

# Industrial Assessment for Helicopters



July 1995

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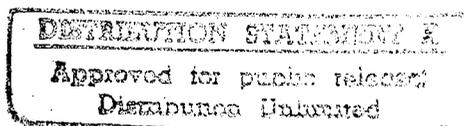


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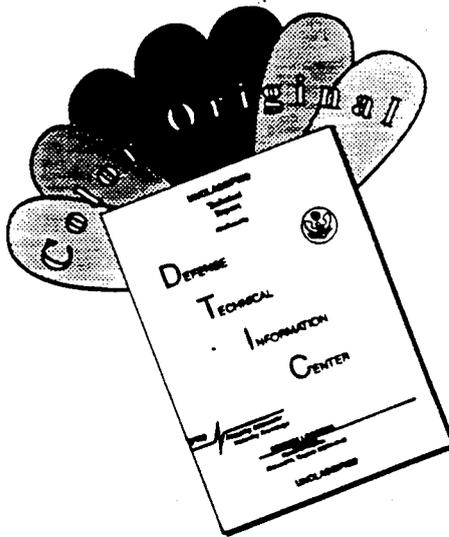
# Industrial Assessment for Helicopters

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## PREFACE AND ACKNOWLEDGMENTS

Victory in the Cold War era has brought significant changes to the defense industry. Since the peak year in 1985, the defense procurement and research, development, test, and evaluation budgets have declined by more than 50 percent in real terms. Defense suppliers have responded to these cuts in predictable ways. Factories have been restructured, reduced, or closed. Skilled personnel have been laid off. Some firms have merged or restructured; others have abandoned defense production entirely, and still others threaten to follow that course. These changes are vitally important to the Department. Therefore, the Department is taking steps to determine the effects of these changes on its ability to meet future mission requirements.

To this end, the Department is preparing selected industry studies to identify and analyze the effects of industrial concerns and to form the basis for budget and program decisions. This report describes the results of one of those studies--the Department's assessment of the helicopter industry.

This study was prepared under the direction of Mr. John Goodman, Deputy Assistant Secretary of Defense for Industrial Affairs. It was led by Mr. Larry Holcomb, Deputy Program Executive Officer, Army Aviation and Mr. Martin Meth, Director, Industrial Capabilities and Assessments, Office of the Secretary of Defense. Representatives from each of the Military Services, the Defense Logistics Agency, and the Office of the Secretary of Defense actively participated throughout the conduct of the study. The Department especially would like to acknowledge the contributions of Mr. Pete Bzdak and Mr. Ron Klein who served as primary technical advisors. Additionally, numerous individuals throughout the Department contributed substantial time and energy. This report would not have been possible without the support of Mr. Gilbert Decker, Assistant Secretary of the Army (Research, Development and Acquisition) and Vice Admiral William Bowes, Principal Deputy Assistant Secretary of the Navy (Research, Development and Acquisition) and the knowledge, professionalism, and hard work of Don Altholz, John Furey, Pat Guy, Sandy Korman, Bob Lauck, Steve Martinez, CAPT Ed Mihalak, Gary Powell, Paul Roche, Dan Rubery, and Mr. Andrus Viilu.

We welcome comments on this report. Please address them to Mr. John Goodman, Deputy Assistant Secretary of Defense (Industrial Affairs), 3300 Defense Pentagon, Washington, DC 20301-3300.

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## Executive Summary

The Department of Defense (DoD) uses helicopters<sup>1</sup> to meet a variety of military missions. The unique demands of these missions -- principally engaging an enemy -- require military helicopters to have capabilities that non-military "civil" ones do not need (Table ES-1). Although most civil helicopters are generally spin-offs of military models, they lack the specialized navigation and electronic equipment, weapon systems, and related systems that provide military capabilities.

Table ES-1  
Helicopter Missions

Role	Military	Civil
Combat	<ul style="list-style-type: none"> <li>• Attack</li> <li>• Armed Reconnaissance</li> <li>• Anti-Submarine Warfare</li> <li>• Airborne Mine Counter Measures</li> <li>• Special Operations</li> </ul>	
Combat Support	<ul style="list-style-type: none"> <li>• Aeromedical Evacuation</li> <li>• Observation</li> <li>• Search and Rescue</li> <li>• Utility (assault)</li> </ul>	
Services	<ul style="list-style-type: none"> <li>• Cargo (internal and external sling loads)</li> <li>• Utility</li> <li>• Courier</li> <li>• Training</li> </ul>	<ul style="list-style-type: none"> <li>• Aeromedical Evaluation</li> <li>• Personnel Transport</li> <li>• Cargo Transport</li> <li>• Utility</li> </ul>

The ability of the helicopter industry to meet DoD's requirements in the coming years has been a key question. This assessment finds that DoD can be confident that the helicopter industry will be able to meet military requirements for the foreseeable future. Specifically, this assessment finds that:

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<sup>1</sup> In this report, the term "helicopter" is used to refer to all helicopters and rotor aircraft, including the V-22 Osprey tiltrotor. The technology, design, production, hover, and low-speed flight characteristics of these aircraft are similar, and significantly different from fixed-wing aircraft.

- The Department relies on four domestic prime contractors for the majority of its helicopter needs.<sup>2</sup>
- Despite declining military sales, significant excess capacity, and strong foreign competition, all four of these prime contractors are currently profitable.
- Each of the four prime contractors possesses adequate capabilities for systems engineering and integration, and there are several capable suppliers for required subsystems and components.
- Although DoD is buying fewer helicopters, worldwide demand for larger, multi-engine turbine military and civil helicopters with modern electronic systems is expected to grow. Major US prime contractors believe that they are well positioned to compete vigorously for this business.
- Many analysts and industry observers believe that US helicopter industry prime contractor consolidation is likely. Subsystem/component suppliers have already begun to consolidate.
- Funded DoD programs, plus revenues from domestic civil sales, foreign sales, and DoD overhaul and maintenance demand will ensure that a sufficient number of capable suppliers remain to meet DoD's helicopter requirements for the foreseeable future.

## **A. Helicopters**

### **1. Helicopter Development**

Helicopters have evolved significantly since their initial development. The generation of helicopters now under development is substantially more capable than earlier generations. For example, whereas mission systems used to be added separately to the airframe, they are now being designed into helicopters, like the RAH-66 Comanche, from the beginning.

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<sup>2</sup> Prime contractors integrate components that they make and buy into final products.

Helicopters under development make extensive use of electronics, flat panel color displays, composite airframe structures, and fly-by-wire flight controls.<sup>3</sup> In addition, they have been designed to reduce visual, radar, acoustic, and infrared signatures, and hence their vulnerability to enemy weapons.

## 2. Design Requirements

Because military and civil helicopters have different missions, they have significantly different performance requirements and designs. For example, although both military and civil users seek to maximize payload, i.e., how much the helicopter can carry, military users also require extended range -- sometimes including air refueling capability -- and the ability to hover at high altitudes in hot climates. Since combat helicopters operate at night and come into direct contact with the enemy, they require integrated systems to fly at night, acquire targets, and reduce signatures. Additionally, military helicopters routinely operate at altitudes of 100 feet or less. Such "nap-of-the-earth flying" stresses flight components much more severely than routine civil operations. High-flying civil helicopters experiencing aircraft malfunctions normally have sufficient time to perform safe landings. Low-flying military helicopters may not have as much time, and, therefore, have special design features to minimize personnel injury from crashes.<sup>4</sup> Also, military helicopters must be able to fire weapons safely and accurately and, to the maximum extent possible, continue to operate after being hit by enemy fire. Combat support helicopters must have many of the same capabilities as attack and armed reconnaissance helicopters because they too must survive and function in complex and dynamic battlefield environments.

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<sup>3</sup> Fly-by-wire controls allow the pilot to command flight control surface movements electronically, a significant weight savings over previous mechanical linkages.

<sup>4</sup> Since the main rotor blades preclude ejection systems, onboard military personnel must ride the helicopter to the ground. Crashworthiness features include shock absorbing landing gear, crew seats, and aircraft structures; fuel bladders and lines that minimize post-crash fires; and cockpit designs that minimize injuries.

Helicopters may be grouped into three categories according to their gross vehicle weight: light helicopters weigh less than 12,000 lb.; medium helicopters weigh between 12,000 and 35,000 lb.; and heavy helicopters weigh more than 35,000 lb. Military helicopters are predominantly of medium and heavy size, use multiple turbine engines, and frequently have integrated systems. Current civil helicopters are predominantly light, use single piston or turbine engines, and have only basic communication, navigation, and weather radar equipment.

### **3. Major DoD Helicopter Prime Contractors**

DoD relies on four domestic prime contractors to meet the majority of helicopter requirements: Bell Helicopter Textron, Inc. (BHTI), a subsidiary of Textron, Inc.; Boeing Helicopters, a division of the Boeing Space and Defense Group; McDonnell Douglas Helicopter Systems (MDHS), a division of McDonnell-Douglas Aerospace Corporation; and Sikorsky Aircraft Corporation, a subsidiary of United Technologies. DoD buys spare parts from another domestic supplier, Kaman Corporation, but currently has no contracts with it for the development or production of new helicopters.

### **4. Similarities and Differences in Civil and Military Helicopters**

Military requirements for helicopters are generally more stringent than civil ones. The very nature of combat operations drives military designs to more capable aircraft that are more complex and expensive than their civil counterparts. For the most part, advanced helicopter technology flows from military research and development to civil applications.

The clear differences between the two applications diminish, however, when one examines the individual parts and components that make up the final products. Of the approximately 20,000 parts on a military helicopter, several thousand are standard aerospace catalog parts. For example, the wiring, fasteners, hydraulic tubing, composite fibers, and

resin used in military helicopters are widely used in commercial applications throughout the aerospace industry.

A key element in DoD acquisition reform policy is to replace, whenever practicable, military-unique components with commercial ones. DoD is inserting more commercial electronics, microprocessors, information technologies, and advanced displays into military helicopters. For example, DoD frequently uses commercial plastic encapsulated microcircuits, instead of military-unique ceramic encapsulated microcircuits. Additionally, electronics software development techniques and commonplace items such as automotive airbags are migrating from commercial applications to military helicopters.

Commercial airplane design technology and production techniques developed by Boeing for its new commercial 777 aircraft are strongly influencing DoD's RAH-66 Comanche and V-22 Osprey programs. Also, MDHS assembles AH-64 Apache and civil helicopters in the same building. Workers switch from one aircraft to another, depending on scheduling, which reduces overhead costs and lowers total costs for both military and civil helicopter production.

## **B. The Helicopter Market**

Although worldwide demand for helicopters is predicted to remain relatively stable in terms of number of units produced, the dollar value of production is predicted to increase. This increase in value reflects expected increased demand for larger, multi-engine turbine helicopters with modern electronic systems for both military and civil applications. All four major US helicopter manufacturers are well positioned to compete in that market.

The number of helicopters produced for civil customers exceeds the number produced for military customers, but the dollar value of the military production greatly exceeds that of the civil production. This is due to the greater complexity and typically larger size of military helicopters.

Figure ES-1 shows the historical and predicted annual dollar value of helicopter production from 1985 to 2004. Dollar value of production is predicted to increase from \$5.98 billion in 1995 to \$8.94 billion in 2004. The annual dollar value of military production alone is expected to decline from a high of \$9.4 billion in 1987 to about \$4.6 billion in 1996 and 1997, then rise and stabilize at about \$6 billion per year in 2001. Both military and civil customers are expected to buy a higher percentage of more expensive, more capable helicopters. In addition, the unit cost of future military helicopters, such as the V-22, is expected to be higher than current models.

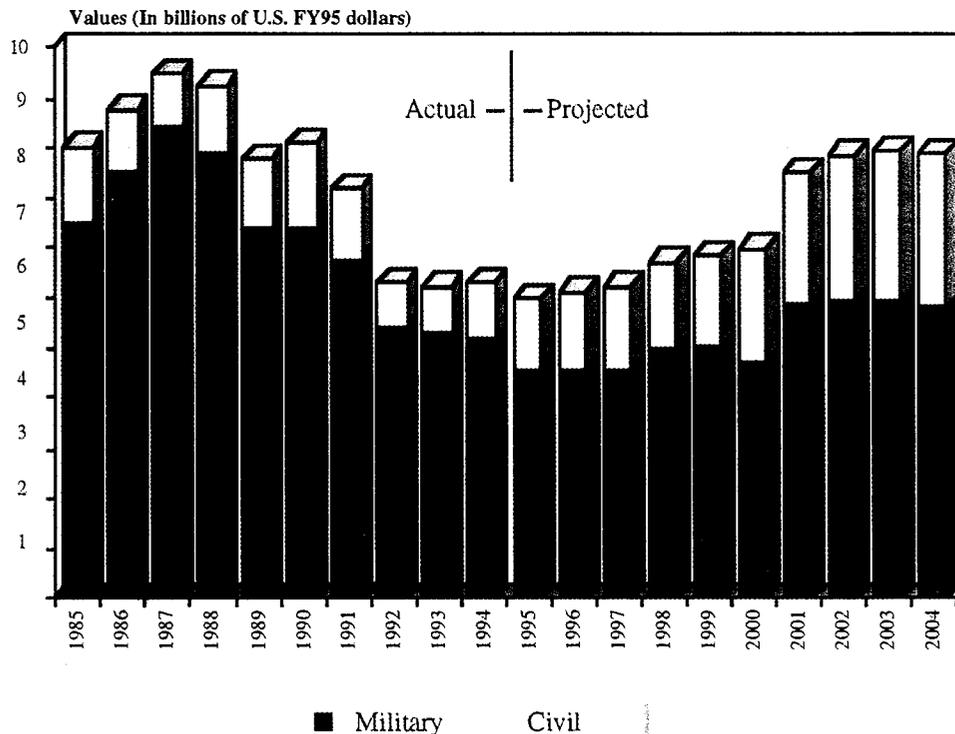


Figure ES-1: World Helicopter Market (1985-2004)<sup>5</sup> Value of Production

<sup>5</sup> Forecast Intl/DMS, in the American Helicopter Society's International Directory, Vol. 41, No. 1, 1995.

Figure ES-2 shows the historical and predicted volume of helicopter production from 1985 to 2004. Combined civil and military helicopter production worldwide reached a low of 1,214 units in 1993. Future combined production is predicted to remain relatively stable at 1,500 units per year through 2004. Military production alone declined from a high of 1,293 units in 1987 to a low of 557 units in 1992. Future military production is predicted to remain stable at about 600 units per year through 2004.

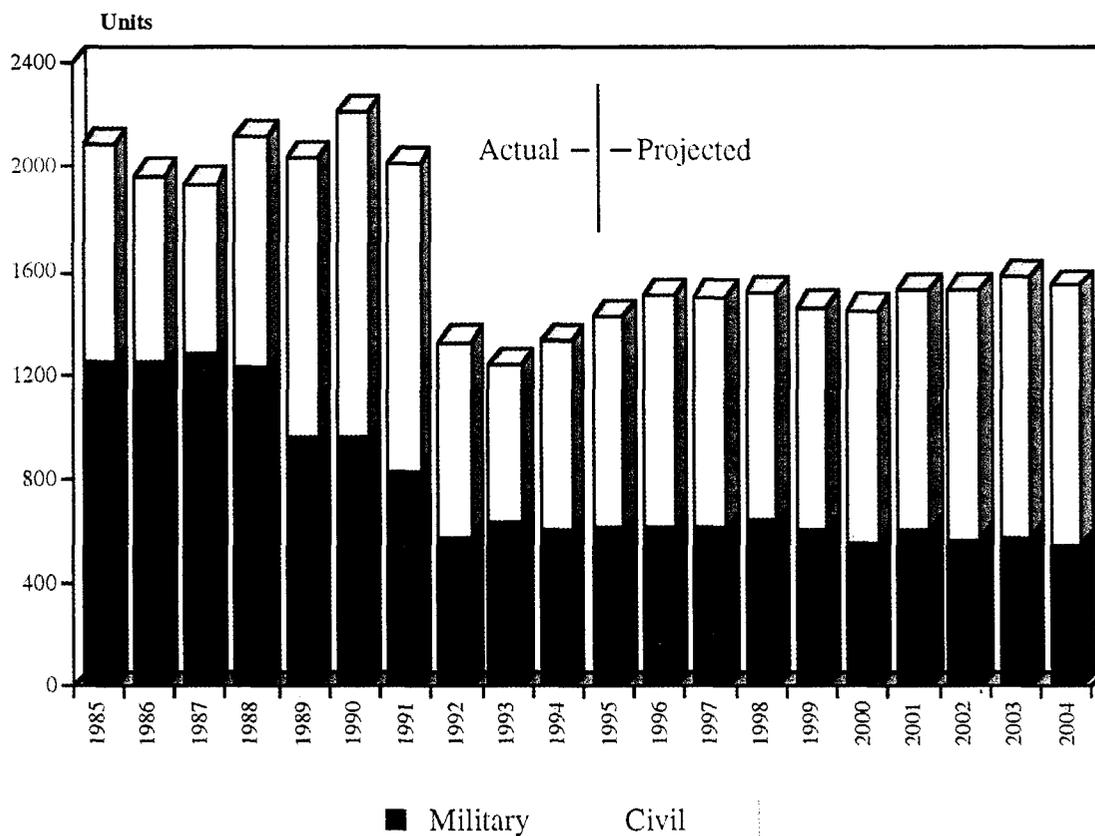


Figure ES-2: World Helicopter Market (1985-2004)<sup>6</sup>  
Unit Production

<sup>6</sup> Forecast Intl./DMS, in the American Helicopter Society's International Directory, Vol. 41, No. 1, 1995.

The four major US manufacturers supplied approximately 60 percent of the dollar value of total worldwide production in 1994. Forecast International<sup>7</sup> predicts that these manufacturers will lose market share, dropping from 60 to 40 percent share over the next ten years -- due to the decline in DoD purchases. The dollar value of their market share will remain relatively constant, between \$3.2 billion and \$3.4 billion in constant 1995 dollars, over that 10-year period. Forecast International expects that European, Russian, and Japanese manufacturers will fill the increased world demand.

## **C. DoD Requirements**

### **1. Research and Development**

DoD helicopter research and development efforts focus on applying existing and evolving design, development, and production techniques to ongoing helicopter development programs. Defense research and development efforts address DoD-unique problems in areas such as dynamics, aerodynamics, propulsion, drive systems, flight controls, vibration, crew station design, stealth, and systems integration. However, military development programs have produced significant advances in helicopter technology over the past fifty years applicable to both civil and military markets. Without DoD helicopter research and development programs, the pace of US helicopter technology advancement would likely slow to a standstill. Figure ES-3 shows the funding for the major DoD helicopter R&D programs for fiscal years 1991 through 2001. Figure ES-4 identifies the major development programs. Only one major military helicopter development program will be ongoing after 1997.

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<sup>7</sup> A private research and forecasting firm that concentrates on defense-related markets.

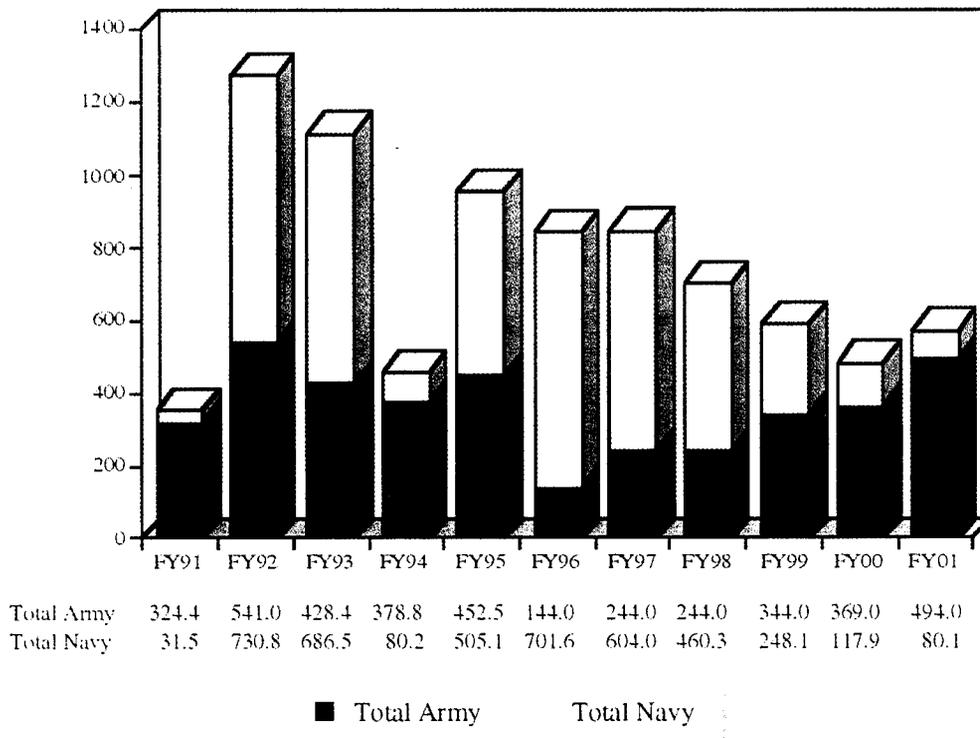


Figure ES-3: Army & Navy Helicopter RDT&E Program Funding (FY95 \$M)<sup>8</sup>

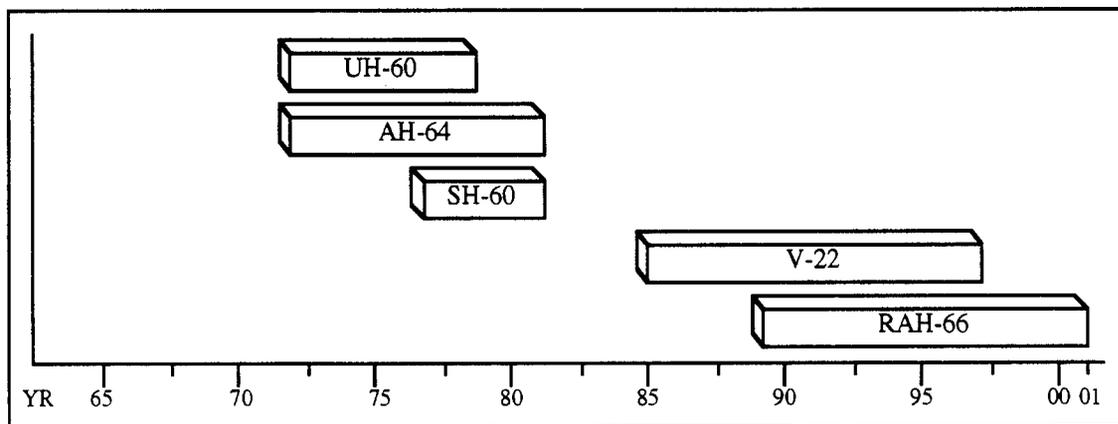


Figure ES-4: Major DoD Aviation Platform R&D Programs

<sup>8</sup> FY96-97 Budget Estimate Submission.

## 2. Production

DoD has five major helicopter production programs in progress. This will drop to three in 1998, two in 1999, and one beyond the year 2000. In spite of the drop in production programs, helicopter procurement funding is projected to increase from about \$1.1 billion in 1997 to about \$1.8 billion in 2001 as DoD transitions from larger quantities of lower cost, less capable helicopters to fewer higher cost, more capable helicopters, in this case the V-22 Osprey. The increased funding also reflects planned programs to upgrade the capabilities of the existing fleet. Figure ES-5 shows DoD helicopter procurement funding for fiscal years 1991 through 2001. Because RAH-66 Comanche production has been deferred, it is not included in Figure ES-5. Figure ES-6 identifies the major DoD helicopter production programs for 1965 through 2005.

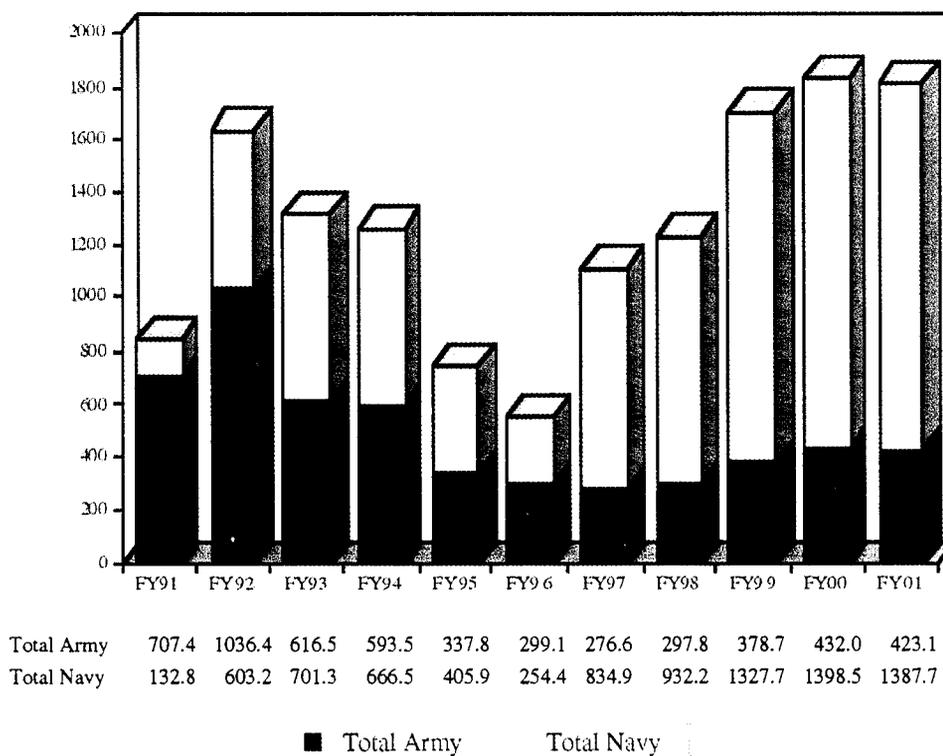


Figure ES-5: Army & Navy Helicopter Procurement Program Funding (FY95 \$M)<sup>9</sup>

<sup>9</sup> FY96-97 Budget Estimate Submission.

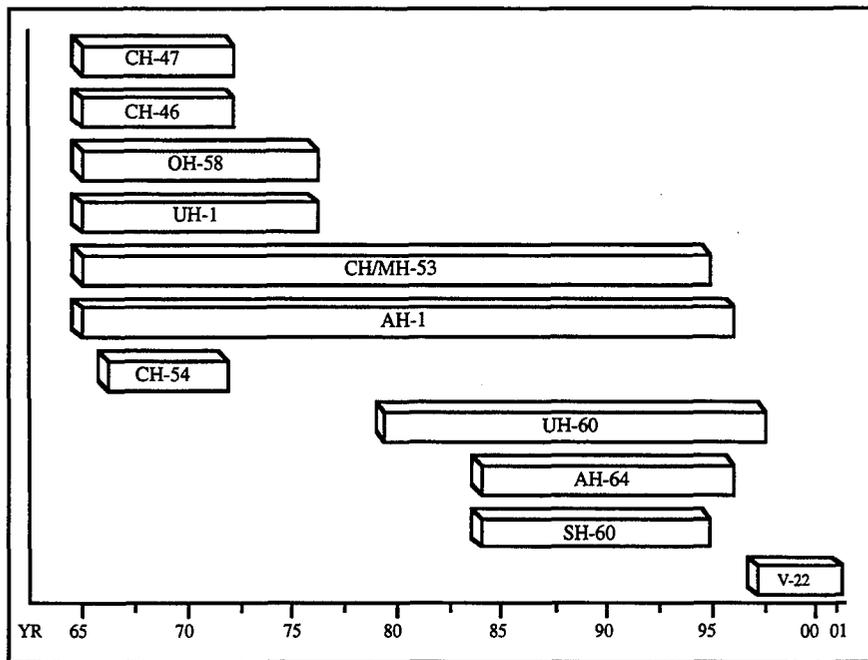


Figure ES-6: Major DoD Aviation Platform Production Programs

### 3. Support

Historically, DoD has relied primarily on a warm production base to support its helicopters during a conflict. An active production line ensured that the prime contractor and, more importantly, the many subcontractors, had the tooling and personnel needed to manufacture needed spare parts and components. War reserve stocks stored in defense depots in quantities exceeding peacetime demand, also provide a “safety net” of readily available spare parts. Spare part demand is much higher during a conflict than in peacetime. For example, during peacetime an AH-64 Apache is in flight about 15 hours a month<sup>10</sup> -- during a conflict flight hours may be four times that number. Factors affecting the demand for helicopter spare parts include:

- The size of the fleet for each model, including civil derivatives.
- The reliability and durability of the individual parts.

<sup>10</sup> Commercial aircraft generally fly at rates considerably in excess of military peacetime rates.

- Flight hours per month.
- The rate of part obsolescence and upgrades (for example, avionics change more rapidly than air frames).
- Geographical and environment stresses, such as desert sand and arctic ice.

When DoD could rely on a warm production base, the Department considered a minimal investment in war reserve stocks to be an acceptable risk. With large helicopter fleets to support and declining new production, DoD is reexamining whether minimal war reserve investment is still an acceptable risk. The supply of spare parts depends on the following factors:

- The extent to which there is an active production program.
- The amount of war reserve stock.
- Anticipated demand, based largely on flight hours.<sup>11</sup>

#### **D. Meeting Future Requirements**

The US helicopter industry will continue to meet DoD requirements for the foreseeable future. Despite reduced DoD procurements, increasing competition, and significant excess capacity, the existing manufacturers of DoD helicopters are profitable businesses. Table ES-2 displays measures of profitability, for the period of 1991 through 1994, for the segments of each of the four major US corporations that produce helicopters for DoD. All four segments remain profitable and within these segments, the helicopter businesses specifically are all profitable.

The helicopter businesses are also becoming more efficient. Aggregate sales of the four helicopter businesses are projected to increase by 9.8 percent, from \$4.88 to \$5.36

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<sup>11</sup> Fewer peacetime flight hours result in fewer spare part purchases and lower inventory levels.

billion, between 1990 and 1995. Over the same period, employment is expected to decline by 17.5 percent, from about 32,200 to about 26,500, resulting in a 33 percent increase in efficiency (sales per worker). Individually, the increases in efficiency range from 20 to 65 percent.

Table ES-2  
Profitability of US Aircraft Prime Contractors -Segments with Helicopter Capabilities<sup>12</sup>

	1991			1992			1993			1994		
	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)
Boeing-Space & Defense Group	5,846	-102	-1.7	5,429	204	3.8	4,407	219	5	4,742	303	6.4
McDonnell Douglas-Military Aircraft Segment	7,795	394	5.1	7,238	8	0.1	6,862	83	1.2	7,804	708	9.1
Textron Corp. Aircraft Segment	1,255	113	9	1,521	128	8.4	1,987	171	8.6	2,186	194	8.9
United Tech. Corp.-Flight Sys. Segment	4,024	-224	-5.6	4,045	275	6.8	3,930	385	9.8	3,218	282	8.8

There is substantial excess capacity in the helicopter industry. The capacity utilization rate for the four major manufacturers was 38 percent in 1990, ranging individually from 33 to 60 percent. As a result of internal consolidation, the industry capacity utilization rate had increased to 48 percent by 1995, ranging individually from 37 to 64 percent. However, because of their reliance on declining DoD business, helicopter manufacturers expect capacity utilization rates to decline between 1995 and 1997. Helicopter manufacturers had a production backlog fluctuating, on average, around \$2.0 billion between 1990 and 1994. However, they expect the backlog to decline to a six year low of \$1.84 billion in 1995.

<sup>12</sup> Source: Company Reports.

Each of the four major manufacturers have systems engineering and integration capabilities that meet DoD requirements. Although continued excess capacity suggests that some future consolidation may occur, those prime contractors remaining are expected to retain sufficient capabilities (i.e. technologies, skills, facilities, and tooling) to meet DoD requirements. Additionally, despite reduced demand and industry consolidation among suppliers of helicopter subsystems and key components and material, suppliers remaining after consolidation will have sufficient industrial and technological capabilities to meet DoD requirements. During this assessment, DoD did not identify a single supplier of helicopter subsystems, components, or materials with unique capabilities that DoD could not obtain from other sources.

Peacetime flying hours will generate sufficient demand to sustain production of spare parts for helicopter models that are part of large fleets, either military or military and civil. However, spare parts for less prevalent models, models with unique military components, and models with low failure rates may not be readily available. DoD is addressing this problem by identifying and evaluating its need for spare parts on a case-by-case basis. The military services will then take steps as needed to ensure that adequate spare parts are available. This may be accomplished by one or more of the following methods:

- Funding more flight hours for the particular model to generate demand for spare parts.
- Stocking war reserve supplies of identified parts.
- Identifying substitute parts.
- Directing spare part purchases and repairs to specific suppliers.
- Paying for the maintenance of specific tooling, facilities, and skills.

## Section I. Helicopters

The Department of Defense (DoD) uses helicopters to meet a variety of military missions. Most have the potential to engage enemy forces. Non-military ("civil") customers use helicopters primarily to perform service (aeromedical evacuation, personnel and cargo transport, and utility) missions. Although current civil helicopter designs are generally spin-offs of earlier military technology developments, they lack the specialized navigation and electronic equipment, weapon systems, and related systems that provide military capabilities.

The helicopter market is characterized primarily by customer/use (civil or military) and size (light, medium, and heavy). The Department relies on four domestic prime contractors for the majority of its helicopter needs. This assessment addresses worldwide suppliers and demand, but focuses primarily on DoD requirements for military helicopters and the four major US firms that provide them. Subsystem and component manufacturers are addressed to the extent necessary to provide an accurate assessment of helicopters and the network of suppliers which build them.

Helicopters are categorized as civil or military depending on the organization that certifies airworthiness. Civil helicopters operated for hire must be certified by the Federal Aviation Administration (FAA) in the US or the DGAC (France). There are reciprocal agreements between the FAA and the DGAC. The Army, Navy, and Air Force "certify" their own military aircraft. Civil certification authorities are not prepared to certify the special characteristics of military aircraft like weapons systems, shipboard operations, and electronic warfare suites. Most sales of military helicopters to foreign countries occur with military airworthiness certifications.

The term "rotorcraft" is frequently used to describe the common technology and similar aerodynamics of helicopters and tiltrotor aircraft. DoD frequently uses the term "rotary wing

aircraft" when referring to helicopters. The technology, design, production, and hover and low speed flight characteristics of these aircraft are similar -- and significantly different from airplanes. In this report, the term "helicopter" is used to refer to all rotorcraft, including the V-22 Osprey tiltrotor.

## **A. Stages of Helicopter Development**

Helicopters have evolved through four stages since initial development. The first helicopters, through the 1950s, had piston engines which limited power, reliability, and capability. Small turboshaft engines employed in the late 1950s ushered in the second stage helicopters of the Viet Nam era. These (AH-1, UH-1, CH-46, CH-47, and CH-53) helicopters used electro-mechanical instruments, incandescent cockpit lighting, pressure gages, redundant components to compensate for poor reliability, and had high crew workload requirements. They were vulnerable to small arms fire and heat seeking missiles. By the 1970s, advances in rotor technology and improvements in weapons systems integration fostered the development and use of third stage helicopters -- the SH-60 Sea Hawk and AH-64A Apache are examples. These aircraft had multi-function displays, inertial and Doppler navigation, warning sensors, and jammers to counter some threat weapons. They had a robust design sufficient to tolerate small arms fire, and increased crashworthiness. Fourth stage helicopters -- typified by the RAH-66 Comanche -- have the mission "systems" designed into the aircraft as opposed to an "add-on" architecture. They make extensive use of electronics (electronic modules, cards, and chips in lieu of "black boxes"); flat panel color displays; composite airframe structures; fly-by-wire flight controls;<sup>13</sup> and reduced visual, radar, acoustic, and infrared signatures to avoid threat weapons. This evolution has been driven by weight and space constraints, and ever more sophisticated radar and infra-red detection threats.

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<sup>13</sup> Fly-by-wire controls allow the pilot to command flight control surface movements electronically, a significant weight savings over previous mechanical linkages.

During the 1950s and 1960s, other than size, there was little distinction between military and civil helicopters. Beginning with the third stage helicopters, DoD began to demand more military-unique performance capabilities (for example, ballistic protection, crashworthiness). Civil operators continued to buy second stage helicopters with upgraded avionics. The new Army reconnaissance scout helicopter, the Comanche, and McDonnell Douglas' new civil helicopter, the MD 900 Explorer illustrate the continuing divergence in military and civil requirements. Both reflect current technology and both were designed with a specific mission in mind. The Comanche will be the most capable military helicopter developed to date. But there are no civil applications for this tandem seat armed reconnaissance aircraft. Conversely, McDonnell Douglas continually solicited ideas from commercial operators during the MD 900 design phase and built a helicopter with minimum operating costs as its primary design consideration. Although a very capable civil helicopter, there are no projected military sales (US or foreign) for the MD 900.

## **B. Missions**

Table I-1 summarizes the missions performed by both military and civil helicopters. Military helicopter missions can be grouped into three categories: combat, combat support, and combat services support. Combat helicopters directly and indirectly engage with the enemy. Combat support helicopters may come in direct contact with the enemy while transporting personnel in and near combat areas. Combat services support helicopters primarily move supplies between ships and shore areas to replenish ground forces. Civil helicopter missions generally fall into the services category. They efficiently move cargo and people over relatively short distances.

**Table I-1  
Helicopter Missions**

Role	Military	Civil
Combat	<ul style="list-style-type: none"> <li>• Attack</li> <li>• Armed Reconnaissance</li> <li>• Anti-Submarine Warfare</li> <li>• Airborne Mine Counter Measures</li> <li>• Special Operations</li> </ul>	
Combat Support	<ul style="list-style-type: none"> <li>• Aeromedical Evacuation</li> <li>• Observation</li> <li>• Search and Rescue</li> <li>• Utility (assault)</li> </ul>	
Services	<ul style="list-style-type: none"> <li>• Cargo (internal and external sling loads)</li> <li>• Utility</li> <li>• Courier</li> <li>• Training</li> </ul>	<ul style="list-style-type: none"> <li>• Aeromedical Evacuation</li> <li>• Personnel Transport</li> <li>• Cargo Transport</li> <li>• Utility</li> </ul>

Military helicopters are not limited by rugged terrain, they can operate at night and in adverse weather, and are lethal when armed. Their versatility and flexibility allow commanders to bring significant firepower to bear, quickly, in response to dynamic combat operations. Military helicopters also can be used to engage in antisubmarine warfare, detect and remove mines, evacuate injured and wounded personnel, and quickly move personnel and supplies between locations on land and sea.

### **C. Design Requirements**

Because military and civil helicopters have different missions, they have significantly different performance requirements and designs (Table I-2).

Table I-2  
Key Design Requirements

Military	Civil
• Maximum range/payload	• Maximum payload
• External (sling) loads for cargo helicopters	• Highly reliable
• Aerial refueling	• Limited avionics systems
• Sufficient power to hover in low density altitudes	• Safety
• Integrated systems (weapons, sensors, etc.)	• High utilization rates
• Low observable/stealth	
• Night vision pilotage/target acquisition	
• Ballistic protection/aircraft survivability equipment	
• Crashworthiness	
• Corrosive environment protection	
• Maintainable/integrated diagnostics	
• Shipboard compatibility	
• Highly reliable	
• Weapons firing effects	
• Safety	

Although maximum payload capability is a requirement for both, military helicopter performance needs also require extended range -- sometimes including air refueling capability -- and the ability to hover at high altitudes in hot climates. Since combat helicopters operate at night and come in direct contact with the enemy, they require the integrated systems to fly at night, acquire targets, and maintain low signatures (radar, visual, acoustic, and thermal). Additionally, military helicopters routinely operate at altitudes of 100 feet or less. Such "nap-of-the-earth flying" stresses flight components much more severely than routine civil operations. High-flying civil helicopters experiencing aircraft malfunctions normally have sufficient time to perform safe autorotational landings. Low-flying military helicopters do not have as much time, and therefore have special design features to minimize personnel injury from crashes. Since the main rotor blades preclude ejection systems, onboard military

personnel must ride the helicopter to the ground. Crashworthiness features include shock absorbing landing gear, crew seats, and airframe structures; fuel bladders and lines that minimize post-crash fires; and cockpit designs that mitigate personnel impact injuries. Military helicopters also must meet military-unique weapons firing effect<sup>14</sup> and dynamic component ballistic tolerance<sup>15</sup> performance requirements. A combat support helicopter must have many of the same capabilities as attack and armed reconnaissance aircraft to survive and function in the complex battlefield environments of the future where friendly and enemy situations are fluid.

Military helicopters operate in unique and harsh environments. Anti-submarine warfare helicopters operate on a 24 hour basis from surface combatant ships with austere maintenance resources -- constantly exposed to the corrosive saltwater environment. Helicopters and the sensitive electronic equipment they carry must be invulnerable to the affects of the electromagnetic interference of an aircraft carrier radar when landing or taking off. Military helicopters also must operate at night, frequently stay below tree top level, in sand and dust, in all weather, and away from fixed maintenance facilities. As a consequence of harsh maintenance environments, the Department places a greater emphasis on automated fault detection capabilities (integrated diagnostics).

Military and civil helicopters typically are divided into weight classes -- light, medium, and heavy -- based on gross vehicle weight.<sup>16</sup> They are further characterized by engine configuration,<sup>17</sup> and the degree to which they possess integrated systems.<sup>18</sup> Table I-3 summarizes the extent to which military and civil helicopters possess these characteristics.

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<sup>14</sup> Recoil effects on the airframe and weapons accuracy; and the prevention of the ingestion of rocket motor debris into the engine after weapons firing.

<sup>15</sup> The ability to withstand the direct impact of a projectile of specified size.

<sup>16</sup> Light - less than 12,000 lb.; Medium - 12,000 - 35,000 lb.; Heavy - greater than 35,000 lb.

<sup>17</sup> Single engine piston (SEP); single engine turbine (SET); and multi-engine turbine (MET).

<sup>18</sup> The term "integrated systems" means avionics integration beyond basic communication, navigation, and weather radar capabilities.

Table I-3  
Military and Civil Helicopters

Classes		Systems Integrated	Non-Systems Integrated	Use
Light	SEP		X	Civil
	SET/MET		X	Predominantly Civil
Medium	MET	X	X	Predominantly Military*
Heavy	MET		X	Predominantly Military

\* Attack helicopters such as the AH-64 are systems integrated. The UH-60 series utility (assault) helicopters are not.

Because of mission and operational requirements, current civil helicopters are predominantly light, use single engine piston (reciprocating) or turbine engines, and have only basic communication, navigation, and weather radar equipment. Generally, these small piston engine helicopters can be flown only in clear weather.<sup>19</sup> DoD has no reciprocating engine helicopters -- they are not as reliable as turbine engines -- and none of the prime contractors supplying helicopters to DoD produce them.<sup>20</sup> The DoD uses "light category" helicopters only for scout and non-combat trainer missions. Military helicopters are predominantly medium and heavy, use multi-engine turbine engines, and frequently have integrated avionics and weapons systems.

Because of these differing characteristics, there are significant differences in the average unit cost of military and civil helicopters (Table I-4).

<sup>19</sup> The Federal Aviation Administration has established equipment and pilot qualification requirements to operate aircraft in obscured weather. Equipment costs range from \$50,000 - \$100,000 and operators of small, inexpensive airplanes and helicopters frequently opt to operate only in clear weather.

<sup>20</sup> Helicopter firms tend to focus on either civil or military helicopters. This generally is a function of significant performance requirement differences (civil operators emphasize price while DoD emphasizes capability) and DoD acquisition practices. These differences are discussed in more detail later in this section.

Table I-4  
Average Unit Costs<sup>21</sup>

Classes	Average Unit Cost		User (Percent)	
	Civil	Military	Civil	Military
Single Engine Piston	\$175K	\$153K*	98	2
Single Engine Turbine	\$877K	\$2.98M	59	41
Multi-Engine Turbine	\$3.5M	\$10.5M	35	65

\* These lower cost military helicopters are operated by foreign militaries who have purchased "lower end" helicopters for selected missions.

As stated earlier, civil helicopter operators require helicopters which are simpler, lower in acquisition and operation cost, can carry heavy payloads (the difference between maximum gross weight and empty weight), and are highly reliable. (Military helicopter operators also emphasize maximum payload, but are willing to accept some additional weight to increase fuel capacity and crash survivability.) The largest single cost for civil helicopter operators is depreciation, normally accounting for 7.5 percent annually of the purchase price. Under these circumstances, acquisition cost is paramount. The fixed costs of depreciation, insurance, and maintenance account for 89 percent of civil flight hour costs. Civil operators, therefore, rarely operate larger helicopters that are both expensive to purchase and operate.

Single engine piston helicopters are almost exclusively used by civil operators. However, the most popular helicopters (based on new unit sales quantity) are those powered by light single and twin turbine engines. The normal cost range is \$700,000 - \$4 million and there is an active used aircraft market.<sup>22</sup> These helicopters routinely carry a single pilot and three to eight passengers. They are used by commercial operators, police departments, and

<sup>21</sup> Source: Forecast International/DMS, in AHS International Directory, Vol. 41, No. 1, 1995.

<sup>22</sup> Approximately nine used helicopters are sold for every new sale. When civil operators buy a new helicopter they will frequently trade in their existing helicopter or sell it in the used market to partially fund the new aircraft.

foreign militaries for observation and courier purposes. Small turbine engines cost approximately \$200,000 each. This accounts for the dramatic cost difference between light piston engine helicopters and the least expensive light turbine engine helicopters. Turbine engines offer a dramatic improvement in power and reliability.

In contrast, US military helicopters are infused with new technologies, survivability enhancements, and integrated systems and armaments. They are considerably more expensive than civil helicopters (per Table I-4, generally more than three times the cost).

The more robust military performance specifications frequently require significant differences between military and civil helicopters, even at the component level. Components (hydraulic actuators, for example) are often manufactured in a facility that produces components for both the military and civil helicopter market. However, even though there may be common piece parts, the facility typically has unique military and civil product assembly lines -- primarily due to the higher performance requirements and additional testing required for military applications. (Additionally, federal government contract cost accounting standards have inhibited the use of common military and commercial production lines by prohibiting the commingling of DoD and commercial property.)

#### **D. Products**

DoD relies on four domestic prime contractors to meet the majority of its helicopter requirements: Bell Helicopter Textron Inc. (BHTI), a subsidiary of Textron; Boeing Helicopters, a division of the Boeing Space & Defense Group; McDonnell Douglas Helicopter Systems (MDHS), a division of McDonnell-Douglas Aerospace Corp.; and Sikorsky Aircraft Corporation, a subsidiary of United Technologies. DoD is buying spares from a fifth domestic

helicopter manufacturer -- Kaman -- but currently has no contracts with that company for military helicopter development or production.

There are however, considerably more helicopters available on the world market. Table I-5 lists a significant sample of helicopters available worldwide, by class/user and manufacturer.

### E. Military Helicopter Subsystems

A helicopter system is comprised of subsystems (Figure I-1), used to varying degrees on most helicopters.

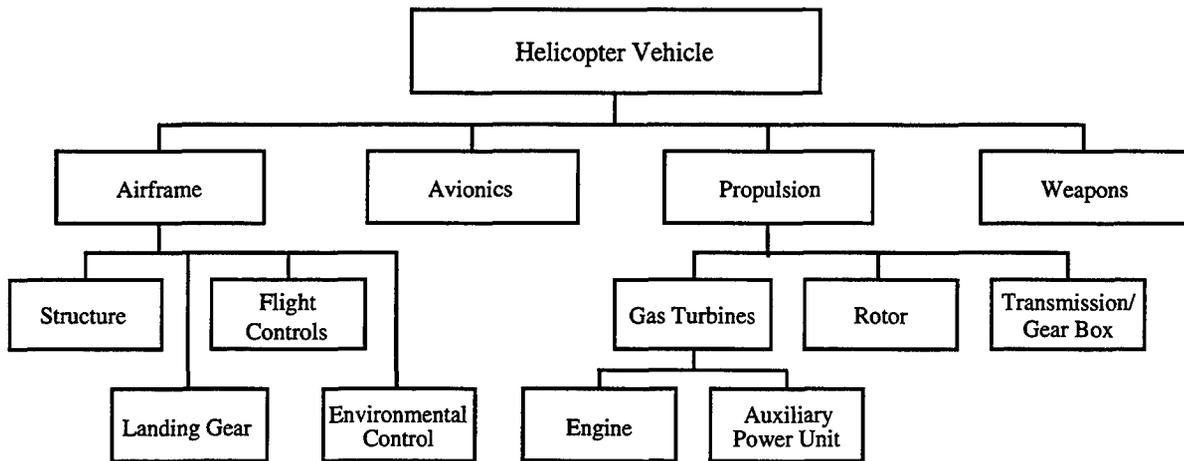


Figure I-1: Military Helicopter Basic Subsystems

Table I-5  
Light Helicopters Worldwide<sup>23</sup>

Helicopter	Max. Gross Take-Off Weight (Lb.)		Manufacturer
206B Jet Ranger	3,200	Predominantly Civil	Bell
206L-III Long Ranger	4,250	Civil	Bell
OH-58D	5,500	Military	Bell
Bell 230	8,250	Civil	Bell
Bell 205A/UH-1H	9,500	Predominantly Military	Bell
Bell 212/UH-1N	11,200	Both	Bell
Bell 412	11,900	Civil	Bell
S-76B	11,700	Civil	Sikorsky
MD 500E	3,000	Civil/Military	MDHS
MD 520N	3,350	Civil	MDHS
MD 500E	3,000	Civil	MDHS
MD 520N	3,350	Civil	MDHS
MD 900 Explorer	5,400	Civil	MDHS
A.109	5,732	Both	Agusta
A.129 Mangusta	9,039	Military	Agusta
EC-120	3,417	Civil	Eurocopter
SA.341/342 Gazelle	4,410	Both	Eurocopter
AS.350 Ecureuil	4,960	Predominantly Civil	Eurocopter
MBB BO-105	5,511	Predominantly Civil	Eurocopter
EC-135	5,511	Civil	Eurocopter
AS.355 F2 Ecureuil	5,600	Predominantly Civil	Eurocopter
BK.117	7,055	Predominantly Civil	Eurocopter
AS.365N Dauphin 2	9,039	Both	Eurocopter
HAL ALH	11,800	Both	Hindustan (India)
Lynx	10,500	Predominantly Military	Westland
K-Max	10,800	Civil	Kaman
Kawasaki OH-X	6,400	Military	Kawasaki

<sup>23</sup> Source: Various.

Table I-5 (Continued)  
Medium Helicopters Worldwide

Helicopter	Max. Gross Take-Off Weight (Lb.)		Manufacturer
AH-1W Cobra	14,750	Military	Bell
CH-46E Sea Knight	24,300	Military	Boeing
RAH-66 Comanche	14,000	Military	Boeing and Sikorsky
SH-60B Sea Hawk	21,884	Military	Sikorsky
UH-60A/L Black Hawk	22,000	Military	Sikorsky
AH-64A Apache	21,000	Military	MDHS
Tiger	13,227	Military	Eurocopter
AS.332 Super Puma Mk I	19,841	Civil Derivatives	Eurocopter
NH 90	20,062	Military	Eurocopter
AS.332 Super Puma Mk II	20,944	Civil Derivatives	Eurocopter
SH-2 Seasprite	13,500	Military	Kaman
KA-25 Hormone	16,093	Military	Russia
KA-32 Helix	24,250	Military	Russia
KA-27 Helix	27,775	Military	Russia
CSH-2 Rooivalk	20,723	Civil Derivatives	South Africa
EH-101	29,830	Military	Agusta and Westland
MI-4 Hound	17,195	Military	Russia
MI-24 Hind	24,250	Military	Russia
MI-8 Hip	26,455	Military	Russia
MI-14 Haze	28,660	Military	Russia
MI-17 Hip-H	28,660	Military	Russia

Heavy Helicopters Worldwide

Helicopter	Max. Gross Take-Off Weight (Lb.)		Manufacturer
V-22 Osprey	60,500	Military	Bell and Boeing
MH/CH-47 Chinook	54,000	Predominantly Military	Boeing
MH/CH-53E Super Stallion	73,500	Military	Sikorsky
MI-6 Hook	93,695	Military	Russia
MI-26 Halo	123,450	Military	Russia

## **1. Airframe Structure**

The airframe structure is the fuselage or body of the helicopter. Metal airframes are being replaced with composite materials in the primary aircraft structure. Composite materials offer weight savings, improved fatigue properties and corrosion resistance.

## **2. Landing Gear**

Landing gear vary significantly based on the size and mission of the helicopter. In general, landing gear are classified as skids (no wheels), non-retractable energy absorbing, and retractable energy absorbing.

## **3. Flight Control**

Flight control systems consist of hydraulic controls (servo-valves, accumulators, and actuators), sensors, and digital electronic computers. These components receive, process, interpret, and respond to pilot commands, vehicle conditions and environmental factors to achieve desired flight control.

## **4. Environmental Control**

Environmental control systems include the heating, cooling, oxygen, and inert gas systems. These systems ensure pilot comfort and survival in adverse temperature and atmosphere conditions, and include inert gas suppression systems to reduce the likelihood of a fire. Some DoD helicopters (MH/CH47, UH-60L, MH/CH-53E, OH-58), do not utilize these systems. However, both the V-22 and RAH-66 rely on environmental control systems.

## **5. Avionics**

Avionics systems are electronic systems essential for communication, navigation, flight control, ordnance dispensing, and electronic warfare. These systems significantly affect performance and mission capability, and can contribute up to 40 percent of the total cost of the helicopter. Electronic warfare, night and all weather navigation, target acquisition, fire control,

and battle field management systems are advanced avionics systems unique to military helicopters.

## **6. Engine**

The engine converts fuel energy to torque which is delivered through the transmission to the helicopter rotor head, and then to the rotating blades to produce lift.

## **7. Auxiliary Power Unit**

Auxiliary power units are small gas turbine engines which supply bleed air for engine starting, and aircraft environmental systems. They also drive a generator that supplies electrical power to the helicopter.

## **8. Transmissions/Gearboxes**

A transmission is primarily a speed changer which receives high speed engine output and converts it to a much larger torque and lower rotational speed. Gearbox configurations vary. They can be used to change the direction of power shafting. They can also receive inputs from two engines and deliver output to two rotors, minimizing the possibility that the loss of a single engine will cause the helicopter to crash.

## **9. Rotor Blades**

Rotor blades provide the basic lift capability for the helicopter.

## **10. Weapons**

Military helicopters carry guns, rockets, missiles, and torpedoes.

## **F. Military Helicopter Industry Barriers to Entry**

The likelihood of a new manufacturer entering the military helicopter market is small. Lockheed California Company (LCC), in the late 1950s, was the last firm to attempt to enter the military helicopter market. Supported by NASA and Army research and development funds, LCC developed the rigid rotor, and in 1964, was awarded a contract to develop the Cheyenne attack helicopter. The program was canceled in 1972 due to technical problems and Lockheed left the helicopter industry. Capital investment, design expertise, and manufacturing capability requirements (as well as market size -- discussed in the next section) pose significant barriers to new firms seeking to enter the military helicopter business.

### **1. Capital Investment**

Capital investment necessary to produce military helicopters is typical of that required for large aerospace firms or manufacturing companies. Historically, the DoD has funded most research and development for the aircraft, and tooling. However, the firm must have sufficient facilities, retain large engineering staffs who can develop and apply advanced technologies, and manage stringent quality programs. Firms must qualify vendors -- necessitating subcontractor management staffs; build and maintain inventory management systems; purchase initial stocks; and develop accounting systems, procedures, and staffs to comply with government requirements.

The likelihood of a small, reciprocating engine helicopter manufacturer winning a major military helicopter contract is small. These manufacturers typically operate in a relatively stable, niche market with no DoD sales. The process of obtaining a major government contract, that is being identified as the best producer during the government's source selection process, requires several million dollars in up-front investment for design engineering, proposal preparation, and the source selection process. This is a prohibitive "at risk" investment for

reciprocating engine helicopter firms that typically have annual sales of \$2 million - \$10 million.

Finally, a firm's management systems must provide for the extensive qualification and documentation required by both the Federal Aviation Administration (FAA) and the military. This detailed documentation allows a failed part to be traced to the specific production lot. In the event of a structural failure after production, the FAA or military service is able to identify production lots and serial numbered parts which may be defective.<sup>24</sup> This is particularly important to safe helicopter operations.

## **2. Design Expertise**

Helicopter design and development is divided into two major processes: (1) design using modern computer-aided techniques, (2) validation using simulation or prototyping.

The aerodynamics of rotary wing aircraft require specialized technical expertise not available at fixed wing (airplane) manufacturers. Issues of aerodynamic phenomena (gyroscopic precession, unsteady aerodynamics, main rotor wake/airframe/empennage/tail rotor aerodynamic interference, autorotational aerodynamics, operating in reverse flow regions, sideward and rearward flight and extreme side slip conditions, retreating blade stall, the rotation of the body of the aircraft under the mast, and shifting center of gravity issues associated with external sling loads) are all peculiar to helicopters. Loading, vibration, weight, failure tolerance, and high rotational speeds require special designs for dynamic components like transmissions.

Helicopter unique design and development challenges require special expertise that flows from many years of experience which can be gained only by designing, building, and

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<sup>24</sup> There are other industries with some of these requirements. For example, extensive documentation is required in nuclear submarines.

maintaining helicopters. DoD estimates the time required to establish a robust developmental design simulation capability is ten years. The DoD has established several university rotorcraft centers of excellence to provide academic and experimental opportunities to replenish this necessary and unique talent.

The increased sophistication required to perform helicopter missions requires more complex, integrated weapons systems. Engineering development simulators that replicate the helicopter cockpit and emulate weapons and mission equipment functions are essential. Combat helicopter mission systems increasingly derive their functionality from software. This requires integration laboratories using actual mission equipment hardware to develop and verify software that works properly. For example there are five system integration laboratories to support the development and testing of the Comanche mission equipment package. The massive amounts of information presented to today's military pilot also presents a new challenge to the crew systems designer. Advanced engineering simulation is a necessity to develop alternative displays; caution, warning, and advisory systems; symbology; and cockpit procedures.

### **3. Manufacturing Capability**

Manufacturing capability requirements, specifically those associated with dynamic components, developing and applying airframe composites, and systems integration also represent significant technical hurdles for any potential new entrant.

#### **a. Dynamic Components**

The dynamic components consists of the rotor head, mast, push-pull tubes, pitch change links, main and tail rotor drive shafts, swashplate, tail rotor, intermediate gearboxes, and main transmissions. All are unique to helicopters, machined to very close tolerances, and are flight critical because failure is catastrophic. In some cases the gears must be capable of transmitting 15,000 shaft horse power (the CH-53E). The Comanche gear spline tolerances

are four millionths of an inch. This is rare and a critical technology unique to the helicopter industry. Dynamic components generally are machined from titanium or specialty steel.

b. Airframe Composites

The use of airframe composites is increasing dramatically with each generation of helicopters. Both the V-22 and the Comanche make extensive use of advanced composite materials technology. Stress fatigue resulting from decades of twisting, vibration, compression, expansion, temperature variances, loads from the tail rotor, and aircraft flight loads is a major concern. To combat these concerns, helicopter airframe composites must meet the same -- sometimes more rigid -- tolerances required for high performance aircraft. Sikorsky's Comanche center box beam is an all composite structure manufactured to precedent-setting tolerances ( $\pm .005$  inches over a length of 25 feet). Composites for major airframe structures require large, expensive autoclaves and expensive tools like digitally controlled filament winding machines -- which use large and expensive mandrels -- designed for fabrication of a single part. Military helicopters have followed the rest of the aerospace industry by using composite materials to reduce weight and increase strength. (Due to the high cost of tooling and raw material, advanced composite materials are not used extensively in civil helicopters.)

c. Systems Integration

Current combat helicopters represent large advancements in mission systems capabilities over previous generations. Forward looking infra-red (FLIR) night vision systems, millimeter wave radar, sonar, targeting, and digitization capabilities are among the most important. The four major helicopter prime contractors have internal systems integration capabilities. However, the prime contractors normally use a systems integrator as a subcontractor to perform some design, testing, and integration. An exception to this was the SH-60B Sea Hawk Light Airborne Multi-Purpose System (LAMPS) integration where the

Navy used IBM (now Loral Federal Systems) as the prime contractor, with Sikorsky a supporting contractor.<sup>25</sup>

## **G. Helicopters and Commercial-Military Integration**

Although civil and military helicopters are significantly different at the end item level, military helicopters take advantage of numerous commercial technologies. Civil technology is moving into military helicopters at the subsystem and component level, and in the design and manufacturing processes. Additionally, developments in helicopter technology made by defense sponsored research favorably impact the competitiveness of the commercial helicopter industry.

Of the approximately 20,000 parts on a military helicopter, several thousand are standard aerospace catalog parts. For example, the wiring, fasteners, hydraulic tubing, composite fibers, and resin represent components and materials widely used in commercial applications throughout the aerospace industry. DoD is inserting more commercial electronics, microprocessors, information technologies (digitization), and advanced flat panel displays into military systems. For example, DoD now frequently uses commercial plastic encapsulated microcircuits instead of military-unique ceramic encapsulated microcircuits. Additionally, electronics software development techniques and commonplace items such as automotive airbags are migrating from commercial product applications to military helicopters.

Commercial airplane design technology, and production techniques developed by Boeing for its new commercial 777 aircraft are strongly influencing DoD's V-22 and the Comanche programs. Also, MDHS assembles AH-64 Apache and civil helicopters in the same building. Workers switch from one aircraft to another depending on scheduling, which reduces overhead costs and lowers total costs for both military and civil helicopter production.

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<sup>25</sup> Since that time, Sikorsky has significantly improved its systems integration capability.

Despite these similarities, advanced helicopter technology generally flows from military research and development to civil applications. Military requirements for helicopters are more demanding than civil ones. Longbow Apache capabilities are clearly different from those of a Bell Jet Ranger. The DoD does operate civil Jet Rangers<sup>26</sup> but not as combat aircraft. The very nature of combat operations drives military designs to robust, heavier, ballistically tolerant aircraft that are more complex and expensive than those required for civil applications. There is little expectation that there will be convergence of the technological needs of civil and DoD helicopters. "The military aerospace firms are driven by technology and capability. Cost and price are the commercial guideposts."<sup>27</sup>

A recent survey<sup>28</sup> of civil helicopter operators listed the best new helicopter technologies:

- Composites
- NOTAR (noise reduction)
- Global Positioning System (navigation equipment)
- Avionics

Each of these originally were military funded programs, with applications to civil helicopters. Additionally, DoD has introduced turbine engines into helicopters, developed advanced rotor systems, and funded component reliability improvements. DoD funding has enabled civil helicopter technology growth.

Turboshaft engines represent a watershed point in helicopter development. Every domestic turboshaft engine began as a DoD funded effort. The modern T-700 and recently FAA certified T-800 series engines are military developments. Over 10,000 T-700 family

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<sup>26</sup> The Army and the Navy use a commercial Jet Ranger as their initial helicopter pilot training aircraft.

<sup>27</sup> The Economist, September 3, 1994, page 8.

<sup>28</sup> Rotor & Wing, May 1994.

engines are in military and commercial use. Commercial applications for the T-700 include turboprop commuter aircraft such as the CASA 222 and the Saab 340. The T-700 engine is also found on the Bell 214T. The T-800 engine, qualified in 1992, has wide commercial potential because of its weight-to-power ratio. Helicopters in the 6,000 to 12,000 pound class can use the T-800 as a single or a twin engine. Commuter airplanes ranging from small six passenger twin engine aircraft to the four engine DeHavilland also represent viable applications.

A commercial variant of the V-22 Osprey is widely discussed. However, the prospects for commercial applications of a tiltrotor aircraft in the near future remain uncertain.

Because the commercial helicopter market is relatively small (approximately 16% of the value of world sales), a high level of research will probably never be supported by civil sales alone. For example, commercial sales will not justify improvements in nap-of-the-earth flying or degraded visual environment capabilities, even though such capabilities may be useful for some civil applications (e.g. air ambulance service).

## Section II. The World Helicopter Market

The worldwide demand for helicopters tends to be somewhat cyclical. In terms of units produced, demand has remained relatively stable at approximately 2,000 units annually between 1985 and 1991. Worldwide demand dropped in 1993 but is expected to rebound and stabilize at approximately 1,500 units annually for the foreseeable future. However, the value of that production is expected to increase as world demand grows for larger, multi-engine turbine military and civil helicopters with modern electronics systems.<sup>29</sup>

### A. Demand

Helicopters are purchased by two sets of customers: civil (foreign and domestic) and military (foreign and DoD). The number of helicopters produced for civil customers exceeds the number produced for military customers, but the dollar value of military production significantly exceeds that of civil production. Figure II-1 summarizes the value of world helicopter production between 1985 and 2004. Figure II-2 summarizes world helicopter unit production over that same period.

The value of world helicopter production (in constant FY95 dollars) is expected to increase 5 percent annually from 1995 (\$5.98 billion) to 2004 (\$8.94 billion). However, predictions for future production remain relatively flat at around 1,500 units through 2004. Both military and civil customers are projected to buy a higher percentage of multi-engine turbine helicopters. Additionally, the unit cost of future military helicopters, such as the V-22, is expected to be higher than current models.

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<sup>29</sup> It is important to note that all market projections in this report are very sensitive to sales for selected key helicopters (V-22, Longbow Apache modifications, MD 500/900 series, EH-101, EC-135, and Mi-38). Changes in anticipated sales for these helicopters would alter the projections.

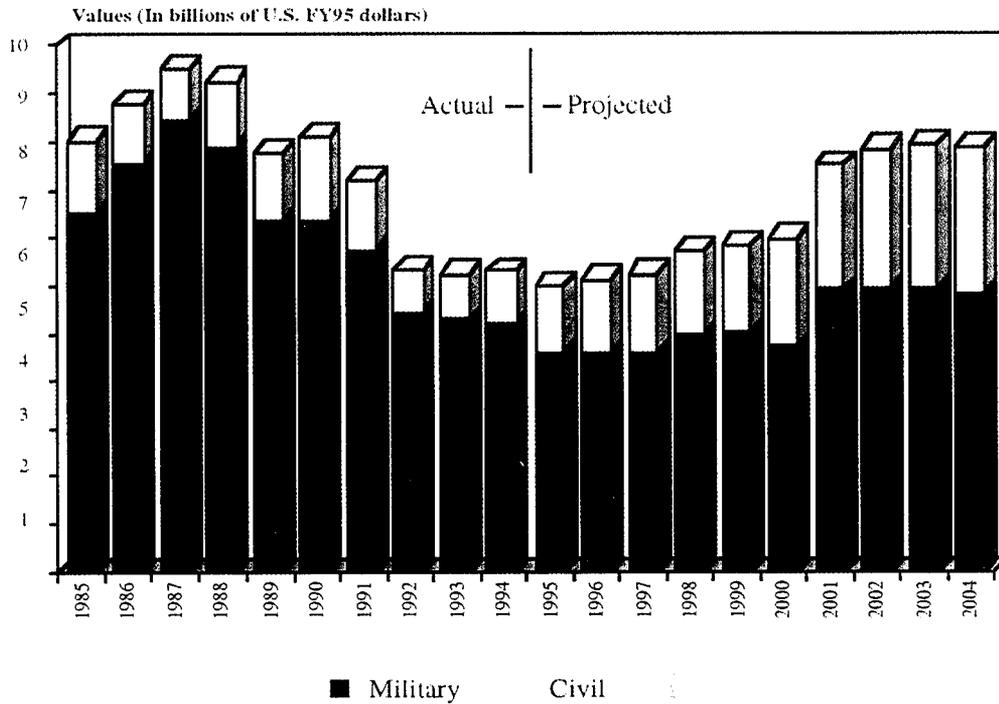


Figure II-1: World Helicopter Market (1985-2004)<sup>30</sup> Value of Production

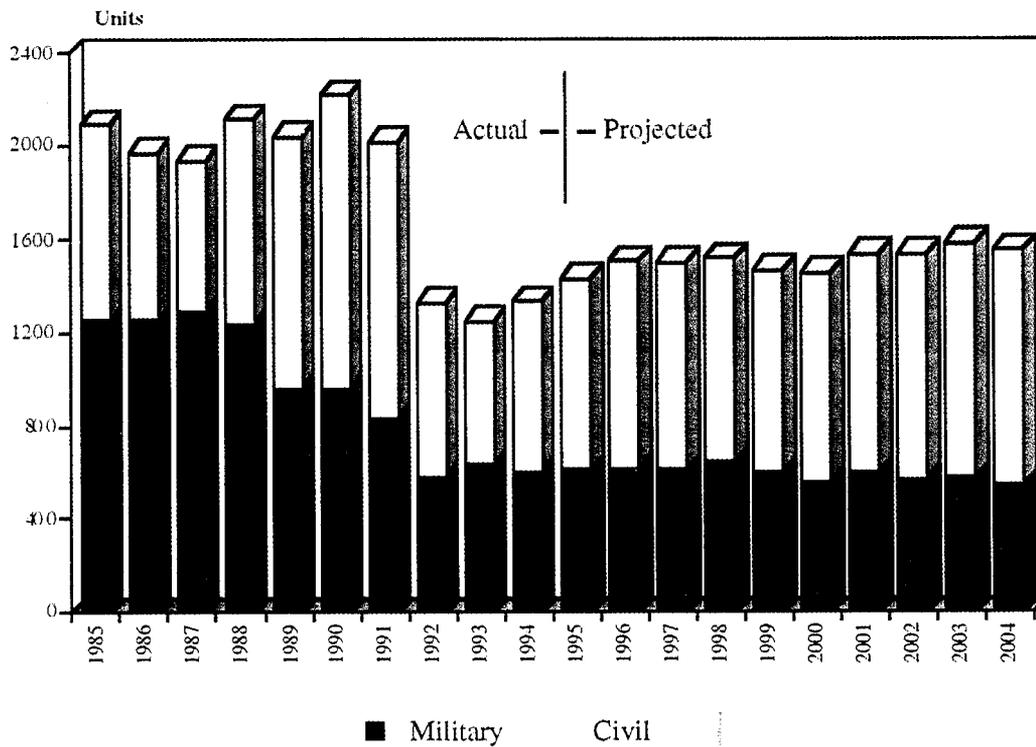


Figure II-2: World Helicopter Market (1985-2004)<sup>31</sup> Unit Production

<sup>30</sup> Forecast Intl./DMS, in the American Helicopter Society's *International Directory*, Vol. 41, No. 1, 1995.

<sup>31</sup> Same as 30.

## B. Civil Market

In 1994, the worldwide operational civil helicopter fleet was estimated to be as large as 24,500<sup>32</sup> helicopters (15,000-18,000 of these are estimated to be turbine powered), operating in 163 countries. Figure II-3 summarizes the 1994 regional civil markets.

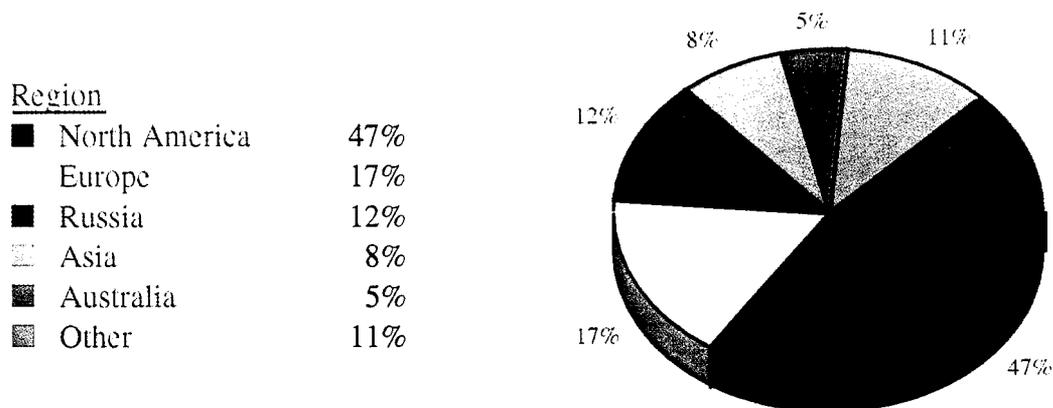


Figure II-3: 1994 Regional Civil Market<sup>33</sup>

While there is disagreement within the industry as to how soon and how extensively the market will rebound in different regions, there is consensus that the Far East will see the most growth.

The value of world civil helicopter production from 1985 to 2004 is shown in Figure II-4. Unit production for the same period is shown in Figure II-5.

<sup>32</sup> Rotor & Wing, January 1995; Computair Consultants, Surrey, UK.

<sup>33</sup> Teal Group Corp. Briefing, World Military and Civil Aircraft, February 1995.

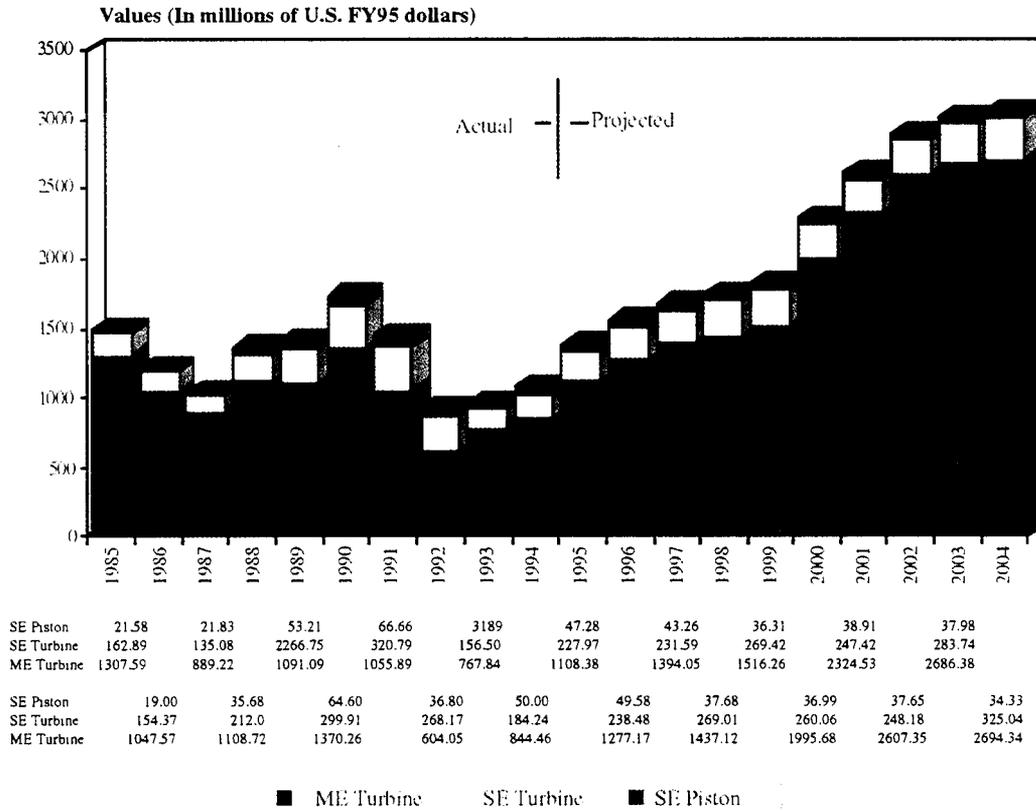


Figure II-4: Total World Civil Helicopter Market<sup>34</sup> Value of Production (1985-2004)

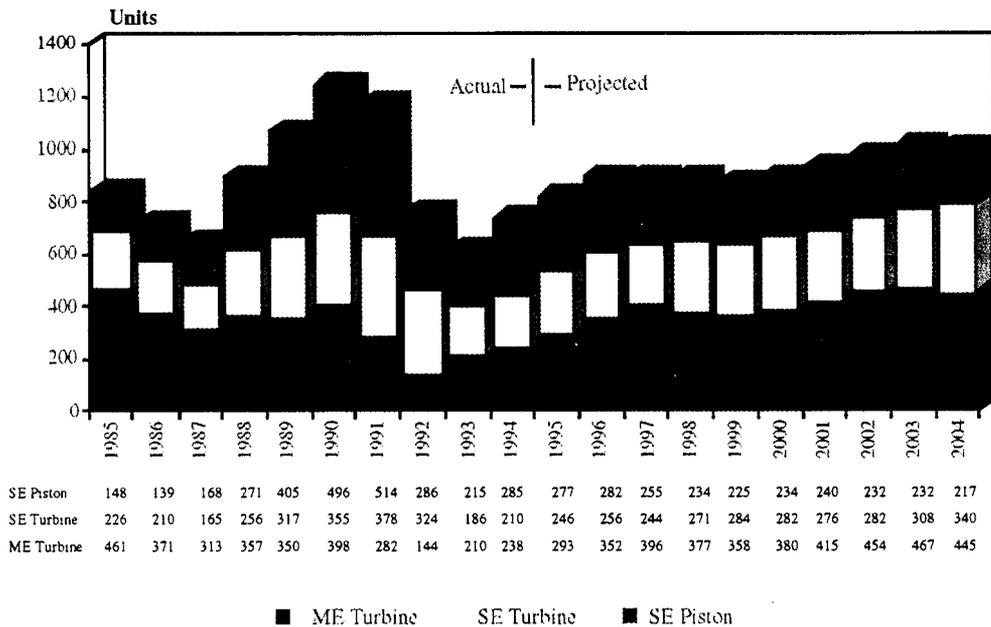


Figure II-5: World Civil Helicopter Market<sup>35</sup> Unit Production (1985-2004)

<sup>34</sup> Forecast Intl./DMS, in the American Helicopter Society's International Directory, Vol. 41, No. 1, 1995.

<sup>35</sup> Same as 34.

The value of civil helicopter production is projected to steadily increase from \$1.4 billion in 1995 to more than \$3 billion in 2004. However, unit production is projected to increase slightly and stabilize at between 800 and 900 units, annually, during this same period. Value of production is predicted to increase more rapidly than unit production because of anticipated increased demand for more capable and expensive multi-engine turbine helicopters.

The estimates for new civil turbine engine helicopter sales do not consider the potential impact of DoD plans to dispose of excess helicopters. Between 1994 and 1999, the Army plans to excess 3150 military helicopters no longer needed due to a downsized force structure and continued modernization. In 1996, the peak disposal year, over 1,000 helicopters are planned for disposal. The Army excessing plan gives preference to other government agencies and foreign military sales. To date, the Army has not utilized the Defense Reutilization Marketing Service to offer the excess helicopters for sale to the public. However, there is a potential for several hundred of these excess assets to be offered for sale to the public, beginning as early as this year. DoD is examining the impact of this disposition of surplus helicopters and is considering options to minimize market disruption.

### **C. Military Market**

In 1994, the worldwide operational military helicopter fleet was estimated to be as large as 20,175<sup>36</sup> units (not including those operated by states of the Former Soviet Union), operating in 166 countries (13,000-15,000 of these aircraft are estimated to be turbine powered). Figure II-6 summarizes the worldwide operational helicopter fleet, by region in 1994.

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<sup>36</sup> Flight International, Air Forces of the World Report, 24-30 August 1994.

Region

■ North America	40%
■ Eurasia	24%
▨ Pacific Rim	13%
▨ Mid East	11%
■ Africa	7%
▨ C/S America	5%

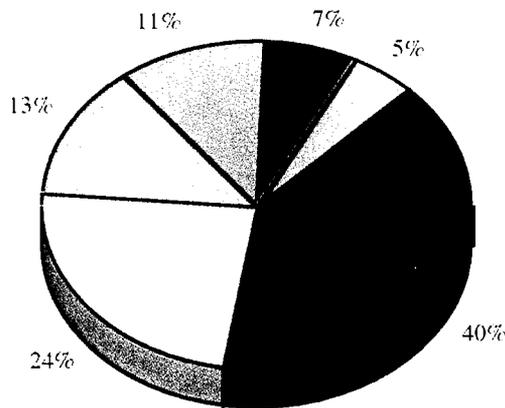


Figure II-6: 1994 Regional Military Market<sup>37</sup>

Figure II-7 summarizes world military helicopter production (including states of the Former Soviet Union) by value for the period 1985 to 2004. Figure II-8 summarizes military helicopter unit production (including states of the Former Soviet Union) for the same period.

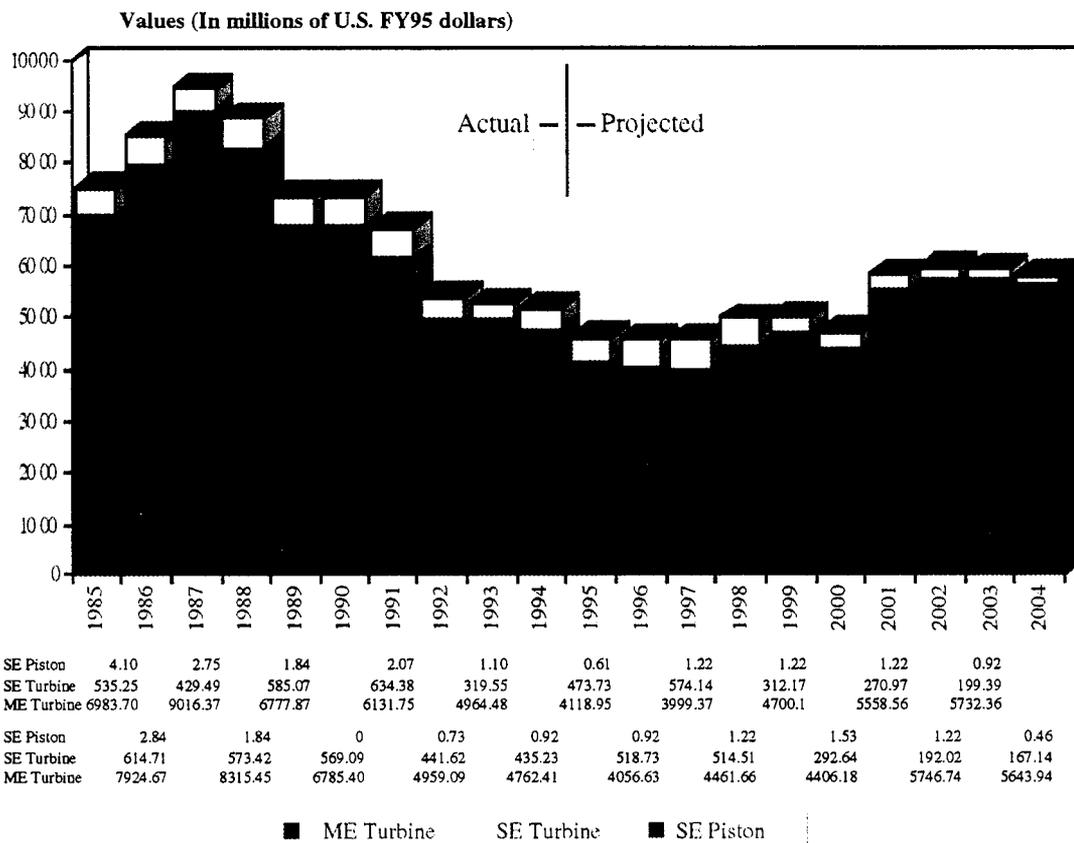


Figure II-7: World Military Helicopter Market<sup>38</sup> Value of Production, 1985-2004

<sup>37</sup>Flight Intl., Air Forces of the World Report, 24-30 August 1994.

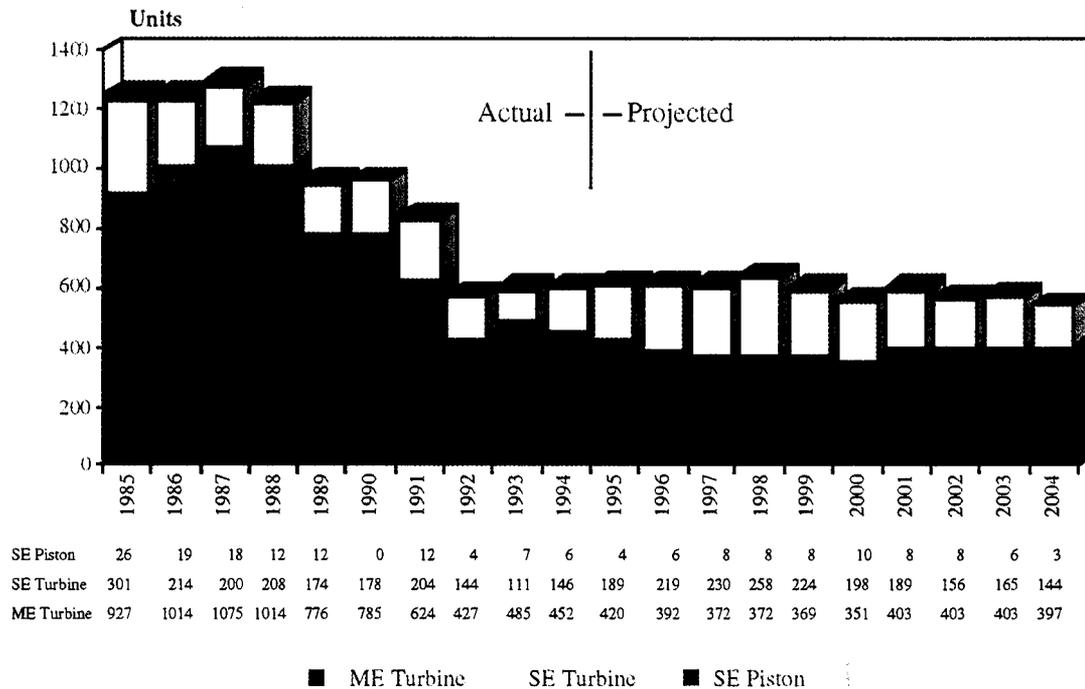


Figure II-8: World Military Helicopter Market<sup>39</sup> Unit Production, 1985-2004

The annual value of world military production is expected to continue to decline from a peak of \$9.4 billion in 1987 to \$4.6 billion in 1996 and 1997, then slowly increase and stabilize at around \$6 billion in 2001. However, world military helicopter unit production declined from a peak of 1,293 units in 1987 to a low of 557 units in 1992 and is expected to remain stable at around 600 units per year, through 2004. The increase in predicted value of production, despite relatively stable unit production, is due to higher unit prices for future military systems, such as the V-22.

Military helicopter sales to foreign governments are either Foreign Military Sales (FMS) or International Sales. Foreign governments frequently use the US government as their agent. These transactions are referred to as FMS.<sup>40</sup> International sales are direct sales from the US prime contractor to the foreign government. This report will refer to both as

<sup>38</sup> Forecast Intl./DMS, in the American Helicopter Society's International Directory, Vol. 41, No. 1, 1995.

<sup>39</sup> Same as 38.

<sup>40</sup> FMS also includes the sale of excess equipment to foreign governments (e.g. UH-1, AH-1).

“foreign sales” of military helicopters. The sale of military helicopters to foreign buyers represents additional revenue to the prime contractor. DoD also benefits. Additional helicopter sales can fill production gaps and spread overhead costs to other buyers. Recently, foreign sales bridged the gap between the end of Apache production in July 1996 and the beginning of the AH-64D modification program in March 1997, with an estimated one time savings of \$300 million.<sup>41</sup>

The sale of civil helicopters to commercial customers is based on price and performance. Military helicopter sales to foreign governments are based only partially on price and performance. Foreign government sales are impacted by broader issues of balance of payments and international agreements. Decisions to purchase a particular helicopter are part of a larger plan that often includes government loans, construction projects, and reciprocal agreements to purchase other equipment and products. Foreign government decisions to purchase military helicopters commonly require offsets and co-production arrangements. Offsets require the seller to purchase something in return from the buying nation. Aerospace firms selling to developing nations often must barter or resell products unrelated to their line of business. Co-production arrangements require that a specified portion of the actual helicopter production must be done in the buying nation.<sup>42</sup> Requirements to produce composite airframe elements, titanium castings, or major components in the buying nation result in the transfer of technology and skills, and improve payment imbalances. In the sale of Apache helicopters to the United Kingdom, for example, MDHS offered a small British helicopter firm, Westland, 51 percent of the production.

Co-production and offset requirements dilute the value of the sale to the US prime contractor, and adversely impact second and third tier suppliers who already may have a

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<sup>41</sup> Army Program Executive Officer, Aviation International Operations.

<sup>42</sup> Offsets and co-production requirements apply to international sales, not FMS.

reduced workload. Nevertheless, all four major US prime contractors consider foreign sales an important component of their business base.

#### **D. After Sales**

All helicopter manufacturers obtain revenue from the sale of spares, engineering change support, technical support, publications, and other ancillary goods and services. These are collectively referred to as "product support." Civil operators generally purchase nearly all spare parts from the airframe manufacturer. Product support revenue can exceed 20 percent of revenues for a firm oriented toward civil helicopters.

The DoD operates much larger fleets and maintains its own parts warehouses. Early in the life cycle of a new helicopter, DoD logisticians rely on the prime contractor to supply almost all required spare parts. As the fleet grows, DoD increasingly purchases spares directly from the second tier suppliers who built them originally for the prime contractors, and qualifies additional suppliers as required. With mature fleets, DoD buys very few spare parts directly from the prime contractor. Consequently, product support revenue for prime contractors which emphasize DoD helicopters is smaller, generally ranging from 2 to 14 percent of sales.

#### **E. Competition in the World Market**

The results of increased foreign competition in the world helicopter market over the next decade are illustrated in Figure II-9 (value of production) and Figure II-10 (unit production).

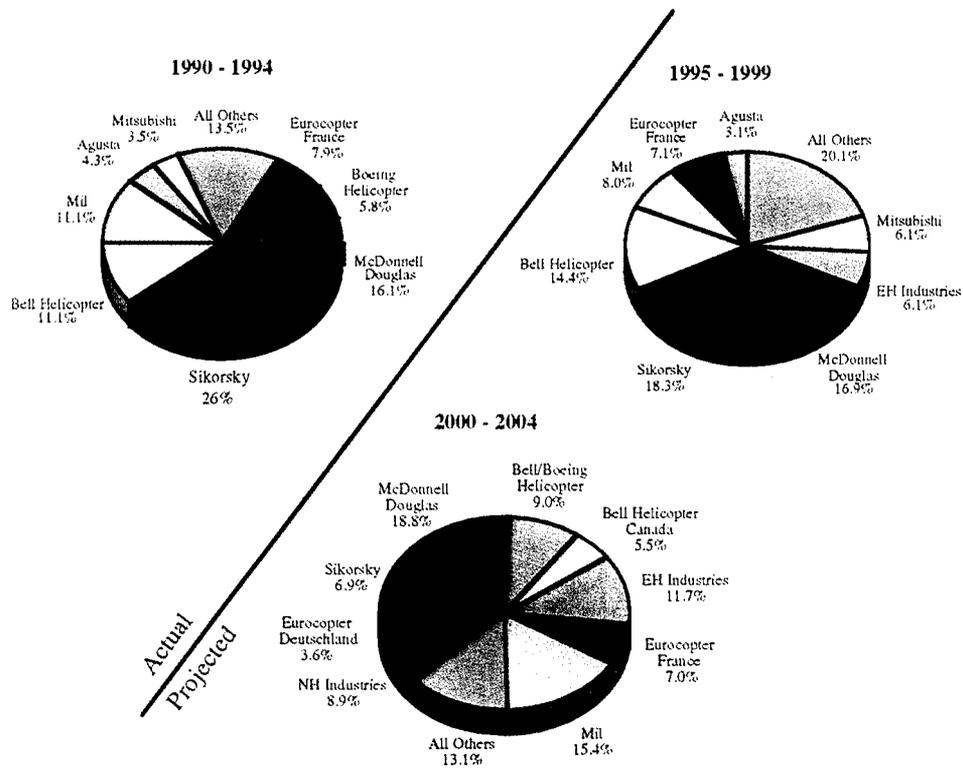


Figure II-9: Market Share (%), World Helicopter Production (1990-2004)<sup>43</sup> Value of Production

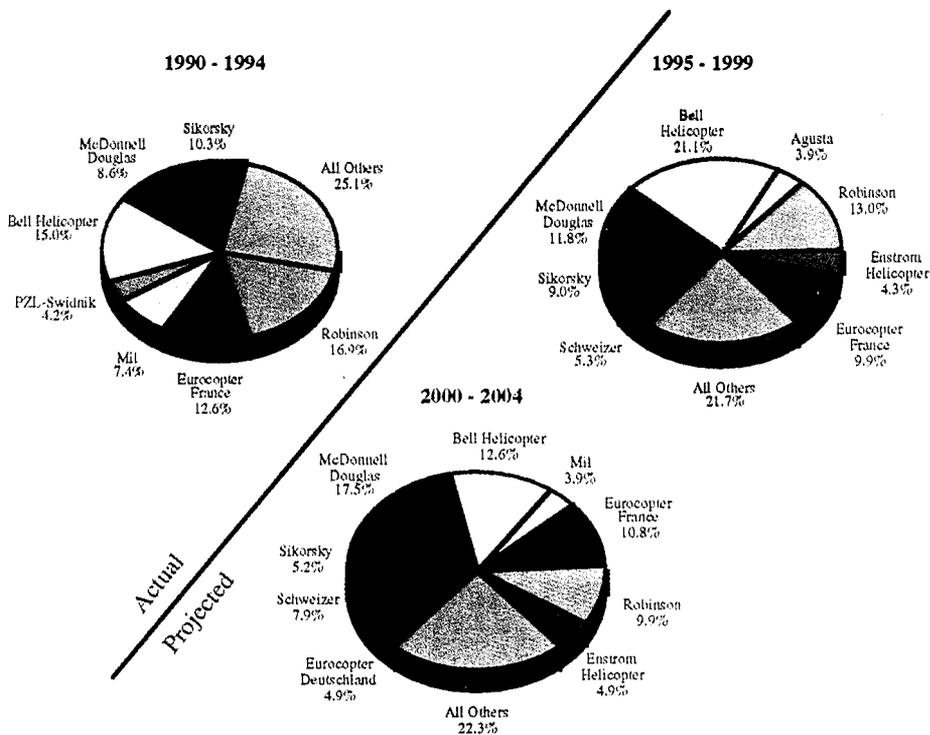


Figure II-10: Market Share (%), World Helicopter Production (1990-2004)<sup>44</sup> Unit Production

<sup>43</sup> Forecast Intl./DMS, in the American Helicopter Society's International Directory, Vol. 41, No. 1, 1995.

US producer (including Bell Canada) unit production (Figure II-9) market share, is relatively high; 51 percent for 1990-1994; 65 percent for 1995-1999; and 58 percent for 2000-2004. However, a large percentage of these units are projected to be inexpensive single engine piston powered helicopters. If single engine piston helicopters are excluded, the turbine powered unit production percentage of the market controlled by the four major US manufacturers from whom the DoD buys its helicopters is 44 percent for 1990-1994; 51 percent for 1995-1999; and 41 percent for 2000-2004. (Boeing is not listed separately in Figure II-9 for the period 1995-1999 because it has only low level production of CH-47s for the export market for this period. Boeing is teamed with Bell for the V-22 Osprey which will enter low rate production in approximately 1997.)

The US prime contractors supplied approximately 60 percent of the value of worldwide production in 1994. Forecast International (a private research and forecasting firm that concentrates on defense-related markets) predicts that US manufacturers will lose roughly 20 percentage points of market share (to 40 percent) over the next ten years -- due to the decline in DoD purchases. However, Forecast International also predicts that the absolute annual value of production controlled by US manufacturers will remain relatively constant (between \$3.2 billion and \$3.4 billion in constant 1995 dollars) over that same period. These numbers are somewhat misleading, however, since U.S. firms are expected to maintain their share of the emerging world civil market. The decline in total market share is due to declining DoD new production -- primarily production of a limited number of V-22 Osprey aircraft. Significant DoD helicopter funds will go to modifications (AH-64 & SH-60) and development (RAH-66).

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<sup>4</sup> Same as 43.

## **F. Foreign Helicopter Manufacturers**

### **1. Italy**

Agusta is an Italian firm that produces three helicopter models. Their A109 is a light helicopter used for emergency medical service, executive transportation, offshore oil support, law enforcement, and a variety of military roles. Over 600 have been produced to date, and continued annual production of 35 to 50 aircraft is likely. Agusta also produces a light attack helicopter, the A129 Mangusta. The Italian army has ordered 60. However, international sales prospects for the A129 Mangusta are limited. Agusta is teamed with the British firm, Westland, on a new medium utility helicopter, the EH-101. Production will begin this year. Civil versions of the EH-101 are expected to cost about \$10 million. Military (including naval) versions are expected to cost between \$18 million and \$40 million. With sales forecasts of 15 to 25 per year, this is an important program for Agusta.

### **2. France and Germany**

Eurocopter, formed by the merger of the largest French and German helicopter firms,<sup>45</sup> is a major global helicopter manufacturer. The majority of the stock is held by the French government. Eurocopter consistently ranks first or second in world sales (depending on whether the rank is based on airframes or value of sales). The main plant is in Marignane, France. Rotor blades are made at its Paris plant. Eurocopter makes both civil and military helicopters. It has had limited success selling civil helicopters in the US, but has been very competitive in both civil and military markets in the rest of the world. Eurocopter has a reputation for providing excellent product support. It frequently ships spare parts overnight, and provides maintenance and operational manuals in English, French, Chinese, German, and Spanish.

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<sup>45</sup> Aerospatiale (French) and Messerschmitt-Bolkow-Blohm (German) merged in January 1992.

### **3. Japan**

Kawasaki is a large Japanese industrial firm with a helicopter subsidiary. It has three helicopter lines. It produces the Eurocopter BK-117, by license, in their Gift, Japan plant. It also produces the McDonnell Douglas MD 500 and the Boeing CH-47 under a license agreement. Kawasaki began developing a light attack helicopter, the OH-X, in 1992. First production deliveries are expected in 1999. Japan's geography and population density are particularly conducive to the widespread use of helicopters and the Japanese have undertaken a major national effort to construct an extensive network of helipads throughout urban areas. Japanese firms (Kawasaki and Mitsubishi) may become major competitors in the large and growing Pacific Rim market.

Japan's Mitsubishi Heavy Industries, under license from Sikorsky, is building UH-60Ls for the Japan Air Self Defense Force and the Japan Maritime Self Defense Force. Mitsubishi also is manufacturing SH-60J Sea Hawks for Japanese anti-submarine and search and rescue missions.

### **4. Russia**

Many of the 20,000 helicopters produced by Russia have been heavy lift. Russia's MilDesign Bureau plans to market its Mi-26, the world's largest helicopter, to the logging industry. Other civil sales are likely to remain limited. There is a potential for the use of Russian helicopters in world military applications, particularly for heavy lift aircraft. Pressed by their hard currency demands and declining economy, Russia offers very attractive prices. Historically poor reliability rates for Russian helicopters could be improved with the installation of Western turbine engines. The one remaining obstacle is a poor product

support record. Teaming arrangements with a European or US aircraft maintenance firm which might also manage spares could dramatically improve product support.<sup>46</sup>

## **5. South Korea**

In 1990, South Korea reached an agreement with Sikorsky to co-produce UH-60P Black Hawks for internal troop transport requirements. They gradually will increase their portion of the production until all of the airframe will be built in South Korea. No follow on sales or production are scheduled.

## **6. United Kingdom**

Westland is a small British firm with one helicopter, the light utility Lynx, currently in low rate production (three to eight annually). A total of 380 have been built to date. Westland is teamed with Agusta on the medium EH-101. With the British selection of the McDonnell Douglas AH-64 as their new attack helicopter, Westland will produce approximately 51 percent of the aircraft. Westland also has a license agreement with Sikorsky to produce UH-60Ls for the European military market, but as yet there have been no sales. Westland's military market prospects (EH-101 and AH-64) are brighter than their civil prospects.

## **7. Manufacturers in Other Countries**

India's Hindustan Aeronautics Limited is developing a twin engine Advanced Light Helicopter similar to the new McDonnell Douglas MD 900. First production deliveries are expected in 1996. Singapore Aerospace Pte. Ltd. is teamed with China National Aero-Technology and Eurocopter to produce the EC-120, a light utility helicopter. Production deliveries are scheduled to begin in 1998. A Brazilian firm, Helibras, began licensed production of the Eurocopter AS350 series in 1979, and by 1991 had delivered over 100 to

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<sup>46</sup> There are several US firms that specialize in military aircraft maintenance including Beech Aerospace Services, Incorporated (BAS), DynCorp, Lockheed Support Services Inc. (LSSI).

Brazilian and neighboring country civil and military operators. South Africa's Atlas Aviation produces the CSH-2 Rooivalk, a medium military attack helicopter.

## G. Summary

The world civil helicopter market is beginning to evolve toward larger, multi-engine turbine helicopters with more advanced electronics systems. This development will create an opportunity for domestic producers to compete for the new civil helicopter business.

Increased foreign sales of military helicopters:

- Frequently fill potential production gaps in DoD programs, keeping production lines open and reducing DoD helicopter costs.
- Will not keep US production lines open for years after DoD programs are canceled. Foreign governments normally do not purchase quantities large enough to support full scale production.<sup>47</sup>
- Lower DoD acquisition costs and allow the Services to procure more aircraft with available funds.<sup>48</sup>

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<sup>47</sup> For example, Greece has purchased 5 Sea Hawks, Spain has purchased 6, and Thailand intends to purchase 6. The aircraft was developed for the US Navy, who will purchase 188.

<sup>48</sup> DoD contracts are negotiated on the basis of costs. As more helicopters are produced, the overhead costs allocated to DoD programs are reduced. This frequently amounts to millions of dollars that can be used to procure additional helicopters. These lower costs also apply to the procurement of spares.

### **Section III. DoD Requirements**

This section describes DoD requirements for helicopter technology development, procurement, and logistics support. The Department's funding for major helicopter research and development programs is expected to decline through the turn of the century. Helicopter procurement funding, however, is expected to increase over that same period. Technology development funding normally declines as the technology is adopted in new production and major upgrade programs. As these helicopters grow older, technology funds are increased to support the helicopter advances necessary to retain technological -- and military -- superiority in the next generation of DoD helicopters.

DoD's helicopter fleet must be sustained during peacetime and the high operation tempo of a conflict. As DoD's helicopter production requirements shift from several mature lines to fewer new lines (V-22 and eventually Comanche), logistics support requirements -- particularly those associated with conflicts -- are being reexamined. Logistics support requirements for conflicts can be expected to be substantially higher than those required to sustain peacetime operations. Therefore, DoD is evaluating the impact that production status, war reserve stock availability, and the number of routine flight hours have on its logistics support requirements.

#### **A. Technology Development**

DoD helicopter research and development efforts focus on applying existing and evolving design, development, and production techniques to ongoing helicopter development programs. Military development programs have resulted in significant helicopter technological advances over the past fifty years. Without DoD helicopter research and development programs, the pace of US helicopter technological development would

likely slow to a standstill. Applied technology efforts in dynamics, aerodynamics, propulsion, drive systems, flight controls, and vibration are specifically unique to helicopters and must be addressed as integrated activities within a systems engineering environment.

An integrated, systems engineering approach is necessary to ensure changes and improvements in one applied technology area do not result in degraded performance in another. In helicopters, changes in scale often result in nonlinear effects which are difficult to predict without extensive testing. Unique helicopter design challenges include: understanding and improving rotor blade tips that operate in the transonic regime, understanding and reducing loads imposed on dynamic components, and developing improved vibration suppression in areas not common with airplanes. The DoD relies on the four major prime contractors for ongoing development activities in these areas. The DoD also relies on the four major prime contractors for development activities in blade and hub design, aerodynamic improvements, dynamic system changes, and the application of advanced composite materials in drive and dynamic components.

The ability to integrate sophisticated mission and electronic systems is less advanced and still evolving. Commercial helicopter mission packages do not approach the sophistication or complexity of the military systems, and the difficulties of integration and crew station design are not comparable. The DoD relied on industry to make significant advances in mission capabilities in third generation helicopters such as the Apache. These advances resulted in major improvements in operational capabilities, but also in very high workloads for the crews -- and frequent task overloads. Considerable effort has been expended in helicopter crew station design and integration to alleviate the high work load conditions while providing yet another significant advance in operational mission capability. These advances have resulted from several years of crew station design made possible by full mission simulation using state-of-the-art high fidelity simulators. Human factors, crew station design, and workload reduction have been systematically addressed.

These efforts have evolved into a fourth stage of helicopter design. Helicopter technology developments have resulted in extremely operationally effective helicopters that do not overload the crew with mission and flight tasks, or saturate them with the information available from the digital sensors and battlefield systems. Military development programs are the only source of support for these advances.

Signature suppression is another technology becoming more critical on the modern battlefield due to the proliferation of advanced weapons systems. The military aircraft industry has made significant advances in signature suppression, as evidenced by the stealth fighter and bomber. Yet the techniques that are applied to airplanes are, in many ways, significantly different from those required for helicopters. For example, rotor body interference, found only on helicopters, can be the dominant contributor to helicopter radar signature. Therefore, DoD is developing improved infrared, acoustic, and radar signature suppression techniques. These techniques are critical to survivability against the inexpensive heat and/or image seeking missiles that are now, or soon will be, available worldwide.

Helicopter development facilities are as critical and essential as the technologies they support. Some are unique to the helicopter industry: low speed wind tunnels; indoor and outdoor radar cross section ranges capable of analyzing dynamic and static signatures; and motion base simulators with high fidelity terrain models to examine nap-of-the-earth flight.

Figures III-1 and III-2 quantify and identify the major DoD research and development programs for helicopters. These funds support the development of new helicopters and upgrades to the existing fleet. The Navy is funding upgrades to the AH-1W, SH-60, and H-53. But the vast majority of their funds supports the continued development of the V-22 Osprey.

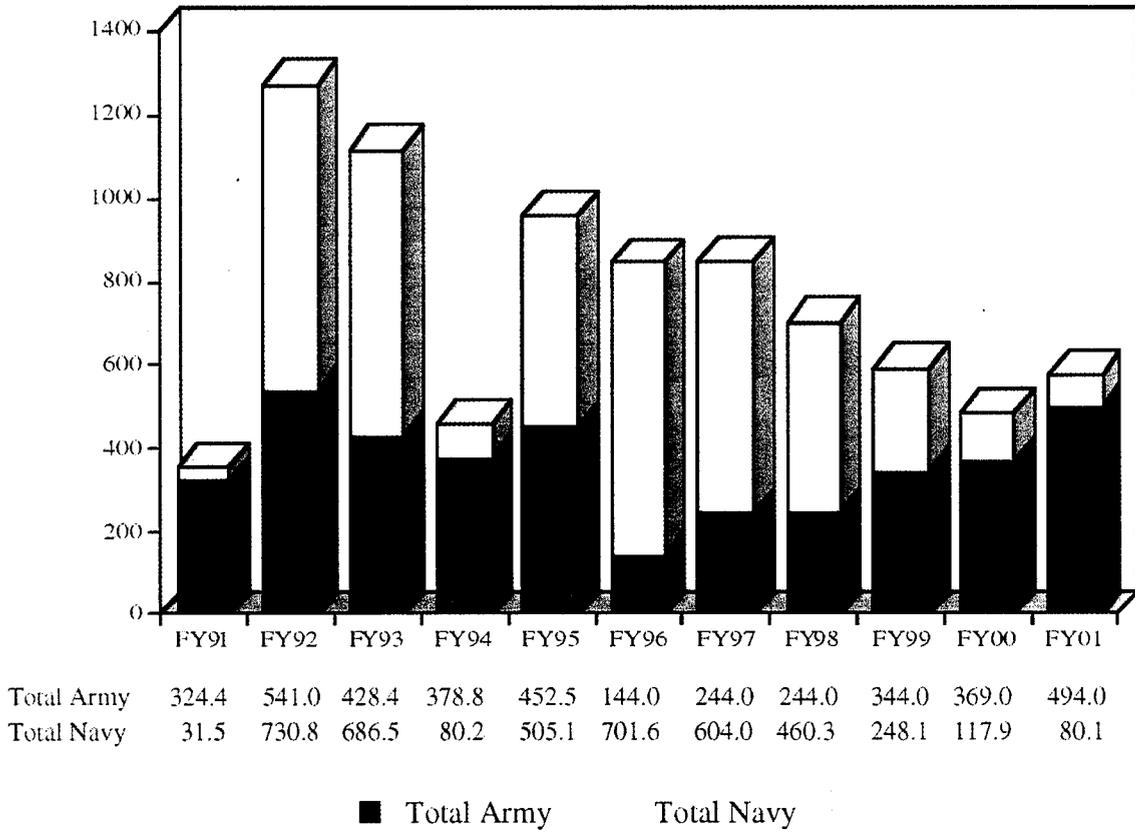


Figure III-1: Army & Navy Helicopter RDT&E Program Funding (FY95 \$M)<sup>49</sup>

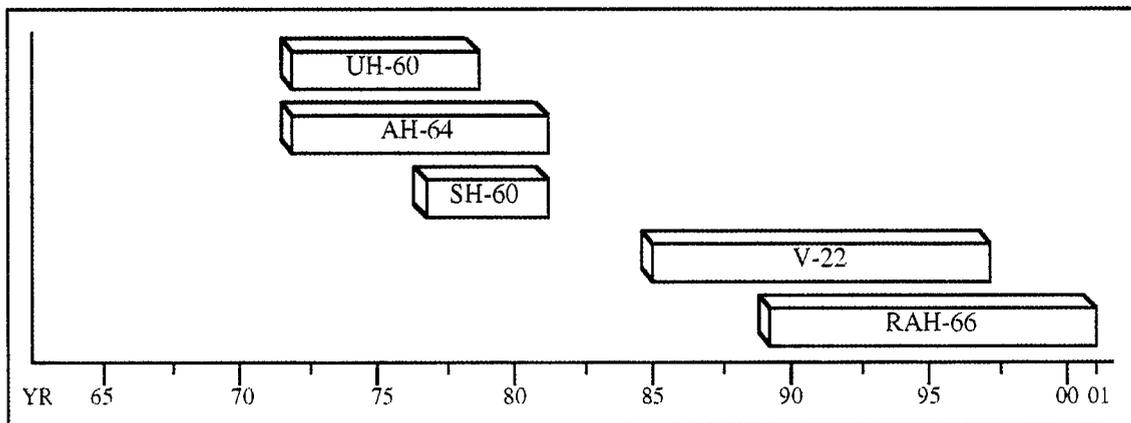


Figure III-2: Major DoD Aviation Platform R&D Programs

<sup>49</sup> Source: FY96-97 Budget Estimate Submission.

The Army is funding upgrades to the OH-58 and AH-64. But the vast majority of their funds supports the AH-64 Longbow modification program and the RAH-66 Comanche. There will be one ongoing major helicopter development program (the Comanche) after 1997.

## B. Production

Figures III-3 and III-4 summarize DoD helicopter production. Future production quantities are expected to be significantly less than those of the early 1990s. However, the value of those future procurements is expected to be significantly greater than those of the early 1990s. These changes reflect evolving DoD requirements from larger quantities of lower cost helicopters in the early 1990s, to fewer quantities of higher cost helicopters (V-22 Osprey and RAH-66 Comanche) in the late 1990s.

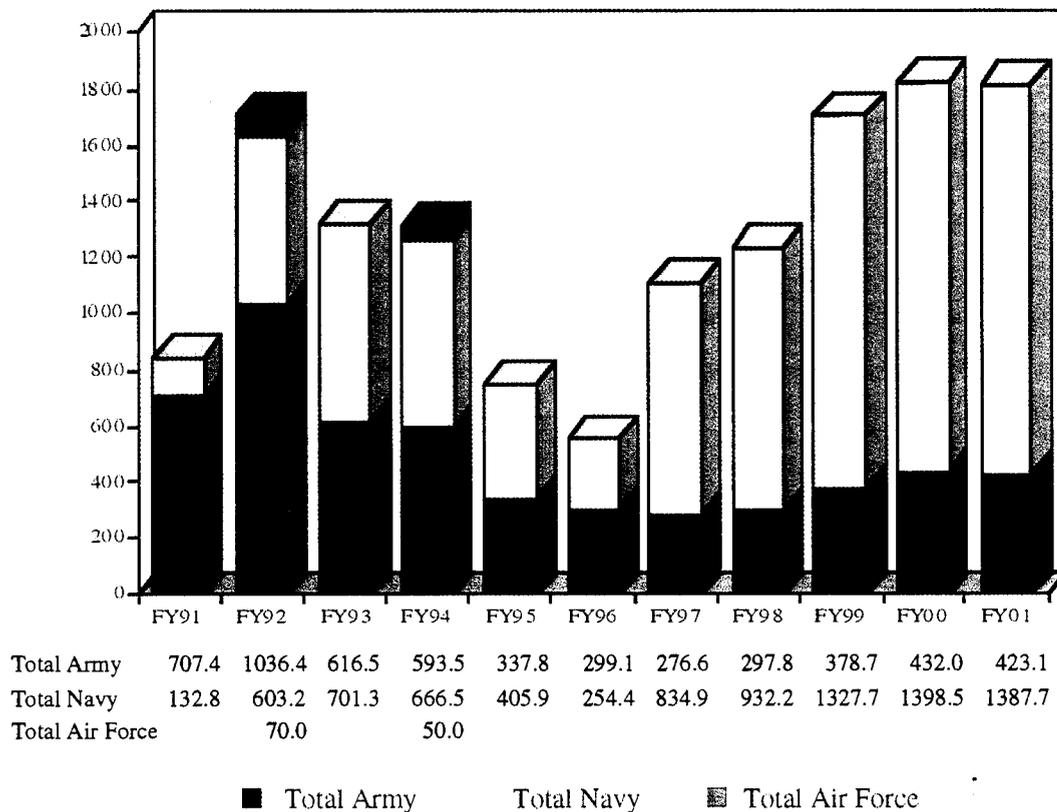


Figure III-3: Army & Navy Helicopter Production Program Funding (FY95 \$M)<sup>50</sup>

<sup>50</sup> Source: FY96-97 Budget Estimate Submission.

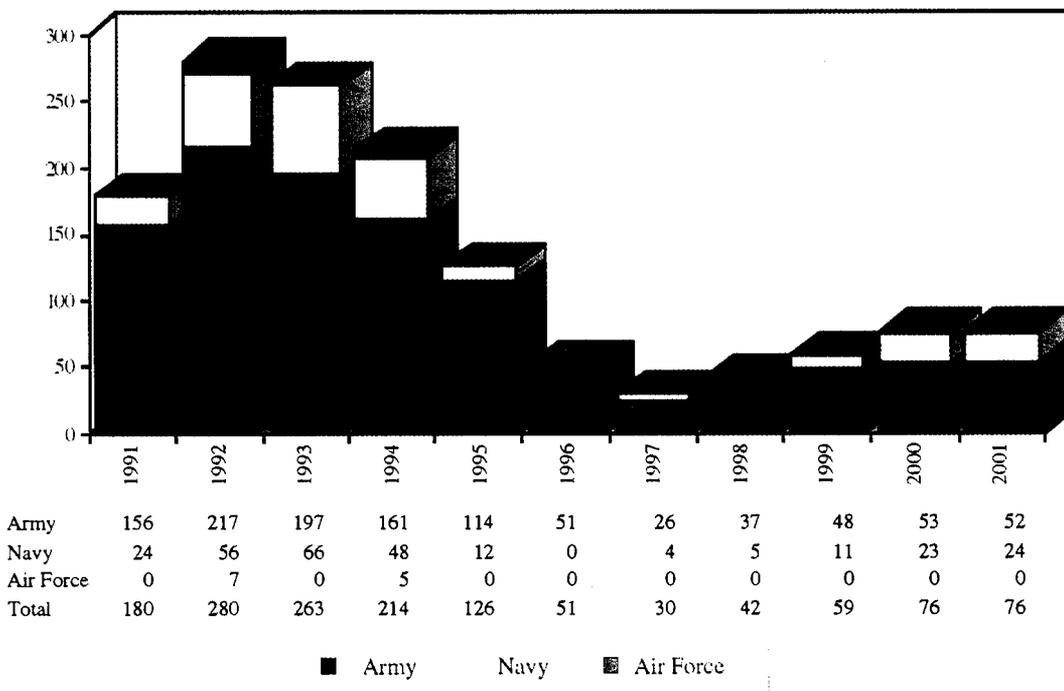


Figure III-4: DoD Helicopter Production Plans (1991-2001)<sup>51</sup>

The percentage of world military production required to meet DoD demand (Section II, Figures II-7 and II-8) also reflects these changes. Between 1991 and 1994, sales to DoD represented 38 percent (based on production units; 23 percent based on value of production) of the world military market for turbine engine helicopters. Between 1995 and 1998, the DoD contribution is projected to decrease to 10 percent (based on production units; 19 percent based on value of production). Between 1999 and 2001, the DoD contribution to world military turbine engine unit production requirements is expected to increase slightly to 12 percent. However, the DoD demand based on value of production is expected to increase significantly to 35 percent of the world market for military turbine engine helicopters.

<sup>51</sup> Source: FY96-97 Budget Estimate Submission.

Figure III-5 identifies the major DoD production programs which comprise those procurements. In 1995, there are five major production programs in progress. This will drop to one in 1997 and beyond. Major modification programs will continue to improve the capabilities of fielded helicopters. Additionally, the modification programs will become an increasingly important revenue source for the DoD prime contractors and will help to sustain industrial capabilities during gaps in new production. RAH-66 production has been deferred and is not included in Figure III-5.

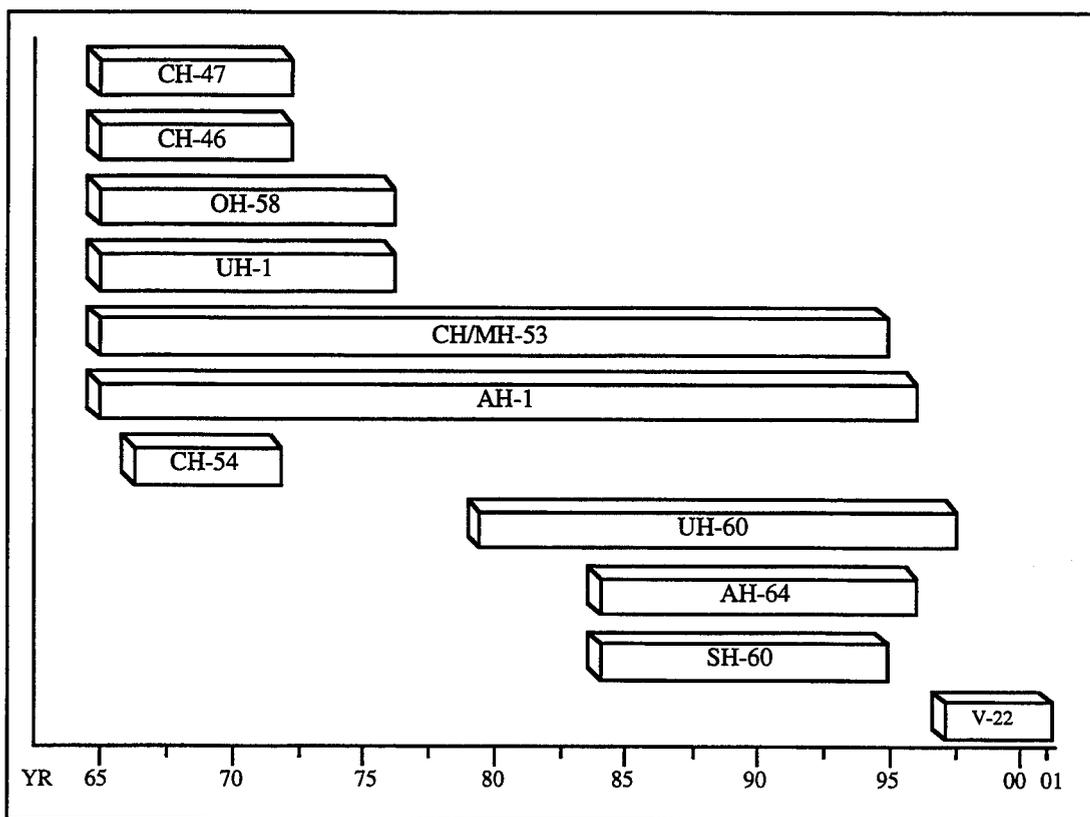


Figure III-5: Major DoD Aviation Platform Production Programs

**C. Estimated Future DoD Program Funding to Prime Contractors**

Figures III-6 and III-7 summarize total projected DoD funding for the four major domestic prime contractors from whom the DoD buys military helicopters. Funding for

government management and government furnished equipment (for example, aircraft engines<sup>52</sup>) is not included. Procurement costs include new procurement, modifications, and spares. Research, Development, Test, and Evaluation costs also are included. In the case of the RAH-66 Comanche and the V-22 Osprey, procurement funding for the out years was divided evenly between the companies involved. The market shares described in Figure III-7 are significantly affected by the V-22 Osprey program.<sup>53</sup>

	1995	1996	1997	1998	1999
Boeing	557.6	490.2	716.7	667.3	869.8
Bell	554.7	429.6	652.6	608.8	560.1
Sikorsky	563.7	316.7	307.7	305.1	515.9
MHDS	174.8	255.1	288.5	278.8	362.8
Total	\$1,850.8M	\$1,491.6M	\$1,965.5M	\$1860.0M	\$2,308.6M

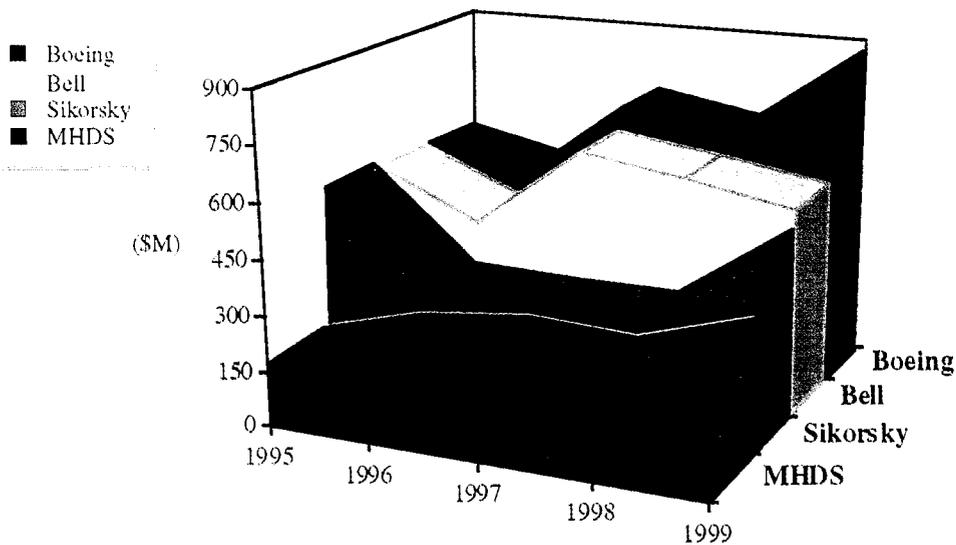


Figure III-6: DoD Projected Funding for the Four Major Domestic Producers (FY95 \$M)<sup>54</sup>

<sup>52</sup> The government's practice has generally been to negotiate and contract separately for major components (e.g. aircraft engines, millimeter wave radar, forward looking infra-red (FLIR) sensors) and then provide these major components as "government furnished equipment" to the prime contractor.

<sup>53</sup> The V-22 program is projected to be funded at \$1 billion annually.

<sup>54</sup> FY96-97 Budget Estimate Submission.

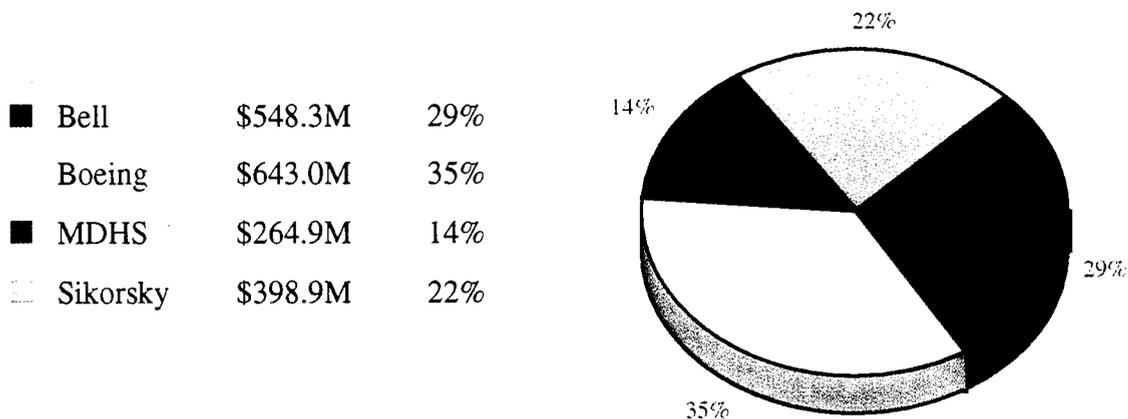


Figure III-7: Five Year Average Share of DoD Funding, 1995-1999 (FY95 \$M)<sup>55</sup>

## D. Logistics Support

With large helicopter fleets and declining new production, DoD is reexamining the way it determines war reserve spare parts requirements.

### 1. Spare Parts

Table III-1 describes the anticipated DoD helicopter fleet in fiscal year 1996. This fleet must be sustained both during peacetime and the high operation tempo of a conflict. With a warm production base, minimal investment in war reserves has been viewed as an acceptable risk and the DoD has relied historically on a warm helicopter production base to support its systems during a conflict. An active production line ensured that the prime contractor and, more importantly, the hundreds of subcontractors, had the requisite tooling and personnel to replenish required helicopter components. War reserves (or contingency stocks) represent a “safety net” of stocks on hand at depots, generally procured in quantities over and above those required to meet peacetime requirements. During normal peacetime training spare parts are required for components which wear out, and the stocks are drawn down. During a conflict, spare part demand is much higher. For example, currently, AH-64

<sup>55</sup> FY96-97 Budget Estimate Submission.

Apache helicopters fly approximately 15 hours per month. During a conflict the Apache may fly four times that operational tempo.

Table III-1  
FY96 DoD Helicopter Inventory

Name	Qty	Type	Manufacturer	Service
AH-1F Cobra	645	Attack	Bell	USA
AH-1W Super Cobra	184	Attack	Bell	USMC
AH-64A/D Apache	758	Attack	MDHS	USA
CH-46 Sea Knight	327	Cargo	Boeing	USN & USMC
CH-47D Chinook	442	Cargo	Boeing	USA & SOCOM
CH/MH-53 Super Stallion	187	Cargo, AMCM	Sikorsky	USN & USMC
H-3	74	Search and Rescue	Sikorsky	USN/USNR
V-22 Osprey	2	Special Operations, Assault	Bell and Boeing	USMC & SOCOM
SH-60 Sea Hawk	272	Anti-Submarine Warfare	Sikorsky	USN
OH-58A/C Kiowa	1,034	Observation	Bell	USA
OH-58D Kiowa Warrior	303	Armed Reconnaissance	Bell	USA
SH-2F	16	Anti-Submarine Warfare	Kaman	USNR
UH-1H/V Iroquois	2,213	Utility	Bell	USA, USN, USAF, USMC
UH/EH60 Black Hawk	1,435	Utility	Sikorsky	USA
Various	205	Special Operations	Various	SOCOM
Total	8,105			

Acronyms

AMCM	Airborne Mine Counter Measures
USNR	US Navy Reserve
USA	US Army
USAF	US Air Force
USMC	US Marine Corps
SOCOM	Special Operations Command
USN	US Navy

However, even when there is no active production, there may be adequate operating requirements to sustain the required industrial capabilities. Sustainment of the UH-60 Black Hawk is a case in point. Production for the Black Hawk is projected to end in 1997. If there were to be a potential for the fleet to experience significant sustainment problems, DoD could consider increased investment in war reserves or continued production. However, with nearly 2000<sup>56</sup> Black Hawks flying an average of 145 hours per year, there is sufficient routine spares demand to sustain prime and subcontractor capabilities. Additionally, many parts associated with military helicopters are similar or identical to those used in commercial fleets flying thousands of aircraft at flying rates considerably in excess of military rates. This commercial usage creates a constant demand which sustains the same vendors who build military parts. Factors affecting the demand for helicopter spare parts include:

- The size of the fleet for each model, including civil derivatives.
- The reliability and durability of the part.
- Flight hours per month (operational tempo).
- The rate of part obsolescence and upgrades (for example, avionics change more rapidly than airframes).
- Geographical and environment stresses, such as desert sand and arctic ice.

With large helicopter inventories and declining new production requirements, DoD is reexamining the manner in which war reserve spare parts requirements are determined. In fact, the availability of sufficient spares to support wartime operations depends on (1) the extent to which there is an active production program, (2) the quantity of war reserves on hand, and (3) the the anticipated demand, based largely on flight hours.<sup>57</sup>

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<sup>56</sup> The 2000 unit figure includes foreign, and civil S-70 series, helicopters.

<sup>57</sup> Spares are purchased to meet demand. Fewer peacetime flight hours result in fewer spare part purchases and lower inventory levels.

In addition to maintaining the capability to provide replacements for parts which experience normal wear, the Department also must consider the need to replace critical life limited components. Such components can experience negligible demand for years until the aircraft are sufficiently mature to require large scale replacement. Suppliers of such components will often have ceased production years before. In such cases, the Department is faced with a difficult decision to restart production of the component, or to upgrade the system. The Department routinely faces such decisions and decides each on a case-by-case basis.

## **2. Sustaining Engineering**

Engineering expertise must be sustained for out-of-production helicopters. For example, DoD has sustained the out-of-production UH-1 for many years. While a few UH-1 variants are produced every year for civil customers, the numbers are very small. The most critical issue for out-of-production helicopters is maintaining prime contractor control and sustaining engineering to solve technical problems, help qualify new vendors, and support the design and approval of crash and battle damage repairs.

## **Section IV. Capabilities Meet DoD Requirements**

Despite declining military sales, significant excess capacity, and strong foreign competition, all four major prime contractors supplying helicopters to DoD are profitable. US helicopter industry consolidation may occur -- subsystem and component manufacturer consolidation has already begun.

The four major prime contractors all possess adequate systems engineering and integration capabilities. There are several capable suppliers for all required subsystems and components. Additionally, although DoD helicopter requirements have declined, worldwide demand for larger, multi-engine turbine military and civil helicopters with modern electronics systems is growing. All four major US prime contractors are positioned to vigorously compete for this business.

There are several capabilities essential to developing, producing, and supporting technologically superior helicopters for DoD:

- World class rotorcraft aerodynamic design.
- Stealth technology.
- Developmental and design simulation.
- Systems integration expertise to identify opportunities, define requirements, select a systems integration vendor, and manage the effort.
- Composite airframe development and production.

Prime contractors and suppliers are sustaining -- and improving -- these capabilities as they work on on-going DoD helicopter programs (V-22, Comanche, and various upgrades). DoD will continue to fund these programs, even as, or if, the industry consolidates. Additionally, domestic civil sales, foreign (civil and military) sales, and DoD

overhaul and maintenance demand will contribute to needed revenues. For these reasons, the Department expects that those firms remaining in the industry will be healthy and will retain the industrial and technological capabilities necessary to meet DoD helicopter requirements for the foreseeable future.

## A. Prime Contractors

Table IV-1 summarizes recent profitability, at the corporate level, for the four major US prime contractors that currently produce DoD helicopters. Table IV-2 summarizes recent profitability at those segments of the corporations in which the helicopters are produced. The tables indicate that both the corporations and their helicopter segments remain profitable. In 1994, operating profit margins for the relevant segments ranged from 6.4 percent of sales for Boeing's Space and Defense Group to 9.1 percent for McDonnell Douglas' Military Aircraft segment. Moreover, the helicopter businesses within these segments are all profitable.

Table IV-1  
Profitability of US Aircraft Prime Contractors - Corporate<sup>58</sup>

	1991			1992			1993			1994		
	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)
The Boeing Corporation	29,314	1,954	6.7	30,184	2,040	6.8	25,438	1,691	6.6	21,924	1,327	6.1
McDonnell Douglas Corporation	18,045	866	4.8	17,354	321	1.8	14,474	492	3.4	13,162	1,067	8.1
Textron Corporation	7,823	797	10.2	8,344	846	10.1	9,075	933	10.3	9,681	1,036	10.7
United Technologies Corporation	21,262	-497	-2.3	22,032	589	2.7	21,081	1,314	6.2	21,197	1,544	7.3

<sup>58</sup> Source: Company Reports

Table IV-2  
Profitability of US Aircraft Prime Contractors - Segments with Helicopter Capabilities<sup>59</sup>

	1991			1992			1993			1994		
	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)	Sales (\$M)	Operating Profit (\$M)	Operating Margin (%)
Boeing-Space & Defense Group	5,846	-102	-1.7	5,429	204	3.8	4,407	219	5	4,742	303	6.4
McDonnell Douglas-Military Aircraft Segment	7,795	394	5.1	7,238	8	0.1	6,862	83	1.2	7,804	708	9.1
Textron Corp. Aircraft Segment	1,255	113	9	1,521	128	8.4	1,987	171	8.6	2,186	194	8.9
United Tech. Corp.-Flight Sys. Segment	4,024	-224	-5.6	4,045	275	6.8	3,930	385	9.8	3,218	282	8.8

The helicopter businesses within the segments are also becoming more efficient. Aggregate sales of the four major US helicopter prime contractors are projected to increase by 9.8 percent (from \$4.88 billion to \$5.36 billion) between 1990 and 1995. Employment in the four major US prime contractors is projected to decline by 17.5 percent (from about 32,200 to about 26,500) over that same period. All of the firms are projected to achieve increased efficiency. Collectively, the efficiency of the four firms is projected to increase 33 percent (from approximately \$152,000 annual sales per employee to approximately \$202,000 annual sales per employee) between 1990 and 1995. Individually, the range of efficiency increases is projected to range from a low of 20 percent to a high of 65 percent.

Substantial excess capacity exists in the industry. The capacity utilization rate for the four major US prime contractors was 38 percent in 1990. (Within the four firms, capacity utilization ranged from a low of 33 percent to a high of 60 percent.) By 1995, as a result of considerable internal consolidation, the industry capacity utilization rate had increased to 48 percent (ranging from 37 percent to 64 percent within the four firms). Because of their reliance on declining DoD business, industry and individual firm capacity utilization rates are expected to decline between 1995 and 1997. The average helicopter division backlog

<sup>59</sup> Source: Company Reports

fluctuated around \$2.0 billion between 1990 and 1994, but is projected to decline to a six year low of \$1.84 billion in 1995.

Excess DoD helicopters provided to other government agencies, or to foreign governments through foreign military sales, may exacerbate US industry overcapacity by reducing new production civil helicopter sales opportunities. Bell and MDHS would feel the most impact from these disposals. Boeing and Sikorsky would be only minimally affected. Currently, DoD plans to offer the helicopters to government agencies, for foreign military sales, and possibly for public sale. DoD is examining the impact of this disposition of surplus helicopters and is considering options to minimize market disruption.

Each of the four major prime contractors possess adequate systems engineering and integration capabilities to develop new helicopters as necessary to meet future DoD requirements. Although the continued existence of excess capacity suggests that some consolidation is likely and that one or more of these prime contractors may merge with another, those firms which remain are expected to retain sufficient capabilities (technologies, skills, facilities, and tooling) to meet DoD requirements.

As DoD procurement budgets have declined, firms have increasingly sought other revenue sources -- including product support. Specifically, the four major US helicopter prime contractors have indicated they would benefit from a larger portion of the helicopter maintenance work now performed in organic government depots. US law now prohibits the DoD from contracting out to private firms more than forty percent of its depot maintenance workload. Secretary Perry, on April 25, 1995, recommended to Congress that the law be changed to allow DoD the flexibility to allocate depot maintenance workload between public and private facilities as necessary to best meet Department requirements.

## 1. **Bell Helicopters, Textron, Inc. (BHTI)**

Bell Helicopters, with headquarters near Fort Worth, Texas, is a division of Textron Corporation. Textron ranks twentieth in size among DoD contractors.

### a. History

Bell is one of the pioneer firms in the development of helicopters. During the late 1960s, Bell was the primary supplier of Army helicopters. Its annual military and civil sales exceeded 2,000 aircraft. The Bell Jet Ranger, a derivative of the aircraft they proposed in the original Army Light Observation Helicopter competition in 1961, is the most widely flown helicopter in the world. Sales of the 206B Jet Ranger continue to be strong.

In the early 1970s, Bell competed for, but was not awarded, two major US Army programs: the Utility Tactical Transport Aircraft System and the Advanced Attack Helicopter. In both cases, Bell proposed a two-bladed teetering rotor blade design. Having lost the two major military helicopter production contracts of the 1970s and 1980s, Bell focused on their other strength, the civil market. Over the past two decades Bell Helicopter civil sales have increased while their military sales (production and modifications) have decreased. In the mid-1980s Bell teamed with Boeing on the V-22 Osprey, their first military new production program in thirty years.<sup>60</sup>

### b. Skills and Capabilities

Bell has remained first or second in the world civil market by offering reliable price-competitive helicopters and providing responsive spares support. Approximately 34 percent of its revenues come from spares and product support. Low costs have been realized, in large part, by a reliance on evolutionary modifications of existing helicopters to meet market demands. Its civilian 206B Jet Ranger is a modification of the OH-4 military helicopter.

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<sup>60</sup> In 1993, Bell won the Army New Training Helicopter (NTH) contract -- basically, a civil helicopter with slight modifications, including crashworthy fuel tanks and crew seats designed and installed by a subcontractor.

The OH-4 became the Army OH-58A in the 1960s. The 206B has since been modified to a 206L (Long Ranger) version. Its model 407 uses the dynamic components of the Army OH-58D. Bell's model 222 has been improved once to the model 230, and again to the model 430. Bell still sells new model 212s (the original Navy "Twin Huey" helicopter). More recently, Bell modified the 212 model to become the 412 civil helicopter. Bell's US Marine Corps (USMC) AH-1W attack helicopter is an evolution of the USMC's AH-1T, using some dynamic components from the Bell 214ST.

Bell is teamed with Boeing on the V-22 Osprey. Together, Bell and Boeing have become world leaders in tiltrotor technology. Bell has retained most of their buildings and has invested heavily in new industrial plant equipment. It has the greatest raw production capacity of the four major US helicopter prime contractors. Bell has demonstrated production rates in excess of 200 aircraft per month (AH-1s and UH-1s). Bell makes rotor blades and dynamic components, does modifications, performs V-22 work, and maintains their primary engineering staff, all at its Texas facility. Bell's commercial fabrication and final assembly work have been moved to its Canadian facility. With a worldwide marketing network, extensive spares inventories, and first class technical and maintenance support, Bell enjoys an excellent product support reputation.

c. Current Production

Bell primarily produces civil helicopters. It is working on a major modification program -- the Army's OH-58D Kiowa Warrior -- and will complete USMC AH-1W production in 1996. Bell's co-development of the V-22 Osprey program has expanded its expertise in state-of-the-art composite technology and in aerodynamic engineering. The V-22 will be the most complex and technologically advanced aircraft Bell has produced. It will also have a significant impact on revenues. At a projected \$1 billion annual program

funding level, Bell's estimated annual revenue is \$350 million,<sup>61</sup> the equivalent of selling 400 commercial Jet Rangers.

d. Future Business

Forecast International has projected that Bell's world market share will decline as it encounters significantly increased competition in the commercial market. From its peak of 2000 per year in the late 1960s, the production rate is projected to decline toward 200 per year in the next ten years. As DoD and foreign military helicopter sales decline for all US firms, all may increasingly turn to the civil market. This area had previously been left to Eurocopter and Bell. MDHS has recently introduced the MD 900 twin Explorer. Eurocopter has introduced the EC-135. Both are advanced civil helicopters targeted at the largest segment of the civil market. Bell has countered with the 407 with a new composite aft fuselage and modern four-bladed composite rotor. MDHS is likely to introduce the MD 600 soon. Eurocopter's BK-117 has been improved and is popular with civil operators. The Singapore, China, and France consortium on the EC-120, Hindustan Aeronautics Ltd.'s ALH, and various Kawasaki and Mitsubishi helicopters are expected to provide serious competition in the Far East markets. It is unlikely that the Bell-Boeing team will realize any sales of civil tiltrotors within the next decade. However, Bell has the broadest business base, with thousands of civil and military helicopters in service throughout the world. Of all the helicopter producers, Bell is the least vulnerable to the loss of a single product (except the DoD V-22), therefore its revenue from post-sale support services will continue to be substantial for the foreseeable future.

## 2. **Boeing Helicopter Division**

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<sup>61</sup> Bell and Boeing will each split the revenue on a 50-50 basis. Generally, Bell retains approximately 70 percent of its program revenues for work performed internally. The balance is applied to government furnished equipment and other costs. A basic 206B Jet Ranger sells for approximately \$700,000.

Boeing Helicopters is a division of the Defense and Space Group of the Boeing Corporation -- the world's largest aerospace firm, with annual sales ranging from \$22 billion to \$30 billion. Boeing's primary emphasis is commercial aircraft.

a. History

Boeing concentrates on larger helicopters. Over the past thirty years, it has produced one medium helicopter (the Navy and USMC CH-46 Sea Knight) and one heavy helicopter (the Army and Special Operations Forces CH-47 Chinook). Production of the CH-46 ended in 1972. CH-47C production ended in 1982. From 1982 through 1994, Boeing remanufactured CH-47A/B/C helicopters to the CH-47D configuration. This was a major rebuild program costing approximately \$12.5M each and requiring 11 months. However, the large helicopter market is limited, and civil sales are small. Boeing has sold a total of thirteen CH-47 helicopters in the civil market. Boeing teamed with Bell to win the V-22 Osprey development contract in 1982, and with Sikorsky for the RAH-66 Comanche development contract in 1991.

b. Skills and Capabilities

Boeing's principal new production is CH-47 Chinooks for international customers. Most of its recent experience has been in the modification and remanufacture of existing helicopters. Boeing has not had extensive experience in the production of dynamic components, but that capability has been improved with the recent acquisition of Litton Precision Gear. Boeing is among the aerospace industry's leaders in the application of composite technology, and experience gained on Boeing's 777 transport production is being effectively applied to the V-22 and Comanche development programs. Participation in these two development programs also has enabled Boeing to develop advanced rotorcraft systems integration and simulation capabilities.

c. Current Production

Boeing does not have a large scale new production program comparable to MDHS' AH-64 Apache or Sikorsky's UH-60 Blackhawk. Current new production is limited mostly to CH-47s for international sales. Boeing has minimal civil spares or product support business, and its after market business base is considerably smaller than that of either Bell or Sikorsky. The largest components of Boeing's current business base are V-22 engineering and manufacturing development, RAH-66 development, and commercial subcontracts from the Boeing Corporation's airplane line.

d. Future Business

Boeing Helicopters' emphasis on large aircraft has led the company to focus on the military, rather than the commercial, market. Boeing Helicopters has avoided the aggressive, price competitive, small, civil helicopter market. With Comanche production deferred, it continues to focus on large helicopters. A replacement for the CH-47D, or another life extension program, is several years in the future. The existing CH-47D fleet is expected to be sustained until 2020. The Navy and USMC will need a Medium Lift Replacement or life extension/upgrade for the aging CH-46 fleet soon. The Navy is conducting a cost and operational effectiveness analysis for its vertical replenishment mission, but existing helicopters (for example, the UH-60L or EH-101) may be preferable to a new development program.

Boeing's most likely near term prospects are Chinook (CH-47) production for foreign customers; some revenue from the Comanche R&D program; and a heavy reliance on the V-22 Osprey. The Russians have several large helicopters and their potential entry into world markets could challenge Boeing's traditionally strong hold. Boeing is expected to continue to emphasize large helicopters (especially the V-22) and the Comanche scout/attack mission until an Army upgrade or replacement for the CH-47D is funded.

**3. McDonnell Douglas Helicopter Systems (MDHS)**

McDonnell Douglas Aerospace is the world's second largest defense contractor.<sup>62</sup>

a. History

Hughes Helicopters, a division of Hughes Tool Company, won the AH-64A Apache contract in 1976. The company was purchased by McDonnell Douglas Corp. in 1982. The first AH-64A was delivered in January 1984.

b. Company Skills and Capabilities

MDHS is unique among major helicopter prime contractors in that it does little machining and manufacturing. Nearly all components of its helicopters are purchased, including the AH-64 airframe and rotor blades. MDHS developed strong systems integration technology and simulation capabilities during the development of the AH-64A and AH-64D programs. MDHS maintains an engineering design staff responsible for systems integration and subsystem design, and requires most subcontractors to "build to print." Additionally, MDHS' industrial and technological capabilities have benefited from a 1993 McDonnell Douglas reorganization which improved the transfer of technical and managerial expertise between McDonnell Douglas Aerospace units. MDHS has emerged as an industry leader in both developmental and engineering simulation, and in systems integration.

c. Current Production

MDHS is converting Army AH-64A models to the AH-64D Longbow Apache configuration, and is producing AH-64A Apaches for foreign military sales and MD 500 and MD 900 helicopters for the commercial market. Additionally, it is expected to commence another commercial line, the MD 600. Unlike the other major US helicopter prime contractors, MDHS DoD sales are limited to a single service, the Army.

d. Future Business

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<sup>62</sup> McDonnell-Douglas was the world's largest defense contractor until the recent merger of Martin Marietta and Lockheed.

At the January 1995 Helicopter Association International convention, MDHS introduced another new civil helicopter, the MD 600. If this program commences, MDHS will have three civil helicopter lines (the MD 500, MD 900, and MD 600) plus the military Apache (AH-64A and AH-64D Longbow).

Production of the Army's AH-64A will end in July 1996. This DoD revenue will be replaced, in part, by the AH-64D Longbow modification program. In the near term, MDHS expects to compensate for declining DoD and foreign military sales with increased sales of its new civil models.

#### **4. Sikorsky Aircraft Corporation**

Sikorsky Aircraft is a subsidiary of United Technologies Corporation and a part of its Flight Systems Division.

##### **a. History**

Sikorsky was the primary supplier of Navy helicopters during the 1950s and 1960s. In 1976, it won the contract for the Army UH-60A Black Hawk. This broadened Sikorsky's military market, and it moved from predominantly heavy lift helicopters to the medium lift category. Sikorsky developed Navy derivatives of the H-60 series -- including the SH-60B, SH-60J (USCG), HH-60H, SH-60F, SH-60R, and HH-60J. It has also sold over 300 of the H-60 series helicopters overseas.

##### **b. Skills and Capabilities**

Sikorsky is the most vertically-integrated of the major US helicopter prime contractors. It maintains a significant internal manufacturing capability. Additionally, its product lines include light, medium, and heavy helicopters. Sikorsky produces helicopters in weight classes from the 11,700 pound civil S-76 to the 73,500 pound military CH-53E. Its

moving base, full motion engineering simulator -- used in the Comanche development program -- is one of the most sophisticated in the aerospace industry.

c. Current Production

Sikorsky's helicopter production mirrors the declining DoD helicopter budget. Sikorsky is almost solely a military (DoD and foreign) supplier, receiving less than 5 percent of its revenue from civil helicopter sales. Of the four major US prime contractors, it has been affected most by the DoD budget declines. Navy and Air Force purchases of the H-60 series and the CH/MH-53E ended in 1994. Funding for the Army UH-60L Black Hawk is expected to end in fiscal year 1996.<sup>63</sup> With RAH-66 Comanche production deferred until 2005, Sikorsky's only significant DoD contracts will be Comanche research and development and a program to modify the Navy's SH-60B and SH-60F aircraft to the SH-60R configuration. This program is scheduled to begin in late 1998. The Army UH-60L and the Navy SH-60 also have potential for foreign sales. Sikorsky faces a significant challenge to reduce costs, despite smaller production runs, in order to make these helicopters affordable on the international market.

d. Future Business

Within the next 36 months Sikorsky will complete work on the Air Force MH-53E, Navy CH-53E and SH-60, and Army UH-60L production. These programs represent the major portion of its business base. To date, its known future DoD business consists of Comanche production. Sikorsky also is actively pursuing foreign military sales.

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<sup>63</sup> The funding is scheduled to end in 1996 which will result in the last Black Hawk delivery in June 1997.

## **B. Subsystem and Key Component/Material Suppliers**

Despite reduced demand and on-going industry consolidation, the Department expects there will be sufficient industrial and technological capabilities to meet its helicopter subsystem and key component/material requirements. The relevant issue is whether sufficient and reliable domestic capabilities exist, not the number of vendors qualified by existing primes. The Department evaluated capabilities associated with nine of the ten major helicopter subsystems. (Weapons subsystem supplier capabilities were not within the scope of this assessment.) The Department also reviewed components and materials within the subsystems to identify potential issues with diminishing or sole source suppliers.

### **1. Airframe Structures**

With the introduction of the V-22 Osprey tilt rotor aircraft and the RAH-66 Comanche, the transition from metal airframes to advanced composite primary aircraft structures is accelerating. In order to support both metal and composite airframe structure requirements, the Osprey and Comanche prime contractors (Bell Textron, Boeing Helicopters, and UTC/Sikorsky) developed capabilities for manufacturing composite airframe structures. Teledyne Ryan Aeronautical and Kaman Aerospace Corporation are supporting DoD with airframe structures. These five manufacturers reported sharply declining military workload between 1988 and 1993, with workload continuing to decline through the mid-1990s. All are facing strong competition from foreign competitors. The airframe structures subsector has excess capacity due to declining defense business and limited commercial and foreign business. As DoD procurements continue to decline, industry observers believe that aircraft structure contractors may consolidate. The key factors which will likely influence industry consolidation are schedule and procurement quantity decisions for the V-22 Osprey and RAH-66 Comanche.

Four of the five contractors in this subsector have the capability to research, develop, design, manufacture, test, and maintain metal helicopter airframe structures. In addition, Bell, Boeing, and Sikorsky have the capabilities required for composite airframe structures.

Composite materials for this subsector are frequently provided by suppliers considered to be single or sole sources. Potential concerns associated with this issue were addressed in a December 1993 Department of Commerce assessment of the US advanced composites industry. The report concluded that very few materials are truly sole source. Rather, many fabricators and prime contractors choose to rely on one or two suppliers because of the expense and time required to qualify new materials and suppliers for DoD products. Few component or material supplies are at risk due to sole source problems. Other suppliers can be qualified to meet product specification requirements.

## **2. Landing Gear**

Currently there are four landing gear manufacturers supporting the DoD helicopter industry: Cleveland Pneumatic, Dowty, Menasco, and Ozone Industries. These manufacturers provide landing gear for commercial and military fixed-wing aircraft, and helicopters. Between 1990 and 1993, firms in this subsector experienced significant declines in employment and in capacity utilization, primarily due to declining DoD procurements. Average capacity utilization for Cleveland Pneumatic and Menasco, for example, declined from 83 percent in 1988 to 58 percent in 1994. Between 1995 and 1997, DoD workload is expected to remain stable while commercial workload is projected to increase slightly.

All four manufacturers possess the industrial capability necessary to meet DoD's landing gear requirements. Declining DoD workload has resulted in short term industry subsector overcapacity. However, three of the four manufacturers are projecting increases in employment, and two are projecting increases in value of shipments over the next several years.

### **3. Flight Control Systems**

There are eleven major contractors providing key flight control system components: Lear Astronics Corp. (computer and sensors), United Technologies Hamilton Standard Division (computer), Parker Hannifin Control Systems Division (hydraulics), Moog Controls Inc. (sensors), Honeywell Defense Avionics Systems (computer), Honeywell Flight Systems (computer), Martin Marietta Control Systems Division (computer), Ozone Inc. (hydraulics), Litton Systems Guidance and Control Division (sensors), Simmonds Precision Aircraft Systems (sensors), and ABEX/NWL Aerospace (hydraulics). These contractors support both the military and commercial fixed wing and helicopter aircraft markets, and other industrial sectors such as missiles. Due to significant decreases in DoD demand, employment at these firms has declined sharply between 1989 and 1994. However, employment and value of shipments are projected to remain stable through 1997. Many of the contractors in this subsector are heavily dependent on DoD workload and closely related foreign military markets.

Ten of the eleven contractors have the full range of industrial capabilities required to research, develop, design, manufacture, and test flight control systems for DoD helicopters. For the near-term, the contractors appear viable. Although further reductions and/or consolidation may be likely, the remaining suppliers would retain those capabilities needed to meet DoD requirements.

### **4. Environmental Control Systems**

Three contractors provide environmental control systems for DoD helicopters: Allied Signal Aerospace Systems and Equipment Division (air conditioning and heating systems), Litton Systems Instruments and Life Support Division (oxygen and inert gas systems), and Hamilton Standard Division of United Technologies (air conditioning systems). These manufacturers support both fixed wing and helicopter (commercial and military) markets, as well as other industrial sectors such as tanks and armored fighting vehicles. All

manufacturers reported declining military demand between 1988-1994, with prospects for additional decline. Commercial demand is projected to remain relatively stable and is a significant factor in maintaining contractor viability in this sector. The commercial business base for firms within this subsector ranges between 24 percent and 60 percent of current demand. Overall, workload is expected to be sufficient to ensure DoD requirements will continue to be met.

## **5. Avionics**

Advanced avionics systems, which employ electronic warfare, night and all weather navigation, target acquisition, fire control, and battle field management systems, are often defense unique. Twenty-two avionics contractors were considered in this assessment. They supply major military helicopter avionics systems including the Longbow Obstacle Avoidance System and the state-of-the-art avionics system for the RAH-66 Comanche. These contractors support fixed-wing aircraft and helicopter programs, and other industrial sectors such as shipbuilding, space, and missiles. These contractors maintain a mix of DoD, domestic civil, and foreign workload. However, most are substantially DoD dependent and the decline in military aircraft procurements has resulted in reduced workload. Continuing military avionics upgrade programs and relatively constant foreign and domestic civil aircraft orders have lessened the impact. Military orders declined 40 percent between 1988 and 1994, but now are projected to remain stable through 1997. Between 1988 and 1994, overall value of shipments declined 22 percent, but are projected to increase a total of 5 percent between 1994 and 1997. Employment declined 48 percent between 1988 and 1994, and is expected to decline another 7 percent by 1997. Non-DoD business will become increasingly important in this subsector. Some consolidation within this subsector has already taken place. Additional consolidation, restructuring, and mergers are likely and will result in a healthier, more efficient base.

## **6. Gas Turbine Engines**

There are three major gas turbine engine contractors supporting the DoD helicopter industry: General Electric Aircraft Engines, Allied Signal Engines, and Allison Engines Company. Additionally, Allied Signal and Allison are participating in a joint venture -- LHTEC -- to produce the T-800 engine for the RAH-66 Comanche. A significant consolidation in this subsector has occurred; in late October 1994, Allied Signal purchased Textron Lycoming's engine division; and in 1995, UK engine manufacturer Rolls Royce acquired Allison Engines Company.

Manufacturers in this subsector support the fixed-wing aircraft and helicopter markets, and other industrial sectors such as shipbuilding and combat vehicles. All manufacturers in this subsector reported sharply declining commercial and military workload between 1990 and 1993. DoD workload is projected to continue to decline through the mid 1990s. However, this decline is expected to be offset by increasing levels of commercial work. Depending on the site, 43 percent to 80 percent of current workload is commercial. This percentage is projected to increase. Overall, the engine subsector is projecting stable and/or slightly increasing workload.

Each of the three contractors supporting this subsector possesses the full range of industrial capabilities required to successfully research, develop, design, manufacture, test, and maintain engines. Although not reviewed in depth for this assessment, several other engine manufacturers appear to have the requisite capabilities to enter the DoD helicopter market -- including Pratt and Whitney, Solar Engines, and foreign firms such as France's Turbomecca and the European engine consortium MTR.

## **7. Auxiliary Power Units**

There are three major auxiliary power unit (APU) contractors supporting the DoD helicopter industry: Allied Signal Inc., (Allied Signal Engines), Sundstrand Aerospace Corp.,

(Sundstrand Power System), and Williams International Corporation. These manufacturers also provide propulsion engines, onboard inert gas systems, ground support equipment, and environmental control systems for fixed wing aircraft, helicopters, shipbuilding (marine power and propulsion systems), and missiles. DoD workload is projected to continue to decline through the 1990s. However this decline is expected to be offset by increases in the commercial and foreign markets. Individual contractor commercial business base varies from 30 percent to 86 percent of current workload. Overall, workload for this sector is expected to be stable.

Each of the three contractors supporting this subsector possesses the full range of industrial capabilities required to successfully research, develop, design, manufacture, test, and maintain APUs, and the associated ground support equipment.

APUs for the next generation of helicopter programs (the RAH-66 Comanche and the V-22 Osprey) are currently in the Engineering and Manufacturing Development (EMD) Program Phase. Williams International is providing the RAH-66 APU. Sundstrand is providing the V-22 APU.

#### **8. Transmissions/Gearboxes**

There are five major transmission manufacturers supporting the DoD helicopter industry: Bell Helicopter Textron, Litton Precision Gear (recently acquired by Boeing), Purdy Corporation, Speco Corporation, and Sikorsky Aircraft Division. In addition, other manufacturers produce precision gears with similar tolerance characteristics for commercial and DoD customers: Philadelphia Gear Corporation, General Electric, Cincinnati Gear, Westech, Westinghouse, and Spar Aerospace.

This subsector is dependent on DoD workload. Among the three DoD prime contractors supporting this subsector only Bell has significant commercial workload.

Average capacity utilization for the transmission industry declined from 69 percent in 1988 to 45 percent in 1994. However, three of DoD's major helicopter prime contractors have the full industrial capabilities required for this subsystem.

Anti-friction (ball, needle, roller, taper-roller) bearings are critical lower tier components necessary for transmissions/gearboxes and other industry subsectors. Industry wide, DoD bearing requirements account for approximately 10 percent of the domestic demand. Seventeen anti-friction bearing manufacturers were identified. No industrial capability concerns related to the design and/or manufacture of anti-friction bearings for helicopter applications were uncovered.

Aerospace quality castings and forgings are key components of transmissions/gearboxes, as well as airframes, landing gear, rotor blades, and engines. Castings are special formula metals cast in molds and delivered to a prime or second tier vendor who machines them into critical aircraft components. There were 75 aerospace casting firms in the late 1980s and 50 in 1992. There are currently 32 firms. There are twelve qualified sources of aerospace quality forgings. Employment and value of shipments trend data indicate several forging contractors have sustained significant losses, and some companies are consolidating and/or restructuring. Nevertheless, for the foreseeable future there are sufficient domestic firms with the required capability to meet DoD's requirements for aircraft quality castings and forgings.

## **9. Rotor Blades**

Rotor blade design emphasizes performance, reliability, maintainability, and life cycle cost. Military rotor blades differ from commercial blades. Military rotor blades must function within a wide range of adverse operational environments, and meet stringent survivability requirements such as the ability to sustain battlefield damage without catastrophic failure. DoD uses several rotor blade designs to meet its performance

requirements -- including all composite (fiber/matrix) blades and blades utilizing a combination of composite materials and a metallic spar of either stainless steel or titanium.

There are five major rotor blade manufacturers supporting the DoD helicopter industry: Bell, Boeing, Sikorsky, Kaman, and Alcoa Composites. Each of the five possesses the full range of industrial capabilities required to successfully research, develop, design, manufacture, test, and maintain rotor blades. On a few occasions, one firm has manufactured rotor blades for another firm's helicopter.

Elastometric bearings are a critical lower tier component supporting certain advanced designs on the V-22, AH-1W, and UH-60 series rotor blades. Three capable elastometric bearing manufacturers have been identified and no industrial capability concerns have been uncovered.

### **C. Industry Consolidation**

Based on the factors described in this assessment, DoD intends to allow the natural forces of the market to determine the make-up of the helicopter industry. Industry consolidation is occurring in response to declining DoD procurements, increased international competition, and excess capacity. To date, most helicopter industry consolidation has occurred in the subsystems/component portion of the base. Many industry observers believe that consolidation at the prime contractor level may occur. This process will eliminate excess capacity, reduce attendant overhead costs, and thereby reduce costs to DoD. DoD will continue to fund helicopter programs (V-22, Comanche, and various upgrades), even as the industry consolidates. There may be non-recurring cost and schedule impacts associated with qualifying new suppliers for selected subsystems and components. These impacts must be assessed and addressed on a case-by-case basis. For these reasons,

the Department expects that helicopter industrial capabilities will be retained after consolidation, and will be ample to meet DoD requirements.

#### **D. Logistics Support**

Routine peacetime demand will be sufficient to sustain spares for helicopters which are part of large fleets (either military or a combination of military and civil). Spares for helicopter models that have a low density, those with unique military components, and those with low failure rates may not be readily available from a shrinking vendor base. These spare parts are being identified and evaluated. The Services will then ensure adequate spares are available. This may be accomplished by a combination of methods:

- Funding more flight hours for the particular model to generate demand for spare parts.
- Stocking more war reserves of identified parts.
- Identifying substitute parts.
- Directing spares purchases and repairs to specific suppliers.
- Paying for the maintenance of specific tooling, facilities, and skills.

The method(s) used will depend on the cost of the parts, the cost and training value of increased peacetime flight hours, the marginal value of continued production, and the rate of technological change.

For example, a low density helicopter like the V-22 will likely have insufficient spares consumption to assure a viable vendor base and the availability of spares. War reserves will be important for the V-22, as will a warm production base. Conversely, a large military fleet, or a small military fleet comparable to a larger commercial fleet, will need considerably fewer war reserves. This suggests the potential benefits arising from greater standardization between Services and the maximum possible use of commercial components.

Additionally, the Department must increase its knowledge and understanding of trade-offs among war reserves, active production lines, and increasing demand by funding higher operational tempos. It may be that modest increases in flying hours would significantly improve spares availability. It may also be appropriate to focus flying hours on the critical "go to war" helicopter systems like the H-60 and AH-64. This would likely increase the availability of the specific spare parts that would be required in a contingency or wartime scenario. Low density systems will still rely on war reserves for spares with limited application to other DoD or civil helicopters.

Department logisticians must increase the precision of war reserve requirements determinations to examine the sustainment base of specific parts. For example, on the low density MH-60K, special actions would not be necessary on the hydraulic pumps because they are the same ones used on the UH-60A/L, SH-60 series, and S-70 series helicopters. With more than 2000 of these flying, each with three identical hydraulic pumps, there is sufficient DoD, foreign military, and civil demand to sustain the vendor base. However, some high reliability (low failure rate), military-unique components may be used on only a small number of DoD helicopters. Fewer replacement parts would be needed and production runs would be infrequent. Routine spares activity may not be sufficient to ensure these components would be available in sufficient quantities during the early months of a conflict.

In summary, the management of spares is a difficult, but not insurmountable, issue which the Department is evaluating on a case-by-case basis. DoD will adjust its provisioning processes as necessary (using potential actions described earlier in this section) to ensure adequate spares are available.

## Section V. Conclusions

- Military helicopters are versatile, flexible, and are used to meet a variety of DoD missions.
- Civil and military helicopters have significantly different missions. As a result of these differences, DoD helicopters are generally, more powerful, complex, and expensive than civil helicopters.
- DoD helicopter requirements have declined. Within two years there will be one new production program (the V-22 Osprey) and one research and development program (the RAH-66 Comanche).
- Worldwide helicopter demand is stable, and demand for larger, multi-engine turbine civil and military helicopters with modern electronics systems is growing.
- Excess DoD helicopters provided to other government agencies, or to foreign governments through foreign military sales, may exacerbate US industry overcapacity by reducing new production civil helicopter sales opportunities. DoD is considering options to minimize market disruption.
- All four major prime contractors supplying helicopters for DoD use are profitable.
- Reduced DoD requirements for helicopters, and strong foreign competition, has led to significant US prime and subsystem contractor production overcapacity.
- Many observers believe that US helicopter industry consolidation is likely. DoD intends to allow the natural forces of the market to determine the make-up of the helicopter industry. Subsystem/component manufacturer consolidation has already begun.
- Consolidation will ultimately result in reduced costs for helicopter development, production, and support -- and lower prices.

- Although the industry will consolidate, the Department expects that helicopter industrial capabilities will be retained after consolidation, and will be ample to meet DoD requirements.
  - The four major prime contractors all possess adequate systems engineering and integration capabilities.
  - There are several capable suppliers for required subsystems and components.
  - DoD will continue to fund helicopter programs (V-22, Comanche, and various upgrades), even as the industry consolidates.
  - Domestic civil sales, foreign sales, and DoD overhaul and maintenance demands will contribute to needed revenues.
    - The management of spares is a difficult, but not insurmountable issue, which the Department is evaluating on a case-by-case basis. DoD will adjust war reserve requirements as necessary to ensure that adequate spares are available to meet wartime requirements.