# NAVAL POSTGRADUATE SCHOOL

**MONTEREY, CALIFORNIA**

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## MBA PROFESSIONAL REPORT

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**Modernizing the Army's Utility Helicopter Fleet To Meet Objective Force Requirements**

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**March 2004**

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The purpose of this MBA Project was to recommend force development solutions, in terms of capabilities, to meet the United States Army's future utility helicopter requirements. The last thorough review of requirements for the utility helicopter fleet of the future was conducted in 2000. This project focuses on changes that have occurred in the Army since then, and the extent to which various alternative courses of action address those changes.

The report begins by briefly considering changes in the Army's operational environment. Next the authors consider what the requirements will be for the utility helicopter as the Army transitions from its current posture to the Objective Force. The study then considers possible materiel alternatives to fulfill the Objective Force requirements. These alternatives are to develop a new aircraft, use an aircraft that is already in production, or to improve the UH-60. The authors conclude that it is technically risky but feasible and cost effective to improve the UH-60 so that it can meet minimum future requirements, while a new aircraft acquisition option offers better performance and suitability at incrementally increasing costs.


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**MODERNIZING THE ARMY'S UTILITY HELICOPTER FLEET TO MEET OBJECTIVE FORCE REQUIREMENTS**

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Submitted in partial fulfillment of the requirements for the degree of

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# MODERNIZING THE ARMY'S UTILITY HELICOPTER FLEET TO MEET OBJECTIVE FORCE REQUIREMENTS

## ABSTRACT

The purpose of this MBA Project was to recommend force development solutions, in terms of capabilities, to meet the United States Army's future utility helicopter requirements. The last thorough review of requirements for the utility helicopter fleet of the future was conducted in 2000. This project focuses on changes that have occurred in the Army since then and the extent to which various alternative courses of action address those changes.

The report begins by briefly considering changes in the Army's operational environment. Next the authors consider what the requirements will be for the utility helicopter as the Army transitions from its current posture to the Objective Force. The study then considers possible materiel alternatives to fulfill the Objective Force requirements. These alternatives are to develop a new aircraft, use an aircraft that is already in production, or to improve the UH-60. The authors conclude that it is technically risky but feasible and cost effective to improve the UH-60 so that it can meet minimum future requirements, while a new aircraft acquisition option offers better performance and suitability at incrementally increasing costs.

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# EXECUTIVE SUMMARY

## A. PURPOSE

The purpose of this study is to recommend force development solutions, in terms of capabilities, to meet the Army's future utility helicopter requirements.

## B. INTRODUCTION

**1. Background.** In 1999, the Army Project Manager, Utility Helicopters (PM-UH) sponsored a study titled The Utility Helicopter Fleet Modernization Analysis. The study recognized that the Army's future requirements for the utility helicopter fleet far exceeded the capabilities of the contemporary aircraft. The study conducted a cost as an independent variable (CAIV) analysis and recommended a blocked approach to attain the best overall fleet mix to meet current requirements. Since 1999, the Army's utility helicopter requirements and its funding priorities have changed as it has shifted its long-range planning from the Army After Next concept to Transformation and the Objective Force. PM-UH is currently sponsoring another study to determine how the changing needs of the Army will affect the utility helicopter fleet

**2. Project Objectives.** This research project is specifically focused on the following primary research question: What should be the Army's strategy for modernizing the utility helicopter fleet to meet Objective Force requirements?

The subsidiary research questions are: What has changed in the Army operational environment since the 1999 study was published, and to what extent are the study's assumptions affected by these changes? What are the Army's Objective Force utility helicopter requirements, and how well does the UH-60 meet those requirements? To what extent is the plan to evolve the existing UH-60 to meet future requirements technically feasible? What alternatives exist to meet future requirements other than evolving the existing UH-60?

## C. METHODOLOGY

1. Identify changes in the operational environment since the 1999 studies and consider the potential impacts of these changes on capabilities planning for the utility helicopter fleet.

2. Identify relevant Objective Force requirements.

3. Assess the extent to which materiel solutions meet Objective Force requirements.

4. Compare the UH-60X, NDI alternatives and a potential new acquisition program against each other in terms of capabilities and cost.

## D. ANALYSIS

**1. Changes in the Operational Environment.** In the Department of Defense, there are three primary changes that will affect the future of the utility helicopter fleet. First is the shift from threat-based planning to capability-based planning, and the second is the mandate from the chairman of the Joint Chiefs of Staff to provide interoperable, joint capabilities in our weapons systems. Third is the Army leadership's response to these changes that will in turn affect the future of the utility helicopter fleet.

**2. Objective Force and UH-60 Helicopter Requirements.** Despite several relatively minor discrepancies, the current UH-60 ORD acknowledges Objective Force requirements and concepts, and attempts to address them within the developmental constraints of the existing aircraft. This may not always be technically possible, however. UH-60 shortfalls in regard to meeting Objective Force requirements include issues in the areas of lift capability, interoperability, flight handling characteristics, survivability, and supportability.

**3. The UH-60 Upgrade Plan.** It appears to be technically feasible to meet the Army's future lift requirements with the development of an improved engine, transmission, and rotor system for the UH-60 – which will require airframe modifications. There appears to be little cost, schedule, or performance risk with the

Army's ten-year plan to develop the new engine, but there may be significant technical risk in modifying the airframe to accommodate a larger rotor system. It is also technically feasible to improve the flight handling characteristics of the UH-60 and improve its performance in a degraded visual environment. Finally, the UH-60 may also be able to meet the Army's requirement for increased reliability, based on the results of computer modeling.

**4. Materiel Alternatives to the UH-60.** No aircraft currently in production meets the Army's requirements for lift capacity and improved flight handling characteristics. The only aircraft in production that meets the Army's lift requirement is the CH-47, which does not meet survivability or flight handling characteristics. The only fly-by-wire aircraft currently in production is the French NH-90, which was screened from consideration due to insufficient lift. Average unit procurement costs for a new acquisition program would be approximately $18.3 million per helicopter, with a required design and development cost on the order of $885 million over about fourteen and a half years.

## E. FINDINGS AND RECOMMENDATIONS

### 1. UH-60M Upgrade Program

**Implement Fly-by-Wire.** The UH-60's lack of improved flight handling characteristics is a serious requirements shortfall, given the Army requirement to conduct precision troop and equipment insertions in all weather and environmental conditions.

In the current two conflicts, more utility aircraft have been lost due to brown-out accidents than any other cause, including enemy fire. As the Army focuses more on asymmetric conflicts, all-weather operation becomes more critical. In a symmetric battlefield, bad weather tends to affect both forces engaged. In an asymmetric conflict, however, where the United States and its allies are the only force with a significant aviation capability, poor weather will limit friendly capabilities more than the enemy's. Without an all-weather capability, inclement weather favors enemy operations.

A fly-by-wire flight control system is needed to meet these requirements, as well as meeting lift and supportability requirements. Because no production aircraft has ever been upgraded to a fly-by-wire flight control system, though, this entails moderate technical risk. A fly-by-wire flight control system may stress the airframe in unpredictable ways, which may require airframe strengthening or other modifications, which may affect aircraft weight or center of gravity.

The Utility Helicopter project office estimates that the fly-by-wire upgrade program will have RDT&E costs of $55 million dollars, and increase the average unit procurement cost of the UH-60M by $600,000. Fully funding the fly-by-wire program and accelerating its introduction, beginning in fiscal year 2007 if possible, will fulfill a crucial component of the acquisition strategy and provide critical operational capability.

**Upgrade the UH-60M engine.** The Army must develop a new, more powerful engine to meet lift requirements, whether it pursues the UH-60X upgrade program or a new aircraft design program. Designing the new engine to be compatible with the current UH-60M drive train will allow integration of the new engine into the UH-60M upgrade program.

The new, more powerful engine could be governed to prevent over-torques, and allow the aircraft to operate up to the limits of the existing transmission. Given the existing drive train limitations, the UH-60M could lift up to 7,600 pounds at 4,000 feet and 95 degrees with more powerful engines. This would be a 27 percent increase in maximum lift capacity over the current UH-60M.

The Utility Helicopter project office estimates that the proposed new engine developed through the Improved Turbine Engine Program (ITEP) would have a unit cost of roughly $1 million, which is approximately $350,000 more than the current 701D engine in the UH-60M. This would increase the average unit procurement cost of the UH-60M from $10.6 million to $11.0 million. This appears to be a very cost effective upgrade, increasing lift capacity by 27 percent while only increasing unit cost by 4 percent, and allowing the Army to capitalize on the significant RDT&E cost of the new engine for the UH-60X/FUR program.

### 2. UH-60X / Future Utility Rotorcraft

**Non-developmental aircraft do not meet Army requirements.** No aircraft currently in production meets the Army's requirements for lift capacity and improved flight handling characteristics. The only aircraft in production that meets the Army's lift requirement is the CH-47, which does not meet survivability or flight handling characteristics. The only fly-by-wire aircraft currently in production is the French NH-90, which was screened from consideration due to insufficient lift.

**Pursue a new utility helicopter to meet Future Utility Rotorcraft requirements.** Meeting requirements by making further modifications to the current UH-60M upgrade plan appears to be more affordable than a new acquisition program, at least in the short term. The Army's Utility Helicopter Project Office estimates that producing an upgraded UH-60X that meets all requirements will have an average unit procurement cost of roughly $15 million per helicopter. Parametric estimates for a new acquisition program suggest that a new utility helicopter meeting lift capacity requirements might have an average unit procurement cost of approximately $18.3 million. However, evolving the UH-60M to the UH-60X involves high technical risk, according to program definitions of risk. Ultimately, even if none of the technical risks develop into significant cost or schedule overruns, and the UH-60X meets performance thresholds, the Army will have a $15 million upgrade to a 20-year old (plus) airframe that marginally meets a lift requirement written in 1999. The Army should consider a new acquisition program to design a new aircraft to meet Objective Force requirements. The new aircraft could be designed around an improved engine that could be retrofitted to the current UH-60M. This would allow the Army to capitalize on the engine design cost for its new helicopter and provide significant increased lift capability for the rest of the utility helicopter fleet.

**Re-evaluate the 9,000 pound external lift requirement in light of cost data.** An analysis of alternatives using cost as an independent variable (CAIV) analysis would determine the program risk associated with stretching the UH-60 airframe to achieve the full 9,000-pound lift requirement. Initial engineering estimates indicate that a new engine and transmission, with the existing rotor system, would allow the UH-60M to lift 8,600 pounds at 4,000 feet and 95 degrees. This upgrade would increase the unit production cost of the UH-60M by approximately $850,000. Further increasing lift capacity to 9,000 pounds will require a larger rotor system, which in turn requires extending the airframe to provide clearance between the main and tail rotors. This upgrade might increase the unit production cost by as much as an additional $3 million.

Our analysis suggests that a UH-60 with an improved engine, transmission, and fly-by-wire capability will cost $12 million and provide 8600 pounds external lift. As previously mentioned, the UH-60X will provide 9000 pounds lift and cost approximately $15 million. It seems that increasing lift from 8600 pounds to 9000 pounds will cost about $3 million. We recommend that the Army study the impact of reducing the objective lift requirement to the more affordable 8600 pounds.

A near-term alternative to lengthening the UH-60 airframe is to transfer some utility helicopter tasks to the CH-47, especially considering that an upgraded UH-60M might only fall 400 pounds short of the Objective Force lift requirement.

**Study the cost and feasibility of a single new development aircraft to fulfill both utility and cargo roles in the Objective Force.** Objective Force literature (specifically the FCS ORD) describes roles for the UH-60 and the CH-47 that are quite similar. The practice of maintaining two platforms to fulfill the single basic mission of aerial transport contradicts the stated Objective Force goals of non-contiguous operations, reach-back logistics, systems commonality, and exceptional reliability. If affordable, a future cargo/utility rotorcraft capable of both the UH-60's versatility and the CH-47's cargo capacity, with increased reliability, supportability, and survivability, could be the ideal solution to Objective Force requirements, especially if developed in coordination with a system to fulfill the requirements the Army has identified for an Air Mobility Transport – Tilt Rotor (AMT-T)-like heavy transport capability.

### 3. Requirements Determination

**Define requirements in terms of capabilities.** When determining both requirements and the criteria for the analysis of alternatives, consider the shift away from threat-based requirements to capabilities-based requirements. In light of the Department of Defense's current and probable future emphasis on inter-service integration, including commonality of processes and equipment, the requirements development effort for the FUR requires the fullest possible representation from other services and agencies

**Quantify all requirements.** Some of the requirements identified in the ORD for the UH-60M and the FUR are not quantitatively defined. For example, neither survivability nor supportability requirements are well-defined in Objective Force literature, and consequently are not well-addressed in the UH-60 ORD. Specifically quantifying requirements wherever possible strengthens them against misinterpretation.

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# I. INTRODUCTION

## A. PURPOSE

The purpose of this study is to recommend force development solutions, in terms of capabilities, to meet the Army's future utility helicopter requirements.

## B. BACKGROUND

In 1999, the Army Project Manager, Utility Helicopters (PM-UH) sponsored a study titled the *Utility Helicopter Fleet Modernization Analysis*. The study recognized that the Army's future requirements for the utility helicopter fleet far exceeded the capabilities of the contemporary aircraft. The study conducted a cost as an independent variable (CAIV) analysis and recommended a blocked approach to attain the best overall fleet mix to meet requirements. Since 1999, the Army's utility helicopter requirements and its funding priorities have changed as it has shifted its long-range planning from the Army After Next concept to Transformation and the Objective Force. Currently, PM-UH is commissioning another study to determine how the changing needs of the Army will affect the utility helicopter fleet.

## C. RESEARCH QUESTIONS

This research project is specifically focused on the following primary research question:

**What should be the Army's strategy for modernizing the utility helicopter fleet to meet Objective Force requirements?**

The subsidiary research questions are:

1. What has changed in the Army operational environment since the 1999 study was published, and to what extent are the study's assumptions affected by these changes?

2. What are the Army's Objective Force utility helicopter lift requirements, and how well does the UH-60 meet those requirements?

3. To what extent is the plan to evolve the existing UH-60 to meet future requirements technically feasible?

4. What alternatives exist to meet future requirements other than evolving the existing UH-60?

## D. SCOPE

The scope of this report is limited to the utility helicopter requirements of the Objective Force, and the degree to which various solutions fulfill those requirements. The body of literature that supports this study includes defense planning rules and policies, Army Objective Force concept and requirements documentation, previous utility helicopter program studies and plans, helicopter industry technical and engineering data, and various articles, both scholarly and popular, regarding utility helicopters and the Army Objective Force.

## E. METHODOLOGY

### 1. Identify changes in the operational environment since the 1999 studies and consider the potential impacts of these changes on capabilities planning for the utility helicopter fleet.

a. Conduct research to determine what changes have occurred and how these changes might affect future utility helicopter planning.

b. Make recommendations about new factors that planners should consider when deciding about the future of the utility helicopter fleet.

### 2. Identify relevant Objective Force requirements.

a. Review UH-60 and Objective Force requirements documentation to identify utility lift requirements for the Objective Force.

b. Crosswalk UH-60 to Objective Force requirements to ensure UH-60 requirements meet objective force needs.

c. Identify UH-60 requirements that have not been met by the current aircraft.

**3. Assess the extent to which materiel solutions meet Objective Force requirements.**

a. Assess the feasibility of a plan to recapitalize the existing UH-60 fleet to ORD-compliant UH-60X aircraft.

(1) Review cost, schedule, and performance estimates from the project office.

(2) Research industry trends and consult with technical experts to estimate the feasibility of the proposed upgrades.

(3) Compare estimates of technical performance to Objective Force requirements.

b. Consider implications of a new helicopter acquisition program.

(1) Research non-developmental item (NDI) alternatives to meet the requirements, including the overall benefits and limitations of NDIs as well as specific NDI systems.

(2) Research past development programs to estimate the cost and schedule for developing a new utility helicopter.

**4. Compare the UH-60X, NDI alternatives and a potential new acquisition program against each other in terms of capabilities and cost.**

## F. THESIS ORGANIZATION

**Chapter I: Introduction.** Identifies the focus and purpose of this project as well as the primary and subsidiary research questions.

**Chapter II: Background.** Provides a basic overview of the evolution of the UH-60 helicopter fleet.

**Chapter III: Analysis of Changes in the Operational Environment.** Describes recent changes in the defense environment and how these changes may affect the utility helicopter fleet.

**Chapter IV: Objective Force And UH-60 Helicopter Requirements Analysis.** Outlines the requirements placed on the utility helicopter fleet by emerging Objective Force doctrine.

**Chapter V: Analysis of the UH-60 Upgrade Plan.** Explores the technical feasibility of evolving the UH-60 to meet the requirements of the Objective Force.

**Chapter VI: Analysis of Materiel Alternatives to the UH-60.** Identifies non-developmental candidates to meet the utility helicopter requirements and explores new acquisition alternatives.

**Chapter VII: Findings and Recommendations.** Summarizes the findings of the research, answers the research questions, and identifies questions for further study.

# II. BACKGROUND

## A. CHAPTER OVERVIEW

The purpose of this chapter is to provide background information on the current state of the Army's utility helicopter fleet. The chapter includes information on the origins of the UH-60, its development history, and current recapitalization programs that the UH-60 program is undertaking. The chapter concludes by describing the Army's specific acquisition strategy.

## B. THE BLACK HAWK FLEET

The UH-60 series comprises the Army's utility helicopter fleet, and is the largest aircraft fleet in the Army at 1570 helicopters. Black Hawks fly 42% of total Army rotary wing flight hours, and have recently seen extensive use in the global war on terrorism, Operation Enduring Freedom, and Operation Iraqi Freedom. Procurement of Black Hawks dates to 1978 with the purchase of the first UH-60A models from Sikorsky Aircraft Corporation.

In 1989, Sikorsky began production of the UH-60L. The 'L' model featured a more powerful engine and an improved durability gearbox that together produced more lift. By this time, the first -A models were over ten years old, and were beginning to experience some problems associated with an aging fleet. An aging fleet is plagued with rising operating and support (O&S) costs, as well as increasing safety concerns. According to data provided by the utility helicopter project office, the readiness rates of the UH-60A fleet have experienced a steady decline as depicted in Figure 1. [1]

[1] Source: AEPCO Utility Helicopter Data, personal correspondence, Nov. 2003.

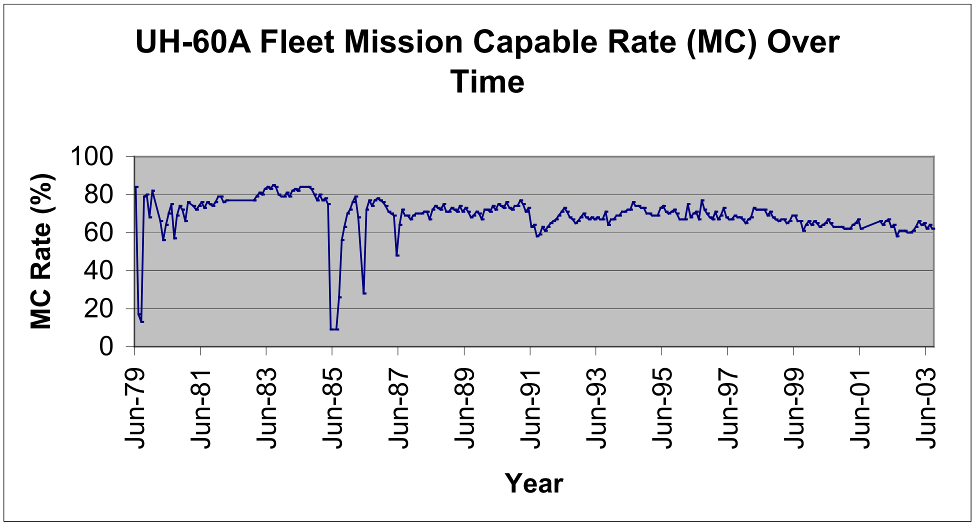


**Figure 1. UH-60A Declining Readiness Rates**

By 1999, Army aviation planners needed to decide how to best support the Army as Army doctrine and tactics changed. The planners also knew that they needed to address the issue of an aging fleet, and that affordability was a top priority. To this end, the Directorate of Combat Developments at Ft Rucker, Alabama initiated an effort to develop an Operational Requirements Document (ORD) for the recapitalization of the UH-60 fleet. At the same time, the Army's Project Manager, Utility Helicopter recognized the need to pave the way for the utility helicopter of the future. According to members of the PM office, "The aging fleet was becoming too costly to operate and maintain and the outdated technology of the 1970s proved incompatible with the Army's new vision for the future". [Ref. 1] To this end, the PM sponsored a study with the following stated purpose:

> The Utility Helicopter Fleet Modernization Analysis was sponsored by the Project Manager, Utility Helicopter (PM-UH); in coordination with Headquarters, Department of the Army (HQDA); Headquarters, U.S. Army Training and Doctrine Command (TRADOC); and the U.S. Army Aviation Center (USAAVNC). The study purpose was to develop a Utility Helicopter Fleet Modernization Strategy that determines the most operationally effective and affordable program to modernize the Utility Helicopter fleet to meet emerging Force XXI and Army After Next (AAN) operational requirements during the time period FY00-FY25. The products of this analysis will be used by HQDA,

> Deputy Chief of Staff for Operations (DCSOPS)- (DAMO-FDV) and the PM-UH to support aviation force structure requirements for FY99 and beyond. [Ref. 2, Executive Summary]

Army analysis and fleet modernization studies resulted in a strategy to extend the life of some of the existing airframes until such time as technologies matured that would allow production of helicopters with greater capabilities. The two major components of this strategy are a rebuild program and an upgrade program.

The rebuild program is necessary to extend the life of the UH-60A fleet until the technology that is necessary for the upgrade program is available. By the time that this technology matures, about 38% of the fleet will be over twenty years old. The rebuild program is a relatively low-cost strategy to extend the service life of the UH-60A fleet and slow the growth rate of the fleet's average age. It will improve readiness and reduce O&S costs, and will allow application of airframe improvements. The program takes 'A' model aircraft and overhauls them at a depot. The 'A' model helicopter is then returned to the fleet in a nearly new condition. This rebuild program is referred to as "'A' to 'A' recapitalization".

The upgrade program takes an evolutionary approach to helicopter acquisition, and seeks to improve the UH-60 fleet by including greater capabilities for the aircraft as they become available. The plan groups upgrades into two developmental blocks, referred to as Block I and Block II. Block I helicopters will be called the UH-60M, and will include several technologies that can be matured by 2007. Block II helicopters will include advances in engine technology that are scheduled to be available by about 2015. The Block II helicopter is called the Future Utility Rotorcraft (FUR), and current Army planning calls for the eventual fielding of 255 FURs.The upgrade plan includes the fleet modernization analysis recommendations for upgrades through recapitalization (recap/ upgrade). This means that the program will take the fleet's aging UH-60A and UH-60L model aircraft, strip them of worn or obsolete components, refurbish the airframes, and rebuild them into nearly new UH-60M aircraft. Concurrent with this program will be the purchase of new UH-60M aircraft from Sikorsky. A summary of the enhancements that the UH-60M will include is depicted in Figure 2. [Ref. 3]


**Figure 2. UH-60M Walk-Around Chart**

The above paragraphs described the evolution of the UH-60 fleet through Block I improvements that will produce the UH-60M. As previously mentioned, the Block II helicopter is referred to as the Future Utility Rotorcraft. According to the UH-PM, Colonel William Lake, the specific materiel form that the FUR will take will be decided after the Army conducts an analysis of alternatives. If the FUR is a further improvement to the UH-60 series, it will likely be called the UH-60X. For clarity, this study continues to use the UH-60X designation when referring to any Block II alternative that uses the existing UH-60 airframe. The FUR title is reserved for non-UH-60-based alternatives.

The Block I upgrades described above were appropriate for the needs of the Army when they were developed. However, as the world situation changes so do the implications for the utility helicopter program. The requirements previously identified for Block II aircraft may no longer be appropriate. The Army Aviation community recognizes the need to update the ORD, and is currently in the process of doing so, with potential impact to the project's development priorities.

Since the last UH-60 ORD was published in 2001, there has been a shift in how the Department of Defense determines requirements. This shift, and its consequences, will be discussed in Chapter III.

## C. THE UTILITY HELICOPTER ACQUISITION STRATEGY

The Army has a specific acquisition strategy that is based on requirements and funding. The plan through 2025 is to field a total of 1325 UH-60 series aircraft, and to field 255 Future Utility Rotorcrafts.

## D. CHAPTER SUMMARY

This chapter described the evolution of the Black Hawk fleet, from the UH-60A model beginning in 1978, through the UH-60L beginning in 1989 to the Block I UH-60M scheduled for full-rate production in 2007. The Block II aircraft is referred to as the Future Utility Rotorcraft and has production predicted to begin in about 2015. Current Army planning requires a fleet of 1325 UH-60 series aircraft and 255 FURs for the year 2025.

The most recently published ORD is the ORD for the Recapitalization of the UH-60 Black Hawk Utility Helicopter Fleet. It was prepared for a 2001 Milestone B decision.

The FUR requirements will likely change as the result of new guidance from the Army and the Department of Defense. Chapter III will discuss the changing nature of the Army's operational environment, and the effect that it will have on utility helicopter requirements.

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# III. ANALYSIS OF CHANGES IN THE OPERATIONAL ENVIRONMENT

## A. CHAPTER OVERVIEW

The purpose of this chapter is to present data on some of the changes that have occurred in the Department of Defense (DoD) and the Army operational environment, and analyze the effects that those changes will have on future planning for the utility helicopter fleet.

In DoD, there are three primary changes that will affect the future of the utility helicopter fleet. First is the shift from threat-based planning to capability-based planning, and second is the mandate from the chairman of the Joint Chiefs of Staff to provide interoperable, joint capabilities in our weapon systems. Third is the Army leadership's response to these changes that will in turn affect the future of the utility helicopter fleet.

## B. DEPARTMENT OF DEFENSE PARADIGM SHIFT

This section outlines two major paradigm shifts in defense planning. The first is the result of the most recent Quadrennial Defense Review and the second is a change to the requirements generation process known as the Joint Capabilities Integration and Development System.

### 1. Quadrennial Defense Review

The Quadrennial Defense Review is required as part of the United States Code, Title 10, Subtitle A, Part I, Chapter 2, Sec. 118:

> The Secretary of Defense shall every four years, … conduct a comprehensive examination (to be known as a "quadrennial defense review") of the national defense strategy, force structure, force modernization plans, infrastructure, budget plan, and other elements of the defense program and policies … with a view toward determining and expressing the defense strategy of the United States and establishing a defense program for the next 20 years. Each such quadrennial defense review shall be conducted in consultation with the Chairman of the Joint Chiefs of Staff. [Ref. 14]

The last QDR, which was published on September 30, 2001, identified a paradigm shift from "threat-based" planning to "capabilities-based" planning. The distinction is best defined in the QDR report:

> A central objective of the review was to shift the basis of defense planning from a "threat-based" model that has dominated thinking in the past to a "capabilities-based" model for the future. This capabilities-based model focuses more on how an adversary might fight rather than specifically whom the adversary might be or where a war might occur…the United States must identify the capabilities required to deter and defeat adversaries who will rely on surprise, deception, and asymmetric warfare to achieve their objectives.
>
> Adopting this capabilities-based approach to planning requires that the nation maintain its military advantages in key areas while it develops new areas of military advantage and denies asymmetric advantages to adversaries. It entails adapting existing military capabilities to new circumstances, while experimenting with the development of new military capabilities. [Ref. 15, p. IV]

The implications of capabilities based planning on the UH-60 fleet are beginning to be explored to an increasing degree. Under threat-based planning against the Soviet threat, determination of requirements was easier in many respects. On a linear battlefield against an enemy whose capabilities are largely known there are fewer variables than on a non-linear battlefield.

To conduct thorough capabilities-based planning we must develop a greater appreciation for the range of tasks that the Army might be called upon to execute. The RAND corporation suggests that a "new analytical architecture is needed with modernized constructs for:

- Identifying capability needs
- Assessing capability options for effectiveness in …missions
- Making choices about requirements and ways to achieve them, and doing so in an integrative portfolio framework that addresses future war-fighting capabilities, force management, risk tradeoffs, and related matters in an economic framework". [Ref. 7, p. xi]

Using this broad range of constructs as an example, we see that the utility helicopter fleet must consider multiple factors. Planners need to decide not only what the fleet needs to defend against, but also the extent to which its capabilities can develop to serve the greater Army. However, at the same time the utility helicopter may assume new capabilities-based requirements, it faces an increasing array of threats as well:

> The missiles that militants have regularly fired at planes in Iraq are typically Russian- designed Strelas, or SA-7s, or similar models. Weighing 30 pounds and measuring about five feet long, they are easy to smuggle across Iraq's porous borders. They can be fired as high as 14,000 feet, beyond the normal cruising altitude... [Ref. 53, p. 1]

Shoulder fired anti-aircraft weapons coming out of the former Soviet Union, a technologically savvy international terrorist organization, and the use of weapons of mass destruction by rogue nations or terrorist groups are all examples of possible emerging threats. Newer versions of the system threat analysis report (STAR) will likely address the specific dangers utility helicopters will face in the future.

New roles for the utility helicopter fleet need to be explored. Special operations forces are becoming increasingly important to America, as they take on a much larger role in our global war on terrorism. Another new role for the utility helicopter might involve command and control, or integrating the various unmanned aerial vehicles as they become more critical to ongoing operations.

### 2. Joint Capabilities Integration and Development System

Consideration of joint requirements is nothing new. The concept of joint requirements was born of the necessity to eliminate redundancy and promote flexibility. The passage of the Goldwater-Nichols legislation in 1986 gave greater emphasis to the benefits of joint processes and decision-making within the Department of Defense:

> The goal of the Goldwater-Nichols legislation was to give the CINCs a stronger voice in defining operational requirements, as well as the resources necessary to perform their missions. The CINCs' spokesperson was the CJCS, whose job it was to integrate CINC requirements, prioritize them, and show how these requirements related to readiness. The CJCS was now responsible for providing independent resource assessments (e.g., readiness to resources) to SECDEF on all matters considered joint, which included requirements, programs, and budget. [Ref. 17, pp. 14-15]

Goldwater-Nichols legislation alone, however, did not seem to provide a thorough framework for ensuring truly joint requirements generation process: "Unfortunately this has led the Joint Staff, combatant commands, and services to derive coordinated joint processes (in doctrine, training, requirements, et al.) that are stovepiped —isolated from one another instead of thoroughly integrated." [Ref. 16, pp. 25-26]

In an attempt to better integrate the requirements generation process among the services, Chairman of the Joint Chiefs of Staff, Air Force General Richard B. Myer recently adopted the Joint Capabilities Integration and Development System (JCIDS). This mandate, dated June 24, 2003 seeks to ensure that our forces are equipped with interoperable systems.

> The Joint Capabilities Integration and Development System (JCIDS) has been approved. JCIDS was developed … to foster efficiency, flexibility, creativity and innovation. JCIDS is defined in Chairman, Joint Chiefs of Staff (CJCS) Instruction 3170.01C and an accompanying CJCS Manual 3170.01. The manual provides guidance on how to frame the analysis and procedures used to identify and document capability gaps. JCIDS will support DoD's aim of providing interoperable, joint capabilities that best satisfy the needs of future warfighters. …JCIDS sets the stage for transition to a process founded on joint concepts and integrated architectures. [Ref. 18]

The effect that JCIDS will have on the future of the utility helicopter fleet could be significant. Future utility helicopter requirements planning personnel will likely include members outside of the Army. These planners might mandate that the utility helicopter of the future be built around a modular design that allows its configuration to be easily changed to meet the demands of multiple roles. Drug interdiction packages for the Coast Guard, anti-submarine warfare packages for the Navy, and Homeland Defense implications are all examples of new considerations for planners.

In the current world situation, with focus on Iraq, Afghanistan, and elsewhere, the Army must guard against allowing history to repeat itself. Admiral William Owens, former Vice Chairman of the Joints Chiefs of Staff, has expressed the view that "history reveals a tendency for the services to diverge rather than coalesce during periods of relative fiscal austerity. That is, each service tends to put planning priority on assuring and protecting core competencies at the expense of those capabilities that support and facilitate operations of the other services." [Ref. 33, p. 56] The point of JCIDS is that, in an ever-shrinking world, this type of behavior is no longer viable. Joint considerations must take precedence over narrow service goals, and the next-generation utility helicopter must answer more needs than just the Army's.

## C. THE ARMY'S RESPONSE TO CHANGING PLANNING GUIDANCE

As described in Chapter II, the Army's utility helicopter needs were last formally and thoroughly analyzed in 1999 and 2000. At that time, much of the primary planning guidance and documentation for the Army came from Army After Next concepts. This planning guidance helped the Army transition away from the Soviet threat.

The Army After Next concepts were supported by then Chief of Staff of the Army General Dennis J. Reimer. "We're changing from a Cold War Army to a post-Cold War Army, from an Industrial Age Army to an Information Age Army.... The process of taking today's Army to what we refer to as the Army After Next is known as Force XXI." [Ref. 21, pp. 2-6] Army After Next concepts were to shape what the Army would look like in the year 2025.

The next Army chief of staff, General Eric K. Shinseki, ushered in a new focus. When he assumed duties as chief of staff, the Department of Defense was no longer focused on the Soviet Union. The United States was becoming more involved with operations other than war and with peace building operations. General Shinseki's vision was for the Army to become much lighter and more easily deployable.

> ...one of his top priorities was to create an Interim Brigade Combat Team capable of deploying anywhere in the world within 96 hours. His vision of units equipped with vehicles lighter than Bradleys and Abrams M-1 Tanks would serve as a bridge for the Army's future Objective Force while providing the Army a more lethal, mobile and survivable force than the light forces which initially held the line in Saudi Arabia against Iraq during the Gulf War. [Ref. 21]

General Shinseki's vision of how the Army would transition itself from its then-current posture to a more capable force of the future is known as Army Transformation. Transformation involves maintaining current force (also known as the Legacy Force) capabilities, while working on the technological advances that will allow development of the Objective Force. To capitalize on technological advances in the near term, the Interim Force will help bridge the gap between the Legacy and Objective Forces. UH-60 variants will support the Army throughout Transformation.

Shortly after taking over in August 2003, the new Chief of Staff of the Army General Peter J. Schoomaker described his vision of "The Army Future Force":

> The Army Future Force will provide joint force commanders a much broader array of multidimensional options in any future contingency. As a knowledge-based force, the Army will exploit the power of advanced information technologies and space-based capabilities to enable network-centric battle command, fully integrated within the emerging joint, interagency, and multinational framework. [Ref. 42, p. 5]

General Schoomaker has also ordered the study of several proposals that will impact the future of the utility helicopter fleet, including a proposed reduction in the number of aircraft types in the Army fleet, and an increasing reliance on unmanned aerial vehicles (UAVs).

## D. CHAPTER SUMMARY

This chapter describes changes in the DoD and Army environments since the 1999 UH-60 ORD was drafted. These changes will be important to consider when planning for the future of the utility helicopter fleet. Chapter IV will explore in detail the emerging requirements for utility helicopters in order to support the Army's next evolutionary step – the Objective Force.

# IV. OBJECTIVE FORCE AND UH-60 HELICOPTER REQUIREMENTS ANALYSIS

## A. CHAPTER OVERVIEW

The purpose of this chapter is to derive from the Objective Force White Paper, and from the refinements and recommendations that followed it in official concept documents, study reports, and requirements documents, as well as unofficial studies and sources, the specific consequences of Objective Force initiatives to the Army's UH-60 Black Hawk helicopter requirements. To achieve this objective, the chapter outlines Objective Force operational and organizational concepts, describing overall concepts first, then general aviation missions, and next the implications for utility rotorcraft. It then describes the current requirements for the Black Hawk helicopter, and finally compares the Objective Force utility rotorcraft requirements to those for the Black Hawk.

## B. OBJECTIVE FORCE CONCEPTS

In November 2001, the U.S. Army published the "Objective Force White Paper", outlining a revolutionary new concept for the future Army. Endorsed by Army Chief of Staff Gen. Eric K. Shinseki, the white paper describes the future Army as a new force unhampered by the limitations of "light" and "heavy" force structures, able to conduct "operational maneuver from strategic distances" without recourse to traditional ports of debarkation, capable of decisive victory on a non-contiguous battlefield, and empowered to "see first, understand first, act first, and finish decisively" [Ref. 49, p. iv].

The Army's vision in the Objective Force White Paper and in the subsequent "Objective Force in 2015" white paper includes a number of changes in Army operations and organizations, and several distinct concepts upon which the force will be centered. The first and primary of these is the transformational effect of the "information revolution", enabling an unprecedented and exponentially empowering level of situational knowledge at all levels of command and at all points on the battlefield. [Ref. 49, p. 2] All military functions and components, including the Army Reserves, will be affected by this transformation, made possible by a global, ubiquitous, unitary command, control, and communications system.

The second new concept for the Objective Force is the capability for all maneuver units to be dominant across the full spectrum of military operations, from major theater war to smaller scale contingencies to stability and support operations. Integral to this concept is the need for Objective Force units to be masters at transitioning from one type of operation to another quickly and without losing operational momentum as typically occurs in such a change. [Ref. 49, pp. 3-4] A derivative of full-spectrum dominance, as well as other Objective Force concepts, is the need to develop a new family of combat vehicles, called the Future Combat System (FCS), capable of fulfilling the full spectrum of missions to which the Objective Force might be assigned. [Ref. 41, p. 2]

Third, the Army envisions the Objective Force to be much more integrated than the current force. This includes intra-army integration of air, ground, maneuver, support, and sustainment operations, and also better interoperability with joint, inter-agency, and multi-national forces. This interoperability will include the ability to conduct "operational maneuver from strategic distances", and Army headquarters specifically designed to function as Joint Force Commands, enabling information superiority for the entire force by integrating it into the Army's common operational picture. [Ref. 49, p. 6]

Fourth, the Objective Force is optimized for success at the tactical level of war. Following the "see first, understand first, act first, and finish decisively" principle, it aims to use technological enablers to achieve tactical success by "developing situations out of contact; maneuvering to positions of advantage; engaging enemy forces beyond the range of their weapons; destroying them with precision fires; and, as required, by tactical assault." [Ref. 49, p. 6]

Fifth, the Army is designing the Objective Force organization from the ground up, around generic unit constructs called Units of Action (UAs) and Units of Employment (UEs), that are roughly equivalent to today's brigades and divisions, respectively, in order to shed the prejudices of the past and build a new force that is optimized to be:

- Responsive – through the ability to conduct operational maneuver from strategic distances using advance multi-modal capabilities,

- Deployable – able to send brigade-equivalent anywhere in the world within 96 hours, a division in 120 hours, and five divisions in theater in 30 days, without reliance on traditional ports of debarkation,
- Agile – at transitions, enabled by superior situational information and training,
- Versatile – through full spectrum dominance and unmatched tactical mobility (including vertical maneuver),
- Lethal – enabled by superior information and communication, distributed fires networks, high operational tempo through force cycling, and proficiency at urban operations,
- Survivable – achieved by retaining the tactical initiative and through technologies providing "low observability, reduced electronic signature, ballistic protection, long-range acquisition, early discrete targeting, shoot first every time, and target destruction" on every shot, and
- Sustainable – through reduced "logistics footprint and replenishment demand," performance-based logistics, and multi-modal distribution. [Ref. 49, pp. 9-15]

Sixth, the Objective Force concept is heavily reliant on the development of technological and procedural advancements in the realms of space-based capabilities and logistics efficiency. Both of these concepts relate to the transformational effects of evolving information technology and communications technology, enabling the total asset visibility that is essential for predictive, high-speed sustainment. They also contribute to Objective Force agility, lethality, information connectivity, and the efficient use of the nation's capable but limited strategic lift assets. [Ref. 49, pp. 15-17]

Finally, the Objective Force will be centered on an Army of highly skilled, highly motivated, and well-equipped soldiers. These soldiers must have the knowledge, training, and stamina to transition between and execute a variety of missions with a much higher degree of autonomy than at present, made possible by "full-spectrum training" and a "knowledge-based battle command" network. They must also adopt a universal new "Warrior culture" that overcomes the Army's traditional heavy force and light force cultures and applies what were formerly special operations techniques to all maneuver operations. [Ref. 49, pp. 19-20]

## C. OBJECTIVE FORCE AVIATION MISSIONS

Stated mainly in terms of the Army's primary ground-based operational focus, the Objective Force White Paper nonetheless contains tremendous implications for Army Aviation. It advocates a ground force able to conduct tactical vertical envelopment, and "optimized for decentralized, non-contiguous operations." [Ref. 49, pp. 11-12] This implies two primary roles for general aviation forces: maneuver support for vertical maneuver, positioning ground mounted and dismounted forces at tactical and operational positions of advantage, and maneuver sustainment, providing critical supplies to maneuver forces over extended distances or across unsecured ground lines of communication (LOCs)[2]. Both of these tasks establish a continuing role for utility helicopters in the Objective Force, and in fact suggest a possible need for more robust aviation organizations than are presently resourced.

The Objective Force Aviation Concept of Operation describes six tasks for Army Aviation in support of the Objective Force: reconnaissance, security, mobile strike, vertical maneuver, close combat with ground forces, and maneuver sustainment support. [Ref. 43, pp. 7-10] Of these six, four are purely combat tasks; only vertical maneuver and maneuver sustainment support include general aviation components.

Objective Force literature also contains scattered references to aviation tasks in the areas of command and control (providing aerial command and control platforms, such as the Army Airborne Command and Control System (A2C2S)), maneuver support (emplacing counter-mobility minefields and other obstacles, similar in concept to the UH-60-mounted M139 Volcano), and combat search and rescue (CSAR).

### 1. Vertical Maneuver

In describing the idea of vertical maneuver, the Objective Force White Paper states:

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[2] Defined as "A route, either land, water, and/or air, that connects an operating military force with a base of operations and along which supplies and military forces move." [Ref. 48]

> Objective Forces will possess the organic capability to conduct tactical vertical envelopment and air assault in both independent actions and as complementary maneuver in support of committed ground forces. Executed rapidly, vertical maneuver provides positional advantage, achieves surprise, overcomes difficult terrain, exposes enemy capabilities to destruction throughout the JOA [Joint Operational Area], and blocks, isolates, or otherwise dislocates enemy forces. [Ref. 49, p. iv]

The white paper identifies "vertical envelopment" and "air assault" as distinct tactical maneuvers. This implies that the well-established concept of air assault, validated by the 11th Air Assault Division (Test) in 1963 [Ref. 30, p. 10], does not encompass the new concept of vertical maneuver. So the question remains: what does vertical maneuver comprise?

To bolster the Objective Force White Paper's somewhat weak implication that Objective Force units will be capable of both mounted and dismounted vertical maneuver [Ref. 49, pp. 11-12], the Objective Force Aviation Concept of Operation asserts clearly that "Vertical maneuver consists of air assault of dismounted infantry, along with selected equipment from their future combat system (FCS), and the air movement of mounted forces." [Ref. 43, p. 9]

This definition classifies air assault and air movement as subsets of vertical maneuver. The connotation in the Aviation Concept is that the riskier air assault mission is generally reserved for dismounted forces, while air movement operations will normally suffice for mounted forces. It goes on to say that the role of aviation in vertical maneuver operations is to provide aircraft for lift, combat escort, and reconnaissance, and that additional elements of vertical maneuver include non-line-of-sight communications, a shared air/ground common situational picture, dynamic sensor tasking, advanced target detection, synchronized air/ground fires and effects, aerial re-supply until ground link up occurs, battle command on the move, and suppression of enemy air defenses. [Ref. 43, p. 9]

Among its conclusions, the March 14, 2003 draft report of the Army's Air-Ground Concept Exploration Program (CEP) confirmed that "the FCS is an incomplete family of systems without the capability to rapidly maneuver across all types of terrain at all operational distances. Without mounted vertical envelopment at operational depth – specifically a capability to lift FCS vehicles – the Objective Force cannot assure dominant maneuver." [Ref. 27, p. 5-1] Consequently, it can be inferred that mounted vertical maneuver in the context of the Army Objective Force comprises the aerial transport of combat-configured FCS vehicles through enemy airspace to and from unimproved landing zones under the Army's standard of high altitude (4000 feet), hot (95° Fahrenheit) conditions, in order to achieve tactical advantage on the battlefield.

The Air-Ground CEP recommended that the Army procure a new development aviation system to meet the operational need for Objective Force vertical maneuver. Specifically, the CEP's analysis indicated that the Air Mobility Transport – Tilt Rotor (AMT-T), presently in early development, would best fit the Objective Force's lift requirements in support of vertical maneuver. [Ref. 27, p. A-1-1] With a 20 ton payload and a 500-1000 kilometer mission radius (depending on whether the initial take-off is vertical or rolling), the AMT-T would accommodate Objective Force C4ISR interoperability requirements, and includes advanced infra-red signature reduction and reduced acoustic signature compared to a comparable fixed-rotor helicopter. [Ref. 27, p. A-1-2]

The AMT-T, though, while it might be capable of air assault operations, would probably not be ideally suited for them, due to its projected larger signature and LZ size requirements. Air assault operations pose a somewhat different situation than air movement. In air assault operations, "assault forces (combat, combat support, and combat service support), using the firepower, mobility, and total integration of helicopter assets, maneuver on the battlefield under the control of the ground or air maneuver commander to engage and destroy enemy forces or to seize and hold key terrain." [Ref. 37, para. 1-2] They may involve inserting air assault forces into comparatively small, hostile landing zones in close proximity to enemy forces. Air movement operations, on the other hand, are transportation operations, and do not involve task organization of the ground maneuver element and the air delivery element under a single headquarters. Often, a mission is characterized as an air movement, and not given the more detailed planning required for an air assault, because it is not expected to involve immediate combat at the actual point of insertion. The AMT-T, with its inherently larger size and the burden of the FCS it would carry, would probably be required to land in order to discharge its load, thereby presenting itself as an exceptionally vulnerable target during an air assault involving immediate enemy contact.

The basic tasks of the air assault and air movement missions may not change dramatically in the Objective Force; however, some of the conditions will. Objective Force operations require, at maximum, that a UA "be able to make a 400 km operational move by ground and fight for 72 hours without re-supply." [Ref. 44, p. 4-19] Since the Army expects that vertical maneuver in general "will normally be most effective when it is supported by the rapid advance of ground-mobile forces to reduce risk, reinforce, expand/exploit the results of the air-based maneuver, and keep the adversary from isolating the air-delivered force," [Ref. 45, p. 30] it can be deduced that the practical upper distance limit for Objective Force operational and tactical vertical maneuver operations will be approximately 400 kilometers. At the UA level, though, most air assaults are likely to take place within the limits of the UA's 75-kilometer area of influence. [Ref. 44, p. 4-9] Dismounted Objective Force air assault forces will experience many of the same limitations as current light forces, including limited ground mobility once inserted and reduced survivability compared to mounted forces. Additionally, Objective Force air assaults will be conducted at the expense of the unit's unused FCS systems, which will stand idle until the air assault is complete.

In addition to moving dismounted troops to the air assault objective, Objective Force aircraft will be required to transport several major pieces of equipment. Objective Force infantry battalions will leave their FCS manned vehicles behind, but are expected to be equipped on air assaults with the Armed Robotic Vehicle – Assault (Light) (ARV-A(L)), Multi-function Utility/Logistics and Equipment Vehicle (MULE), and Non-Line of Sight - Launch System (NLOS-LS). [Ref. 44, p. 6-6] In fact, the FCS Operational Requirements Document (ORD) specifically states that "All FCS UMS must be capable of being carried during AASLT/air mobile by UH-60 and/or CH-47 helicopters in a high altitude, (4,000 foot pressure altitude), hot temperature (95 degrees F.) scenario for a radius of at least 75-150 km. The vehicle operators/crew will travel inside the helicopter and will be considered as part of the helicopter cargo." [Ref. 34, p. E-3] This requirement agrees with the operational distances derived above, but does not provide a great deal of fidelity upon which to base the expected weights of the three systems under consideration, especially since the ORD also describes the Black Hawk as capable of "external lift in high/hot conditions is 4,500 lbs (threshold) and 10,000 lbs (objective)." [Ref. 34, p. G-3] The U. S. Army Materiel Systems Analysis Activity (AMSAA) Army Future Combat Systems Unit of Action Systems Book (version 1.6), however, does list weights for the ARV-A(L), MULE, and NLOS-LS.[3] The ARV-A(L) and MULE, both based on the same chassis, are projected to weigh 2.5 tons (5,000 lbs), while the NLOS-LS is estimated at 1.4 tons (2,800 lbs). [Ref. 40, pp. 3-16 & 3-18]

In addition to potentially greater operational requirements, Objective Force aviation will be expected to overcome a more capable air defense threat than it has in the past. In Objective Force scenarios, threat experts have determined that "air defense ambushes and the innovative use of air defense weapons with passive acquisition and tracking systems (e.g., MANPADS [man-portable air defense systems], anti-helicopter mines, light AAA [anti-aircraft artillery]) may be encountered anywhere on the battlefield. This can place both manned and unmanned aircraft at greater risk than in previous contingencies. Aviation assets represent the type of targets an opponent, exercising asymmetric tactics, would seek to attack to demonstrate there is no sanctuary." [Ref. 43, p. 12] Consequently, Objective Force aircraft will require more advanced survivability characteristics, similar to the survivability of the FCS, if they are to operate on the future battlefield at all, let alone in an air assault role.

### 2. Maneuver Sustainment

Maneuver sustainment, the Objective Force incarnation of combat service support, comprises all of the assets, capabilities, and actions required to supply, maintain, man, and service maneuver units as they conduct operations. Maneuver sustainment

[3] The AMSAA weight references used in this study represent gross magnitudes only. The FCS systems' physical parameters (weight, dimensions) that were included in version 1.6 have been removed in version 3.0, indicating that they are subject to change.

operations present tantalizing possibilities for fulfilling the tremendous potential of aviation in the Objective Force. Repeated throughout Objective Force literature is the notion that "the maneuver sustainment operational environment will often be characterized by discontinuous, temporarily established LOCs; and aerial sustainment will be required in greater degree to support Objective Force mobility and agility." [Ref. 46, p. 5]

Regarding the role of aviation in sustaining maneuver, the Objective Force Aviation Concept asserts:

> Objective Force operations will be sustained through distributed, transportation-based, globally-networked, and reach-back supported logistics capabilities without reliance on traditional and/or fixed intermediate staging bases (ISBs). This will of necessity place greater reliance on aerial distribution platforms as a means of providing responsive and agile support from multiple locations within the theater. [Ref. 43, p. 9]

The Aviation Concept also lists sustainment-focused capabilities that will be required of Objective Force aviation. These fall mainly into two broad categories: support for critical, time-sensitive supply and evacuation, and sustainment support over long or broken ground LOCs. [Ref. 43, p. 10]

The first category of requirements, for critical sustainment, includes medical evacuation and supply, and resupply of ammunition, fuel, and repair parts. These events are likely to occur throughout a campaign, becoming more frequent during times of heavy maneuver engagement due to increases in casualty rates, battle damage, and fuel and ammunition consumption.

Aerial sustainment over unsecured ground LOCs, on the other hand, includes a broader and deeper array of sustainment functions than critical sustainment. It is likely to occur during the early stages of a campaign, while enemy forces are still able to employ anti-access measures against theater-level ground sustainment forces. "Because of the inability to rely on fixed airports and seaports, aviation will play a major role in resupply and evacuation, and movement of supplies and personnel to deployed units." [Ref. 43, p. 17]

Aerial sustainment is also likely to be important when ground maneuver forces are employed in a non-contiguous manner, without secured ground LOCs, even after the initial stages of a campaign. Scenarios under which this might occur include vertical maneuver of either mounted or dismounted forces, or penetrating ground maneuvers such as turning movements, encirclements, or envelopments. Objective Force UAs are much more capable of these types of maneuvers than current forces, and thereby present opportunities to improve sustainment efficiency, survivability, and economy of security forces through the use of aerial sustainment.

In an independent analysis of the Army's Objective Force sustainment requirements, Maj. Jason R. Vick concluded that:

> A logical solution to the challenges of Objective Force sustainment is to develop an aerial-based sustainment and distribution system. Sustaining from the air supports vertical envelopment and offers the ability to rapidly sustain Objective Force units as they maneuver across long distances. Such a system allows greater responsiveness, agility and survivability while increasing CSS [i.e., logistics] reach. It will also increase logistic velocity, provide for execution of time definite deliveries and reduce the logistics footprint in the battlespace. Finally, given the proper aerial vehicles, an aerial-based sustainment system could reduce theater distribution infrastructure requirements while improving capacity and control. Given the expected operational environment, the Army cannot successfully execute its Objective Force transformation without an operational level aerial-based sustainment and distribution system. [Ref. 55, p. 47]

Like air assault, the conditions under which maneuver sustainment occurs in Objective Force operations are likely to be much different than those currently in effect. Changes to the operational conditions for maneuver sustainment will include a U.S. force that is more widely dispersed. A key example of this is the previously mentioned UA target of a 75-kilometer area of influence – a much wider force footprint than today's conventional forces occupy. Another example is the Objective Force requirement to be prepared to move up to 400 kilometers from unimproved access points in order to initiate operations – 400 kilometers is a nearly impossible mission radius for a UH-60L even with no cargo whatsoever. In addition, the Objective Force principle of non-contiguous operations presents new challenges for maintaining tactical security in what would formerly have been considered rear area operations. Enemy forces that are bypassed or otherwise not subdued could prove highly successful at interdicting traditional ground LOCs and air LOCs alike. Recent anti-aviation ambushes in Operation Iraqi Freedom highlight the vulnerability of current U.S. aircraft to MANPADS of all types, especially on lightly secured but regularly traveled air routes.

Unlike air assault, the basic nature of the maneuver sustainment mission will also change dramatically under Objective Force doctrine. According to the Objective Force Maneuver Sustainment Concept:

> Operations will be effectively and efficiently sustained through distributed, transportation-based, globally networked, and reach-back supported logistics capabilities. The theater sustainment concept envisions a combination of "direct from CONUS" and theater-centric support structures. Surface transportation or fixed / rotary-wing lift aircraft will deliver materiel and service support in mission configured loads directly to forces in the objective area. Supply systems must be interoperable to facilitate the strategic-national and theater lines of communication (LOC) segments supporting global distribution thereby reducing unnecessary duplication. Because local shore logistic facilities may well be threatened or denied, temporary operating bases and sea-based logistics will be used. [Ref. 46, p. 9-10]

The concept of distribution-based logistics, supplanting the current practice of inventory-based logistics, will require an entirely new approach to the problem of sustainment. This approach will rely on a comprehensive common logistical picture that tracks every item of supply at all levels, and on a highly mobile and responsive distribution system including multiple modes of transportation.

Helicopter-based delivery, while likely to play a prominent role in the new logistics concept, is not the only available method of air transport even at the tactical level. "Short take-off / landing aircraft, precision guided parafoils, unmanned aerial vehicles, and airdrop" are all valid alternative methods fulfilling the principle of aerial sustainment. Regardless of the efficacy of these methods, though, utility helicopters will play an important role in sustaining Objective Force maneuver. To do so effectively, they must be both capable of carrying Objective Force loads over Objective Force distances, and survivable against the growing ground-based threats discussed earlier.

## D. CONSEQUENCES FOR UTILITY LIFT

In separating the Objective Force requirements for utility lift from those for cargo and heavy lift, it is important to first understand the definitions of the different lift categories. The U.S. Joint Doctrine Division's *Department of Defense Dictionary of Military Terms* defines a utility helicopter as a "multi-purpose helicopter capable of lifting troops but may be used in a command and control, logistics, casualty evacuation or armed helicopter role," [Ref. 48] but fails to define cargo helicopters or heavy lift helicopters. It does define heavy-lift cargo, although in Navy/Marine Corps terms, as "1. Any single cargo lift, weighing over 5 long tons, and to be handled aboard ship, or 2. In Marine Corps usage, individual units of cargo that exceed 800 pounds in weight or 100 cubic feet in volume." [Ref. 48]

Army Field Manual 1-113, while not specifically defining the difference between lift categories, points out differences in the way utility and cargo helicopters are employed. Specifically, "the AHB [Assault Helicopter Battalion, consisting of 30 UH-60s] provides division and corps commanders with a highly mobile, flexible, and responsive combat force. This force can plan and execute combat, combat support and combat service support operations. The AHB's speed and mobility enable the commander to adjust force ratios across the entire battlefield, carrying the fight to the enemy." Simultaneously, heavy helicopter battalions, consisting of 32 CH-47s located at Corps-level echelons, "provide the force commander a highly mobile and rapid means of moving priority combat systems, personnel, and supplies throughout his AO. Additionally, the heavy helicopter battalion, coupled with AHBs, provides the force commander with a robust air assault force capable of moving large numbers of combat soldiers great distances." [Ref. 36, para. 1-3]

These differences in employment are based on differences in capabilities and limitations. In general, higher lift ratings are accompanied by higher operating costs, greater fuel consumption, slower speed, shorter flight endurance, larger threat signature, and greater gross weight. These characteristics make it economically and tactically more efficient to use utility helicopters (i.e., Black Hawks) for missions involving smaller payloads, particularly troop and casualty transport.

## E. UTILITY HELICOPTER MISSIONS

The current FCS ORD describes Objective Force missions for both the UH-60 and the CH-47. For the UH-60, it says: "The UH-60 Black Hawk will provide lift, command and control, and logistical support to units in the FCS-equipped UA Force. It will operationally and tactically move forces throughout the battlespace to achieve full spectrum dominance." [Ref. 34, p. G-3] For the CH-47, it states: "The CH-47 Chinook is designed to transport ground forces, supplies, ammunition and other battle-critical cargo in support of worldwide combat and contingency operations." [Ref. 34, p. G-3] Excepting the reference to command and control, these are essentially variations on the same mission, reaffirming the traditional role of the UH-60 as a forward area utility packhorse and the CH-47 as a rear echelon cargo wagon.

In addition to sustainment support, the Black Hawk is expected to support Objective Force air assault operations. According to the UA Organizational and Operational Concept, the UA must have the capability to "conduct air assault operations by a dismounted unit with manned or unmanned mission equipment packages dismounted from their platforms; enables ability for overmatching combat power until linkup can be accomplished." [Ref. 44, p. 6-5] Furthermore, as discussed previously, "this must include the capability to airlift MULE, ARV-A(L), and NLOS-LS systems via UH-60 aircraft, and ARV (A) [Armed Robotic Vehicle (Assault)] and ARV (RSTA) [Armed Robotic Vehicle (Reconnaissance, Surveillance, Target Acquisition)] via CH-47." [Ref. 44, p. 6-6]

To summarize, then, the Black Hawk must be capable of two basic missions in support of the Objective Force. It must provide sustainment transport suited to its capabilities (i.e., moderate loads, relatively forward), and it must provide lift for battalion-size and smaller dismounted air assault and air movement. These will typically be conducted over distances of approximately 75 to 150 kilometers, but could extend for up to 400 kilometers during initial entry operations.

## F. OBJECTIVE FORCE UTILITY LIFT REQUIREMENTS

Classifying the Black Hawk as the Army's utility lift helicopter for the first increments, at least, of the Objective Force, it is possible to derive a number of specific requirements for Objective Force utility. These can be further divided into specified and implied requirements. Specified requirements are those in which Objective Force literature specifically names the Black Hawk or utility helicopters as performing a particular task or possessing a particular attribute. Implied requirements are those derived tangentially from Objective Force concepts and requirements for other systems, especially the FCS.

References for specified utility lift requirements are shown in Table 9 at Appendix A. They specifically require only that the Black Hawk (1) provide lift, command and control, and logistical support to the Objective Force, (2) display the same common operational picture as Objective Force units, and (3) lift the 2.5 ton ARV-A(L), 2.5 ton MULE, and 1.4 ton NLOS-LS under high/hot conditions for a radius of at least 75 to 150 kilometers. The FCS ORD appears to assume that the CH-47 will be required to lift the Armed Robotic Vehicle – Assault (ARV-A) and Armed Robotic Vehicle – Reconnaissance/Surveillance/Target Acquisition (ARV-RSTA) unmanned system variants. [Ref. 34, p. E-2-A-2] However, full combat weight for the ARV-A and ARV-RSTA are projected at 10,000 pounds each [Ref. 40, p. 3-42] – a weight that is marginally within the UH-60X objective lift requirement. Fielding of the ARV-A and ARV-RSTA is additionally planned for deferral until supporting technology matures. Consequently, these platforms should be considered as potential utility helicopter loads.

The FCS ORD also specifies a requirement for the CH-47 to sling-load the Class IV Unmanned Aerial Vehicle (UAV), which is projected to have a gross weight of 4000 pounds. [Ref. 40, p. 3-57] For tactical distances (less than 200 kilometers) or under benign conditions (less than high/hot), the UH-60L is already capable of handling this load. The UH-60M could also lift 4000 pounds for distances of less than 100 kilometers. The Class IV UAV should therefore also be considered a potential utility helicopter load.

In addition to specified requirements, Objective Force concepts yield a number of implied requirements for utility lift systems. These requirements, summarized below, are also detailed in Tables 10 through 14 at Appendix A, organized according to the subject headings of responsiveness and deployability, agility and versatility, survivability and lethality, sustainability, and information and interoperability.

Objective Force responsiveness and deployability requirements for utility helicopters include an extended employment radius of 475 kilometers, world-wide self-deployment, full-spectrum operability in any environment, automated loading/unloading, precision maneuver, cognitive crew aids, command post suitability, and organizational support for force cycling.

Survivability and lethality requirements include signature reduction, low observability, situational awareness, threat warning, active countermeasures, chemical/biological/radiological/electromagnetic survivability, obstacle avoidance, weapons effects survivability, accident effects minimization, NLOS effects direction, dash speed, and directed energy/radio frequency survivability.

Sustainability requirements include reduced maintenance and supply demand, increased reliability and availability, embedded readiness monitoring, component and tools standardization, expert ground diagnostics, two-level maintenance support, and graceful degradation when components fail.

Information and interoperability requirements include integrated mission planning and rehearsal systems, battle command network integration, LOS and NLOS communications, fast data transmission, communications interoperability, networked training systems, and combat identification.

## G. UNFULFILLED UH-60 HELICOPTER REQUIREMENTS

The Operational Requirements Document (ORD) for Recapitalization of the UH-60 Black Hawk Utility Helicopter Fleet, prepared in March 2001 by the Directorate of Combat Developments at Fort Rucker, Alabama, identifies several shortcomings of the existing UH-60A/L helicopter. The analysis that follows in Section H of this chapter (comparing current UH-60 requirements to Objective Force utility helicopter requirements) considers not only these shortcomings but all of the requirements stated in the UH-60 ORD. However, describing the shortcomings provides a convenient way to summarize the current force utility lift requirements that have not been met by the L-model UH-60 helicopter, which is presently in production. The UH-60L's shortcomings include:

### 1. Lift Capability

The Army has identified the need for a utility helicopter with a 9,000 pound external lift capability. Helicopter performance is degraded at higher altitudes and hotter temperatures. On a relatively cool day (75 degrees Fahrenheit) at sea-level, the current UH-60L has the capability to externally lift 9,000 pounds over short distances. The ORD, however, identifies the requirement to externally lift 9,000 pounds over a combat radius of 73 nautical miles at pressure altitudes of 4,000 feet and temperatures of 95 degrees Fahrenheit. The criteria of 4,000 feet pressure altitude and 95 degrees is an accepted standard for the high/hot environments in which the Army must be able operate. Under those environmental conditions, the current UH-60L can externally lift only 6,000 pounds in a basic mission configuration. "The aircraft is presently not capable of transporting numerous current and projected weapon systems, e.g. HMMWV family, Avenger, the artillery's lightweight 155mm howitzer (LW155) and light forces' direct support artillery as a complete mission package, and Line of Sight-Anti Tank (LOSAT). This is especially so in high density altitude (DA) environments such as Southwest Asia." [Ref. 38, pp. 13-14]

### 2. Interoperability

"The UH-60A/L Black Hawk does not have the necessary digital avionics architecture to meet current and future Army and Joint Vision 2010/20 communications interoperability and information exchange requirements." The current Black Hawk, except in the specialized A2C2S configuration, is not able to integrate either current or future digital command and control systems that will link it to the Objective Force battle command network, nor does it have the architecture to support the Army's next generation radio systems. In particular, the system does not have a digital bus, required to integrate digital radios to digital command and control components. In addition, "power fluctuations and increased load requirements" in the current power system make the UH-60 further unable to support future avionics and survivability equipment improvements. Finally, the UH-60's current communication and navigation suites have not been certified as meeting the latest International Civil Aviation Organization (ICAO) and Federal Aviation Administration (FAA) air traffic management requirements, and are likely to require upgrades in order to comply. [Ref. 38, p. 14]

### 3. Flight Handling Characteristics

Navigation and flight control systems do not allow the UH-60 to conduct precision troop insertion in a degraded visual environment (DVE) such as extreme darkness or reduced visibility due to weather, blowing dust, or snow. Army Regulation (AR) 95-1, Flight Regulations, specifies minimum safe weather conditions for operation of current U.S. Army aircraft. AR 95-1 prohibits daytime rotary-wing operations if the visibility is less than one-half mile. Nighttime rotary wing operations are prohibited if visibility is less than 1 mile. In order to increase the margin of safety, many Army installation and division commanders have imposed more restrictive environmental limitations on helicopter operations. The 101st Airborne Division, which specializes in helicopter troop and equipment insertion operations, also specifies minimum ceilings of 300 feet for daytime operations and 500 feet for nighttime operations in addition to the visibility restrictions in Army Regulation 95-1. [Ref. 39]

The ORD specifies threshold requirements to minimize pilot workload in all phases of flight and all mission configurations. "The aircraft must maintain a position over the ground within 15 feet and hover altitude within 8 feet for altitudes up to 50 feet above ground level (AGL) for 4 minutes in winds up to 25 knots with a gust spread up to 10 knots". The ORD further states that "Current and future combat operations require day and night, adverse weather, precision (land and over-water) navigational accuracy for the aerial assault of troops and equipment, resupply, special operations, medical evacuation, noncombatant operations, and worldwide deployability" and, "The UH-60 helicopter . . . must be capable of operating from unimproved land surfaces and seaborne facilities, day or night, and in adverse weather (battlefield conditions less than visual meteorological conditions) including moderate icing." [Ref. 38]

#### 4. Survivability

"Aircraft survivability equipment (ASE) suites do not provide sufficient capability to counter current and future advanced threat anti-aircraft weapon systems." [Ref. 38, p. 14] The current UH-60A/L aircraft are equipped with multiple survivability countermeasures designed to mitigate the risk of anti-aircraft weapons and missiles. The aircraft has countermeasures to protect against infra-red (IR) missiles (commonly called heat-seeking missiles), radar guided missiles or air defense artillery (ADA), and small arms fire.

To protect against the threat of IR missiles, the aircraft is equipped with the AN/ALQ-144 infra-red countermeasures device, which emits an IR signal designed to jam incoming IR missiles and confuse their internal IR missile guidance system. This is an active device that operates continuously when turned on. The primary heat source on the aircraft, which incoming IR missiles target, is the engine exhaust. To reduce the IR signature of the aircraft engines, the UH-60 is equipped with the Hover Infrared Suppression Subsystem (HIRSS).

> The hover IR suppressor provides improved helicopter survivability from heat-seeking missiles throughout the flight envelope. The HIRSS kit has no moving parts. It contains a three-stage removable core which reduces metal surface and exhaust gas temperature radiation

> and prevents line-of-sight viewing of hot engine surfaces. The HIRSS channels hot exhaust gasses through the three-stage core and inner baffle to induce the flow of cooling air from the engine bay and the inlet scoops. The three-stage core and inner baffle cold surfaces are coated with low reflectance material. For further cooling, hot exhaust gas is ducted o outboard and downward by the engine, away from the helicopter by the exhaust deflector, where additional cooling air is provided by the main rotor downwash. [Ref. 8, pp. 2-36]

Also, to reduce the IR signature, the aircraft is painted with low reflective paint to reduce IR signature caused by reflected sunlight.

To protect against the threat of radar guided ADA weapons, the aircraft is equipped with the AN/APR-39 radar detector. This is a passive sensor that, when turned on, detects radar signal that may be tracking the aircraft and alerts the pilot to the signal's direction, intensity, and potential source. The aircraft is also equipped with the M-130 chaff dispenser system that, when fired by the pilot, deploys a cloud of chaff--small metal flakes that float in the air--which are designed to temporarily diffuse threat radar guidance systems and allow the pilot to conduct evasive maneuver to avoid radar guided missiles or ADA weapons systems.

The aircraft with the Kevlar blanket installed in the floor of the cabin provides the crew and passengers ballistic protection against 7.62mm ground-fired armor-piercing projectiles. The internal fuel cells are self-sealing when penetrated by fully tumbled 7.62mm projectiles. The external fuel cells offer no ballistic protection from small arms fire.

The ORD specifies threshold requirements for aircraft survivability equipment to maintain at least the UH-60L IR signature and active and passive countermeasures. Also the aircraft must employ a balance of signature reduction, passive countermeasures, and active countermeasures to protect against detection and engagement by threat radar and laser weapon systems. The current aircraft, however, fails to meet the objective requirements specified in the ORD. Objective requirements are reduced acoustic and radar cross section signatures, integration of passive and active countermeasure suites with the aircraft's tactical displays, and improved ballistic protection for the crew and the internal fuel cells to 14.5mm.

### 5. Operating Costs and Reliability

The UH-60 was originally designed with a service life of 20 years. [Ref. 2] The fleet will begin reaching its 20-year service life goal in 2007. As the fleet ages, the annual cost per flying hour is beginning to increase above budgeted levels. A dedicated recapitalization plan is needed in order for the UH-60 fleet to meet availability, maintainability, and affordability goals. Current cost per flying hour of the UH-60A is $2,304, and current cost per flying hour for the UH-60L is $1,802. The Department of the Army goal for UH-60 readiness is 80%. Currently, during Operation Enduring Freedom, the Army's UH-60 fleet is maintaining only a 60-65% mission capable rate. The ORD specifies a threshold requirement for mean time between misson-affecting failure of 18 flight hours (21 flight hours is the objective) and a threshold requirement for mean time between essential maintenance of 4.5 flight hours (5.2 flight hours is the objective).

## H. OBJECTIVE FORCE AND UH-60 REQUIREMENTS COMPARED

In order to focus development of the UH-60 to fulfill the utility lift requirements of the Objective Force in the future operational environment, it is important to compare the Objective Force's requirements for utility lift to known Black Hawk helicopter shortcomings documented in the UH-60 ORD. This will also facilitate discovering previously unknown actual or potential shortfalls of the current development plan. Each of these two requirements perspectives has been described in detail in the preceding sections of this chapter. This section is dedicated to comparing them, and to deriving information that may, when analyzed in conjunction with technical, schedule, and cost data, help guide future development efforts for the Black Hawk program.

Discrepancies between Objective Force and Black Hawk requirements are discussed below. Specified Objective Force utility lift requirements are addressed first. Then implied requirements are examined, following the five subject areas used previously: responsiveness and deployability, agility and versatility, survivability and lethality, sustainability, and information and interoperability:

### 1. Specified Requirements

Objective Force specified requirements boil down to a need for utility aircraft to integrate into the Objective Force common operating picture, and to transport the ARV-A(L), MULE, and NLOS-LS, weighing at most 5,000 pounds, for 150 kilometers in high/hot conditions, with operators. The term "operators" is not well defined, though, since neither the ARV-A (L) nor the MULE has a designated operator, and could range from one person weighing approximately 290 pounds [Ref. 34, p. G-3] to an 11-man squad weighing 3,200 pounds. Assuming that the most efficient lift would include one of the infantry squads that the unmanned vehicle supports, allowing an infantry platoon to air assault via only four aircraft, the maximum load requirement would equal 8,200 pounds, or 9,000 pounds after adding a 10% error margin.

### 2. Responsiveness and Deployability

The UH-60 ORD specifies 4,500 pounds (Block I) and 9,000 pounds (Block II) of lift with a combat radius of 135 kilometers, and 10,000 pounds of lift with a 275-kilometer combat radius (Objective). Block II satisfies the Objective Force lift requirement identified above, but not the 475-kilometer distance requirement that Objective Force concept documents imply for initial entry. In-air refueling would mitigate this deficiency.

### 3. Agility and Versatility

The UH-60 ORD identifies requirements or current design deficiencies for continuous operations, precision navigation, mission management, and airborne command posts. The ORD does not identify a requirement for a rapid or automatic internal or external loading system, or address the Objective Force concept of robust unit design to facilitate force cycling (although this is addressed in the Objective Force Aviation Concept).

### 4. Survivability and Lethality

The UH-60 ORD acknowledges survivability deficiencies in the UH-60A/L models, and requires specific improvements in crew protection, directed energy weapon countermeasures, chemical contamination protection, and onboard suppressive weapons. It also presents general requirements for signature reduction and defensive maneuverability, and an objective requirement for an infra-red optical imaging system to aid in navigation and obstacle detection. However, the ORD does not address any sort of active, automatic threat detection and/or response system or link to networked NLOS fires.

### 5. Sustainability

The UH-60 ORD acknowledges the planned Army two-level maintenance system, but does not project that the UH-60 can be properly maintained under such a system. The ORD presents requirements for reducing the logistics footprint the system creates by increasing reliability (primarily through rebuilding airframes) and maintainability, integrating onboard diagnostics and prognostics, and use of the Global Combat Service Support automated logbook. The ORD does not address expert ground maintenance systems or advanced embedded readiness systems.

### 6. Information and Interoperability

The UH-60 ORD mandates interoperability with the Air Mission Planning System, and an open systems architecture to accommodate future systems. It also requires support for joint, military, and civilian communications including and objective requirement for satellite communications, as well as onboard integration of both current and future battle command systems and support for all critical top-level IERs (threshold) and all top-level IERs (objective), as well as support for basic interaction with interactive training applications. The ORD does not mention combat identification of friend, foe, or unknown entities.

## I. OBJECTIVE FORCE REQUIREMENTS FOR THE UH-60

Although the current UH-60 ORD pre-dates the definition of several Objective Force requirements, the requirements it contains are largely accurate in terms of meeting Objective Force needs. In particular, the five current UH-60 shortfall categories described in Section G also offer a logical means of grouping the UH-60's shortfalls in terms of Objective Force requirements:

Lift capability is, as always, the most important consideration for the UH-60 in supporting the Objective Force. This is why it is the only requirement that is spelled out in the FCS ORD. The FCS ORD specifies that the UH-60 carry the ARV-A(L), MULE, and NLOS-LS, but as explained in Section H above this requirement translates to increasing the UH-60's external lift capacity to approximately 9,000 pounds at 4000 feet pressure altitude and 95 degrees Fahrenheit, with an operating range of 150 kilometers under normal conditions and 475 kilometers under extraordinary conditions.

Interoperability, a relatively new priority for the Army, is also critical in order to meet Objective Force needs. The FCS Organizational and Operational Concept specifically calls for Objective Force utility rotorcraft to be equipped with the same common operating picture as ground forces, which means integration into the Objective Force battle command network. However, integration into the Objective Force mission planning and rehearsal system, LOS and NLOS communications, fast data transmission, communications interoperability, networked training systems, and combat identification also fall under this requirement.

Improved flight handling characteristics will allow the UH-60 to fulfill Objective Force requirements for full-spectrum operations, including conducting precision insertion of troops and equipment in conditions of darkness, adverse weather, and adverse environmental conditions. Mission management systems, support for airborne command posts and automated loading systems are also included in this requirement.

Survivability, always important, will be become more critical and also more difficult under Objective Force doctrine.  Crew protection, directed energy weapon countermeasures, chemical contamination protection, onboard suppressive weapons, signature reduction, defensive maneuverability, obstacle detection, threat detection and response, and networked fires are all elements of this requirement.

Supportability requirements, encompassing operating costs and reliability, are contained in the analysis of sustainability requirements in Section H above.  They include support for a two-level maintenance system, increased reliability and maintainability, onboard diagnostics and prognostics, expert ground maintenance systems, and advanced embedded readiness systems.

## J. CHAPTER SUMMARY

This chapter sequentially explored the Objective Force's operational and organizational concept, the Army Aviation and utility helicopter missions that arise from that concept, and the subsequent Objective Force requirements for utility lift helicopters. It also described the current state of UH-60 helicopter requirements in terms of requirements the aircraft has not yet met, and finally it compared Objective Force utility helicopter requirements to current UH-60 helicopter requirements, identifying Objective Force requirements that need to be addressed by the UH-60.

The chapter concluded that, despite several relatively minor discrepancies, the current UH-60 ORD acknowledges Objective Force requirements and concepts, and attempts to answer them within the developmental constraints of the existing aircraft, by identifying shortfall within the five categories outlined in this chapter (lift capacity, interoperability, flight handling characteristics, survivability, and supportability).  This may not always be technically possible, however.  Chapter V addresses the technical feasibility of upgrading the UH-60 to meet Objective Force requirements.

# V. ANALYSIS OF THE UH-60 UPGRADE PLAN

## A. CHAPTER OVERVIEW

This chapter examines the planned and potential upgrades to the UH-60 fleet. As indicated in Chapters I and II, the UH-60 fleet has evolved from the UH-60A to the UH-60L to the UH-60M. The next utility helicopter evolution could either be a non-developmental item, a newly designed helicopter (the FUR), or it could be a further upgrade to the UH-60M known as the UH-60X. This chapter focuses on the technical feasibility of developing the UH-60X to meet the Army's requirements among five dimensions: lift capacity, interoperability, improved flight handling characteristics, survivability, and reliability.

The conclusion of each sub-section considers risk, and classifies it as either high, medium, or low in terms of the technological goals according to the Utility Helicopter Project Management Office's risk management definitions (Appendix B):

> The risk management process identifies a hierarchy of risks that may potentially impact the successful achievement of program goals, objectives, thresholds, and/or established program milestone exit criteria. For consistency throughout the program, the risk level definitions have been developed. [Ref. 57, pp. 16-17)

## B. LIFT CAPACITY

Requirement: Increase external lift capacity to 9,000 pounds at 4,000 feet pressure altitude and 95 degrees Fahrenheit.

In order for the UH-60 to meet this requirement, all elements of the drive train must be improved. The helicopter drive train consists of the engines, the rotor system, and the transmission. The lift capacity of the current UH-60 helicopter is limited by the power provided by its two engines. As engine performance is increased, however, the aircraft transmission becomes the limiting factor. If both the engine and the transmission are improved, the efficiency of the rotor system then becomes the limiting factor. This section first examines the planned upgrades to the engines, and then examines the potential upgrades to the transmission and rotor system.

The Army's Improved Turbine Engine Program (ITEP) is a ten-year, $275 million program intended to develop a production engine that weighs the same as the UH-60L's current engine (456 pounds), but produces 30 percent more shaft horsepower while consuming 25 percent less fuel. [Ref. 6] The technology has existed for years to produce an engine this powerful. Turbine engines are essentially scalable, meaning that it is technically feasible to build a bigger engine with a similar thrust-to-weight ratio using a similar design. In other words, all one has to do to get more power is to build a bigger engine. The problem with today's technology is that this more powerful engine would be larger and heavier.

Similarly, the larger engine would require more fuel. Engine fuel consumption is measured in terms of Specific Fuel Consumption (SFC), which is defined as fuel consumption in pounds per hour per shaft horsepower. The ITEP goal is an engine with an SFC of .40 at 4,000 feet and 95 degrees, which represents a 25 percent improvement over the current engine. [Ref 6]

ITEP's goal to allow only 10 years to develop an engine with a 30 percent increase in power, *and* 25 percent decrease in fuel consumption, *and* no increase in engine weight is very aggressive. Historical trends in turbine engine technology indicate that a longer research and development period would be more appropriate. For example, the General Electric T-700 engine first went into production in 1978. That engine produced 1,622 shaft horsepower at sea level, with an SFC of 0.467. In 1989, General Electric began production of the T-700-701C engine. The -701C produces 1,890 shaft horsepower at sea level with an SFC of 0.462. In eleven years, General Electric was able to achieve only a 17 percent increase in horsepower with less than 1 percent reduction in SFC. Also, the more powerful -701C engine was 5 percent heavier than the less powerful engine it replaced. [Ref. 10] This trend would indicate that the ITEP goals might be overly aggressive.

Since 1989, however, there have been significant advances in turbine engine technology. In 1988, the Department of Defense, the National Aeronautics and Space Administration (NASA), and other leaders in the turbine engine industry launched a joint venture called the Integrated High Performance Turbine Engine Technology (IHPTET) program. The program established aggressive timelines to advance turbine engine technology with specific goals to increase shaft horsepower while decreasing specific fuel consumption.

The IHPTET goals and timelines established three phases, each with its own performance improvement targets:

- Phase I, to be complete in 1991, set targets of a 40 percent increase in horsepower/weight ratio, with a 20 percent reduction in specific fuel consumption.
- Phase II, set to end in 1997, targeted an 80 percent higher horsepower to weight ratio with a 30 percent lower specific fuel consumption (relative to 1988 technology).
- Phase III was to be completed in 2003, with target goals of 120 percent increase in horsepower to weight ratio with a 40 percent reduction in specific fuel consumption.

Currently, the IHPTET program has only demonstrated technology that can accomplish the Phase II goals (80 percent increase in horsepower/weight ratio and 30 percent reduction in specific fuel consumption). The primary improvements in technology that allowed these increases are improved materials and improved manufacturing techniques. The improved materials allow the engine to run at hotter temperatures. The improved manufacturing techniques provide closer tolerances for clearance in the compressor section of the engine.[4]

Dr. Ray Shreeve, an expert in turbine and jet engines and a former professor at the jet propulsion laboratory at the Naval Postgraduate School, reviewed the current ITEP plan. According to Dr. Shreeve, the accepted standard for progression from demonstrated technology to a production engine is 10 years. This is in line with the program schedule estimates for the ITEP. Also, according to Dr. Shreeve, it costs

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[4] Interview with Dr. Garth V. Hobson, Professor, Department of Aeronautics and Astronautics, Naval Postgraduate School, Oct. 14, 2003.

roughly a quarter of a billion dollars in RDT&E to progress from demonstrated technology to a flight-tested engine ready for production. This is in line with the program budget estimates.

Dr. Shreeve concludes that the Army's ITEP goals (30 percent more power with 25 percent less fuel consumption) for the UH-60X engine are well within the demonstrated technology improvements of the IHPTET program and are technically feasible within ten years.

Improvements to the engine alone, however, will not allow the UH-60 to lift 9,000 pounds. In support of this project, Mr. John Davis, an engineer at the Aviation Engineering Directorate – Aeromechanics Division, performed a computer engineering assessment of the impact of putting a new, more powerful engine in the current UH-60L helicopter. He showed that increasing the horsepower of the existing engines by 30 percent, given the current aircraft transmission limits, would allow the aircraft to operate at gross weights up to 22,191 pounds at 4000 feet and 95 degrees. This computer assessment indicates that improving the engine alone will result in a 7,691-pound external lift capacity.

To achieve the ORD threshold of 9,000 pounds external lift, other performance upgrades will be required. Once engine performance is improved, the next limiting factors would be the 1989 vintage aircraft transmission, drive shafts, and gearboxes. According to Mr. Davis, advances in manufacturing and materials would probably make it feasible to design new transmissions, drive shafts, and gearboxes that could be rated at the required horsepower without increasing the weight of the components. This will not necessarily be without technical risk, and will require considerable time, effort, and expense to design, produce, and flight test these components. From a program management standpoint, however, developing these components appears to have low technical risk given the current fielding schedule of the UH-60X.

Mr. Davis performed another computer engineering simulation, using the current UH-60L configuration. For this second simulation, he again used the 30 percent more powerful engines, but also assumed that the aircraft transmission was not a limiting factor. With the improved engine and transmission, the aircraft would be capable of lifting external loads up to 8,670 pounds at 4,000 feet and 95 degrees. Mr. Davis concluded that achieving a lift capacity of 9,000 pounds by increasing engine power and transmission capability alone may not be technically feasible because the rotor system becomes increasingly inefficient at the higher loadings in this high/hot atmospheric condition.[5]

To fully meet the Army's requirement for 9,000 pounds external lift, further modifications to the UH-60 would be required. Such modifications would include the previously noted upgrades to the engine and transmission, plus an increase in the diameter of the rotor system. Using Sikorsky's S-92 rotor system as a model, this would require lengthening the airframe to achieve clearance between the main and tail rotor.

Lengthening the airframe adds significant technical risk. The required airframe modifications would likely increase aircraft gross weight and would adversely affect the center of gravity of the aircraft by placing the tail rotor and tail rotor gearbox further aft of center. This would require other airframe modifications to maintain proper center of gravity. Also, making a significant change to the rotor system and the airframe may affect the natural frequency of the aircraft. This, in turn, may increase vibration during certain modes of flight and require further airframe modifications to compensate. The effects of lengthening the airframe are impossible to predict accurately without actual flight-testing data.[6]

Increasing external lift from 6,000 pounds to 7,600 pounds poses relatively little technical risk. It appears to be technically feasible by developing a production engine with 30 percent more power than the existing engine. Further increasing lift capacity to 8,600 pounds is probably technically feasible by developing an improved transmission, drive shafts, and gearboxes and poses low technical risk. Fully meeting the Army's requirement for external lift capacity of 9,000 pounds may be technically feasible, but will require significant airframe modifications and high technical risk.

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[5] Source: Interview with Mr. John Davis, Nov. 14, 2003.

[6] Source: Interview with Dr. E Roberts Wood, Professor, Department of Aeronautics and Astronautics, Naval Postgraduate School, Sep. 11, 2003.

Table 1. Technical Risk of Lift Capacity Upgrades

| Lift Capacity | Required Upgrade | Technical Risk |
|---|---|---|
| 6,000 pounds | Current capacity | None |
| 7,600 pounds | Improved engine (ITEP) | Low |
| 8,600 pounds | Improved transmission, drive shafts, gear boxes | Low |
| 9,000 pounds | New rotor system, airframe modifications | High |

## C. INTEROPERABILITY

Requirement: Interoperability with the Army's digital forces.

The UH-60M (increment 1) essentially meets this requirement. It includes the system architecture to support digital avionics and communication equipment, and is projected to be able to accept the Army's new Joint Tactical Radio System (JTRS) when it is fielded. The UH-60M (increment 2) is scheduled to be fielded with the JTRS already installed. Because the UH-60M was specifically designed with open systems architecture and interoperability as a priority, meeting the Army's requirement for interoperability appears to offer relatively low technical risk.

## D. FLIGHT HANDLING CHARACTERISTICS

Requirement: Conduct precision insertion of troops and equipment in conditions of darkness, adverse weather, and adverse environmental conditions.

### 1. Operation in Adverse Environments (Brown-Out)

The primary technical problem in conducting helicopter operations in a degraded visual environment (DVE) is the inherent instability of the aircraft at low airspeeds. Without visual reference it is impossible for the pilot to properly determine the aircraft's attitude with relation to the ground. At low airspeeds the current aircraft instrumentation is insufficient to provide this visual reference. Therefore, it is unsafe to operate the current configuration UH-60L at low airspeeds (i.e. hovering or landing) without a visual reference of the ground.

> Helicopter pilots have four means of control: heading with pedal, altitude with the collective, pitch attitude and forward speed with fore/aft cyclic, and roll and sideward flight with lateral cyclic. Actively controlling all four of these motions at the same time with no visual reference outside the cockpit is an *extremely* difficult task. Pilot workload manipulating these four controls must be reduced to make low-visibility approach and hover a tactic available to the operational commander. [Ref. 12, p. 1]

The technology to overcome this limitation has existed for some time. Coast Guard helicopters have had the ability to approach and land without outside visual reference for over 40 years. [Ref. 13] They are equipped with a "hover indicator" display, which uses either on-board Doppler radar or global positioning system data to give the pilot drift information and drift velocity vectors. The figure below shows a typical hover indicator.


**Figure 3. Rockwell-Collins Hover Display**

According to a point paper prepared at the Army Aviation and Missile Research, Development, and Engineering Center, it would be easy to retrofit the UH-60A/L with this technology. [Ref. 13]

A hover indicator provides the pilot with increased situational awareness, but does not assist in controlling the aircraft and is therefore only a partial solution. To achieve the capability to approach and land without visual reference with satisfactory pilot workloads, the aircraft needs a hover-hold capability. Hover-hold uses a digital flight computer, coupled with the aircraft flight controls to maintain the aircraft's attitude and position over the ground.

With hover-hold, the number of axes that the pilot must control is reduced from four down to one. This hover hold technology is also available on other commercial and military aircraft, and it has been demonstrated on the UH-60M prototype. The UH-60M is able to achieve hover-hold through the dual digital flight control computer (DDFCC) upgrade. The DDFCC upgrade essentially replaces the current UH-60 analog flight stability augmentation system (SAS) with a digital stability augmentation system coupled to the aircraft's onboard flight control computer.

The current special operations version of the UH-60, the MH-60K, has a hover-hold capability and has hover symbology instrumentation. This aircraft demonstrated the ability to operate safely in brown-out conditions during operation Iraqi Freedom. The planned UH-60M will have similar flight handling characteristics to the MH-60K, which will allow the aircraft to meet all ORD threshold requirements, and will allow pilots to approach and land in severely degraded visual environments.

Bringing the Army's UH-60 fleet in line with the Special Operations MH-60K is not a full solution to the brown-out problem, however. CW4 Savage, a former MH-60K instructor pilot and current project officer in the Systems Integration Management Office (SIMO) 160th Special Operations Aviation Regiment (Airborne), made the following assessment:

> There are a lot of factors involved with a brown-out landing, and a DDFCC will not satisfy all those factors. The only viable material solution is a change in the handling qualities that we will enjoy with fly-by-wire. DDFCC is certainly a benefit, and we use our AFCS in a Kilo in one of three brown-out landing techniques. We are normally too heavy to use the AFCS to recover an aircraft in a brown-out, because the AFCS will exceed the environmental TQ limit of our engine, and droop the rotor. Our other two techniques the pilots use hover symbology to ensure there is no side drift, and to determine proximity to the ground as he flies the aircraft to the ground. This requires a great deal of training to become proficient. The Kilo that we rolled over in the desert was the result of an unexpected brown-out, and the pilot was unable to detect or correct a sideward drift. This resulted in a dynamic rollover.

The DDFC upgrade in the UH-60M (increment 1) is only a partial solution to brown-out because it will also require extensive training in addition to the upgrade. A full material solution to the problem will require new aircraft handling qualities, which will require an upgrade to a fly-by-wire flight control system.[7]

The UH-60, like all other fielded Army helicopters, has mechanical flight controls. This means that the aircraft cyclic, collective, and pedals are mechanically linked through push rods and cables to the main and tail rotor systems. The UH-60 cockpit flight controls are mechanically linked to hydraulic servos, which adjust the pitch and attitude of the rotor system.

On a fly-by-wire flight control system, the cockpit flight controls (cyclic, pedals, and collective) send a digital signal to the flight control computer, which sends a digital signal to the hydraulic servos controlling the rotor system. A fly-by-wire system would allow the UH-60 to adopt new helicopter control laws that would fundamentally change the handling characteristics and reduce the inherent instability of the aircraft at low airspeeds or hover. Control laws refer to the manner in which the aircraft responds to control inputs from the pilots.

Changing the UH-60 from its current control laws to velocity command control laws would allow the aircraft flight control computer to automatically adjust the aircraft attitude to maintain a constant velocity based on cyclic displacement. The principal advantage of this system, as it relates to making a precision approach and landing in a DVE, is that if the pilot released the cyclic (to a neutral or zero displacement position) the aircraft will automatically assume zero velocity, or hover. This effectively reduces the number of axes the pilot must control in order to hover from four to zero, and would eliminate any inherent instability of the aircraft at low airspeeds or hover.

The current UH-60L has a flight control computer, but simply upgrading the computer will not allow the aircraft to adopt new control laws. The existing flight control computer makes inputs to the flight control system through stability augmentation system

[7] Source: Interview with Chris Blanken, Flight Control and Cockpit Integration Branch, Army/NASA Rotorcraft Division, Ames Research Center, Oct. 16, 2003.

actuators, which have only 10% control authority. This means that the flight computer can only make small inputs to the rotor system in addition to the mechanical inputs made by the pilot. This limited control authority is not sufficient to allow the computer to control the aircraft with velocity command control laws. This is why the aircraft must be upgraded to a fly-by-wire system.[8]

Equipping the UH-60X with fly-by-wire technology would allow the flight control computer 100 percent control authority over flight controls, which would allow the UH-60X to upgrade the flight control computer and adopt a velocity command system. This would be a complete material solution to the problems posed by brown-out.

Fly-by-wire technology is mature in both fixed wing and rotary wing aircraft. It has been flying in commercial and military fixed wing aircraft for years. The Army's Comanche helicopter has flight-tested fly-by-wire technology, to include application of translation rate control laws. To date, however, no production rotary wing aircraft has been upgraded or modified to a fly-by-wire flight control system. "There may be some unknown unknowns... when dealing with something that has never been previously attempted, there is always the possibility that it simply won't work."[9] The most significant are of technical risk is that the fly-by-wire system will require dramatic control inputs from the flight control computer, which may stress the airframe in unpredicted ways. This, in turn, may require strengthening of the airframe which will increase the weight of the aircraft and decrease its lift capacity.

### 2. Operation in Adverse Weather

There are currently no program upgrades planned for the UH-60X that address the requirement to fly in a degraded visual environment caused by adverse weather (instrument meteorological conditions). This technology exists, and is currently

[8] Source: Interview with Chris Blanken, Flight Control and Cockpit Integration Branch, Army/NASA Rotorcraft Division, Ames Research Center, Oct. 16, 2003.

[9] Source: Interview with Rear Adm. (Ret.) Donald R. Eaton, Logistics Chair, Graduate School of Business and Public Policy, Naval Postgraduate School, Nov. 4, 2003.

employed on the special operations MH-47 helicopters. The MH-47 employs a terrain following, terrain-avoidance multimode radar which enabled the aircraft to conduct precision troop insertion operations in Afghanistan in weather conditions of near-zero visibility. [Ref. 28]

The MH-47 and the UH-60 have similar flight control systems and flight control computers, and use the same flight control laws. From an engineering standpoint, adapting this technology from one helicopter platform to another is relatively straightforward and poses little technical risk. The addition of the new radar equipment would add weight to the UH-60 platform, however, and might jeopardize the aircraft's ability to meet threshold lift requirements.

**Table 2. Technical Risk of Handling Characteristics Upgrades**

| Capability | Upgrade | Technical Risk |
|---|---|---|
| Land in brown-out conditions (with additional training) | Dual digital flight controls | Low (technology flight tested) |
| Land in brown-out conditions (full material solution) | Fly-by-wire flight control system, new control laws | Medium (design iterations required) |
| Precision troop insertions in adverse weather (IMC) | Terrain following radar (not included in UH-60M or UH-60X) | Low (technology flight-tested) |

## E. SURVIVABILITY

Requirement: Improve aircraft survivability systems.

The UH-60 ORD specifies that future aircraft must maintain at least the same radar cross-section and infra-red (IR) signature as the UH-60L. The Army plans to reduce the IR signature of the UH-60 with an Improved Hover Infrared Suppression Subsystem (IHIRSS). This study could obtain no technical information about the IHIRSS upgrade. However, the plan to increase the lift capacity of the UH-60M involves the development of new engine that will operate at higher temperatures. Unless the IHIRSS can offset the increased engine temperature, the UH-60X may have a larger IR signature than the UH-60L.

## F. SUPPORTABILITY

Requirement: Improve system reliability and maintainability.

The UH-60 ORD specifies threshold and objective requirements for aircraft reliability. It specifies a threshold requirement for mean time between failure (MTBF) of 18 flight hours (21 flight hours is the objective) and a threshold requirement for mean time between maintenance (MTBM) of 4.5 flight hours (5.2 flight hours is the objective).

The Army's plan for the UH-60M includes a reliability improvement plan to reduce the operation and support costs and increase reliability. The reliability projections for the UH-60M indicate "a nominal 15 to 20 percent improvement can be expected in overall UH-60M reliability and maintainability over the UH-60L". [Ref. 11] Projections indicate, however, that the UH-60M will not meet the threshold requirements for MTBF and MTBM.

The plan to upgrade the UH-60A to the UH-60M includes replacing 75 depot-level reparable (DLR) items with new or improved components. In addition to replacing DLRs, the plan seeks to improve reliability by strengthening the airframe.[10] Lessons learned from the UH-1 fleet, which is approaching 40 years of service, show that aging airframes begin to develop structural weakness in the cabin and tail sections of the airframe. To address this issue, the entire cabin section of the airframe is being replaced with a new cabin that has a more robust design and is manufactured with improved composite materials. The UH-60M upgrade also replaces the entire aircraft wiring system, strengthens the tail boom, and inspects the tail pylon for signs of structural fatigue.

Mr. Lindell Whaley, a reliability and maintainability engineer for the Aviation and Missile Command Research and Development Center (AMRDEC), analyzed the UH-60M upgrade program and developed a reliability growth model to estimate the achievable reliability, availability, and maintainability (RAM) values for the UH-60M aircraft. To develop his model, Mr. Whaley used historical maintenance data from the

[10] Source: Interview with Mr. Bill Hanks, UH-60 Systems Engineering Integrated Product Team Leader, 15 October, 2003

Army's UH-60A and UH-60L fleet, as well as data supplied by Sikorsky. Mr. Whaley adjusted his model to include design modifications for the UH-60M.

The reliability growth model predicts the UH-60M will have a mean time between failure (MTBF) of 15.3 flight hours, and a mean time between maintenance (MTBM) of 4.3 flight hours. [Ref. 11] The largest factors accounting for the projected increases in reliability of the UH-60M over the UH-60L are: (1) a reduction in aircraft vibrations due to the introduction of the Active Vibration Control System (AVCS). The AVCS will provide an estimated 5 to 10 percent reduction in incidents related to airframe cracking, popped rivets, loose hardware, and avionics failures, (2) the elimination of the currently required battery and rotor blade indicator inspections, which is estimated to reduce overall required inspections by 5 percent, and (3) an estimated 10 percent reduction in maintenance of structural components, drive subsystems, and airframe-mounted components due to decreased vibration.

Although the UH-60M is projected to fall slightly short of the threshold requirements for MTBF of 18 hours and MTBM of 4.5 hours, and fall significantly short of the 21 hour MTBF and 5.2 hour MTBM objective requirements, it may still be feasible for the UH-60X to meet these requirements. The UH-60X improved turbine engine is projected to be 20 percent more reliable than the current 701D engine in the UH-60M. The fly-by-wire flight control system eliminates 471 mechanical parts and is projected to improve the reliability of the flight control system by over 200 percent, according to Utility Helicopter project office estimates. Using Mr. Whaley's methodology to adjust the reliability model to account for these two changes alone would allow the UH-60X to meet the Army's threshold requirement for MTBM of 4.5 flight hours.[11] This analysis, however, is based on UH-60M projected improvements that rely heavily on reduced vibration. The true extent to which vibration is reduced cannot be known without actual flight-test data.

Michael E. Ryan, in his master's thesis, *The Reliability Challenge: Common Pitfalls, and Strategies for Maximizing Inherent Reliability Performance of Weapon*

[11] Source: Interview with Mr. Lindell Whaley, Nov. 2003.

*Systems* concludes that "Demonstration of required reliability performance levels prior to system fielding has remained a challenge for the Army, and in recent years, the success rate of systems achieving their stated reliability performance in operational tests has declined." He cites the Army Test and Evaluation Command's (ATEC) claim that from 1998-2000 only 36 percent of Army systems in development or operational testing were able to demonstrate the required mean time between failures (MTBF). Of those programs that failed, 61 percent failed to achieve half of their reliability requirement. [Ref. 51, p. 25]

Considering that Army systems historically fail to meet reliability targets, and considering that reliability predictions are based on models, rather than actual testing data, there appears to be at least some probability that an upgraded and recapitalized UH-60 fleet would not meet supportability requirements as specified in the ORD. This makes the supportability risk level moderate, using the program office definitions of supportability risk. Low supportability risk implies that the system is likely to meet reliability targets.

## G. PROJECTED UPGRADE COSTS

This chapter makes estimates regarding the technical feasibility of upgrading the UH-60 fleet to meet more aggressive performance requirements. The chapter does not offer a thorough analysis of what the unit cost of the UH-60X would be. There are many variables that will affect unit cost, and members of the UH-PMO are not yet able to assert what the UH-60X would cost while in full-rate production. As a rough estimate, the Program Manager suggests that for the purpose of our analysis, an upgraded UH-60X that meets all requirements might have a unit production cost of approximately $15 million[12].

Certain elements of the upgrade program have been examined in sufficient detail to develop cost estimates. The fly-by-wire upgrade is projected to have RDT&E costs of

12 Interview with COL William Lake, Program Manager, Utility Helicopters, 17 Dec 2003.

$55 million and increase the unit production cost of the helicopter by $600,000[13]. The Army's new engine program ITEP has an RDT&E budget of $275 million, and is expected to have a unit production cost of one million dollars, which is approximately $350,000 more than the current production engine in the UH-60M[14]. The Project Office does not have official estimates for upgrading the transmission and drive train, which is necessary to capitalize on the increased power of the new engines. The transmission and gearboxes from Sikorsky's new H-92 are sufficient to meet power requirements, and will fit into the UH-60 airframe. The H-92 transmission and gearboxes cost approximately $500,000 more to manufacture than the current UH-60M transmission and gearboxes[15]. This might be a reasonable estimate for the transmission and drive train upgrade production costs.

## H. CHAPTER SUMMARY

It appears technically feasible that the UH-60 fleet can be upgraded to meet the Army's 9,000-pound lift requirement at 4,000 feet and 95 degrees with the development of an improved engine, transmission, and rotor system – which will require airframe modifications. There appears to be little cost, schedule, or performance risk with the Army's ten-year plan to develop the new engine. There may be significant technical risk, however, in modifying the airframe to accommodate a larger rotor system.

It is also technically feasible to improve the flight handling characteristics of the UH-60 and improve its performance in a degraded visual environment (DVE). The technology required to allow the aircraft to operate in all weather environments is also mature, and although no program is currently planned or funded, there is little technical or performance risk. Fully meeting the Army's future requirements for improved flight handling qualities, however, will require equipping the UH-60 with a fly-by-wire flight

[13] Interview with COL William Lake, Program Manager, Utility Helicopters, 17 Dec 2003.

[14] Interview with COL William Lake, Program Manager, Utility Helicopters, 17 Dec 2003.

[15] Interview with Mr. Andy Kieth, Manager, Sikorsky U.S. Government Advanced Designs.

control system and adopting new flight control laws. Fly-by-wire technology and velocity command control laws are both mature technologies, and have been demonstrated on the Army's Comanche prototypes, but no existing production aircraft (rotary or fixed wing) has ever been upgraded or modified to a fly-by-wire system. This upgrade should be considered moderate technical risk because design iterations and testing are required.

The UH-60 may be able to meet the Army's requirement for increased reliability. Computer modeling and analysis indicates the UH-60M will be able to achieve moderate (10-15 percent) improvements over the UH-60L. [Ref. 11, p. 11] Modeling and analysis show that the UH-60M will fall short, however, of the Army's requirement for MTBF and MTBM. Adjusting the UH-60M reliability growth model to include the increased reliability that is projected for the improved turbine engine and fly-by-wire flight control system indicates that the UH-60X might meet the requirements for both MTBF and MTBM. This should be treated as an area of moderate risk, however, because the analysis is based on computer models of projected component performance, not flight-test data. A summary of the various UH-60 models' performance is shown in the chart below.

**Table 3. UH-60 Models Performance Comparison Chart**

| **Requirement** | **UH-60L** | **UH-60M (Increment 1)** | **UH-60 M (Increment 2)** | **UH-60X** |
|---|---|---|---|---|
| Lift capacity (9000 lb in high/hot conditions) | 6,000 pounds **Does not meet requirement** | 6,000 pounds **Does not meet requirement** | 6,000 pounds **Does not meet requirement** | 9,000 pounds **Projected to meet requirement** *Significant risk in lengthening tail |
| Interoperability (1553B bus, open archit.) | **Meets requirement** | **Meets requirement** | **Meets requirement** | **Meets requirement** *Low risk |
| Flight Handling Characteristics (fly-by-wire, assisted flight) | **Does not meet requirement** | **Does not meet requirement** *Partial solution to brown-out | **Meets brown-out reqmt.** *Moderate technical risk in fly-by-wire **Does not meet all-weather requirement** *Technology is mature | **Meets brown-out requirement** *Moderate technical risk in fly-by-wire system **Does not meet all-weather requirement** *Technology is mature & low risk |
| Survivability | **Meets requirement** | **Meets requirement** | **Meets requirement** | **Meets requirement** |
| Supportability | Does not meet requirement | Does not meet requirement | Does not meet requirement | **May meet requirement** *Moderate technical risk |
| 4.5 hrs MTBM<br><br>18 hrs MTBF | 3.8 hours<br><br>12.6 hours | 4.3 hours (projected)<br>15.5 hours (projected) | 4.4 hours (projected)<br>Unknown | 4.5 hours (projected)<br>Unknown |

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# VI. ANALYSIS OF MATERIEL ALTERNATIVES TO THE UH-60

## A. CHAPTER OVERVIEW

The purpose of this chapter is to explore the material alternatives to meeting the Army's future utility helicopter requirements. The current utility helicopter fleet does not meet requirements, nor does the planned version of the UH-60M that is in the prototype phase of development. As noted previously in this report, there are essentially three material alternatives to meet future requirements: (1) make further upgrades to the existing fleet in order to meet requirements, (2) procure a non-developmental item (NDI) aircraft which meets requirements, and (3) start a new acquisition program to design an aircraft which meets requirements. This chapter addresses alternatives two and three.

## B. NON-DEVELOPMENTAL ITEMS

A market survey was conducted to select aircraft for consideration from among all domestic and international production aircraft. According to *Jane's All the World's Aircraft* there are 147 rotary wing aircraft currently in production. Of these 147, 75 are considered utility helicopters. [Ref. 58, p. 27] To narrow the field of options, the aircraft can be screened according to maximum external lift capability. Because the Army has a requirement for 9,000 pounds of lift capacity, aircraft with maximum external lift capacity below 9,000 pounds can be screened from further consideration. The eight helicopters meeting these initial screening criteria are listed below.

**Table 4. NDI Aircraft Lift Capacity at Sea Level**

| Aircraft | Maximum External Lift (pounds) |
|---|---|
| Mil Mi-26 | 44,090 |
| Mil Mi-38 | 15,432 |
| Mil Mi-17 | 11,023 |
| Boeing CH-47D | 28,000 |
| Sikorsky UH-60L | 9,000 |
| EH Industries EH101 | 12,000 |
| Eurocopter Super Puma Mk II | 11,023 |
| Sikorsky H-92 | 10,000 |

Due to regional economic instability and longstanding political alliances, it seems unlikely that the United States would consider the purchase of a Russian Federation aircraft, so the three Russian Federation Mil helicopters can also be screened from further consideration. This leaves five production aircraft for consideration, one of which is the Army's current UH-60L, which does not meet future requirements. This section of the paper examines the remaining five aircraft in greater detail; specifically with respect to how well each might meet the Army's future requirements for lift capacity, interoperability, flight handling characteristics, and survivability.

### 1. Lift Capacity

The Army has identified a requirement for a 9,000-pound external load capability at 4000 feet pressure altitude and 95 degrees Fahrenheit. However, specific information about aircraft performance at 4,000 feet and 95 degrees is not readily available for aircraft manufactured outside the United States. Table 5 shows the maximum external lift capacity of each aircraft at sea level as cited in *Jane's All the World's Aircraft*.

**Table 5. Lift Capacity of NDI Alternatives**

| Aircraft | Max external load (lbs) at sea level | Estimated lift capacity (lbs) at 4000 ft & 95° | Empty weight (lbs) | Total shaft horse power (SHP) | Payload/ SHP | Weight/ SHP |
|---|---|---|---|---|---|---|
| UH-60L | 9,000 | 6,300 | 11,516 | 3,800 | 2.37 | 3.03 |
| CH-47D | 28,000 | 19,600 | 25,463 | 8,150 | 3.44 | 3.12 |
| H-92 | 10,000 | 7,000 | 15,200 | 4,068 | 2.46 | 3.74 |
| EH101 | 12,000 | 8,400 | 20,613 | 6,000 | 2.00 | 3.44 |
| Super Puma | 11,000 | 7,700 | 10,900 | 3,314 | 3.32 | 3.29 |

Source: Ref. 58

A simple technique to estimate aircraft performance at 4,000 feet and 95 degrees is to compare the lift capacity of the Army's current UH-60L at sea level with its lift capacity at 4,000 feet. The UH-60L loses approximately 30 percent of its lift capability between sea level and 4,000 feet. Using this as a general approximation, it is possible to roughly estimate the performance of each aircraft at 4,000 feet and 95 degrees by reducing its performance at sea level by 30 percent.

Using this estimation technique, only the CH-47 meets the Army's lift requirement, although the EH101 is too close to rule out on the basis of a general estimate. It seems almost certain, however, that both the H-92 and the Super Puma would require modification to meet the lift capacity requirement.

### 2. Interoperability

In order to be interoperable with the Army's future digital forces, an aircraft must: (1) have a system architecture including the MIL-STD-1553 data bus, (2) be able to accept the new Joint Tactical Radio System (JTRS) currently under development, and (3) have an open systems architecture that will support integration of future digital command and control systems. Both the EH101 and the H-92 have the MIL-STD-1553 data bus and would likely require little modification for interoperability. Neither the current production CH-47 nor the UH-60 has the MIL-STD-1553 data bus, although the upgraded MH-47E does. The Super Puma does not support the MIL-STD-1553 data bus. The current production versions of the UH-60, CH-47, and Super Puma would require modification and design integration to achieve the required interoperability.

### 3. Flight Handling Characteristics

Fully meeting the Army's requirement for improved flight handling characteristics will require an aircraft optimized for operations in a degraded visual environment (DVE) with the capability to conduct precision troop insertions in all weather and environmental conditions. To meet this requirement an aircraft will need a fly-by-wire flight control system with new flight control laws and some form of integrated terrain-following radar or forward-looking infrared (FLIR) radar.

None of the production aircraft under consideration are fly-by-wire. The only production helicopters in the world with a fly-by-wire flight control system are the U.S. Army's Comanche and the French NIH-90, both of which are still in the prototype phase. (The NIH-90 is a utility helicopter but was screened from consideration because it did not meet lift criteria.)

The H-92 and the EH101 were both designed with optional FLIR, and the H-92 was designed with optional terrain-following radar. Upgraded versions of the CH-47 have been modified with terrain-following radar, and have demonstrated the ability to operate in all weather conditions. The Super Puma does not have FLIR or terrain-following radar. Consequently, none of the NDI alternatives will meet the Army's requirement for improved flight handling characteristics without modification.

**4, Survivability**

The Army threshold requirement for survivability dictates that future utility helicopters have an aircraft survivability suite at least equal to that of the UH-60, and have a radar cross-section and IR signature not greater than that of the current UH-60L.

The UH-60L is approximately 65 feet long and does not use stealth technology to minimize its radar cross-section. It has two 1,860 shaft horsepower (SHP) engines, and is equipped with an exhaust suppression system that reduces the engines' IR signature. The UH-60L is also equipped with a threat radar detection system, a threat radar countermeasure (chaff), and a countermeasure to reduce the effectiveness of incoming IR seeking missiles. Finally, the aircraft is equipped with two 7.62 mm machine guns and provides armament protection for the crew against small arms fire up to 7.62 mm.

Radar cross-section is basically a function of aircraft size. Without some type of radar cross-section reduction (i.e., stealth) measures, larger aircraft will have larger radar cross-sections. None of the NDI aircraft have any stealth characteristics. The CH-47 and the EH101 are significantly larger than the UH-60L, and will have larger radar cross-sections. The H-92 is five feet longer than the UH-60L and can be estimated to have a slightly larger radar cross section.

Countermeasures are considered mission equipment and would likely be easy to integrate into any of the NDI aircraft under consideration. Unlike radar cross-section, the UH-60 countermeasure suite could be integrated into any new production aircraft.

Survivability attributes of the five NDI alternatives are outline in the table below. Of the five, only the UH-60L meets the UH-60's survivability threshold requirements without modification.

**Table 6. NDI Survivability Characteristics**

| | UH-60L | EH101 | CH-47D | Super Puma | H-92 |
|---|---|---|---|---|---|
| Length | 64' | 75' | 99' | 64' | 69' |
| Radar Warning Receiver (RWR) | Yes | Yes | Yes | Yes | Countermeasures TBD No military version produced as of 2003 |
| Missile-approach warning system (MAWS) | Yes | Yes | Yes | Yes | |
| IR suppression | Yes | No | No | No | |
| Chaff dispenser | Yes | Yes | Yes | Yes | |
| Flare dispenser | No | Yes | Yes | Yes | |
| Ballistic tolerance to 7.62mm | Yes | Yes | No | No | |

Data Source: Ref. 58

In summary, as explained in the table below, there is no helicopter currently in production that will meet the Army's Objective Force requirements. Adopting any of these existing helicopters would require an unacceptable decrease in Objective Force requirements.

**Table 7. NDI Comparative Summary**

| | UH-60L | EH101 | CH-47D | Super Puma | H-92 |
|---|---|---|---|---|---|
| Lift capacity (9000 lbs at 4000 feet and 95° F) | No (6,250 lb) | Perhaps (Estimate 8,400 lb) | Yes (Estimate 19,000 lb) | No (Estimate 7,700 lb) | No (Estimate 7,000 lb) |
| Interoperability | No (UH-60M yes) | Yes | No (CH-47E yes) | No | Yes |
| Flight handling characteristics | No | No | No | No | No |
| Survivability | Yes | No (Radar cross-section, IR signature) | No (Radar cross-section, IR signature) | No (IR signature) | No (Radar cross-section) |
| Purchase price in millions (2003 dollars) | $9.2 | $24.5 | $32 | $16.3 | $14 |

Data Source: Ref. 58

## C. NEW ACQUISITION PROGRAM

Estimating the cost of a new acquisition program is difficult, particularly when there are requirements to incorporate new technologies. There are many interdependent variables to consider, and cost overruns in the defense industry are common. A technique to estimate design and development costs for a new acquisition program would be to average the three most recent utility helicopter development programs. *Jane's All the World's Aircraft* lists design and development costs for the EH-101, H-92, and NH-90 as shown in the table below. Also included in the table below are the design and development costs for the UH-60 as provided by the Project Management Office. Using these programs as a baseline, the cost of an average utility helicopter design and development program can be estimated at approximately $989 million. The time to develop each aircraft in the sample, computed as the time between the initiation of concept development and the delivery date of the first production aircraft, yields an average development time of about 14 years.

**Table 8. Utility Helicopter Development Costs and Timelines**

| **Helicopter** | **Design Cost (2003 dollars)** | **Time to Develop** |
|---|---|---|
| EH-101 | $456M | 14 years |
| H-92 | $600M | 12 years |
| NH-90 | $1.6B | 18 years (delivery projected in early 2004) |
| UH-60 | $1.3B | 11 years |

Source: Ref. 58

It is possible to estimate the unit procurement cost of a potential new aircraft using the parametric estimation method. According to the Utility Helicopters Project Office, the three main cost drivers on utility helicopters are the engine, transmission, and rotor system. These three components make up the aircraft drive train, and drive train determines lift capacity. A comparison of maximum external lift capacity to average unit procurement cost reveals that there is a positive linear relationship (with a correlation coefficient of approximately 0.85) between lift capacity and unit cost (assuming unit price equals unit cost for the aircraft.) A regression analysis of the NDI alternatives considered in this chapter suggests that a potential new aircraft meeting the Army's external lift requirements would have an average unit procurement cost of approximately $18.3 million[16]. Figure 5 shows the average unit procurement cost of the five NDI aircraft and the maximum external lift capacity of each aircraft.

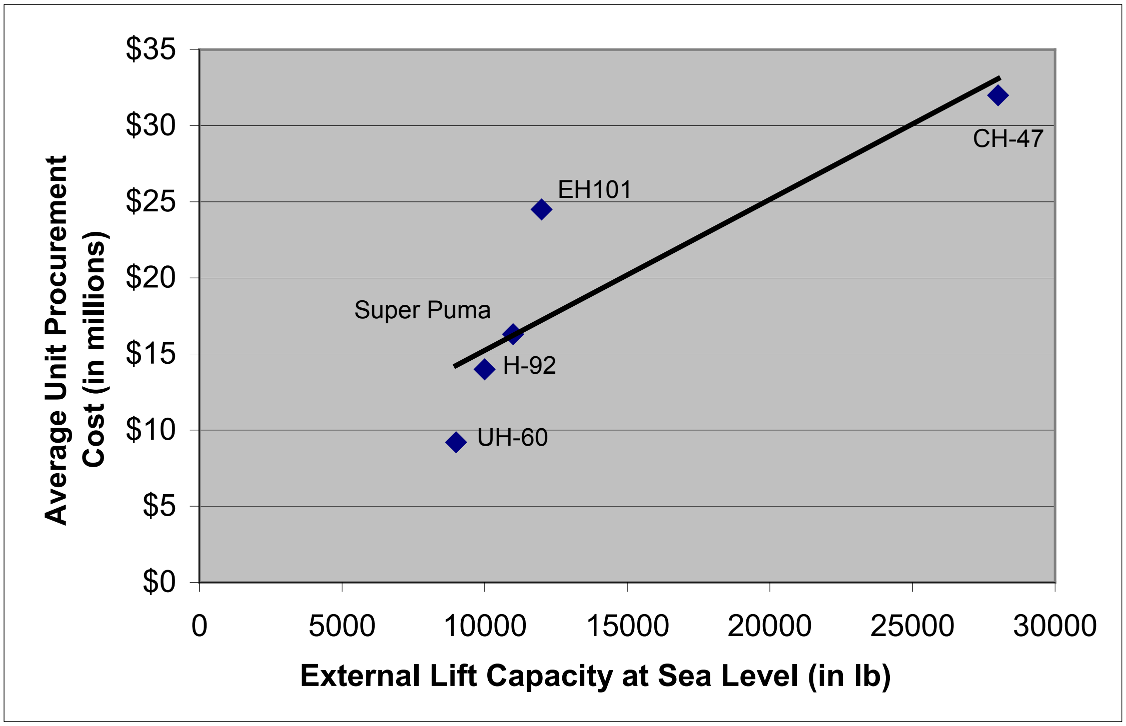


**Figure 4. Cost Trend Analysis Based on Payload**

To produce an aircraft with maximum external lift capacity greater than the H-92, but less than the CH-47, it would be reasonable to estimate that the unit cost would be approximately $18.3 million.

## D. CHAPTER SUMMARY

This chapter presents analysis to suggest that there is not a helicopter currently in production in the world that can meet the Army's Objective Force requirements. The chapter also provides analysis to indicate that a new acquisition program would require

[16] Assuming aircraft lose approximately 30 percent of sea-level lift capacity at 4,000 feet, the Army would need an aircraft capable of lifting approximately 13,000 pounds at sea level to meet requirements.

on the order of about 14 years and $989 million for development, and would produce helicopters with an average unit procurement cost of approximately $18.3 million.

# VII. FINDINGS AND RECOMMENDATIONS

## A. CHAPTER OVERVIEW

As noted in Chapters I and II, the Army conducted its most recent evaluation of the requirements for the Utility Helicopter fleet in 2000. This evaluation resulted in a plan to provide an incrementally more capable fleet, first with the UH-60M starting in 2007, then with the FUR starting in about 2015.

Since 2000, Department of Defense needs and priorities have since changed. The Aviation Director of Combat Developments, the Utility Helicopters Project Office and others recognize the need to review requirements and acquisition strategies in light of these changes. This chapter makes recommendations for consideration for the new requirements generation process and the analysis of alternatives that precedes the selection of a new acquisition strategy.

## B. FINDINGS AND RECOMMENDATIONS

### 1. UH-60M Upgrade Program

**Implement Fly-by-Wire.** The UH-60's lack of improved flight handling characteristics is a serious requirements shortfall, given the Army requirement to conduct precision troop and equipment insertions in all weather and environmental conditions.

In the current two conflicts, more utility aircraft have been lost due to brown-out accidents than any other cause, including enemy fire. As the Army focuses more on asymmetric conflicts, all-weather operation becomes more critical. In a symmetric battlefield, bad weather tends to affect both forces engaged. In an asymmetric conflict, however, where the United States and its allies are the only force with a significant aviation capability, poor weather will limit friendly capabilities more than the enemy's. Without an all-weather capability, inclement weather favors enemy operations.

A fly-by-wire flight control system is needed to meet these requirements, as well as meeting lift and supportability requirements. Because no production aircraft has ever been upgraded to a fly-by-wire flight control system, though, this entails moderate technical risk. A fly-by-wire flight control system may stress the airframe in unpredictable ways, which may require airframe strengthening or other modifications, which may affect aircraft weight or center of gravity.

The Utility Helicopter project office estimates that the fly-by-wire upgrade program will have RDT&E costs of $55 million dollars, and increase the average unit procurement cost of the UH-60M by $600,000. Fully funding the fly-by-wire program and accelerating its introduction, beginning in fiscal year 2007 if possible, will fulfill a crucial component of the acquisition strategy and provide critical operational capability.

**Upgrade the UH-60M engine.** The Army must develop a new, more powerful engine to meet lift requirements, whether it pursues the UH-60X upgrade program or a new aircraft design program. Designing the new engine to be compatible with the current UH-60M drive train will allow integration of the new engine into the UH-60M upgrade program.

The new, more powerful engine could be governed to prevent over-torques, and allow the aircraft to operate up to the limits of the existing transmission. Given the existing drive train limitations, the UH-60M could lift up to 7,600 pounds at 4,000 feet and 95 degrees with more powerful engines. This would be a 27 percent increase in maximum lift capacity over the current UH-60M.

The Utility Helicopter project office estimates that the proposed new engine developed through the Improved Turbine Engine Program (ITEP) would have a unit cost of roughly $1 million, which is approximately $350,000 more than the current 701D engine in the UH-60M. This would increase the average unit procurement cost of the UH-60M from $10.6 million to $11.0 million. This appears to be a very cost effective upgrade, increasing lift capacity by 27 percent while only increasing unit cost by 4 percent, and allowing the Army to capitalize on the significant RDT&E cost of the new engine for the UH-60X/FUR program.

### 2. UH-60X / Future Utility Rotorcraft

**Non-developmental aircraft do not meet Army requirements.** No aircraft currently in production meets the Army's requirements for lift capacity and improved flight handling characteristics. The only aircraft in production that meets the Army's lift requirement is the CH-47, which does not meet survivability or flight handling characteristics. The only fly-by-wire aircraft currently in production is the French NH-90, which was screened from consideration due to insufficient lift.

**Pursue a new utility helicopter to meet Future Utility Rotorcraft requirements.** Meeting requirements by making further modifications to the current UH-60M upgrade plan appears to be more affordable than a new acquisition program, at least in the short term. The Army's Utility Helicopter Project Office estimates that producing an upgraded UH-60X that meets all requirements will have an average unit procurement cost of roughly $15 million per helicopter.[17] Parametric estimates for a new acquisition program suggest that a new utility helicopter meeting lift capacity requirements might have an average unit procurement cost of approximately $18.3 million. However, evolving the UH-60M to the UH-60X involves high technical risk, according to program definitions of risk. Ultimately, even if none of the technical risks develop into significant cost or schedule overruns, and the UH-60X meets performance thresholds, the Army will have a $15 million upgrade to a 20-year old (plus) airframe that marginally meets a lift requirement written in 1999. The Army should consider a new acquisition program to design a new aircraft to meet Objective Force requirements. The new aircraft could be designed around an improved engine that could be retrofitted to the current UH-60M. This would allow the Army to capitalize on the engine design cost for its new helicopter and provide significant increased lift capability for the rest of the utility helicopter fleet.

**Re-evaluate the 9,000 pound external lift requirement in light of cost data.** An analysis of alternatives using cost as an independent variable (CAIV) analysis would

[17] Interview with Colonel William Lake, Project Manager, Utility Helicopters, 17 Dec 2003.

determine the program risk associated with stretching the UH-60 airframe to achieve the full 9,000-pound lift requirement. Initial engineering estimates indicate that a new engine and transmission, with the existing rotor system, would allow the UH-60M to lift 8,600 pounds at 4,000 feet and 95 degrees. This upgrade would increase the unit production cost of the UH-60M by approximately $850,000. Further increasing lift capacity to 9,000 pounds will require a larger rotor system, which in turn requires extending the airframe to provide clearance between the main and tail rotors. This upgrade might increase the unit production cost by as much as an additional $3 million.

Our analysis suggests that a UH-60 with an improved engine, transmission, and fly-by-wire capability will cost $12 million and provide 8600 pounds external lift. As previously mentioned, the UH-60X will provide 9000 pounds lift and cost approximately $15 million. It seems that increasing lift from 8600 pounds to 9000 pounds will cost about $3 million. We recommend that the Army study the impact of reducing the objective lift requirement to the more affordable 8600 pounds.

A near-term alternative to lengthening the UH-60 airframe is to transfer some utility helicopter tasks to the CH-47, especially considering that an upgraded UH-60M might only fall 400 pounds short of the Objective Force lift requirement. The chart below shows estimated cost and lift capacities of various versions of the UH-60 airframes.

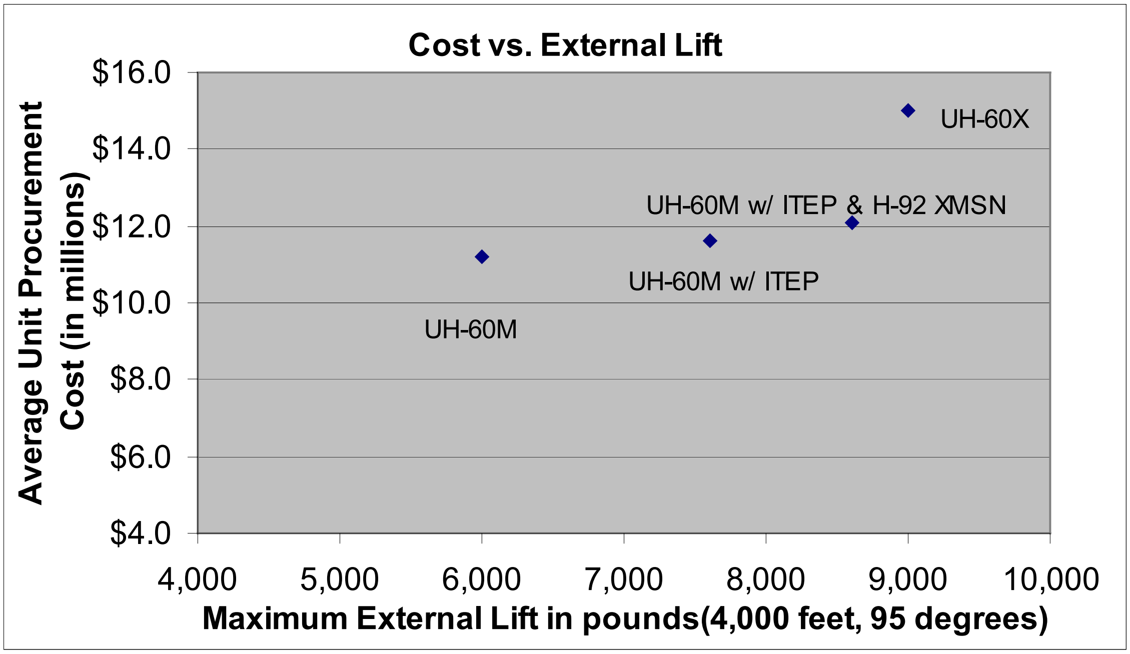


**Figure 5. Cost vs. Lift Capabilities of UH-60 Upgrades**

**Study the cost and feasibility of a single new development aircraft to fulfill both utility and cargo roles in the Objective Force.** Objective Force literature (specifically the FCS ORD) describes roles for the UH-60 and the CH-47 that are quite similar. The practice of maintaining two platforms to fulfill the single basic mission of aerial transport contradicts the stated Objective Force goals of non-contiguous operations, reach-back logistics, systems commonality, and exceptional reliability. If affordable, a future cargo/utility rotorcraft capable of both the UH-60's versatility and the CH-47's cargo capacity, with increased reliability, supportability, and survivability, could be the ideal solution to Objective Force requirements, especially if developed in coordination with a system to fulfill the requirements the Army has identified for an Air Mobility Transport – Tilt Rotor (AMT-T)-like heavy transport capability.

### 3. Requirements Determination

**Define requirements in terms of capabilities.** When determining both requirements and the criteria for the analysis of alternatives, consider the shift away from threat-based requirements to capabilities-based requirements. In light of the Department of Defense's current and probable future emphasis on inter-service integration, including commonality of processes and equipment, the requirements development effort for the FUR requires the fullest possible representation from other services and agencies

**Quantify all requirements.** Some of the requirements identified in the ORD for the UH-60M and the FUR are not quantitatively defined. For example, neither survivability nor supportability requirements are well-defined in Objective Force literature, and consequently are not well-addressed in the UH-60 ORD. Specifically quantifying requirements wherever possible strengthens them against misinterpretation.

# APPENDIX A. DETAILED OBJECTIVE FORCE UTILITY HELICOPTER REQUIREMENTS

**Table 9. Objective Force Specified Utility Lift References**

| **Source** | **Objective Force Requirement** |
|---|---|
| FCS ORD 2952 | "All FCS UMS [unmanned systems] must be capable of being carried during AASLT/air mobile by UH-60 and/or CH-47 helicopters in a high altitude, (4,000 foot pressure altitude), hot temperature (95 degrees F.) scenario for a radius of at least 75-150 km. The vehicle operators/crew will travel inside the helicopter and will be considered as part of the helicopter cargo. (Objective)" |
| FCS ORD 3828 | "A fully loaded FCS ARV-A (L) must be carried by UH-60 with one of these platforms per helicopter under high-hot conditions, with supplies and with the operators and their equipment inside the helicopter. (Threshold)" The ARV-A(L) is expected to have a full combat weight of approximately 2.5 tons, including a basic load of 1000 7.62mm rounds and 2 Javelin missiles. [Ref. 40, p. 3-18] |
| FCS ORD 1341 | "A fully loaded FCS MULE must be carried by UH-60 with one of these platforms per helicopter under high-hot conditions, with supplies and with the operators and their equipment inside the helicopter. (Threshold)" The MULE is expected to have a full combat weight of approximately 2.5 tons, [Ref. 40, p. 3-18] including 2400 pounds of squad/platoon equipment and supplies. [Ref. 34, p. E-2-B-2] |
| FCS ORD 3264 | "The [NLOS-LS] launch unit must be transportable by (sling load) UH-60." The NLOS-LS is expected to have a full combat weight of 1.4 tons, including a basic load of 15 missiles. [Ref. 40, p. 3-26] |
| FCS ORD p. G-3 | "The UH-60 Black Hawk will provide lift, command and control, and logistical support to units in the FCS-equipped UA Force. It will operationally and tactically move forces throughout the battlespace to achieve full spectrum dominance." |
| UA O&O p. 4-49 | "The UE utility aircraft that support the air assault are equipped with the same COP [common operating picture] as the ground element." |

**Table 10. Objective Force Responsiveness and Deployability Requirements**

| Source | Objective Force Requirement |
|---|---|
| FCS ORD 1015, 1021 | Employ and return over operational distances of up to 475 kilometers (400 km operational movement plus 75 km tactical radius) without in-flight re-supply, to keep pace with Objective Force ground maneuver during the initial stages of a campaign. |
| OF Avn Concept p.21 | Self-deploy worldwide and be rapidly operational with minimal support upon arrival. Be air-transportable with minimal preparation effort. Operate in and from unimproved areas. Conduct shipboard operations. |

**Table 11. Objective Force Agility and Versatility Requirements**

| Source | Objective Force Requirement |
|---|---|
| OF Avn Concept p.18, FCS ORD 1020 | Operate precisely, effectively and continuously (24 hours a day) over a non-contiguous battlefield, in any threat environment, day and night, in a wide assortment of terrain, weather, and visibility, in order to enable the Objective Force to conduct full spectrum operations. |
| OF Avn Concept p.21 | Perform internal cargo transport with rapid loading and unloading, requiring minimum manpower, to include pallets able to be preloaded, rolled onto cargo aircraft, dropped at unit locations for unloading, and recovered on the next airlift mission. Perform external cargo transport with automatic hookup and sling load stabilization. |
| FCS ORD 1159 | Accomplish position/navigation (horizontal and vertical) to within one meter error with a low probability of detection or interception and in the presence of electronic jamming, to enable precision maneuver and improve survivability. |
| OF Avn Concept p.19 | Employ cognitive tools to aid crew members in system awareness and mission management during execution, allowing the crew to operate with their "eyes out of the cockpit" by monitoring aircraft status, assisting in communication, route planning, threat detection, and countermeasures. |
| OF Avn Concept p.22 | Provide mobile command posts that can operate on the ground and in the air, stationary or on the move. System must have NLOS communications capability. System must be interoperable across Army and joint C2 systems. System must be deployable, and air transportable. |
| OF Avn Concept p.24 | Design aviation units "with enough subordinate units to rotate them into and out of action without diminishing engagement tempo and intensity." Units will be modular, tailorable and standardized between echelons and components of the force. |

**Table 12. Objective Force Survivability and Lethality Requirements**

| Source | Objective Force Requirement |
|---|---|
| OF Avn Concept p.20, FCS ORD 1243 | Employ passive aircraft survival by avoiding detection by the threat, through the balanced use of signature reduction, low observables, SA, and systems capable of providing warning about the total spectrum of ground and air threats. |
| OF Avn Concept p.20 | Employ active aircraft survival by neutralizing threat detection acquisition, and by countering weapon systems through active countermeasures, or by attacking with fire and forget, rapid-reaction weapons at maximum ranges. |
| OF Avn Concept p.20, FCS ORD 3708, 3709 | Detect and avoid chemical, biological, and radiological contamination and, if exposed, to be rapidly and safely decontaminated. Be fully survivable against the effects of electro-magnetic pulse, and hardened against the material damaging effects of contaminants and decontaminants. |
| OF Avn Concept p.20 | Detect and avoid natural and man-made obstacles to include anti-helicopter mines, wires and cables. |
| OF Avn Concept p.20 | Survive ballistic impact, thermal, and overpressure effects of weapons. |
| OF Avn Concept p.20 | Protect crew and passengers from injury in aircraft accidents. Minimize aircraft and systems damage in accidents. |
| FCS ORD 3567 | From standoff range, detect, identify, report through the C4ISR architecture, mark, and neutralize ground-to-air threats, to improve survivability on a non-contiguous battlefield. |
| FCS ORD 2838 | Be capable of directing precision, cooperative NLOS effects, to preserve the system's own freedom of movement in the presence of threats. |
| FCS ORD KPP 7 | Be capable of dash speed in order to escape threats that cannot be otherwise countered. |
| FCS ORD 2737 | Survive the effects of directed energy weapons and radio frequency (RF) threats. |

**Table 13. Objective Force Sustainability Requirements**

| Source | Objective Force Requirement |
|---|---|
| FCS ORD KPP 5 | Significantly reduce logistics footprints and personnel efficiencies in the area of operations through reduced demand for maintenance and supply. |
| FCS ORD 1239, 3806 | Increase systems reliability and availability, commensurate with ground maneuver system improvements, to reduce maintenance requirements. |
| FCS ORD 1240 | Incorporate an embedded readiness system that monitors the status of components/subsystems, crew, and consumables, forecasts equipment degradation/failure and communicates real-time system readiness status across the battle command network. |
| OF Avn Concept pp.15, 27 | Standardize aircraft components to facilitate logistics support, and incorporate open system design where new must integrate with the old.. |
| OF Avn Concept p.22 | Improve ground maintenance efficiency through diagnostic, prognostic and expert systems to isolate failures and potential failures, and to optimize maintenance scheduling. Maximize the use of common tools and equipment, and minimize peculiar support equipment. |
| FCS ORD p. 65 | Be fully supported by a two level maintenance system of field maintenance (consisting of on-system component replacement) and sustainment maintenance (consisting of off-system component repair). |
| OF Avn Concept p.22 | Reconfigure systems in response to component degradation or failure during mission execution, so that the mission can be completed rather than aborted. |

**Table 14. Objective Force Information and Interoperability Requirements**

| Source | Objective Force Requirement |
|---|---|
| OF Avn Concept p.19, FCS ORD 1016 | Integrate into the Objective Force mission planning and rehearsal system during movement by air, land, and sea, in order to ensure effective situational understanding and airspace utilization. Have the capability to plan, rehearse, re-plan, and revise aviation missions enroute, and readily communicate with adjacent and theater-wide mission planning systems. |
| FCS ORD KPP 2 | Integrate into the Objective Force battle command network and airspace management systems, and provide situational awareness at the platform level, to enable distributed operations. |
| OF Avn Concept p.18 | Be capable of inter-theater secure, jam-resistant, air-to-ground, ground-to-air, and air-to-air transmission and receipt of voice and data secure communications while in nap-of-the-earth flight conditions in both LOS and NLOS situations. |
| OF Avn Concept p.18 | Employ data transmission rates fast enough to permit rapid handover of voluminous messages and situational awareness data. |
| OF Avn Concept pp.18, 26, FCS ORD 1120 | Employ communications systems compliant and interoperable with Army, joint, combined, coalition, and interagency voice, data, and imagery communication standards, that degrade gracefully when components fail, are hardened against information warfare threats, and will support all top-level FCS and Objective Force information exchange requirements (IERs). |
| FCS ORD 1093 | Include networked, embedded, virtual, Full Task Training (FTT) to support individual, crew, and multi-echelon training without reconfiguration of the equipment. |
| FCS ORD 2850 | Provide combat identification (CID) of friend or unknown in a Joint/ Allied/Coalition environment to the individual soldier level under all battlefield and weather conditions across the spectrum of operations, compatible with the Battlefield Combat Identification System (BCIS) and Identification, Friend or Foe (IFF) systems. |

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# APPENDIX B. RISK MANAGEMENT METHODOLOGY

The basic strategy of the UH-60M risk management approach is to identify critical areas and risk events, both technical and non-technical, and take necessary actions to prevent cost, schedule, and/or performance impacts. The IPTs serve as the key focal point for accomplishing risk management activities and performing the risk management process. This approach allows the UH-60M project to gain multi-functional information from team members with functional expertise in all areas.

Integrated risk management efforts focus on monitoring and managing program elements which may impact the success of the program by utilizing technical performance measurement, cost, and schedule tools, in existence and in use by the PM and the Contractor. Identification of these areas through the IPT process may result in further evaluation of the risk management process and the identification of new risk elements. The continuous feedback and update cycle of the RMP provide the UH-60M program with the means to predict future resource requirements, as well as manage near term goals.

The risk management process identifies a hierarchy of risks that may potentially impact the successful achievement of program goals, objectives, thresholds, and/or established program milestone exit criteria. For consistency throughout the program, the risk level definitions in have been developed.

**Table 15. Risk Management Matrix**

| Rating | Technical | Schedule | Cost | Supportability |
|---|---|---|---|---|
| Low | Previously demonstrated technology. Requires integration and testing. Manageable within PM's discretion. | Plans and forecasts indicate successful accomplishment of milestone within 10% of planned schedule. | Actuals plus forecasts indicate completion within < 10% growth of anticipated costs. | Likely to meet supportability requirements. |
| Moderate | Brassboard technology demonstrated. Design iterations and testing required. Potential serious impacts, but manageable within current requirements. | Plans and forecasts indicate a potential of >10% but <20% additional schedule growth may be required. | Actuals plus forecasts indicate >10% but £ 20% growth of anticipated costs. Manageable within current management reserves. | Possible support constraints or deficiencies. Sustainment cost constraints. |
| High | Concept and/or technology not demonstrated. Current analysis is not conclusive. Potential major impact that would require program restructure and/or revision of requirements. | Plans and forecasts indicate a potential of >20% additional schedule resources may be required. | Actuals plus forecasts indicate >20% growth of anticipated costs. Resources required exceed management reserves. | Potential major impact on supportability. |

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