a decade of constant activity for the Mediterranean deployed Marines, the role of a dedicated attack helicopter is limited. Civil unrest, famine and natural disasters have all resulted in frequent high-visibility noncombatant evacuation operations (NOE's) and humanitarian assistance efforts.

As recently as 1997, the 22nd and 24th MEU's executed three NEO's in the span of just six months, evacuating U.S. citizens from Albania, the Congo and Sierra Leone.[35]

Does the historical analysis suggest a case can be made for less emphasis on the attack role? The dramatic rescue of Captain Scott O'Grady by the 24th MEU(SOC) on June 8, 1995 is a perfect example of why an armed helicopter capability is critical to the MEU. As any military unit, the Marine Corps must prepare and structure itself for combat. Indeed, a fundamental aspect of the desire to merge the utility and attack roles is to provide *more* firepower to the Marine on the ground.

It is clear that if an airframe could be designed which could perform both the utility and attack roles, the overall capability and effectiveness could be greatly improved for the MEU Commander. The current HMLA detachment consists of 4 AH-1W's and 3 UH-1N's. For the Rotary Wing Close Air Support (RWCAS) role, this aircraft mix is hard-pressed to deliver any sort of continuous support. A best-case scenario, two sections of AH-1Ws, would have a difficult time providing fire-support for any operation lasting more than three hours.

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35 Marine Corps Historical Division HQMC. *Fifty Years of Real World Operations--and Still Pumping.* Marines, Vol. 27 Issue 4, April 1998. 12.

Consider the following MEU(SOC) scenario. The mission is an airfield seizure. To insert the Marines from the Battalion Landing Team, six CH-46's and two CH-53E's will be required. The airfield is located 20 miles inland and the Amphibious Ready Group is approximately 10 miles off-shore. Because all the deck spots will be required for the transports, the Cobras are sent over to the LPD to operate, refuel and rearm. A Huey or other transport aircraft is required to shuttle the arming crews and maintenance teams over to the LPD for support.

For the pre-dawn assault, a Command and Control UH-1N, the Navy's Search and Rescue (SAR) CH-46 and the two CH-53's are spotted thirty minutes prior to their launch time. Approximately three miles off the port bow, the activity aboard the LPD increases as ordnance crews hustle in the darkness to upload pods of 2.75 inch rockets, Hellfire missiles and 20mm ammunition onto the Cobras. Back on the LHA, the infantry Marines board the CH-53E's five minutes before launch time. The Mission Commander, the Fire Support Coordinator and a radio operator strap into the back of the Huey.

The first wave launches on time, with the CH-53's and the UH-1N joining the Navy SAR helicopter in the starboard delta holding pattern. Navy Deck handlers quickly begin spotting the second wave of transports. Thirty minutes later, they too launch with their cargo of Marines. As the CH-46's take several laps in the starboard delta pattern, the Huey lands to top off with fuel. Minutes later, the first section of Cobras call with the codeword that they are "pushing to the objective." The Assault Flight Leader (AFL) acknowledges the call and turns to his initial bearing as the elements of his flight drop into formation. The Huey brings up the rear.

Five minutes prior to the planned assault landing time, the Cobras report the primary zone is occupied with enemy vehicles and suggest the alternate while they suppress the threat. The

Mission Commander becomes concerned about the Cobra's remaining ordnance load and relays back to the LPD to launch the second section of AH-1Ws immediately. The original plan called for the second section to launch at L+45, arriving on station at L+60. Now, with both sections of Cobra's committed, the Mission Commander worries about a looming gap in his rotary wing fire support. Given this scenario, his worries are not unfounded.

The firepower assets available to the MEU Commander are paper thin. While the scenario described above did not make use of any AV-8B assets, most MEU planners will concede that incorporating fixed wing aircraft into the deck cycle increases the difficulty and limits subsequent flexibility exponentially. The capability is there; it is just very difficult to tap into it.

The realization that the firepower is lacking was addressed in the after-action report delivered by the 15th MEU(SOC) Commander after his 44 months of command. In his report, Brigadier General Whitlow's suggested dropping the UH-1N from the MEU(SOC) composite squadron altogether and increasing the number of AH-1W's to six.[36] Of course, this remedy is risky considering the limited flexibility of the AH-1W. The ability to land a helicopter on an urban street to rescue Marines from an untenable situation is a capability that should not be lost. This capability saved several Army Rangers from certain death in the streets of Somalia following the Blackhawk shootdown on 3 October, 1993.[37] The lessons learned from that day show how fast the situation can escalate in the "three block war."

The ideal solution is one that does not limit itself to either extreme. If the spectrum is viewed as pure attack on the left and what some would regard as "pure utility" (cargo and troops only) on the right, the direction is clear. Starting on the left, design in capability that allows a

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36 Whitlow, William A. BGen. Interview, 24 February 1999.

37 Bowden, Mark. *Blackhawk Down: An American War Story.* Philadelphia Online. 16 Nov 1997.

move towards the right. If degradation begins to appear in the attack role, either accept it, or stop and back up. Perhaps the result will be nothing more than an attack aircraft that can also carry a set of golf clubs to Nellis AFB. The point is, every small improvement gives the Marine Corps a greater capability than it has today.

A future MEU Commander would be well served with an HMLA detachment consisting of seven or eight truly multi-mission aircraft spotted on the deck. This fleet of small, maneuverable platforms would be invaluable in humanitarian or similar low-threat operations, particularly in urban terrain. Conversely, when the need for firepower arises, the ability to upload three or four sections with precision guided munitions and a formidable cannon, gives the MEU the kind of offensive punch and sustainability it needs to fight tomorrow's battles. The MEU(SOC) missions demand this kind of versatility.

II. Operational Maneuver From the Sea

The concept which will drive Marine Corps doctrine for the next quarter of a century is known as Operational Maneuver From the Sea (OMFTS). The vast majority of the world's population is contained in the littoral regions, concentrated along shorelines and rivers. For the Navy and Marine Corps, the vast waterways adjacent to the littorals can be used to greatly increase combat effectiveness. Properly exploited, these sea lanes can simultaneously provide an avenue of approach for our friendly forces, while presenting an effective barrier to the enemy.

As General Charles C. Krulak has noted, "In the 21st Century, the Navy-Marine Corps team must field a more versatile, capable, and responsive naval power-projection capability." To

meet this end, he recognizes that successfully implementing OMFTS will require a critical examination of the way the Naval services conduct business.[38]

A cornerstone to the OMFTS concept is sea-based logistics. This idea, while controversial, has gained momentum over the last two years. It is rooted in the belief that traditional amphibious assault operations will not be viable on the future battlefield. Proponents believe that taking a beachhead and establishing a logistics base ashore presents too lucrative a target to the future threat and therefore represents a critical vulnerability which can be exploited by the enemy.

The answer to this problem is ship-to-objective maneuver (STOM). It is controversial because of the tremendous burden it places on the logistics effort. The vast majority of the resupply for units ashore is going to be delivered by air, via either MV-22 or CH-53E. Preliminary analysis shows the MV-22 could become a full-time logistics shuttle in any prolonged OMFTS operation utilizing the STOM concept.[39]

In addition to taxing the MV-22 to the limit of its capabilities, ship to objective maneuver will have a tremendous impact on traditional helicopter operations. Any lift requirement which does not make full use of the MV-22's capability will spill over, increasing utility helicopter requirements greatly. Since no shore based facilities are envisioned, medevac flights, for even simple injuries such as a sprained ankle, will become routine. Small unit tactical movements and emergency resupply will also be in high demand.

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38 Krulak, Charles C. General (USMC) *Operational Maneuver From the Sea*, Proceedings January 1997. 26-31

39 Beddoes, Mark W. Lt. (USN) *Logistical Implications of Operational Maneuver from the Sea,* Naval War College Review, Autumn 1997, Vol.L,. No.4. 32-47.

Fortunately for the Marine Corps, the introduction of the upgraded UH-1Y will offer greatly improved capabilities to meet these future requirements. A maximum airspeed of 170 knots and a payload of over 6,000 pounds will give the MAGTF the versatility in mission and employment which has long been lacking.[40] It will also help fill any gaps in the MV-22's capabilities in sustaining operations ashore.

If OMFTS becomes a reality for future Marine Corps operations, the increased lift requirements will serve to push the JRA design further towards a multi-mission platform.

III. Roles and Mission of the Marine Light/Attack Helicopter Squadron

Each of the six active Marine Light/Attack Helicopter Squadrons are authorized (18) AH-1Ws and (9) UH-1Ns. The mission of the Cobra includes rotary-wing close air support, enroute escort/protection of assault helicopters, landing zone preparation and fire suppression, anti-armor and anti-helicopter defense, armed and visual reconnaissance, and control of supporting arms. The mission of the Huey includes airborne command and control, supporting arms control, medical evacuation, maritime special operations, troop insert/extraction and search and rescue.[41] Though Hueys were used extensively in Operation Desert Shield and Desert Storm for rotary-wing escort missions (to free Cobras for anti-armor missions), this capability is not considered doctrinal.

In fact, the "utility" role is widely misunderstood within the Marine Corps, both internal and external to the UH-1 community. Fears of a utility aircraft encroaching on the missions of

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40 Greene, David S. Capt (USMC) *The UH-1N Upgrade: At a Crossroads.* Marine Corps Gazette, May 1996. 44-45.

41 Magnus, Robert. BGen (Asst. DCSA, USMC) *The Combat Advantage: Excerpts from testimony before the Air Land Forces Subcommittee of the Senate Armed Forces Committee,* Marines, May 1996.

other aircraft are at odds with the basic concept. Instead of enhancing the multi-mission aspects of the airframe, to augment firepower or lift shortages, attempts have been made to narrowly define its role. Thus a capability, Command and Control, is listed as its primary function and many would like to see specialization in this direction. The Marine Corps would be much better served with a *capable* fleet of multi-mission "utility" helicopters, rather than 105 specialized Command and Control aircraft. When the UH-1Y brings the "capability" aspect back to the utility mission, the Marine Corps will rediscover the benefits of versatility.

A future multi-mission aircraft could accomplish all HMLA mission tasks without requiring tremendous cargo or troop carrying requirements. In addition to providing increased fire support, this balanced approach would allow the ability to insert reconnaissance teams, medevac wounded, facilitate command and control, pick up downed pilots and deliver emergency resupply. The focus should always be on increasing the *versatility and capability* of the MAGTF.

CHAPTER 4

FUTURE DESIGN CONSIDERATIONS

Any analysis to determine the Marine Corps' aviation requirements twenty years in the future is difficult. Fortunately, the impending introduction of the MV-22, brings a unique set of capabilities that help define roles and missions for the next 15 to 20 years. Although many of these capabilities have yet to be tested in an operational environment, they have been studied enough that speculation on future doctrine and tactics is much easier.

Fig. 5

I. MV-22 Osprey: Defining the Future

The tilt-rotor technology incorporated in the MV-22 (Figure 5) will add tremendous capabilities to the Aviation Combat Element. It has been enthusiastically embraced by the Marine Corps, remaining the number one acquisition priority since the mid 1990's.[42] The current plan is to buy 425 aircraft to replace the aging fleet of CH-46E helicopters, though the Quadrennial Defense Review proposed reducing this number to 360 aircraft.

42 Magnus, Robert. BGen. Marines, May 1996.

Whatever the final outcome on numbers, replacing the Corps medium lift aircraft with the MV-22 will have a dramatic impact on the future of the MAGTF's other aviation assets. With the introduction of the MV-22, the supporting helicopters face the formidable task of complementing a platform that is twice as fast and has five times the range.[43]

Worse still, the Marine Corps seems intent on using this capability by focusing at the limits of the performance envelope. For example, the Ship to Objective Maneuver (STOM) concept negates the threat from mines by locating naval assets over the horizon, up to 100 nautical miles offshore.[44]

As the Marine Corps pursues doctrine of this kind, the requirements for an HMLA multi-mission aircraft increase. The ability to transport ordnance teams and equipment to the beach, to establish hasty forward arming and refuel points (FARPs) would be valuable. Linking with a section of CH-53's for fuel and ordnance resupplies, these same HMLA aircraft could then transition to the attack role, cycling in for support. The whole operation would provide for more capability and flexibility with less aircraft.

II. Role of Attached Escort

As the Marine Corps adopts the MV-22 and develops the OMFTS concept, the traditional role of attached escort must be evaluated. It is clear that a long-term "gap" of at least a decade is on the horizon for any HMLA based attached escort of MV-22 aircraft. The future requirements for attached escort of the MV-22 is still a question.

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43 Thompson, Loren. *Marine Corps Tilts Into the Future.* Sea Power. Nov 1997. 43-46

44 Davis, Jeffery P. Major, USMC. *Ship to Objective Maneuver: Will This Dog Hunt?* Proceedings, Aug 1998. 31-34

The Marine Corps and MV-22 proponents have made much of the improved survivability of the airframe. The acoustic signature is 85% less, while the IR signature is reduced by 95% over older transport helicopters. Composite construction, armor shielding and special fuel tank designs have reduced its vulnerably to ballistic damage as well.[45] With all its built in survivability features, a strong case could be made for dropping the HMLA attached escort mission for the MV-22 entirely. Should a capable air threat arise, fixed-wing assets would have to provide the necessary protection.

A hint on where the Marine Corps stands on this issue can be found in the aviation requirement proposed in 1994 by Headquarters Marine Corps for the ill-fated Marine Attack/Observation (VMAO) concept. This concept, a precursor to the JRA, looked for a single fixed-wing aircraft to replace the AH-1, UH-1 and OV-10. The primary mission of VMAO was to be armed escort of the MV-22, with a published requirement that called for airspeeds 30% higher.[46] Clearly the intent here was a traditional attached escort role, to include a "dash" capability that allowed security for the landing zone.

Currently, the role of attached escort is getting less emphasis. Most often, escort requirements are fulfilled by providing detached escort, where the attack aircraft "sweep" the route for the assault forces enroute to the landing zone. This technique addresses another tactical concern, the limited deck space aboard amphibious shipping. As mentioned previously in the MEU(SOC) scenario, aircraft launches must be cycled for most large scale operations. Given this requirement, detached escort makes the most efficient use of all the aircraft available. Instead of wasting valuable on-station time orbiting near the ship, the escort platforms instead proceed

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45 Thompson, 46.

46 Bamberger, Mark. Maj USMC *Trip Report: USMC Visit to McDonnell Douglas*. Aviation Weapons Systems Requirements, Headquarters Marine Corps. 1994

towards the landing zone. The MV-22 then uses its greater airspeed to effect a rendezvous in the objective area. During the ten year "gap" phase, detached escort will no doubt be the technique employed by rotary-wing assets to cover the MV-22.

If the threat is such that attached escort is absolutely required for mission success, then the MV-22 will simply have to slow down enough to allow it. When the AH-1Z and the UH-1Y become available, an escort capability in excess of 150 knots should allow the MV-22 to operate comfortably in the fixed-wing mode.[47]

The only remaining question is whether the Joint Replacement Aircraft should pursue a 300 knot capability to provide attached escort to the MV-22. The prudent answer is no. Currently, major steps are being taken in the ability of all aircraft to consolidate and share battlefield data. An ongoing Army project is linking the Joint Surveillance Target Attack Radar System (JSTARS) with the AH-64D Longbow Apache attack helicopter, which can then pass on this critical information to other Army helicopters via digital data link.[48] This and similar projects will make avoidance of the threat enroute far superior to the deterrence offered by an attached armed escort platform.

III. Future Threats to Aviation

The danger posed by future threats has driven the acquisition side of aviation since the start of the Cold War. Though the Cold War is over, the value of a credible threat in acquiring new aircraft has not been forgotten. Rear Admiral Dennis V. McGinn, director of the Navy's Air Warfare Division, has dubbed this technique "Dial-a-Threat." While the threat justifications make

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47 Janes, 195.

48 Keller, John. *Military to Data Link JSTARs Radar, AH-64D Attack Helicopter.* Military & Aerospace Electronics, April 1998. 7.

sense when viewed from within each service group, they tend to become confused when DOD is judged as a whole. Both the Navy and the Air Force, looking at identical future threats, asked for wildly different aircraft. The Air Force, continuing its endorsement of stealth technology, wants 440 F-22's at a cost of $160 million each. The Navy is committed to development of the F/A18E/F, hoping to purchase 1,000 at a cost of $80 million each. The Marine Corps has opted to pass on the F/A18E/F and wait for the Joint Strike Fighter.[49] The reason for this is the F/A18E/F and F-22 do not offer much more from a *capability* standpoint than the F/A18C or F-15. Paying an extra $80,000,000 per F-22 to address the radar threat is a high price to pay. Particularly when other services are willing to do without it.

The point is, many threats can be overcome by tactics instead of technology, at much less expense. Given the looming fiscal constraints, future platforms should be developed to provide capabilities first. It is of little value to spend mightily on aircraft survivability equipment, if the aircraft cannot find the objective area. While this may seem obvious, it has been a problem in the rotary-wing community. This decade has seen helicopters outfitted with costly laser warning receivers and sophisticated missile plume detectors, prior to receiving their first onboard navigation system, which they needed more critically.

Most of the future threats to the Joint Replacement Aircraft can be easily identified. They have been on the battlefield for years. Small arms and anti-aircraft artillery will continue to be a threat. They are simple, reliable and inexpensive. Several countries are trying to upgrade older systems with new sights which provide an improved night capability, but with limited success.[50]

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49 Wilson, George C. *Dial-A-Threat A Costly Game*. Army Times, Feb 2 1998.

50 Jane's Land Based Air Defence. Jane's Information Group. Alexandria, VA. 1998. 10.

One recent AAA innovation, the Bofors 40mm programmable projectile, will certainly pose a threat to the JRA. This sophisticated anti-aircraft round contains a proximity fuse which can be programmed in the weapon to activate at a predetermined range. This allows the weapon system to effectively engage a target hovering behind obstacles or terrain that would otherwise prematurely detonate the fuse.[51]

Infrared missiles will continue to pose a threat, with ever-increasing resistance to countermeasures. Precision Anti-Tank Guided Missiles (ATGMs) will also be effective against low-flying aircraft operating at reduced airspeeds. Radar guided guns and missiles will force continued reliance on terrain flight profiles in 2015.

Stealth technology will not provide safety for low altitude aircraft. Electro-optical (EO) tracking continues to improve for both missiles and AAA. If the target can be seen, it can be engaged. In the case of AAA, when coupled with laser range-finders and computer lead predictions, targeting becomes exceptionally accurate.

Future development of helicopter mines has been proposed to counter the helicopter threat. These would be placed in likely avenues of approach and would self-launch and target helicopters based on a variety of means, including acoustic signatures.[52]

Acoustic signatures are also being proposed for numerous weapon systems, both as initial guidance and in determining if suspected targets are friend or foe. Homing on acoustic signatures will theoretically work even if the target is not maintaining line of sight, which is the major limiting factor for today's precision weapons. Every target that creates a characteristic acoustic

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51 Jane's Land Based Air Defence. 228

52 Alexander, David R. Capt USA. Helicopter Mines: *The emerging threat to helicopter operations.* U.S. Army Aviation Digest, no. 3. May-June 1993. 37.

signature, such as a tank or aircraft, could conceivably be cataloged and targeted.[53] For example, a T-72 could be identified through the acoustic patterns it emits, both running and at idle. While several low-tech countermeasures come to mind to defeat this technology, the use of acoustic-seeking weapons might be viable in the future.

The bottom line is there is no proposed future threat that makes the introduction of the JRA in 2015 unwise. Virtually all high-velocity weapons require line of sight to the target, which can be defeated by terrain masking and NOE flight. Slower, precision guided weapons can be defeated in a similar manner, with active countermeasures providing a backup defense.

In addition, the cost of developing, acquiring and maintaining sophisticated "state of the art" anti-aircraft systems is proving cost prohibitive for the vast majority of countries.[54] To think that the future battlefield will be littered with them is to discount the current world situation.

From a design perspective, the future threat does not overwhelmingly favor one JRA concept over another. Both a conventional helicopter or an advanced technology aircraft could survive on the future battlefield.

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53 Attenborough, Keith. *Coupling Between Airborne Sound and the Ground: Models and Applications.* US Army Corps of Engineers, Technical Report EL-89-8, May 1989. 6.

54 Jane's Land-Based Air Defence 5.

CHAPTER 5

CURRENT TECHNOLOGY DESIGN OPTIONS

The ability to design an aircraft that meets both the attack and utility role for the Marine Corps is predicated on a clean slate. As mentioned previously, the design must focus on capabilities, particularly as they relate to the attack mission. The goal is to develop an attack platform that offers true multi-mission capability. Most multi-mission helicopters in use today were not designed as such. They are an adaptation of an existing design to "make do." To produce a credible multi-mission JRA platform, it must be designed from the ground up, with capabilities "built-in" rather than "added-on."

Before looking at future technology options, a critical evaluation of some current technology options are in order. These can provide cost savings and reduce risk by using ideas that have already enjoyed some measure of success.

I. Conventional Helicopter

The notion of a conventional helicopter operating effectively on the battlefield in 2020 may seem incomprehensible to some, but it is already programmed. The Army began its Light Helicopter Experimental Program (LHX) in the early eighties with dreams of a single-piloted "X" wing aircraft, capable of rotating the wings like a helicopter for vertical flight and locking them in place to act as normal wings for high speed flight.[55] Nearly twenty years later the results of that

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55 Ambrose, James R. *The Light Helicopter Experimental (LHX) Program.* Army Aviation. January 31, 1987. 2

effort is the Comanche, a helicopter that looks much like Bell's 1962 mock up design. At a program cost expected to reach $30 billion, the last Comanche is scheduled for delivery in the year 2025.[56]

Obviously, the Comanche is a capable scout/attack aircraft, but other than its stealthy exterior and internal weapon stores, much of the capability is built into its electronic systems. At nearly $15 million per aircraft, the Comanche will join the Apache AH-64D Longbow which is programmed for deliveries as late as 2008.[57]

In addition to the United States, numerous other countries are planning to field conventional helicopters well into the 21st century. France and Germany are continuing joint development of their attack helicopter, the Tiger, which is expected to rival the Comanche. South Africa's dedicated attack helicopter, the Atlas Rooivalk, is a new machine that presents an economical solution to countries seeking an alternative to the Apache A or B.[58] It is clear that whatever the design for the JRA, it will be sharing the battlespace with numerous conventional helicopters.

II. Vectored Thrust Ducted Propeller

A funded US Army contract is evaluating a Vectored Thrust Ducted Propeller (VTDP) design for both the AH-64 Apache and the AH-1W (see Figure 6). This promising concept involves adding a shrouded "pusher" type propeller in place of the tail-rotor. At a hover and during low-speed flight, the propeller thrust is ducted sideways to offset main rotor torque. As

56 Williams, Robert H. *Army's Helicopter Program Attracts Alternative Schemes from Congress*. National Defence. April 1996. 12.

57 Colucci, Frank. *Army Helicopter Programs Advancing*. Army. January 1998. 21.

58 Biass, Eric H. *Chopper Shopping.* Armada International. June 1995. 12-13.

the helicopter picks up speed, less anti-torque thrust is needed due to the slip-stream effect of the fuselage and tail. The propeller thrust can therefore be allowed to produce additional thrust for

Fig. 6

forward flight. The prototype AH-1W was fitted with small lifting wings in addition to the VTDP tail. This configuration allowed increased weapons stores and propelled the compound helicopter to a maximum level airspeed of over 200 knots. A separate US Navy program is looking into VTDP technology for the AH-1Z.[59]

III. Coaxial Helicopters

This type of rotor design dates back to the earliest days of helicopter design. It is essentially two rotors, mounted one above the other, on a single mast. The rotors turn in opposite directions, eliminating the torque-effect of a single main rotor and the need for a tail rotor. This increases the power available to drive the main rotor. In addition, counter-rotating rotors (and propellers) tend to cancel out unwanted wake turbulence from the blades. This offers increased lift by improving laminar flow and reducing drag. The down side of this design is that

59 Kulikov, Igor. *Compound Helicopter Design*. //home.sprynet.com/~Kulikov 19 Feb 99.

it requires a heavier gearbox. In addition, the tall mast and twin rotor heads increase the drag penalty over conventional designs.[60]

Coaxial helicopter design has been widely used in Russia. The KA-25 Hormone and the KA-27 Helix are both utility designs. The latest addition, the KA-50 Hokum, is a dedicated attack helicopter produced in both the domestic and export versions.[61]

In the United States, Sikorsky Helicopters has been evaluating this type configuration as a part of the S-69 ABC (Advancing Blade Concept) development vehicle (Figure 7). This aircraft

Fig. 7

features a much lower mast profile than any Russian coaxial helicopter to date and has potential for much greater airspeeds than any current USMC helicopter.[62]

IV. Biaxial Helicopters

Biaxial helicopter design is similar in concept to the coaxial arrangement, except the two rotors are on separate masts, located side by side. The rotors rotate in opposite directions, so the advancing blade moves forward on its respective side, while the retreating blades mesh along the aircraft centerline. The rotors are canted slightly to avoid hitting the opposite mast. This is

60 Kulikov, Igor. *Coaxial Helicopter Design.* //home.sprynet.com/~Kulikov 19 Feb 99.

61 Jane's. All the World's Aircraft. 441.

62 Kulikov, Igor. *Coaxial Helicopter Design.* 2.

another design which has been around for many years. Kaman, who produces the Navy's H-2 Sea Sprite, has introduced many biaxial helicopters. The HH-43B Huskie was an early Navy model that was introduced in 1956 with a Lycoming turbine engine. As late as 1994, Kaman introduced the K-1200 K-Max "Aerial Truck" which is being marketed for the civilian logging market and was tested by the US Navy as a vertical replenishment vehicle.[63]

V. Tilt-Rotor Aircraft

The fan-fare and excitement generated from the impending introduction of the MV-22 would lend one to believe this technology is relatively recent. In fact, this idea is nearly 50 years old. The XC-142A Tilt Wing (Figure 8) was a 35-place vertical/short take off and landing (V/STOL) medium transport aircraft built in the early sixties, that bears a striking resemblance to the Osprey.[64]

Figure 8

For obvious reasons, a tilt-rotor capability has been a military goal since the early 1950's. Two major design themes for tilt-rotor operations predominate. The first, which formed the

63 Jane's. *All the World's Aircraft*. Jane's Information Group. Alexandria, VA. 1998. 299.

64 Army Aviation, January 31, 1987. 111.

backbone of early tilt-rotor experiments, was a tilting wing concept. These early aircraft featured an aircraft wing that tilted from horizontal to vertical, usually fitted with two turbo-prop engines per wing. The advantage to this design over the MV-22 system, where only the engine nacelles rotate, was increased efficiency in the hover mode. The downwash from the propellers is not impeded by the horizontal wing area as on the Osprey.

The disadvantage to the tilting wing variation comes when maneuvering the aircraft in the helicopter mode. The vertical plane of the wing induces a large parasitic drag coefficient when forward helicopter flight is attempted. For commercial tilt-rotor use, this is not considered a problem. For this reason the Japanese are developing their civilian tilt-rotor transport using a tilting wing design.[65]

65 Jane's. *All The World's Aircraft*. Jane's Information Group. 1998. 219

CHAPTER 6

FUTURE TECHNOLOGY DESIGN OPTIONS

There are very few aviation ideas that have not been considered in the past. In particular, the 1960's saw radical experimentation on many fronts. Flying cars, ducted propeller V/STOL aircraft, jet-packs and converti-planes were all built and flown. Most ideas did not survive the test of time because they were simply not practical. That decade also witnessed Americans landing on the moon, but the nation quickly realized it was not very productive.

Similarly, the anticipated introduction of the MV-22 and the Advanced Armored Amphibious Vehicle (AAAV), has "raised the bar" for the Joint Replacement Aircraft. Though both are unproven, many senior leaders now feel that a "leap ahead technology" is required for the JRA. The fact that a new century is looming only adds to the pressure.

In general, a radical new design is only warranted if it does the mission significantly better. Otherwise, subtle improvements are in order. Although there is no end to the design possibilities given enough time and money, several promising future technologies and ideas have gained some measure of validation. These will be discussed in this section.

I. Folding Rotor Technology

Conceived as an outgrowth of the current tilt-rotor technology, the folding rotor approach is meant to surpass the airspeed limitation of a turboprop aircraft. Still in the conceptual stage, this design could theoretically offer a tremendous airspeed advantage over the MV-22.

A folding rotor aircraft would take off vertically like a tilt-rotor. To transition to airplane mode, the aircraft is propelled forward by jet exhaust. As this happens, the rotors slowly rotate aft and begin to unlock at the hub. As the aircraft continues to increase speed, the rotors are allowed to fold back until they form a solid extension aft from the wingtip. In this configuration, the aircraft would achieve jet aircraft speeds. Converting from airplane to helicopter mode would be the reverse of this process, though it would appear to be the more difficult transition.[66]

II. Canard Rotor/Wing Technology

The Canard Rotor/Wing concept is the latest attempt to deliver both helicopter and fixed wing performance in the same aircraft (see Figure 9). The technology involves a canard type airframe which takes off vertically with a thick, symmetrical, two-bladed rotor. Both the leading

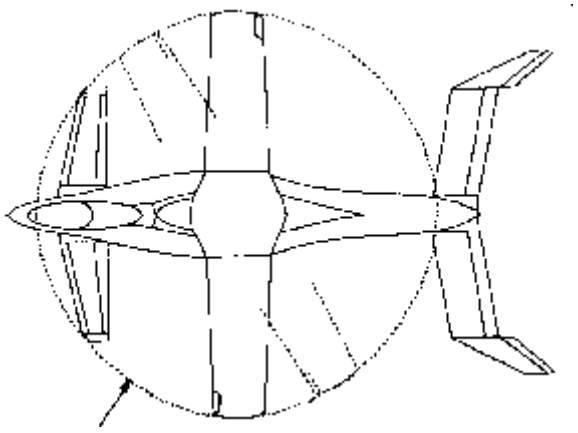

Fig. 9

and trailing edges of the rotor are identical. The rotor is propelled by jet exhaust ducted through the blades and vented opposite rotation at the blade-tips. In the helicopter mode, conventional rotor control techniques are used.

As the aircraft transitions for airplane mode, jet exhaust begins to exit along the fuselage centerline and propels the craft at higher airspeeds. As airspeed increases, the fuselage mounted

66 Hill, Timothy LtCol Ret. (USMC) Interview, December 14, 1998.

canards begin to unload the main rotor. Once this has been accomplished, the main rotor is stopped at the 3 and 9 o'clock position and acts as a conventional wing. Engineers predict airspeeds as high as 400 knots would be attainable with this type configuration.[67]

The Department of Defense is currently evaluating this Canard Rotor/Wing concept for Unmanned Aerial Vehicle development. If the technology proves successful, future manned aircraft designs are envisioned.[68]

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67 Weigl, Otto LtCol (USMC) *FY-98 Advanced Technology Demonstration.* OPNAV Program Sponsor: N85 November 20, 1995.

68 Aldridge, A. Maj (USMC) H-1 Desk, APW-53, HQ USMC. Interview. 12 Nov, 1998.

CHAPTER 7

DESIGN EVALUATION AND ANALYSIS

In order to select the appropriate design for development of a multi-mission HMLA aircraft, a prioritized list of capabilities must be established. Each of the design alternatives described in the proceeding chapters have inherent strengths and weaknesses. In many cases, as efforts are taken to increase one capability, another desired capability is decreased. Often, hard choices will have to be made.

I. Attack Versus Utility Mission.

The goal of this project is to produce a multi-mission HMLA platform that can perform the attack mission as well as a dedicated attack platform. The multi-mission role should not detract from ordnance payload, ordnance delivery, airspeed, range or time on station. In addition, several questions must be answered.

Can a side-by-side cockpit arrangement perform the attack mission as well as fore and aft seating? From a weapons delivery standpoint, given a proper sight, both configurations work equally well. In fact, for targets off the nose, a case could be made in favor of side-by-side seating. From a threat detection standpoint, fore and aft seating has an advantage in allowing both pilots to look out to the same side simultaneously. Of course, this is offset by the reduced visibility to the front by the pilot in the rear seat. In any case, neither configuration can be called a hands-down winner.

Can a multi-mission airframe perform the attack mission as well as the traditional narrow fuselage of a dedicated attack platform? When considering two aircraft of equal power to weight ratios, whether the fuselage is three feet wide or ten feet wide will have a negligible effect from a weapons delivery standpoint. An argument is often advanced that a thin dedicated attack platform offers a smaller target when viewed from the front. While this is true, it must also be noted that it offers a significant profile. In addition, the same critical components are contained in both configurations. A wider fuselage would simply increase the chances of hitting a non-vital component.

The increased reliance on precision guided munitions reduces any airframe specific advantages of a dedicated attack platform further. The first combat testing of Tube-launched, Optically-tracked, Wire-guided (TOW) missiles was conducted by utility helicopters. During the 1972 Easter Offensive, two TOW equipped Hueys were deployed to Vietnam. In a period of eight months, these aircraft managed to destroy 27 tanks and 61 other targets without any losses.[69] There is little argument that successful employment of Hellfire missiles is even less dependent on specific airframe characteristics.

II. Enroute Airspeeds Versus On Station Abilities

A primary consideration in development of the JRA is obtaining airspeeds complementary to the MV-22. Though not critical for mission success, it makes sense to attempt to close the performance gap if it can be done effectively. Given the outlook of current and future technologies as they appear today, a trade-off is required on this issue. For the Joint Replacement Aircraft to successfully fulfill the attack requirement, it must be able to maneuver in a

69 Allen. 24.

"helicopter-like" fashion once arriving on station. This requirement is critical to maintaining a responsive offensive capability, as well as for survivability reasons. Developing an aircraft that can meet or exceed the airspeed performance of the MV-22 is of no value if the attack capabilities are lost as a result.

These factors make a strong case for dropping any consideration of a tilt rotor design, such as the Bell XV-15 prototype (Figure 10). Tilt-rotors, while ideal for transport aircraft, are optimized for the enroute portion of the flight. Performance in the helicopter mode is a compromise. The airplane wing decreases vertical lift efficiency in the helicopter mode, while the

Fig. 10

high disk loading increases dust signatures during terrain flight. The rotor design is not conducive to low altitude hover-hold and terrain masking operations because of the increased risk of the wide rotor arcs contacting vegetation, terrain or obstacles. The design itself favors landing zones wider than they are long, complicating glide slope considerations, particularly in urban areas. Finally, the weapon engagement envelope of a turreted gun would be reduced in the airplane mode because of the twin rotors and crew served weapons in a multi-mission design would be severely restricted.

The Canard Rotor/Wing aircraft is attractive because it appears to offer the delicate balance between fixed-wing and rotary-wing performance. The transition to fixed-wing mode is

a primary weakness, as the conversion would not be as seamless as offered by a tilt-rotor. A slight loss of altitude might be experienced, as well as several seconds of less than precise control inputs. The real problem to this design is the tremendous fuel requirements that "jet plane" performance entails and the weight penalty involved. It is doubtful the design could overcome these limitations and provide any useful capabilities beyond employment as a small Unmanned Aerial Vehicle (UAV).

Conventional helicopters offer acceptable on-station performance, but their slower enroute airspeeds are a concern. Tail-rotors decrease hover performance, present a danger to ground crews and are vulnerable in combat operations, confined areas and NOE flight. Additionally, they are a significant source of acoustic signature.

CHAPTER 8

JOINT REPLACEMENT AIRCRAFT PROPOSAL

This proposal for design of a Joint Replacement Aircraft is intended as a framework for consideration of further design refinements. It reflects a belief that a multi-mission HMLA aircraft is not only achievable, but vital to the kind of versatility the United States Marine Corps is going to need in the 21st Century.

I. Basic Configuration

This Joint Replacement Aircraft proposal is based on an *advanced concept helicopter* configuration (see Figure 11). Attempts have been made to offer significant improvements to existing capabilities, but no true "leap ahead" technology is needed to meet mission requirements. This should provide significant cost savings over more radical designs.

The proposed design is based on a desire to provide airspeeds beyond any helicopter on the market today, while retaining the necessary maneuverability once in the objective area. While this configuration is probably not capable of exceeding the airspeeds of the MV-22, it should easily reach airspeeds of at least 250 knots.[70] This would reduce response time and provide a tremendous advantages in a myriad of missions.

This aircraft features a coaxial rotor, a shrouded "pusher" tail-propeller and short external stores wings mounted high on the fuselage. It duplicates the weight of the AH-1Z, but the overall length is shorter. The aircraft has a tricycle landing gear, with two forward and one back,

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70 Kulikov, Igor. Interview, February 24, 1999.

to allow landings on uneven terrain and to protect the shrouded tail propeller. The placement of the rear wheel closer to the midpoint of the aircraft, allows a quicker transition for landing and reduces the size of the zone needed.

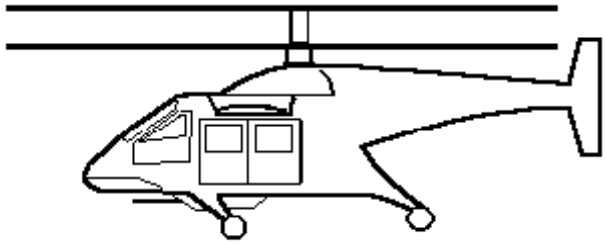

Fig. 11

The cockpit features a side-by-side seating arrangement, with the right seat prioritized for the pilot, and the left seat prioritized for the gunner/copilot. Controls are conventional, with the exception that the cyclic stick in either seat could telescope down to below lap-top level for greater mission performance when not flying.

II. Rotor Design

The coaxial rotor offers efficiency advantages while retaining a smaller rotor diameter than current HMLA aircraft. Because the rotor design provides an advancing blade on either side of the aircraft, problems associated with retreating blade stall are minimized. The compressibility effects, as the rotor tips approach the speed of sound, can be offset by reducing main-rotor RPMs during maximum speed flight.[71]

71 Kulikov, Igor. Interview, February 24, 1999.

The coaxial rotor is controlled using new Solid State Adaptive Rotor Geometry technology (where rotor pitch change occurs from within the blade due to an electrical charge and internal twisting), resulting in a cleaner rotor head design that minimizes drag penalties.[72] The tail contains a shrouded propeller to boost enroute airspeeds, with the capability to disengage when not desired.

Hover performance would be exceptional, with tremendous lift capability and no tail rotor concerns in confined areas. Stability in a hover would be greatly improved, with much less disruption from crosswinds. Finally, acceleration from a hover would be much faster than a purely conventional helicopter design could provide.

III. Weapons Stores

Weapon stores, comparable to the AH-1Z, are mounted on the stubwings above the rear-cabin doors. If stealth concerns are validated, these stub-wings could hydraulically fold down into the rear cabin cavity enroute, similar to the Comanche, to eliminate radar signatures associated with external weapons stores. A belly mounted turret contains a large caliber cannon and is fed via a ammunition box that doubles as a seat base in the forward cabin area. Available as a mission kit, this cannon can be removed for routine training missions. All aircraft have onboard target detection and laser designation capability.

Crewchiefs and crew-served weapons would be optional depending on the mission. In the anti-armor or armed reconnaissance role, most would go without. In urban terrain, the extra eyes and crew-served weapons would no doubt be useful. Crew served weapons mount on a

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72 Auburn University. *Solid State Adaptive Rotor Geometry and Operational Characteristics*. www.eng.auburn.edu/department/ae 1.

hinged pintle, with the ability to be drawn back into the cabin, or locked forward to shoot while the door remained closed.

IV. Multi-Mission Capability

In a utility role, the cabin area accommodates 6-8 Marines. Lightweight, crashworthy seats are incorporated into the transmission bulkhead and quickly fold flush when not required. The wing stores contain provisions for adding fast-rope, rappel, hoist, external fuel tanks and in-flight refueling capabilities.

Visibility for Command and Control missions is excellent. Antennas for the communications suite to be used by ground commanders, would be a permanent part of the fuselage, increasing the reliability over current packages. Provisions for controlling and viewing the Forward-Looking Infrared Radar (FLIR), will allow commanders to "see" the ground situation from a survivable stand-off range.

V. Shipboard Considerations

For shipboard use, the rotors incorporate a manual blade-fold mechanism. The wheeled landing gear aid in spotting the aircraft and reduce equipment requirements when operating aboard other ships or in remote areas ashore. The coaxial design decreases restrictions associated with landing conventional tail rotor helicopters aboard ships and reduces wind limitation considerations for all deck spots. In addition, the ability to secure the ducted tail propeller is much safer for deck personnel.

CHAPTER 9

CONCLUSIONS

The Marine Corps began its quest for armed helicopters largely in a reactionary mode. This is evident in the early efforts to strap weapons on the UH-1 and in the rapid development cycle of the AH-1 in response to Vietnam.

Since the introduction of the Cobra, development has proceeded in a evolutionary manner. The HMLA attack mission continues to develop, while the utility (or multi-mission) aspect has declined. By the middle 1990's, largely because of an obsolete airframe, the utility assets assigned to HMLA squadrons were cut in half. Many during this period began regarding "multi-mission" as synonymous with "no-mission."

The challenge that confronts the Marine Corps requires a step back from this evolutionary course. The MV-22 has provided a glimpse of the "revolutionary" thinking that can propel the Marine Corps into a successful 21st Century. The revolution required for a similar step in the HMLA community does not involve the embrace of a radical new technology. Instead, it requires the acceptance of an old idea. That a multi-mission platform has value.

Developing a single multi-mission HMLA platform will add a tremendous offensive capability to the MAGTF. Assuming a one for one conversion, the proposed airframe would add nearly 100 attack capable rotary-wing aircraft to the inventory. In addition, this vision offers improved versatility. No matter what the mission, the JRA could be tailored as needed to ensure mission success.

The flexibility and responsiveness of such an aircraft will be a key component in responding to future requirements. The Marine Corps has positioned itself as the force in readiness, to respond to a wide variety of contingencies across the globe. As the nature of conflict continues to shift towards the "three block war," the reliance on a dedicated attack platform serves to reduce the Marine Corps' overall capabilities. The volatility of such missions, as seen in Somalia, requires a platform that can change roles as fast as the mission requirements.

As the Marine Corps embarks on its journey into the next century, a single multi-mission HMLA aircraft makes perfect sense. The Cold War is over. Conflict has changed. The Marine Corps must be prepared to meet challenges presented over the full spectrum of human interaction. A Joint Replacement Aircraft, in the form of a multi-mission *advanced concept helicopter,* can help meet these future needs.

BIBLIOGRAPHY

Allen, Matthew. *Military Helicopter Doctrines of the Major Powers, 1945-1992: Making Decisions About Air-Land Warfare.* Westport, CT: Greenwood Press, 1993

Alexander, David R. Capt USA. Helicopter Mines: *The emerging threat to helicopter operations*. U.S. Army Aviation Digest, no. 3. May-June 1993.

Ambrose, James R. *The Light Helicopter Experimental (LHX) Program*. Army Aviation. January 31, 1987.

Attenborough, Keith. *Coupling Between Airborne Sound and the Ground: Models and Applications.* US Army Corps of Engineers, Technical Report EL-89-8, May 1989.

Auburn University. *Solid State Adaptive Rotor Geometry and Operational Characteristics*. www.eng.auburn.edu/department/ae

Bamberger, Mark H., Maj. *Are Non-Precision Munitions a Viable Weapon for Attack Helicopters?* Fort Leavenworth, KS: MMAS Thesis, U.S. Army Command and General Staff College, 1992

Bamberger, Mark H. Maj USMC *Trip Report: USMC Visit to McDonnell Douglas*. Aviation Weapons Systems Requirements, Headquarters Marine Corps. 1994

Beddoes, Mark W. Lt. (USN) *Logistical Implications of Operational Maneuver from the Sea*, Naval War College Review, Autumn 1997, Vol.L,. No.4.

Biass, Eric H. *Chopper Shopping.* Armada International. June 1995.

Braden, James W. *From Hot Air to Hellfire: The History of Army Attack Aviation*. Novato, CA: Presidio Press, 1994

Bowden, Mark. *Blackhawk Down: An American War Story.* Philadelphia Online. 16 Nov 1997.

Colucci, Frank. *Army Helicopter Programs Advancing*. Army. January 1998.

Davis, Jeffery P. Major, USMC. *Ship to Objective Maneuver: Will This Dog Hunt?* Proceedings, Aug 1998.

Francillion, Rene J. *The Naval Institute: World Military Aviation 1997-1998.* Annapolis: Naval Institute Press, 1997. 234.

Geddes, J. Philip. *Apache*. Washington D.C.: International Defense Images, 1988

Grayson, Eugene H. Jr., *Helicopter Support to Infantry: Dusting Off the Lessons of the Past.* Infantry, January-February 1996.

Greene, David S. *"The UH-1N Upgrade: At a Crossroads."* Marine Corps Gazette, May 1996

Jane's. *All The World's Aircraft*. Jane's Information Group. Alexandria, VA. 1998.

Jane's. *Land Based Air Defense*. Jane's Information Group. Alexandria, VA. 1998.

Keller, John. *"Military to Data Link Joint STARS Radar Jet, AH-64D Attack Helicopter."* Military & Aerospace Electronics, April 1998

Kulikov, Igor. *Compound Helicopter Design*. //home.sprynet.com/~Kulikov 19 Feb 99.

Kutta, Timothy J. *"The Revolutionary Lockheed AH-56 Cheyenne Attack Helicopter Was Shot Down by its Cost and Complexity." Aviation History*, September 1997

Krulak, Charles C. General (USMC) *Operational Maneuver From the Sea*, Proceedings January 1997. 26-31

Ludvigsen, Eric C. *Fielding a Light Helicopter Is Vital to Future Army*. Army (August 1990)

Magnus, Robert. BGen (Asst. DCSA, USMC) *The Combat Advantage: Excerpts from testimony before the Air Land Forces Subcommittee of the Senate Armed Forces Committee*, Marines, May 1996.

Masarella, Mark N., MAJ. *Adequacy of U.S. Army Attack Helicopter Doctrine*. Fort Leavenworth, KS: MMAS Thesis, U.S. Army Command and General Staff College, 1994

Peoples, Kenneth. *Bell AH-1 Cobra Variants*. Arlington, TX: Aerofax, Inc., 1988

Seffers, George I. *"Comanche Faces Cloudy Future."* Army Times, April 13, 1998

Thompson, Loren. *Marine Corps Tilts Into the Future.* Sea Power. Nov 1997.

U.S. General Accounting Office. *Army Budget: Potential Reductions in Helicopter Programs.* December 1989

Weigl, Otto LtCol (USMC) *FY-98 Advanced Technology Demonstration*. OPNAV Program Sponsor: N85 November 20, 1995.

Weinert, Richard P. *A History of Army Aviation - 1950-1962*. Fort Monroe: United States Army Training and Doctrine Command, 1991.

Williams, Robert H. *Army's Helicopter Program Attracts Alternative Schemes from Congress*. National Defence. April 1996.

Wilson, George C. *"'Dial-A-Threat' A Costly Game."* Army Times, February 2, 1998

Marine Corps Historical Division HQMC. *Fifty Years of Real World Operations--and Still Pumping.* Marines, Vol. 27 Issue 4, April 1998.

Posture Statement 1994. *U.S. Special Operations Forces*.

Interviews:

Aldridge, A. E. Maj (USMC) H-1 Desk, APW-53, HQ USMC. 12 November, 1998.

Hill, Timothy LtCol Ret. (USMC) 14 December, 1998.

Kulikov, Igor. 24 February, 1999.

Whitlow, William A. BGen. 24 February, 1999.