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THE V-22 TILT ROTOR, A COMPARISON
WITH EXISTING COAST GUARD AIRCRAFT

by

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The V-22 Tilt Rotor, A Comparison
with Existing Coast Guard Aircraft

by

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Submitted in partial fulfillment
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ABSTRACT

The Coast Guard Office of Aviation Plans and Programs continues to receive inquiries from several sources about the service's intentions concerning the V-22 tilt rotor aircraft. Officially, decision makers acknowledge that tilt rotor capabilities could be readily adaptable to the service's missions, but acquisition of the V-22 is not contemplated unless the aircraft is first fielded by a Department of Defense component. This thesis serves as a preliminary inquiry into tilt rotor applications for the Coast Guard. The purpose of the study is to determine the implications of a favorable V-22 production decision on the Coast Guard's current mix of aircraft. As background material, the thesis reviews the history of tilt rotor development and outlines the key economic issues at the center of the public policy debate likely to decide the V-22's future. Then, the V-22 Osprey is compared with each aircraft already in Coast Guard service. Both performance characteristics and costs are examined. Lastly, potential Coast Guard V-22 assimilation strategies are discussed.

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I. INTRODUCTION

This thesis serves as a preliminary inquiry into the feasibility of acquiring the V-22 tilt rotor aircraft for Coast Guard aviation. The study is predicated on the assumption that the V-22 Osprey will enter production and become available to organizations outside the Department of Defense.

This chapter briefly addresses the Coast Guard's reaction to previous improvements in aircraft technology and outlines the objectives of the research. The chapter also includes a section on literature reviewed, scope and limitations and the organization of the thesis.

A. BACKGROUND

Since its infancy in 1915, one of Coast Guard aviation's central functions has been to locate the lost, aid the injured and save the distressed on the high seas and navigable waters of the United States. As time passed and the responsibilities of the Coast Guard increased, the air arm's job expanded as well. Today, Coast Guard aviation supports all of the service's primary missions: search and rescue, enforcement of laws and treaties, marine environmental protection, defense readiness, ice operations and marine safety. In turn, this mission variety means that sortie objectives are extremely diversified. Coast Guard aircraft fly port security patrols, look for pollution, map oil spills, operate with Navy battle groups and track suspicious boats and airplanes attempting to enter the country illegally.

While still standing alert duty, performing searches and plucking survivors from the sea, the service's air resources provide important transportation and logistics support to other elements of the Coast Guard. These activities include flying provisions to remote Coast Guard stations, transporting pollution response forces and equipment to spills in the United States and around the world, conducting shipboard helicopter operations and ferrying repair crews and materials to isolated navigation aids. In summary, the operating arena calls for flexible, versatile and cost effective aircraft. Some would say the Coast Guard represents an ideal environment for the V-22 tilt rotor aircraft.

From humble beginnings, the scope and complexity of Coast Guard air operations has increased dramatically. Several times during its 76 year history Coast Guard decision makers have demonstrated a willingness to become involved with aeronautical advancements that could enhance operations or improve service. Although its still unclear whether or not the V-22 forebodes a new era in aviation, tilt rotor technology could potentially rival past aeronautical innovations placed in Coast Guard service.

In 1916, Bryon R. Newton, the Assistant Secretary of the Treasury,[1] Glen H. Curtiss, pioneer aircraft designer, and Captain Chiswell, commanding officer of the cutter Onondaga, discussed the practicality of building a flying "lifeboat" plane. Although the original idea to attach wings, engine and propeller to an actual surf boat proved unfeasible, Curtiss did go on to build several successful boat hulled airplanes. (*Air Search and Rescue: 63 Years of Aerial Lifesaving*, 1978, pp. 3-19)

Recognizing the helicopter's potential, the Coast Guard designated Air Station Brooklyn as a rotary wing training site late in 1943. In January of the next year, Commander Erickson made the first life saving helicopter flight by transporting two cases of blood plasma from New York City to a hospital in Sandy Hook, New Jersey. With the end of World War II, the Coast Guard gradually added more helicopters to the seaplanes and shore based aircraft already in operation. (*Air Search and Rescue: 63 Years of Aerial Lifesaving*, 1978, pp. 3-19)

By the 1960's, other significant changes occurred in Coast Guard aviation. Piston powered helicopters were retired in favor of amphibious

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[1] In 1967 the Coast Guard was moved to the Department of Transportation.

helicopters with turboshaft engines. Turboprop aircraft appeared as well. As the late 1970's approached, the Coast Guard modernized by acquiring a pure jet, a derivative of the Falcon 20 business airplane.

More recently, in the mid 1980's, the service began replacing its amphibious helicopters. Although the replacement helicopters can not land on the water, they possess greater speed and reliability than their amphibious counterparts. With rescue swimmers aboard, they remain every bit as capable as their water landing predecessors.

Currently, much of Coast Guard aviation's work is performed by four types of aircraft (see Appendix A for aircraft diagrams including the V-22). This mix includes:

- The HH-65A, a short range and recovery helicopter.
- The HH-60J, a medium range and recovery helicopter.
- The HU-25A[1], a medium range surveillance aircraft.
- The HC-130H, a long range surveillance aircraft.

Since this fleet of aircraft is relatively young, a favorable Coast Guard V-22 acquisition determination probably depends on three key factors:

- A favorable production decision by the Department of Defense.
- Significant performance advantages over existing air assets.
- Unit costs within Coast Guard budget constraints.

Although the Coast Guard has a history of upgrading and improving its air resources, the relative newness of the service's air fleet may make near term procurement of the V-22 extremely uneconomical. On the other hand, potentially lower maintenance costs combined with the tilt rotor's unique capabilities could make it a very cost effective air resource. Because a viable tilt rotor could have a major impact on current air resource employment strategies, the Coast Guard needs to compare it with

[1]"B" and "C" models are also flown in the Coast Guard.

aircraft already in service and consider what role or roles it might play in Coast Guard air operations.

B. OBJECTIVES

This study will determine the implications of a favorable Department of Defense V-22 production decision on the Coast Guard's existing mix of aircraft. As background material, the thesis reviews the history of tilt rotor development and outlines the key economic issues at the center of the public policy debate likely to decide the V-22's future. Then, the V-22 Osprey is compared with each aircraft already in Coast Guard service. The goal of the research is to determine if these comparisons suggest an affordable role for the V-22 in Coast Guard aviation.

The following specific questions will be addressed:

- What is the history of tilt rotor development?
- What are the major economic arguments shaping the tilt rotor debate?
- In terms of cost and performance, how does the V-22 compare with aircraft already in the Coast Guard inventory?
- Can the V-22 replace more than one fielded aircraft type?

C. SCOPE AND LIMITATIONS

For the past 20 years the Coast Guard has operated with the following air assets: a short range helicopter, a medium range helicopter, a medium range patrol plane and a long range transport. However, the V-22 Osprey could conceivably make this aircraft mix obsolete. Although the direction of the tilt rotor program is unsettled, this study attempts to compare the performance characteristics of the Osprey and its projected costs to Coast Guard aircraft already in the field. The study is subject to the following assumptions:

- The number of aircraft potentially procured by the Coast Guard would not appreciably change V-22 unit costs.
- Learning curve trends and contract incentives associated with potential orders beyond those currently proposed by the V-22 program office were not considered in the analysis.

- With the exception of cost of living increases, fiscal constraints will demand that expenses remain commensurate with today's funding levels.
- The V-22 Osprey is produced in quantities reflected in the Naval Air System Command's advance vertical lift Selected Acquisition Report of December 31, 1988. The report calls for a production run of 663 aircraft.
- Aircraft types presently in the Coast Guard inventory will remain available in the foreseeable future. HH-60 helicopters and C-130 aircraft are being produced by Sikorsky and Lockheed respectively. Although Coast Guard models of the HH-65 and HU-25 are out of production, commercial variants of these aircraft are still being built.

In some cases, available research time and the use of non computerized cost data limited the breadth of the study. Spares and upgrade costs were not available for the HH-65A, the HU-25A and the HC-130H. The V-22's operating and maintenance costs were under internal review by the Marine Corps and not available to the author. Consequently, the thesis does not calculate each aircraft's life cycle costs. Instead, the study attempts to highlight the strengths and weaknesses associated with each aircraft type.

D. LITERATURE REVIEW

Information about the V-22 Osprey was collected from the Naval Air Systems Command Joint Service's Advanced Vertical Lift Aircraft Program Office and publications provided by the aircraft's manufactures, Bell and Boeing. Several periodicals and professional journals were consulted to learn the history of tilt rotor development and to ascertain the major issues at the center of the tilt rotor debate. V-22 cost information was extracted from the *Joint Services Advanced Vertical Lift Aircraft Selected Acquisition Report* dated December 31, 1988 (see Appendix B). Data on Coast Guard aircraft was supplied by the Coast Guard Aviation Plans, Programming and Budgeting Office in Washington, D.C. A list of references is provided at the end of the thesis.

E. ORGANIZATION

The body of this thesis is organized into eight chapters. Each chapter addresses a different aspect of the research questions.

Chapter II looks at the history of tilt rotor technology. It provides a foundation for understanding the risks and benefits associated with this aircraft design concept.

Chapter III outlines the public policy issues at the heart of the tilt rotor debate. Although production is not assured, several members of Congress appear to be moving to introduce legislation that would overturn Secretary of Defense Richard Cheney's decision to cancel the V-22 program.

Chapter IV briefly reviews the service's aviation's requirements for the short range recovery, the medium range recovery, the medium range surveillance and the long range surveillance resources. These requirements serve as a basic framework for outlining potential tilt rotor applications in the Coast Guard.

Chapter V examines data contained in the National Search and Rescue Data Base to determine whether or not there is a need for the V-22. Both, historic response levels and the rescue site's distance offshore are addressed.

Chapter VI compares the V-22 with existing Coast Guard aircraft. A series of performance and cost categories highlight the strengths and weaknesses of each aircraft type.

Chapter VII offers ideas for assimilating the V-22 into Coast Guard aviation air operations. The Osprey is evaluated in the following roles:

- Short range and recovery.
- Medium range and recovery.
- Medium range patrol and surveillance.
- Long range patrol, surveillance and transport.
- Use as a gap filling resource.

Chapter VIII summarizes the study. It draws some general conclusions about whether or not the V-22 is affordable and recommends areas for further analysis. Factors that might influence the Osprey's contribution to future mixes of Coast Guard aircraft are also addressed. Finally, areas of additional research are proposed.

II. TILT ROTOR HISTORY

This chapter provides a historical overview of the efforts made to merge the hover capabilities of the helicopter with the high speed characteristics of the airplane. The chapter is divided into three sections. Drawing heavily on R. W. Prouty's resource (1984), the first section reviews the early design attempts to combine the helicopter and airplane. Subsequent sections of the chapter discuss validation of the tilt rotor concept and the V-22 itself.

A. EARLY HISTORY

Although some current periodicals, government officials and members of Congress hail the V-22 as new technology, it actually represents the culmination of several design efforts that began approximately 40 years ago (if the V-22 is produced, one could reasonably argue that the Osprey will not only dramatically influence warfare and recovery operations, but change the scope of the short haul commuter airline transportation system as well). For over four decades a number of aircraft designs sought to combine the vertical take off and landing capabilities of the helicopter with the speed, endurance and reliability of fixed wing aircraft. These in flight conversion concepts included compound autogiros, tilt wing and tilt rotor aircraft. In retrospect, the most promising designs were the tilt wing and tilt rotor aircraft.

1. THE TILT WING CONCEPT

The tilt wing appeared to be a "simpler" and "more pragmatic" approach than the tilt rotor. The Boeing Vertol Model 76, also known as the VZ-2, was the first tilt wing to fly. After a contract award in 1956, the VZ-2 design called for a Lycoming YT53-L-1 turboshaft engine to be firmly mounted on the aircraft's fuselage. The engine drove two rotors mounted on a pivoting wing as well as twin fans. One fan was attached to the rear fuselage and the other to a T-tail empennage. At slow speeds or in a hover the twin fans controlled pitch and yaw. In forward flight, with the wing pivoted forward, control was maintained by using conventional ailerons, elevators and a rudder. The VZ-2 made its first vertical flight in April of 1957. At the conclusion of testing in 1959, it had successfully completed 34 transitions to forward flight. (Thornborough, 1990, pp. 1-5)

Follow-on tilt wing prototypes, including the Hiller X-18, the LTV-Hiller-Ryan XC-142 and the Canadian CL-84, were evaluated, but none ever quite reached production. Lateral instability, generated when strong cross winds or the rotor downwash caused the wings to dip, hover inefficiency and a series of fatal crashes effectively ended tilt wing research by 1974 (Thornborough, 1990, pp. 1-5). However, recent advances in stability augmentation and construction materials are renewing interest in the tilt wing design concept.

2. THE TILT ROTOR CONCEPT

In a program that began in 1950, the Air Force hoped to develop a fast flying helicopter for itself and the Army. Since the helicopters of the day flew at speeds under 100 knots, engineers naturally contemplated helicopter like designs that might achieve the speeds of fixed wing aircraft. Prouty indicates that the "convertiplane" project began at Wright Field in Ohio. Three aircraft manufactures, McDonnell Corporation, Sikorsky and Bell received contracts to construct competing "convertiplane" aircraft. These competing designs became known as the XV-1 (McDonnell), XV-2 (Sikorsky) and the XV-3 (Bell).

McDonnell's XV-1 was designed like an airplane with twin tail booms, wings and a pressure jet rotor system. For high speed flight, a 550 horsepower Continental piston engine powered a fixed pitch propeller. At slow speeds or in a hover, the engine drove a pair of compressors that supplied air to the three-bladed rotor system. A fuel line in each of the three blades fed tip burners that created the thrust necessary to drive the rotor. The design of the XV-1's horizontal stabilizer allowed it to align itself with the rotor downwash at slow speeds and function as a conventional elevator at higher speeds. Ducted fans on each tail boom were used for directional control in slow speed flight while transitioning to and from a hover (pressure jet main rotor systems do not require anti-torque controls). Both ailerons and rudders provided control at high speeds.

The XV-1's first flight took place in February of 1954. A year later it successfully converted from helicopter flight to airplane flight where it attained speeds approaching 174 knots.

Among the XV series aircraft, Sikorsky's proposal was by far the most advanced. The concept involved a single bladed, counter balanced pressure jet rotor that could be started or stopped in flight. Propulsion came from a jet engine that could be directed aft for high speed flight or into a compressor that provided air for the rotor system in slow speed flight. At high speeds, lift came from a straight or delta shaped wing. But, the lack of suitable jet engines and concerns over the viability of an in-flight start-stop rotor system kept the concept on the drawing board.

The XV-3 was a true tilt rotor and the forerunner of the V-22 design. Bell's entry was powered by single Pratt and Whitney radial engine installed on the aircraft's fuselage. Through cross shafting in the wings the engine drove rotor/propellers mounted on each wing. Conventional airplane controls operated at all times; however, rotor controls were phased out during transitions to airplane flight.

Early in the program, designers faced the unique engineering challenge of developing rotors that could function in a hover and act as high speed propellers when tilted for forward flight. The first XV-3 crashed in 1956 when it experienced rotor system mechanical instability. After redesigning the rotor system, a second XV-3 prototype entered a cautious flight test program in 1957. By 1966 it had accomplished 110 fu`ı in flight conversions from helicopter to airplane and achieved forward airspeeds up to 155 knots (Thornborough, 1990, p. 4).

3. SUMMARY

The results of the XV program were mixed. The two flying XV prototypes showed that a helicopter could undergo an in flight transition and become a moderately fast airplane. Advocates of the XV-3 observed that the tilt rotor technology was sound. The tilt rotor was almost as efficient as a helicopter in a hover, and by tilting the rotor/propellers forward in cruise it eliminated the very high rotor drag associated with conventional helicopters. At that time, it seemed reasonable to assume that tilt rotors could achieve twice the helicopter's cruise speed for about the same power. (*The Case for the V-22 Osprey Program*, 1990, p. 1)

But the penalties were high. Extra weight reduced performance and the complex designs generated concerns about reliability and operating costs. Air Force test pilots found the flying qualities of the XV-1 and XV-3 good, but considered both aircraft greatly underpowered. Simultaneously, conventional helicopters were achieving higher speeds and airplanes were being designed to land and take off on shorter and shorter runways. Neither the XV-1 or the XV-3 entered production.

B. TILT ROTOR DESIGN VALIDATION

The idea of a hybrid helicopter airplane continued to live through the late 1960's. A newly designed rotor blade, incorporating much more twist and better airframe materials, allowed engineers to envision a 300 knot tilt rotor. In 1972, Bell received a joint NASA/Army research contract to develop the XV-15. A far cry from the XV-3, the first XV-15 rolled out of the factory on October 22, 1976. A pair of 1,550 shaft horsepower Avco Lycoming LTC1K-4K turboshaft engines were mounted at the end of the wings and connected by a mid-wing gearbox and cross-shaft. The aircraft's first hover took place in May of 1977. After a two years of ground tests and wind tunnel evaluations, the XV-15 made its first successful conversion on July 24, 1979. At the conclusion of testing in 1988, the XV-15 had significantly expanded the tilt rotor envelope. Accomplishments included level flight forward speeds of 322 knots, flights to 26,000 feet and more than 1800 conversions to airplane mode. (Thornborough, 1990, pp. 1-5)

Besides expanding the tilt rotor flight envelope, the XV-15 proof-of-concept aircraft demonstrated a high degree of safety and reliability. The technology also validated several other important flight characteristics:

- Ease of handling and good stability in a hover.
- Continuous operations at intermediate conversion angles which is useful for short takeoff and landing situations and medium speed loiter missions.
- Minimal conversion time (approximately 12 seconds).
- No additional pilot workloads making the XV-15 comparable to helicopters or airplanes.
- Vibration levels at or below those of equivalent helicopters or turboprop airplanes.
- Single engine operations.
- Improved autorotation capabilities.
- Efficient cruise fuel consumption. (*The Case for the V-22 Osprey Program*, 1990, p. 2)

With a successful June 1981 exhibit at the Paris Air Show, the XV-15 captured the attention of several military, political and aeronautical industry leaders. At long last a true vertical takeoff and landing "airplane" seemed a reality. The stage was set for further tilt rotor development.

C. THE V-22 OSPREY

In December 1981, the Department of Defense released a request for proposals for a Joint Services Advanced Lift Aircraft, designated the JVX. Bell and Boeing joined forces in April 1982 and submitted a preliminary JVX proposal in February of the following year. The design was based on a scaled up version of the XV-15. In April of 1986, the Pentagon awarded a $1.81 billion fixed price incentive contract for full scale development to the Bell and Boeing team. Under the terms of the contract, six aircraft were ordered. Planning, budgeting and contract administration would be performed by the Naval Air Systems Command.

After 46 months of design, tooling, fabrication and testing, the V-22 first hovered on March 19, 1989. Achieving a speed of 150 knots at an altitude of 6,000 feet, the Osprey completed its first full-in-flight conversion on September 14, 1989. Since that time the flight envelop has been expanded to 8,300 feet and 280 knots. By the end of February 1990, 85 test flights had accumulated more than 70 flight hours. Even though much of the 4145 hour flight test program remains, the results are encouraging. It appears that the V-22 will meet or exceed all the manufacturing team's performance guarantees. (*The Case for the V-22 Osprey Program*, 1990, pp. 4-5)

The Bell-Boeing V-22 is an advanced vertical or short takeoff and landing aircraft that is made primarily of graphite-epoxy solid laminate material. The composite structure reduces weight, offers good ballistic tolerance and is resistant to corrosion. The all composite airframe and buoyant fuel sponsons give the V-22 fairly good flotation characteristics that eliminate the need for an emergency flotation system. (*The Bell-Boeing V-22 Osprey Tilt Rotor Aircraft Program*, 1990, pp. 1-30)

When operating like a helicopter, control is accomplished by changing the cyclic-pitch angle on each rotor blade. While hovering, the V-22 can slide right, left or rearward at up to 30 knots or move forward at speeds up to 100 knots. Functioning as an airplane, control is maintained by using flaperons (at the wings trailing edge) for roll, elevators for pitch and rudders for yaw. In addition, the V-22 contains a computerized flight management and fly-by-wire flight control system. It has triple redundancy and can be used to adjust some flight characteristics by making software changes only. (*The Bell-Boeing Tilt Rotor Aircraft Program*, 1990, pp. 10-11)

The V-22 is 57.9 feet from nose to tail and 84.5 feet wide with rotors turning overhead in a horizontal plane. The Osprey's short takeoff and landing maximum gross weight is 59,000 pounds (500 foot runway required). Its maximum vertical takeoff and landing weight is 47,000 pounds. In the helicopter mode the V-22 can lift external loads up to 15,000 pounds or carry an internal payload of 8300 pounds (usable volume 858 cubic feet). In a word, it is a very versatile aircraft. (*The Bell-Boeing Tilt Rotor Aircraft Program*, 1990, pp. 11-12)

Though they incorporate many advanced features, the T406-AD-400 Allison engines mounted on the V-22 are proven 6,000 shaft horsepower engines. Some of their more impressive attributes are digital electronic controls, a digital monitoring system, and a vertical lubrication system for continuous hover operations. According to Bell and Boeing, the engines 39 field replaceable units can be serviced or changed with ten tools. Furthermore, the maintenance target is a 35 flight hour or 15 day inspection cycle. The T406-AD-400 is a derivative of the T56 engines that power C-130 and P-3 airplanes. However, the gas generator is not mechanically connected to the power turbine permitting the engines to be started without engaging the rotor blades. (*The Bell-Boeing Tilt Rotor Aircraft Program*, 1990, pp. 19-21)

The V-22 is the product of four decades of research and development involving the Department of Defense, NASA, and private industry. Many of its technologies are already proven in conventional helicopters and airplanes. Currently, the Osprey's combination of turboprop speeds and a vertical takeoff or landing capability make it unique among the world's aircraft.

Since rapid response, slow flight and recovery capabilities are intimately entwined with Coast Guard aviation operations, the V-22's performance characteristics seem well suited for the service. In a maritime search and rescue role, the V-22 can transit at turboprop speeds, yet, search and hoist much like a helicopter. Flying law enforcement missions, the Osprey can patrol an area similar in size to that covered by some conventional fixed wing aircraft, while retaining the ability to easily identify suspect vessels. Lieutenant Goward called the Coast Guard and the tilt rotor "a perfect match" (Goward, 1990, pp. 83-85). If the V-22 is affordable, he may be right.

III. THE TILT ROTOR DEBATE

In April of 1989 Secretary of Defense Richard Cheney canceled the V-22 program. His decision caused V-22 advocates in Congress, industry and tne Marine Corps to rally in defense of the tilt rotor. Subsequently, Congress appropriated funds for continued research and development on the Osprey. Although the program does not enjoy official support from the Department of Defense, prototypes one through four are undergoing tests. Prototype number five crashed on June 11, 1991, and prototype number six is scheduled for completion in September of 1992. At the present time, the House Armed Services Committee and the House Appropriations Committee are meeting with their Senate counterparts to decide whether or not to include $960 million in the fiscal year 1992 budget for six to ten production representative V-22 aircraft (Gisolo, telephone conversation, October 25, 1991).

This chapter concentrates on several factors that will determine whether or not the V-22 enters production. First, it examines the position of the two major stake holders, the Marine Corps and the Department of Defense, in the tilt rotor debate. Then, the chapter provides a brief overview of Congressional involvement with the V-22 program as well as the key public policy issues underlying the V-22 debate.

When it comes to deciding the future of the V-22 program, the Marine Corps, the Department of Defense and Congress have different views about entering full scale tilt rotor production. For the Marine Corps, the V-22 was to replace the CH-46 helicopter and fulfill medium lift requirements into the next century. For Secretary Cheney, the problem revolved around competing defense programs and a declining defense budget. Though certainly political, Congress' concerns about the V-22 involve balancing national defense priorities, aerospace industry needs and budget constraints to determine the best course of action for the country.

Since Bell and Boeing have threatened to stop V-22 development without a firm order from the Department of Defense, the results of the public policy debate may determine the future of the tilt rotor program. A Congressional decision to withdraw funding probably means that V-22 development will be delayed or stopped altogether. Consequently, the V-22 may not be available for Coast Guard or commercial use.

A. THE MARINE CORPS POSITION

As part of a force modernization program to improve amphibious assault capabilities, the Marine Corps wants to replace its aging Boeing CH-46 helicopters with V-22 tilt rotors. While serving as Commandant, General Gray stated that finding an aircraft to meet medium-lift requirements was the most pressing issue facing the Marine Corps. The CH-46 is over 28 years old and nearing the end of its useful service life. Since its introduction, battlefield threats have increased dramatically. Precision guided munitions and hand held surface-to-air missiles now place the CH-46 and the troops it carries at risk. Despite the Osprey's on again off again status, the Marines consider the V-22 the front running candidate to replace the CH-46 helicopter. (Donovan and Steigman, March 5, 1990, p. 4)

If the V-22 does not enter production, the Marines have two broad options for replacing the CH-46:

- Build a new helicopter that matches V-22 performance.
- Use a mix of helicopters already in production.

According to the Marine Corps, neither option will be cheap. The first alternative is probably the least attractive. Since helicopter technology is already approaching its design limits, significant advances may not be possible without an expensive development effort (Donovan and Steigman, March 5, 1990, p. 4). Furthermore, it may be several years before the performance and technological advances already present in the V-22 are available in another single aircraft.

Even if it can be demonstrated that a new helicopter could meet V-22 performance characteristics, there appears to be little interest among American aircraft manufactures in building it. The financial risks of such an undertaking are high and the Defense Department's vacillation with the V-22 project seems to have cooled industry interest. Moreover, any effort to push conventional rotary wing design limits to gain what is already available with the Osprey would probably result in an extremely expensive venture. Lastly, the time lag associated with a new design effort further delays CH-46 replacement.

The second option weighs the merits of the V-22 against several conventional helicopters already in the field. One plan being championed by the Office of the Secretary of Defense is a mix of CH-53 and UH-60 helicopters. It calls for 376 CH-53's and 590 UH-60's instead of 552 V-22's (Donovan and Steigman, March 5, 1990, p. 4). The Marine Corps countered that this proposal would cost $6 billion more than the V-22 program. The Office of the Secretary of Defense then revised the mix to 225 CH-53's and 478 UH-60's. But, the Marines insist that the revision is flawed because CH-53's must simultaneously carry double external loads[3] and troops to meet Marine Corps lift requirements (Donovan and Steigman, March 5, 1990, p. 4). Other Marine Corps objections include:

- Employing the CH-53 in an assault role.[4]
- Reducing squad size and equipment loads (currently accommodated by the CH-46) to be compatible with an UH-60 helicopter.

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[3]The double sling method requires vehicles to be bolted together for aerial delivery. It reduces lift requirements by increasing aircraft loads. But, the double sling method impedes the speed and flexibility of an assault because vehicles must be unbolted before they can be used.

[4]The CH-53 has a large radar signature and difficulty using the landing surfaces associated with assault missions.

The Marines have also urged the Pentagon to consider the V-22 for other defense related missions. In General Grey's view, V-22 baseline requirements (an ability to lift internal and external payloads of up to 10,000 pounds, a 200 nautical mile combat radius, and shipboard compatibility) make the Osprey an extremely versatile aircraft capable of meeting needs in other U.S. military components. As the Marines point out, a dual use approach avoids costly parallel acquisitions programs.

Understandably, the Marine Corps baseline requirements are closely related to their over-the-horizon amphibious assault mission. The over-the-horizon principle is important. The farther from shore assault waves can be launched, the greater the overall area where they can potentially land. With a greater speed and range than conventional helicopters, the Osprey enhances tactical surprise and forces any adversary to defend a much larger area ashore.

The V-22 also makes detection and forward engagement of the amphibious task force much more complicated. Its over-the horizon vertical-lift capability significantly increases the flexibility and responsiveness of deployed Marine Expeditionary Units.[5] The central issue for the Marine Corps is the cost and relative effectiveness of each CH-46 alternative. Despite repeated service life extension programs, the CH-46 helicopter is old and technologically obsolete. The Marines favor the V-22. They insist that the marginal benefits of the V-22 exceed the marginal costs. While their opinion receives strong support in some quarters (especially for the amphibious assault mission),[6] the V-22 may or may not be the right choice for the Department of Defense or the country at large.

[5]The primary method of deploying Marine forces.

[6]The Janus Simulation, Lawrence Livermore National Laboratory and the Institute for Defense Analysis study are two examples.

B. THE DEPARTMENT OF DEFENSE POSITION

Within the Department of Defense, the V-22 program was canceled on the advice of Dr. David Chu, Director of Program Analysis and Evaluation. He advised Secretary Cheney that a mix of helicopters was more cost effective than buying the tilt rotor weapons system. (Flanagan, 1990, pp. 39-43)

In economic terms, Secretary Cheney faced a constrained optimization problem. The Secretary's job was to allocate the defense budget among several competing programs. In his opinion the B-2, stealth bomber, the strategic defense initiative and the advanced tactical fighter offered greater benefits than those gained from the V-22 (Lake, 1989, pp. 23-28). In his view, the opportunity costs of continuing the tilt rotor program were too high. Since adequate funding for the V-22 was only possible by cutting something else, the Secretary canceled the Osprey.

In testimony before the House Armed Services Committee on April 25, 1989, Secretary Cheney defended his decision to cancel the Osprey. He cited cost figures prepared by the Department of Defense, the limited mission of the V-22, the shrinking Defense budget, decreasing V-22 procurement quantities, and delays as factors in his decision. While testifying he stated:

> In examining the missions of the V-22, we have concluded that, although the V-22 does provide a marginal increase in capability over a narrow range of missions, we can adequately perform those missions by other means. For the most part, we are already performing those missions today and will continue to do so in the future. In addition, if we had retained the V-22 in the budget, we would have been required to remove other programs with value over a broader range of defense missions (Congress, House Armed Services Committee, *Hearings on National Defense Authorization Act for FY90: H.R. 2461*, 101st Cong., 1st sess., April 25, 1989, p. 135).

The V-22 alternative proposed by the Defense Department's Program Analysis and Evaluation Office involved a combination of CH-53 and UH-60 helicopters. Although disputed by the Marine Corps for the reasons cited in the previous section, the study indicated that this mix of helicopters could perform the same mission as the V-22 with an estimated three to five billion dollars in savings over 20 years.

When questioned about abandoning an investment of more than two billion dollars in the V-22, Secretary Cheney responded:

> The research and development investment for the V-22 is not lost. If there is a commercial market for the aircraft, that effort will have been aided in no small part by the advances we made in tilt-rotor technology. The broader issue we face, however, is how to get the most defense -- current and future -- from limited budgetary resources available (Congress, House Armed Services Committee, *Hearings on National Defense Authorization Act for FY90: H.R. 2461*, 101st Cong., 1st sess., April 25, 1989, p. 122)

Clearly, Secretary Cheney focused on defense programs at large rather than the Marine Corps amphibious assault mission alone. A national perspective about tilt technology was left to Congress.

C. CONGRESSIONAL CONCERNS

Both the Defense Department and the Marine Corps are engaged in a high powered debate to win approval for their respective positions. Any objective Osprey production decision based on Marine Corps needs and defense requirements would be difficult enough. Add in the forces of military parochialism, pork barrel congressional politics, a declining defense budget, special interest groups and expectations for a peace dividend and the decision becomes extremely complex.

For the Marine Corps, several sources indicate that the V-22 is the superior alternative in terms of cost and capabilities.[7] But, this conclusion is not necessarily true for other applications of tilt rotor technology. For example, even if the V-22 becomes an operational aircraft within the Department of Defense, there is no guarantee that the tilt rotor will become a commercial success. The question remains, can the country afford a major new weapon system in the face of a declining budget and an uncertain threat?

In broad terms, two major forces, politics and economics, are creating different assessments about the same weapons system. Not surprisingly,

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[7] Again, the Janus Simulation and Institute for Defense Analysis study are two examples.

with major V-22 contractors in Pennsylvania, Texas and Indiana and given the strength of aerospace industry lobbies, Capitol Hill has continuously opposed Secretary Cheney and supported the Osprey. Interestingly, it appears more likely that a V-22 production decision will hinge on a combination of political factors and economic issues rather than pure tilt rotor performance advantages over the CH-46 helicopter. These matters include:

- Commercial applications.
- Externalities associated with the introduction of the V-22 into the commercial market place.[8]
- Foreign competition and trade.
- Unemployment.
- The national defense industrial base.
- Contractor relations.

Politics and interservice rivalries aside, a purely economic analysis regarding V-22 production should consider the marginal benefits and marginal costs associated with the issues listed above as well as those related to specific Marine Corps needs and Department of Defense requirements. Although the outcome is not yet clear, the following paragraphs discuss political and economic considerations that are influencing Congressional members as they wrestle with the V-22 production decision.

1. COMMERCIAL APPLICATIONS

In 1981 the XV-15 demonstration of tilt-rotor technology at the Paris Air Show captured the attention of the aviation world. For the first time it appeared feasible to combine the vertical lift capabilities

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[8] Steven E. Rhodes defines externalities as effects on third parties which are not transmitted through the price system. Generally, externalities consist of incidental by-products associated with a person's or firm's activities. Their impact on the economy may either be positive or negative (Rhodes, 1990, p. 67).

of helicopters with the forward speed of conventionally powered military and civilian aircraft.

But, commercial aviation operators seem reluctant to accept the Osprey until it proves itself in the Marine Corps or some other Department of Defense component. A major concern is cost. In 1986, Boeing Vertol's President Joe Mallen warned that a commercial derivative of the V-22 cheap enough for public use was not yet available (Harvey, May 1989, p. 15). Nevertheless, some aviation industry analysts believe that a tilt rotor aircraft seating 40 to 44 passengers is reasonably possible. Additionally, they suggest that many of the arguments being used against the V-22 are similar to those that confronted the Boeing 707 at the beginning of the commercial jet age. When the Boeing 707, a variant of the Air Force's KC-135 tanker, was introduced, many people believed it did not make economic sense. Yet, it became one of the most successful commercial aircraft ever.

What would be gained by adapting tilt rotor aircraft to the commercial aircraft business? Initially, tilt rotor aircraft could replace existing commuter aircraft that connect small cities with hub airports ("The V-22 Tilt-rotor Aircraft," January 15, 1990, p. 15). Potentially, air transportation from city center to city center could become viable by using the hybrid airplane/helicopter to directly link downtown areas. In another scenario, the V-22 could connect major airports to metropolitan centers or key business districts in the surrounding area. According to John Leverton, Operational Development and Environmental Projects Officer for EH Industries, air traffic congestion in and around large metropolitan areas will create a market for vertical passenger flight service by the mid 1990's (Leverton, January/February 1990, pp. 26-32). In addition, travellers may be willing to pay a premium fare to avoid the excessive time delays that affect many major airports.

Both a Port Authority of New York/New Jersey study and a British Aerospace study indicated that a civilian tilt-rotor (CTR) was feasible provided the aircraft could be made affordable ("Civil Tilt Rotor Studies," June 1990, p. 36). In particular, the British study showed that 11 CTR's with 31 seats and 65% load factor could gain a 30% market penetration on routes linking London, Paris and Glasgow. The Market potential for CTR's in the United Kingdom was 30 to 50 aircraft for passenger transportation, 20 to 30 for the offshore oil industry and 10 for corporate use ("Civil Tilt Rotor Studies," June 1990, p.36). Other studies are underway in Canada, Puerto Rico, Japan and Europe.

Although the parameters of CTR economic analysis are still a matter of debate, there appears to be several marketing opportunities for civilian derivatives of the V-22. The key variable is suitably low unit costs. A Congressional decision supporting the Marine Corps' acquisition of the V-22 may result in lower follow on commercial tilt rotor unit costs. Additionally, V-22 procurement within the Defense Department provides Bell and Boeing the opportunity to document the aircraft's on line performance, reliability and operating expenses. This information is needed, Bell and Boeing contend, to make headway in commercial aviation.

2. EXTERNALITIES

If the V-22 enters military production and unit costs become attractive to commercial interests, several externalities may follow the introduction of the Osprey into the market place. Tilt rotor aircraft could significantly reduce crowding on main runways at major airports and unload the nearly saturated air traffic control system . Provided initial CTR operations begin at existing relief airports and helicopter landing sites, an immediate savings should be realized from reduced runway and taxi construction. With the development of the "vertiport" concept, the load on air traffic controllers could be evenly distributed into separate operations not only reducing costs but improving safety. ("Civil Tiltrotor Study," June 1990, pp. 68-69)

Other externalities may be tradeoffs. Noise, pollution and environmental effects may decline at large airports but increase at feeder facilities or newly constructed "vertiports". However, the short field capabilities of a CTR seem to suggest more positive externalities than negative ones.

3. FOREIGN COMPETITION AND TRADE

A Japanese trade minister recently said:

> If you build the V-22 Osprey, we certainly will buy it. If you don't build it we will make it and sell it back to you (Harvey, June 1990, p. 34).

It appears that a technological race is underway to build the world's first hybrid airplane/helicopter. Bell and Boeing, the V-22 manufactures, have the edge but the slow moving tilt rotor program has awakened world competition in this aerospace field.

In the summer of 1990, the Ishida Corporation (Japan) broke ground on a factory in Texas where it intends to produce the TW-68, its own version of the Osprey. The TW-68 differs from the V-22 in several ways:

- Its development is solely for the civil aviation market.
- The TW-68 will have a tilt wing configuration rather than a tilt engine/rotor structure.
- Metal materials will be used rather than composites.

Unlike the Bell-Boeing V-22, Ishida's goals are passenger comfort and a desire to be the low cost producer. Metal cutting should start this year and fly-off is anticipated for 1992. (Kocks, June 1990, p. 41)

Besides Japan, EUROFAR,[9] a multinational tilt rotor developer, is studying the European market for a possible tilt rotor proposal of its own (Briganti, May 1989, pp. 20-21). It appears that if the Bell-Boeing team does not start production of the V-22, then other firms in the

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[9]EUROFAR stands for European Future Advanced Rotorcraft. It is a five nation seven company cooperative venture to investigate the feasibility of European tilt rotor. The program consists of Europe's four helicopter manufactures, Aerospatiale, Agusta, Messerschmitt-Boelkow-Blohm and Westland plus three aircraft manufactures Aeritalia, British Aerospace and CASA.

international market place stand to capitalize on the hybrid helicopter/airplane concept.

Although the Bell-Boeing approach is different than the Ishida concept, the potential payoffs could be roughly equivalent. As suggested earlier, a Marine Corps buy of 550 aircraft may make the V-22 commercially competitive with the TW-68. Without a Department of Defense commitment, Bell and Boeing have threatened to end their investment in the tilt rotor aircraft.

4. UNEMPLOYMENT

In an economic sense, unemployment associated with a final decision to cancel the V-22 is a pecuniary cost.[10] Since the V-22 program will not increase the overall Defense Department expenditures (given the declining defense budgets projected for the future), no new jobs will be created within the American economy. In essence, a V-22 production decision only effects the distribution of jobs in the economy. In purely economic terms, the pecuniary losses of individuals in one sector of the economy will be offset by individual gains in another (Mansfield, 1988, pp. 512-514).

According to economic theory, resources flow from stagnant or declining areas of the economy to areas which are experiencing growth. If the Osprey is produced, the project will attract resources from other sectors of the economy. If the V-22 is canceled, some engineers, machine operators and managers, will probably seek employment with foreign firms that are developing their own tilt rotor variants. Others will face the cold reality of adapting old talents or learning new skills to obtain work in more promising areas of the economy. Therefore, economic theory suggests that unemployment should not be a factor in the V-22 production decision.

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[10]Pecuniary benefits and costs occur when individuals in one sector of the economy gain at the expense of others in another sector of the economy without altering the overall welfare of the society.

Nevertheless, unemployment is a major political rallying point for Osprey supporters. If a full scale production decision is made, Boeing estimates that it will need from 3,000 to 4,000 workers at its V-22 assembly plant in Pennsylvania. The United Auto Workers claim that 35,000 jobs in the machine-tool and related trades are closely tied to U.S. production of the V-22 (Harvey, June 1990, p.39). With foreign firms in Japan and Europe already tooling up for their versions of a hybrid helicopter/airplane, it is doubtful that American firms could catch up and enter these markets. Other potential losers would include Allison, whose T406-AD-400 turboshaft engines are on the Osprey, and U.S. avionics manufactures.

The scope of the V-22 project is immense. If the V-22 enters full scale production, approximately 1,000 subcontracts could be awarded to firms located throughout the United States. According to Bell-Boeing, the value of the contracts will exceed several billion dollars and result in thousands of jobs (*The Bell-Boeing V-22 Osprey Tilt Rotor Program*, 1990, p. 21). With subcontractors in 45 states it is no wonder the V-22 continues to enjoy Congressional support.

5. THE NATIONAL DEFENSE INDUSTRIAL BASE

As recent events in the Persian Gulf demonstrated, the United States defense industrial base is capable of producing the most advanced equipment in the world. In both macro and micro economic terms, the firms composing the defense industrial base represent an important national asset. But, global competition and reduced tensions with the Soviet Union are leading to declines within the defense industrial base. If the V-22 is not produced, resources will be reallocated to other areas of the economy. Though economically efficient, the reallocation process associated with a V-22 cancellation decision could result in an even greater downturn in the defense industry. Of course, backlogged or highly diversified defense contractors could actually benefit from the new supply of resources made available by discontinuing the V-22 program. However, the country's present advantage in tilt rotor technology would be ceded to Europe or Japan.

Although it is extremely difficult to quantify, national benefits are derived from a healthy industrial base. A positive V-22 production decision would help to maintain the base and keep several manufactures in a position to respond to national emergencies. In the future, a purely competitive market might not respond rapidly enough to meet defense emergencies. While an appropriate Osprey production decision would balance national security benefits gained from a favorable V-22 production decision against the opportunity costs of employing these resources in other areas of the economy, a definitive determination is difficult to establish.

Clearly, V-22 production would simultaneously sustain the industrial base and provide the Marine Corps with a weapons system well suited for military actions like those in the Persian Gulf, Panama and Grenada. On the other hand, V-22 production could prevent resources from moving into areas of the economy where the United States enjoys a comparative advantage over foreign producers. In the final analysis, national security may justify government action to preserve resources for the defense industrial base while foregoing the comparative advantages associated with free international trade.

6. CONTRACTOR RELATIONS

According to Beverly F. Dolan, Chairman and Chief Executive Officer of Bell Textron, Incorporated, former Secretary of the Navy, John Lehman, indicated that a "tight price" on the development program would encourage government acceptance of a "proper" profit on the V-22 production run (Schemmer, August 1990, p. 1). Consequently, Bell and Boeing funded significant portions of Osprey research and development costs under a fixed price contract. The primary contractors have absorbed

300 million in tooling costs[11] and maintained the program's schedule by injecting team funds to fabricate mockups and perform component testing (*The Bell-Boeing V-22 Osprey Tilt Rotor Aircraft Program*, 1990, p. 18). Final termination of the V-22 would mean financial setbacks for Bell and Boeing. On future contracts both companies would probably insist on the government assuming a greater portion of the research and development costs. The aerospace industry's position is best summed up by Mr. Dolan:

> The government talks about being your partner... you are always a partner going in, but they divorce you in a second and leave industry hanging on a limb (Schemmer, August 1990, p. 1).

D. LATEST DEVELOPMENTS

In June of 1991, Secretary Cheney told V-22 supporters in Congress that an understanding could be reached about the Osprey's future. Sources on Capitol Hill indicated that President Bush, who is growing tired of the bickering surrounding the tilt rotor program, would include V-22 funding in his FY-93 budget request. Some Congressional staff members suggested that the President wants to include the V-22 in the budget request so that higher priority defense programs would not be tapped by Congress to fund the tilt rotor. (*V-22 Program Can Be Accommodated, Cheney Tells Congressional Backers*, August 26, 1991, p.1)

Although the status of a V-22 line item entry in the FY-92 budget was not addressed, Secretary Cheney's remarks hint that he is becoming more sensitive to mounting Congressional support behind the tilt rotor aircraft. Since Congress appeared to be prevailing, further debate would only increase the price of the V-22. By accommodating Congress, the Office of the Secretary of Defense can acquire the Osprey at a lower price than at some mandated time in the future.

Aviation industry officials welcomed the President's move, but expressed caution. If the FY-93 funds are for production, then the administration's proposal would be regarded as a very strong signal in

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[11] The contractors are expected to recover tooling costs through depreciation over the life of the program.

favor of the V-22. However, a budget request to continue full scale development and testing would leave the program in the same position as it is today. (*V-22 Program Can Be Accommodated, Cheney Tells Congressional Backers*, August 26, 1991, p. 8)

If Secretary Cheney approves the V-22 for production, the Air Force and the Army may publicly express their desire for additional Ospreys. The existing Air Force requirement is for 55 aircraft, but under an officially supported program that number may rise to more than 100 tilt rotors. In 1987, the Army withdrew from the V-22 development program. Yet, at the 1991 Paris Air Show, Army officials publicly suggested that they wanted to examine tilt rotor technology in an attack role. With its speed and range advantages over conventional helicopters, studies might show the V-22 could replace the Army's AH-64 Apache attack helicopter. However, Army officials later asserted that their statements had been misinterpreted and that they had stopped short of supporting the V-22. Nevertheless, they conceded that the V-22 could replace the CH-47, the Army's main transport helicopter. (*V-22 Program Can Be Accommodated, Cheney Tells Congressional Backers*, 1991, p. 8)

More immediate concerns focus on the June 11, 1991 crash of V-22 prototype number five. Immediately following takeoff the aircraft became unstable in roll. Although pitch control was fine, prototype number five was dangerously slow to react to roll inputs from the pilot. As lateral instability increased, the pilot in command started a gradual descent from 15 feet in an attempt to make a vertical landing. But, the left infrared suppressor hit the ground resulting in further unscheduled role. When the rotors hit the tarmac, the prototype was doomed. The aircraft rolled inverted and crashed. (Harvey, August 1991, p. 24)

Sources close to the V-22 indicated that "hardware" caused the accident. Unofficially, it appears that during the flight control assembly process terminals in a wiring harness connecting the flight control computers to actuator motors were improperly connected. However, the flight control software could also be the blame. If the post crash investigation confirms that "hardware" is the problem, Congressional response is expected to be negligible. But, a software failure may cool Congressional support for the tilt rotor because contractor credibility and tilt rotor reliability may be called into question. (Harvey, August 1991, pp. 23-26)

Although a multimillion prototype was lost, some positive results have emerged from the mishap. Enhancing the V-22's survivability claims, the fuselage broke along predicated paths, the composite structure remained intact and the nitrogen suppressors in the fuel tanks prevented a potentially large fire. Consequently, the pilots were able to egress from the tilt rotor virtually unharmed. (Harvey, August 1991, pp. 23)

In retrospect, the accident probably occurred at the worst possible time. Bell and Boeing are still trying to maintain Congressional support for the V-22 program. But, until the cause of the accident is known, its influence on Congressional funding remains unknown.

E. SUMMARY

From a public policy point of view, a cost/benefit analysis of the tilt rotor production decision should encompass all the costs and benefits to American society, not just those of the Marine Corps or the Department of Defense. Commercial applications and spin-offs related to tilt-rotor technology are very real benefits that are relevant to the analysis. But, they are extremely difficult to address. If private benefits exceed costs, then the government may not need to fund the tilt rotor project. The government is only needed if external benefits are significant and private costs exceed private benefits.

The private sector potential of the V-22 raises several issues about federally supported technology development programs with real or perceived commercial applications. In the private sector, commercial technologies routinely face many alternatives in the market place. To gain widespread use, a product must be "technically" and "economically" competitive. Signals from the market place help decision makers judge uncertainty and decide whether or not to continue the research and development project. Producing the tilt rotor solely for its spin off potential may mask these signals or displace or duplicate private hybrid airplane-helicopter development efforts. Even if the V-22 is acquired by the United States Marine Corps, there is no guarantee that the tilt rotor will be commercially successful. On the other hand, its entirely possible that a successful hybrid airplane-helicopter could emerge (not necessarily in the United States) without government acquisition of the V-22. Therefore, above every other consideration, a V-22 production decision should ensure that the Osprey efficiently and effectively fulfills Marine Corps requirements while simultaneously meeting national defense needs.[12] (Gates, 1988, pp. 27-29)

Nevertheless, public policy is determined in a political arena. Though not assured, a favorable V-22 full scale production decision appears possible. The War in the Persian Gulf underscored the need for speed and mobility on the battlefield. Given President Bush's recent decision to reduce the scope of the Strategic Defense Initiative, the types of military conflicts the United States has engaged in over the last four decades, Congressional concerns about spin off tilt rotor technology, and a legitimate Marine Corps requirement, the political climate seems right for V-22 production.

Since the tilt rotor has unique rescue, law enforcement, surveillance and logistics capabilities, the Coast Guard needs to determine whether or not the Osprey is affordable and functional in the service's aviation environment. The next chapter begins this assessment by reviewing the

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[12] Although the Boeing KC-135, nuclear power reactor projects and the Mercury, Gemini and Apollo space programs produced commercial applications, all were successful research and development efforts in their own right.

mission need statements which led to the Coast Guard's current mix of aircraft.

IV. COAST GUARD AVIATION REQUIREMENTS

The requirements, which led to the selection of the four basic airframes now operating in the Coast Guard, are discussed in this chapter. These requirements establish a foundation for outlining potential tilt rotor applications specifically for the Coast Guard. At a minimum, a Coast Guard version of the V-22 would have to be efficient and cost effective in one of these areas. Alternatively, depending on what assumptions are made, the V-22 could be an efficient replacement in a combination of areas or function as a gap filling resource by incorporating a mixture of these requirements.

This chapter is organized into six sections. The first section presents a broad overview of Coast Guard aviation's major requirements. Then, sections two through five address particular aviation resource requirements in the following order: short range and recovery resource, medium range and recovery resource, medium range surveillance resource and long range surveillance resource. The last section offers a brief synopsis of the chapter.

Historically, the service's search and rescue mission has played a primary role in defining aviation resource requirements. However, Coast Guard air assets actually operate in a multi-mission arena that cuts across several program boundaries. These programs include:

- Search and rescue.
- Enforcement of laws and treaties.
- Marine environmental protection.
- Defense readiness.
- Aids to navigation.
- Ice operations.
- Port safety and security.

While search and rescue remains a fundamental mission and a basis for allocating air resources around the country, requirements from other programs influence the scope of flight operations, drive improvements to existing resources, generate needs for new equipment and force shifts in aircraft basing. Although this chapter reviews the original mission need statements associated with the HH-65A, HH-60J, HU-25A and HC-130H aircraft, the dynamic nature of the service's aviation environment has broadened those requirements over time. Therefore, the following sections include mandated requirements as well as evolutionary requirements on the assumption that future aircraft candidates, like the V-22, would be required to meet or exceed existing capabilities.

A. AVIATION REQUIREMENTS OVERVIEW

Two major terms, recovery and surveillance, dominate Coast Guard air resource requirements. Today, recovery requirements are satisfied by two helicopters, the HH-65A and the HH-60J. Two fixed wing aircraft, the HU-25A and the HC-130H meet surveillance needs.

When late 1960's technology offered a long range recovery helicopter as a viable alternative to the seaplanes then in service, the Coast Guard's two helicopter system was established (*Coast Guard Recovery Aircraft, A Two Helicopter System*, 1986, p. 1-4). Although the Coast Guard's first amphibious short range and recovery helicopter (the HH-52A Seaguard) was acquired in 1963, a long range counterpart (the HH-3F Pelican) was not available until 1969. Three important underlying factors contributed to the dual helicopter strategy:

- The majority of the Coast Guard's rescue cases occur within 150 nautical miles of shore.
- A long range helicopter was more expensive than a short range helicopter.
- Limited small helicopter capabilities and a need to operate in adverse weather conditions necessitated a mix of long range and short range rotary wing aircraft.

As the Coast Guard switched from HH-52A's to HH-65A's and from HH-3F's to HH-60J's, the two helicopter system remained in place. In essence, it balanced mission needs with mission costs.

Recognizing the relatively short range, slow speed and limited navigation capabilities of early helicopters, the Coast Guard also adopted a dual fixed wing strategy to satisfy its patrol and surveillance requirements. The HU-25A jet offers rapid medium range response. It is used to map oil spills, interdict suspicious aircraft, fly law enforcement patrols (both fisheries and drug interdiction) and perform intermediate search and rescue missions that are beyond the range of Coast Guard helicopters (Pumps and rafts can be air dropped from the HU-25A to vessels in distress).

The service's long range requirements are satisfied by the HC-130H. It operates at great distances from shore while conducting pollution overflights, law enforcement patrols and search and rescue missions. Although not possessing the speed of the HU-25A, its endurance and cargo capacity are unmatched by any other Coast Guard air asset.

B. SHORT RANGE AND RECOVERY MISSION NEEDS

The short range and recovery helicopter prosecutes coastal rescue cases, deploys on Coast Guard cutters and icebreakers, performs light load logistics flights and flies relatively short duration patrols. Relevant requirements, which led to the HH-65A short range and recovery resource, are outlined below:

- Cruise speeds greater than the existing short range and recovery helicopter... 90 knots.
- An endurance of 3.0 flight hours.
- An ability to recover three persons from a marine distress situation.
- A radius of action of 150 nautical miles.
- A minimum 1500 pound cargo sling capability.
- Room and adequate power to transport up to five passengers.

- Full operational capabilities in climatic conditions ranging from sub-tropic to polar.
- Compatibility with all Coast Guard cutter flight decks... 378 high endurance class cutters, 270 medium endurance class cutters, 210 medium endurance class cutters and polar class ice breakers.
- Maintainability and reliability characteristics allowing 14 day law enforcement deployments aboard flight deck equipped Coast Guard cutters.
- Night vision goggle compatibility (evolutionary requirement).
- An ability to perform five month deployments aboard Coast Guard icebreakers. (*Acquisition Paper for a Short Range and Recovery System*, 1977, pp. 1-7)

C. MEDIUM RANGE AND RECOVERY MISSION NEEDS

The medium range and recovery helicopter fills the gap between the short range and recovery helicopter and the medium range surveillance aircraft. It has greater endurance and can recover heavier loads from longer distances than the short range helicopter. The essential elements for the medium range and recovery resource are addressed in the following list:

- An ability to operate in the search and rescue mission envelope from 151 to 300 nautical miles off shore.
- At the 300 nautical mile search and rescue mission boundary possess a 45 minute on scene endurance to search, locate, and hoist survivors of a mishap.
- A capability to rescue survivors from the marine environment.
- An ability to transport at least six non-crew members (i.e., passengers, survivors, etc.).
- Compatibility with the flight decks on 270 class medium endurance cutters and 378 class high endurance cutters (Historically, the Coast Guard has chosen not to deploy its medium range and recovery helicopters due to weight and flight deck clearance limitations).
- A capacity to perform support operations for the Navy including full compatibility with the Navy flight decks and ship helicopter equipment.
- Possess an external lift capability up to 8,000 pounds to support marine environmental protection and aids to navigation missions.
- An arrival time on scene equivalent to or earlier than the current medium range and recovery helicopter (an HH-3F helicopter with a cruise speed of 109 knots).

- Night vision goggle compatibility (evolutionary requirement).

- An ability to safely perform all missions in adverse weather conditions over land or sea, day or night, in any season in the service's area of responsibility. "Violent storm" force winds or "mountainous seas" (Beaufort Scale number 11) should not restrict medium range and recovery operations. (*Medium Range and Recovery Acquisition Paper Update*, 1990, pp. 1-8)

D. MEDIUM RANGE AND SURVEILLANCE MISSION NEEDS

In 1981, the HU-25A replaced both the HU-16E seaplane and the HC-131A transport to become the Coast Guard's medium range and surveillance aircraft. The Medium Range Surveillance Aircraft Characteristics Board determined that the Coast Guard lacked the funding to design and build an aircraft to meet the service's peculiar needs. The board recommended acquiring an "off-the-shelf" aircraft that could be adapted to meet Coast Guard requirements. Those requirements, now embodied in the HU-25A, are listed below:

- A multi-engine fan jet powered aircraft weighing at least 20,000 pounds.

- A combined cockpit and interior volume of at least 600 cubic feet.

- An ability to house a full range of flight surveillance electronics including a cabin sensor display console.

- 15 cubic feet for a forward looking multi-mode radar.

- Storage space of at least 19 cubic feet for rescue equipment including dewatering pumps, life rafts and radio beacons, plus 15 cubic feet for crew survival equipment. The storage area must be within a temperature controlled pressurized cabin.

- Accommodations for a crew of five, 225 pounds of aerial delivery stores, 400 pounds of crew survival equipment and 360 pounds of additional payload.

- Two scanner stations with viewing windows unobstructed by wings, exhaust gasses or engines.

- Aerial delivery capability.

- Endurance approaching six hours at or below 2,000 feet.

- An ability to operate continuously between speeds of 150 knots and normal cruise speed.

- Takeoff and landing performance allowing operations from runways as short as 5,000 feet.

- Compatibility with the four primary AIREYE sensors, the AN/ASP-131 side looking airborne radar, the AN/ASQ-174 active television night vision sensor, RS-18C infrared/ultraviolet line scanner, and the KS-87B camera incorporated in the HU-25B avionics package or an equivalent capability (evolutionary requirement).

- Equivalent capacity or capability to use the three primary air intercept sensors, the AN/APG-66 radar, the LTN-72 inertial navigation system and the WF-360 forward looking infrared equipment, aboard the HU-25C (evolutionary requirement).

- Availability for 1,000 flight hours per aircraft per year. (*Medium Range Surveillance Aircraft Characteristics Board Report*, 1974 pp. 1-9)

E. LONG RANGE AND SURVEILLANCE MISSION NEEDS

Since the early 1960's, C-130 type aircraft have met the Coast Guard's long range patrol and search needs. Periodically, newer versions of the C-130 have been procured, but its position as the service's long range air resource has never been seriously challenged. The following parameters define the HC-130H's role in Coast Guard aviation operations:

- Ability to proceed expeditiously to the scene of distress in order to minimize people's exposure to life threatening situations.

- Capability to search open ocean areas (generally more than 300 nautical miles offshore).

- Travel at least 300 nautical miles offshore and still possess an on scene endurance exceeding four hours.

- Provide transportation and the command and control equipment for an on scene commander to control numerous search vehicles in isolated offshore environments.

- Serve as a communications platform or relay station in remote offshore areas.

- Possess the ability to transport pollution response teams and their heavy equipment from staging bases in the United States to locations at or near pollution incidents anywhere in the world.

- Act as the primary means of logistic support for Coast Guard LORAN and OMEGA long range aids to navigation stations at various locations in the North Atlantic and North Pacific.

- Provide long range aerial surveillance of fishing fleets in the waters off Alaska, Hawaii and the western Pacific to enforce fishing treaties.

- Act as a long range platform to detect and interrupt the flow of contraband by surveying and identifying vessels in the Caribbean Sea and Gulf of Mexico as well as those operating far off the eastern and western seaboards of the United States.

- Support the International Ice Patrol by conducting surveillance flights for icebergs over the ocean waters east of Newfoundland.
- Possess the capability to deliver rescue equipment while airborne.
- Have the ability to carry passengers, equipment and large volume cargo to remote areas of the world. (Peterson, telephone conversation, November 1, 1991)

F. SYNOPSIS

Again, this chapter outlines the service's existing aviation requirements. These requirements encompass two broad operating domains, recovery and surveillance, and four major aircraft types. While public demands, technology and the existing Coast Guard budget have contributed to the four air asset strategy, the service should not remain blindly committed to this plan or the resources currently in place. Depending on the marginal benefits and marginal costs, the V-22 could be a reasonable substitute for one or more of the existing aircraft. The unique capabilities of the tilt rotor could also give rise to marginal benefits that would encourage its addition to the fleet. On the other hand, costs could exclude it from consideration all together.

V. SEARCH AND RESCUE INFORMATION

In broad terms, this chapter highlights information contained in the National Search and Rescue (SAR) Data Base. The purpose of the chapter is twofold. First, to outline historic rescue response levels and to profile the general location of offshore search and rescue activities within the maritime SAR region. Second, to lay the ground work for ensuing portions of the thesis that discuss potential assimilation strategies for the V-22. The chapter is divided into two sections. The first section presents general search and rescue case information; the second focuses on rescue efforts made by Coast Guard aviation resources.

A. GENERAL INFORMATION

Appendix C, which covers fiscal years 1986 through 1990, categorizes the number of service-wide search and rescue cases, lives saved and persons assisted by distance offshore. An annual service wide average, derived from the data in Appendix C, is presented in Table 1. It shows that from fiscal year 1986 through fiscal year 1990, over 99% of the Coast Guard's rescue cases occurred within 150 nautical miles of the coast. As a matter of fact, Figure 1 reveals that over 98% of the Coast Guard's fiscal year 1989 search and rescue cases took place within 50 nautical miles of shore (*1989 SAR Statistics*, 1990, p. 27).[15]

Nevertheless, some interesting observations can be made about the service's long distance rescue efforts. While the 151 to 300 nautical mile envelope accounts for only 0.3% of all search and rescue cases, sorties within this region account for 2.0% of the total number of lives saved. Although mission activity in the 151 to 300 nautical mile range is relatively light, a life is saved on an average of every other case.

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[15]There were 52,346 search and rescue cases in fiscal year 1989.

TABLE 1 FIVE YEAR AVERAGE ANNUAL SERVICE WIDE OFFSHORE SAR SUMMARY

	DISTANCE OFFSHORE (NM)			
CATEGORY	0-150	151-300	300 +	TOTAL
NUMBER OF CASES	54,412	191	208	54,811
% OF TOTAL CASES	99.3	0.3	0.4	100
LIVES SAVED	4,855	101	132	5,088
% OF TOTAL LIVES SAVED	95.4	2.0	2.6	100
LIVES SAVED PER CASE	.089	.529	.635	.092
PERSONS ASSISTED	124,886	419	657	125,962
% OF TOTAL PERSONS ASSISTED	99.2	0.3	0.5	100
PERSONS ASSISTED PER CASE	2.29	2.19	3.2	2.30

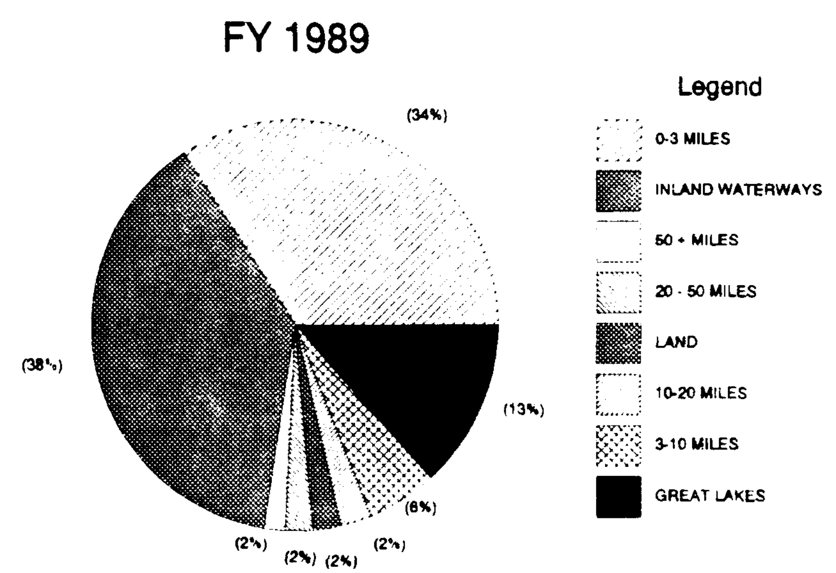

Figure 1 Cases by Distance Offshore

Averages for the greater than 300 nautical miles offshore category are similar to those associated with the 151 to 300 nautical mile offshore envelope. This envelope accounts for 0.4% of the total number of search and rescue cases; however, the rescue operations in this region account for 2.6% of the total number of lives saved. Again, the rescue activity in this region is light, but a life is saved on average more than half the time.

At ranges exceeding 150 nautical miles offshore, case frequency is relatively low. The vast majority of the life saving cases happened within 150 nautical mile of shore. But, Table 1 seems to suggest that cases more than 150 nautical miles offshore usually involve life saving sorties. Although search and rescue mission urgency is not always related to distance offshore, one could reasonably infer that rescue cases more than 150 nautical miles from shore often require life critical responses. Therefore, increased resource speed, especially in areas greater than 150 nautical miles offshore, could conceivably save more lives.

If the Coast Guard becomes interested in adding another resource to its current mix of rescue platforms, it needs to examine the number of failed rescue cases rather than the successful ones. The primary question becomes whether or not the new resource could have made a difference to the outcome of a case. If the answer to that question is yes, then marginal benefits could be evaluated against marginal costs.

Another alternative involves examining the efficiency of current resources. If it can be shown that the new resource is more efficient than an existing resource or mix of resources then marginal costs could again be evaluated against marginal benefits.

Unfortunately, standard data retrieval procedures from the National Search and Rescue Date Base give only the number of lives lost before or after Coast Guard notification of a distress situation. A manual screening of case records is required to subjectively determine whether or not the V-22 could have changed the outcome in any particular instance. Such a screening is beyond the scope of this thesis.

B. AVIATION SEARCH AND RESCUE OPERATIONS

Figure 2 presents the percentage of aviation cases as a function of distance offshore[14]. While over 98% of the service's 1989 cases were within 50 nautical miles of shore, 93% of aviation's responses occurred within 50 nautical miles of the coast. Correspondingly, 7% of aviation's 1989 responses were more than 50 nautical miles offshore compared to 1.7 percent for the service at large. From 1986 to 1990 only 0.7% of the service's total number of rescue cases took place outside 150 nautical miles. But, 2% of aviation's 1989 responses required sorties beyond that distance. (Holden, personal interview, September 6, 1991)

Although further statistical validation is necessary, it seems that Coast Guard aircraft tend to perform a high percentage of the service's long range rescue cases. This is an environment where speed could be the difference between life and death.

Figure 3 shows that in fiscal year 1989 Coast Guard aircraft performed 9.8% of the service's search and rescue responses (*1989 SAR Statistics*, 1990, p. 24).[15] Appendix D depicts the number of cases, sorties, total time on sorties, lives saved, lives lost after notification, persons assisted and property value assisted by the service's aviation assets. As expected, the short range and recovery helicopter, the HH-65A, has the heaviest case load. Yet, each aircraft type contributes to the Coast Guard's overall search and rescue effort.

However, Appendix D indicates that lives are sometimes lost after Coast Guard aviation resources receive notification of a distress

[14]There were 6,130 search and rescue cases in fiscal year 1989 that involved aviation resources.

[15]There were 64,030 rescue responses in fiscal year 1989.

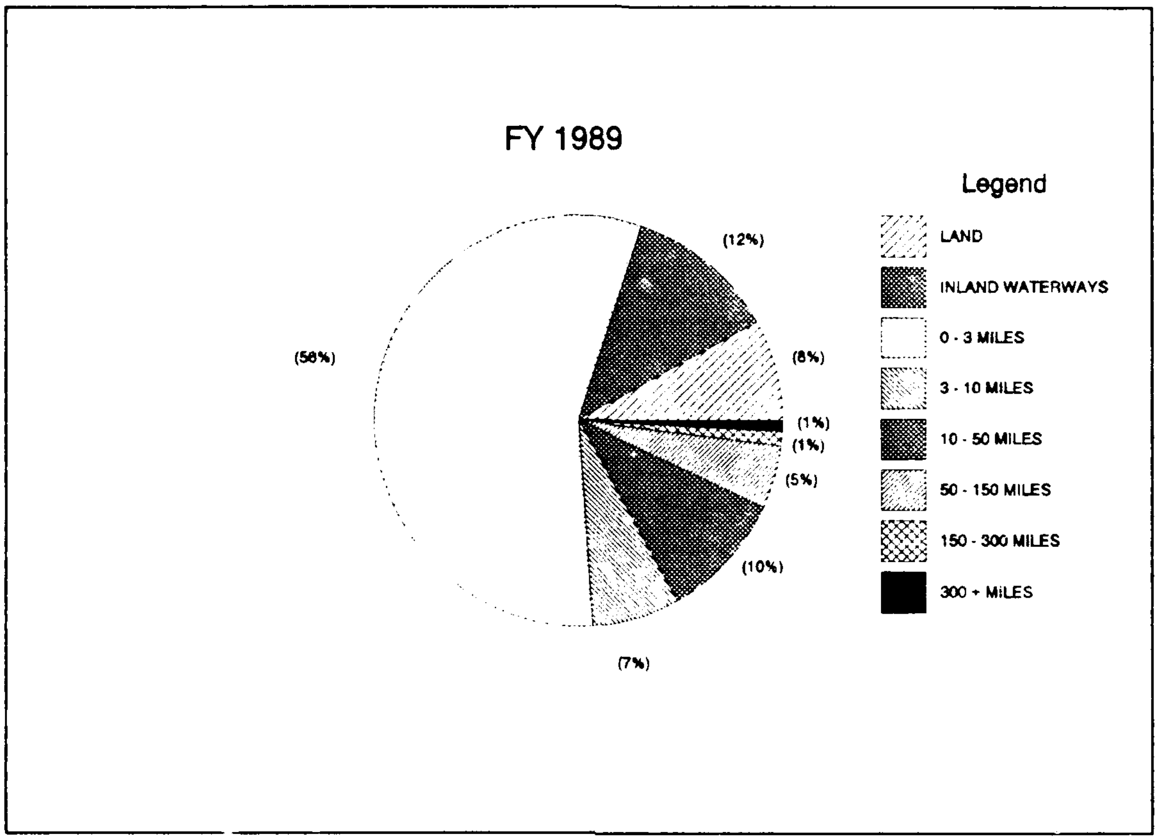

Figure 2 Aviation Cases By Distance Offshore

situation.[16] But, without reviewing individual case records, it is difficult to determine whether or not the V-22 could have changed the outcome of any particular case.

Invariably, one could argue that rescue activity is so light outside 300 nautical miles that the case load does not warrant the Osprey's 600 nautical mile radius of action. While this argument has some merit, the data is somewhat biased against the tilt rotor. Two thoughts come to mind:

- Range limitations prevent current recovery resources from flying farther than 300 nautical miles out to sea; therefore, one would expect correspondingly lower activity levels at distances greater than 300 nautical miles from shore.

[16] In multi-unit cases, "lives saved" and "lives lost" are credited to all responding resources. In reality both numbers are inflated.

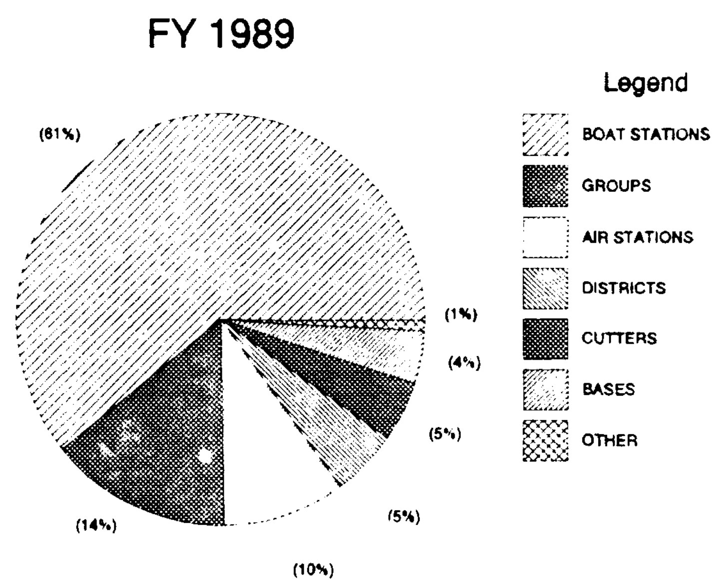

Figure 3 Coast Guard Response Profile

- Although rescue sites can be located close to shore, aircraft may still have to fly long distances to perform searches or even to transit directly to the scene.

Nevertheless, a cursory examination of the search and rescue data does not appear to suggest an operational breakdown that immediately demands the tilt rotor.

As far as the search and rescue program is concerned, two economic issues are important. First, does the cost of lives lost and property lost in situations where the V-22 could have changed the outcome justify the added expenses associated with acquiring and operating the tilt rotor system? If the answer to that question is no, then benefits to other program areas must be considered. If after reviewing other program areas the answer is still no, then the current mix of aircraft is sufficient.

The second issue revolves around V-22 capabilities. Is it more efficient and/or more effective in the search and rescue environment than an aircraft or combination of aircraft already in operation? Again, if the answer is no, contributions to other program areas must be evaluated. If after further review the answer remains no, the existing aircraft mix is satisfactory. Even if the V-22 is more efficient and/or more effective than a current aircraft or combination of aircraft, a favorable acquisition decision depends on those benefits exceeding the costs of acquiring and operating the tilt rotor system.

While every life is precious, the benefits of any lifesaving program should be evaluated in terms of the opportunity costs associated with that effort (Rhodes, 1990, p. 20). In this case, other measures, such as public safety education, the increasing availability of marine band radios, improved electronic navigational aids and/or additional motor lifeboats could prove just as effective at reducing the number of lives lost as the V-22. In addition, these efforts could be less expensive than the tilt rotor.

Although the chapter is not based on a rigorous statistical proof, potential search and rescue mission improvements offered by the V-22 will probably not go unquestioned. However, public opinion could turn out to be a powerful force supporting a Coast Guard version of the V-22. Why should tilt rotor capabilities be reserved solely for the military? Once a Department of Defense tilt rotor performs a military rescue 500 nautical miles offshore, fisherman and pleasure boaters would undoubtedly expect the same service (Goward, 1990, pp. 83-85).

Nonetheless, benefits outside the search and rescue arena could be important factors that determine whether or not the Coast Guard should acquire the V-22. Therefore, the next chapter compares tilt rotor performance characteristics and projected costs to those of existing air assets with an eye toward assimilating how the V-22 could be put into Coast Guard service.

VI. COMPARING THE V-22 WITH EXISTING COAST GUARD AIRCRAFT

Comparing four different types of post production[17] aircraft with a prototype tilt rotor is an extremely challenging task. In some cases available research time and the necessity to investigate non computerized archived cost data limited the scope and thoroughness of the study. In other cases diverse forms of cost and performance information combined with the inherent differences associated with each aircraft design made valid forms of comparison difficult to establish. Nevertheless, this chapter highlights some of the strengths and weaknesses associated with each aircraft type. Aircraft characteristics, cost data and fleet wide comparisons are evaluated in the chapter.

A. AIRCRAFT CHARACTERISTICS

This section compares the V-22's projected aircraft characteristics with the four major aircraft types now in service. Each characteristic is summarized in Table 2 and discussed in the following paragraphs. It is important to note that Table 2 contains average values and that actual aircraft performance will vary with altitude, gross weight, temperature, pressure, wind and airspeed. Each aircraft also offers tradeoffs that sacrifice one attribute to enhance another. For example, fuel load can be decreased to increase cargo payload (within center of gravity, deck loading and volume limits) or maximum range airspeed can be foregone in favor of maximum endurance airspeed or maximum cruise airspeed.

1. CRUISE AIRSPEED

Although not as fast as the HU-25A, the speed of the V-22 is comparable to that of the HC-130H. The HU-25A's 160 knot speed advantage is significant. It enables the HU-25A to intercept civilian aircraft that

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[17]The C-130 and H-60 are still in production. Only the civil aviation versions of the HU-25A and HH-65A are in production (the Falcon 20 business jet and the Dolphin III helicopter respectively).

TABLE 2 AIRCRAFT CHARACTERISTICS

CHARACTERISTIC[1]	HH-65A	HH-60J	HU-25A	HC-130H	V-22
Cruise Speed (KTAS)	125	125	410	290	250
Max Gross Weight (lbs)	8900	21,884	32,000	155,000	51,700 to 60,400
Fuel Capacity (lbs)	19,000	6460	10,000	62,920	13,700 to 29,300
Fuel Consumption (lbs/hr)	611	1001	2015	5600	2600
Maximum Endurance (hrs + min)	3+00	6+00	5+45	14+00	5+00 to 8+30
Maximum Range (NM)	350	700	1940	4500	1150 to 2100
Radius of Action (NM)	150 [2]	300	800	1600	575 to 1050
Cargo Payload (lbs)	0	700	600	20,000	2255 to 10,800
External Cargo Load (lbs)	2000	6000	N/A	N/A	15,000[3]
Rescue Hoist Capacity (lbs)	600	600	N/A	N/A	600

Notes:

1. Coast Guard aircraft characteristics were provided by the service's Office of Aviation Plans and Programs. V-22 information was provided by Mr. James Magee, Program Manager for V-22 Variants, Bell-Boeing Joint Program Office.
2. 125 nautical miles with a rescue swimmer aboard.
3. Double sling required. 10,000 lbs with single sling.

attempt to enter the country illegally (i.e., drug traffickers) and it provides quick response for medium range search and rescue. Although the V-22 could be used to intercept some civilian aircraft, intercept closure rates would be much slower than those achieved with the HU-25A.

Yet, the V-22 has one advantage over the HU-25A. The Osprey can make recoveries while the HU-25A cannot. Even though the HU-25A can air drop pumps and rafts, there are certain rescue missions that absolutely require recoveries (i.e., medical evacuations, people in the water, etc.). While the HU-25A's faster speed conceivably reduces detection time, a helicopter or surface resource is often needed to complete the case. In short, the HU-25A is faster, but the V-22 lessens the need for two resources.

When compared with Coast Guard helicopters, the speed advantage rests with the V-22. It is twice as fast, a significant benefit for most mission scenarios.

2. MAXIMUM GROSS WEIGHT

By Coast Guard standards, the tilt rotor is a fairly heavy aircraft. Only the HC-130H is heavier. Under no wind conditions, the V-22 can accomplish vertical takeoff and landings up to a gross weight of 51,700 pounds. Bell and Boeing recommend a maximum gross weight of 60,400 pounds for short field takeoffs and landings.[18]

The V-22's size and weight prevent it from taking off or landing on Coast Guard cutters (a requirement for the short range and recovery helicopter and a desirable feature for the medium range and recovery helicopter). Although a ship to aircraft in flight refueling system, much like current HIFR[19] systems could possibly be incorporated in the V-22 design, the Osprey's inability to recover aboard Coast Guard cutters complicates matters. In order to guard against an equipment failure, prudent action would dictate that routine refueling operations begin while the V-22 possesses sufficient fuel to reach a shore side refueling site. Given the relatively long range of the V-22, a ship to aircraft refueling system might not be practical for Coast Guard operations.

The weight of the V-22 also suggests that sensor packages aboard present HU-25 models could probably be incorporated into a tilt rotor

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[18]Straight and level flight with one engine inoperative cannot be maintained at gross weights above 60,400 pounds.

[19]Helicopter in flight refueling

especially configured for the Coast Guard. Additionally, the V-22 should be able to carry more rescue equipment than the HH-65A, HH-60J and the HU-25A.

3. FUEL CAPACITY

In general, fuel capacity increases with aircraft weight and radius of action requirements. When considered with fuel consumption, it offers insight into aircraft range and endurance. The V-22 provides several choices. With internal sponson and wing tanks topped off, the Navy's combat search and rescue version of the Osprey is capable of carrying 13,700 pounds of fuel. By installing anywhere from one to four internal cabin auxiliary fuel tanks, fuel capacity can be increased to 29,300 pounds (Each tank weighs 415 pounds and holds approximately 4,000 pounds of fuel).[30]

4. FUEL CONSUMPTION

The V-22's fuel consumption is three times that of the HH-65A, more than twice that of the HH-60J, more than 500 pounds per hour greater than the HU-25A and much less than HC-130H. However, the V-22's speed advantage over the HH-60J makes it more competitive than one might think. Although the V-22 consumes 2,600 pounds of fuel per hour, compared to the 1001 pounds per hour consumed by the HH-60J, the V-22's faster speed allows it to complete missions in less time than the helicopter. For example, on a 300 nautical mile radius of action mission, the HH-60J will take 4.8 hours to fly 600 nautical miles and burn 4,805 pounds of fuel. The V-22 completes the same mission in 2.4 hours and uses 6,240 pounds of fuel, while accumulating less wear and tear on the airframe.

Of course, a similar situation exists between the HU-25A and the V-22. In this case, the Falcon uses less fuel than the Osprey. The HU-25A will fly a 1200 nautical mile sortie in 2.9 hours and consume 5,844

[30]With all four auxiliary tanks installed cabin capacity is reduced.

pounds of fuel. A tilt rotor would take 4.8 hours to perform the same mission and consume 12,480 pounds of fuel in the process.

Fuel consumption also depends on mission profile. Generally, jet engines are more efficient at higher rather than lower altitudes. For example, no matter what the gross weight, a HC-130H on a low level patrol (500 feet above sea level) consumes approximately 6,000 pounds of fuel per hour. At cruise altitudes (20,000 feet mean sea level), the HC-130H burns anywhere from 4,000 pounds of fuel per hour to 6,000 pounds per hour depending on aircraft weight. A similar effect is present in the V-22. At a gross weight of 50,000 pounds the V-22 consumes 2,650 pounds of fuel per hour at sea level, 2,550 pounds per hour at 10,000 feet and 2,850 pounds per hour at 20,000 feet.

5. MAXIMUM ENDURANCE

Maximum endurance is a function of aircraft design, fuel load, pressure altitude, and airspeed. It is achieved by carrying a maximum fuel load and by consciously flying at the aircraft's maximum endurance airspeed.[21] Additionally, endurance tends to vary indirectly with cargo payload. As cargo payload increases, fuel load decreases.

Generally, the V-22 offers the same endurance as the HU-25A. The Falcon can remain airborne for 5.75 hours verses 5 to 9.0 hours for the Osprey. If internal cabin tanks are installed in the Osprey, the tilt rotor exceeds the endurance of all Coast Guard aircraft except the HC-130H. But, maximum endurance does not equate to maximum flyable distance. Maximum distance is achieved by operating at the aircraft's maximum range airspeed for the atmospheric conditions present during the flight.[22]

In a practical sense, endurance determines how long an aircraft can be employed before it must be refueled. But, each operational mission is unique. Urgency, mission, range to scene, search target, weather and

[21]Varies with aircraft weight and altitude.

[22]Varies with weight, altitude and wind direction. Approximately, 4/3's faster than maximum endurance airspeed.

other variables influence a pilot's airspeed selection. Sometimes speed is more important than endurance (i.e., rescuing a person in the water). When an on scene presence is desired, endurance is more important than speed (i.e., maintaining covert contact with a suspect vessel). More often than not, missions require a combination of speeds.

Depending on which tilt rotor auxiliary fuel tank configuration is selected, the V-22 can stay aloft from 5 to 8.5 hours. These times compare favorably with the HH-60J and the HU-25A. However, in the same time period the V-22 will fly much farther than the HH-60J. While the Osprey is slower than the Falcon, its longer endurance would enable it fly approximately the same distances as the HU-25A.

6. MAXIMUM RANGE

Maximum range is a function of aircraft design, fuel load, pressure altitude, wind and airspeed. It too tends to vary indirectly with payload. Maximum range defines the longest distance an aircraft can fly before it must be refueled.[31] Depending on the number of auxiliary fuel tanks in use, the V-22's maximum range exceeds that of the HH-60J by a minimum of 450 nautical miles. With all auxiliary internal tanks installed, it has twice the range of the HH-60J. But, without internal fuel tanks, the V-22 falls short of the HU-25A. However, all four auxiliary cabin fuel tanks allow the Osprey to beat the Falcon.

7. RADIUS OF ACTION

Radius of action represents the maximum distance an aircraft can fly from a refueling site and return to the same place. Again, the V-22 fairs well against existing Coast Guard resources, especially the conventional helicopters. While the HH-65A and HH-60J are limited to 150 nautical miles and 300 nautical mile offshore respectively, the V-22 can operate out to 600 nautical miles offshore. With cabin auxiliary fuel

[31]Historically, Coast Guard air assets have not been equipped for aircraft to aircraft in flight refueling.

tanks installed, the V-22's radius of action would be even farther; however, internal cargo capacity would be reduced.

8. CARGO PAYLOAD WITH NORMAL CREW AND MAXIMUM FUEL

It is extremely difficult to establish a representative value for cargo payload. Generally, fuel can be decreased to increase payload capacity. In a ridiculous sense, maximum payload is achieved with no fuel aboard the aircraft. Since Coast Guard aviation missions often involve surveillance, a measure was selected that provided insight into both cargo capacity and range or endurance.

In terms of cargo payload, the V-22 offers a wider range of options than every aircraft except the HC-130H. Provided auxiliary fuel tanks are not installed, a vertical takeoff and landing can be accomplished with a full fuel load and a cargo payload up to 2,255 pounds (see Appendix E). If a short field takeoff option is available, a fully fueled V-22 without auxiliary fuel tanks can carry up to 10,800 pounds of cargo. If fuel load is reduced, the V-22 can carry 15,000 pounds of cargo over 300 nautical miles.

Among Coast Guard aircraft, only the HC-130H can internally lift more weight than the V-22. Although the V-22 is versatile, it cannot match the cargo capacity of the HC-130H. The HC-130H can carry 43,000 pounds of cargo 2,000 nautical miles or 20,000 pounds of cargo 3,800 nautical miles or 5,000 pounds of cargo 4,500 nautical miles.

Two other cargo related features of the V-22 are worth noting. It has a 858 cubic foot cargo hold and a rear cargo door to facilitate payload handling (more than enough room to meet the medium range and surveillance resource requirement). As a means of comparison, Coast Guard operators are already somewhat concerned about HH-60J volume limitations. Although the HH-60J has reasonable internal payload capacity, the cargo area is limited to less than 234.8 cubic feet (Angert, telephone conversation, November 15, 1991).

9. EXTERNAL CARGO HOOK LIMIT

The Osprey's external cargo hook surpasses the capabilities of current Coast Guard helicopters. However, the extra capability may not be necessary for Coast Guard operations. While the service used its HH-52A and HH-3F to perform external sling work, their volume capacities often permitted cargo to be carried internally. While there are concerns about cargo volume capacity in the HH-60J (with this helicopter pilots may have to think more in terms of external loads rather than internal cargo capacity), there appears to be sufficient room inside the V-22. The Osprey's external load capability would be a desirable feature rather than an essential one.

10. VERSATILITY

Although versatility is not explicitly expressed in any of the preceding sub-sections, the comparison of aircraft characteristics suggests that the tilt rotor is an extremely flexible platform. The V-22 nearly matches the speed of the HC-130H, but falls short of the HC-130H's internal lift capabilities. While the V-22 lacks the pure speed of the HU-25A, it could still accomplish most medium range surveillance resource missions. Electronic detection aids aside, the HU-25A performs its low level work (searches, pump drops, etc.) at 150 knots. In contrast, the V-22 can slow to optimum search speeds during encounters with poor visibility.[34] Finally, unlike the HU-25A, the Osprey can make recoveries.

While differing tremendously in size, the V-22 appears to outclass both helicopters. Its combination of speed, hover ability and cargo bearing capacity make it a unique package containing several desirable features for the Coast Guard (for a graphic comparison of some aircraft characteristics see Appendix F).

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[34]Optimum search speed is a function of target size, visibility, sea state and aircraft altitude.

B. COST CATEGORIES

Available cost data prevented a complete life cycle cost analysis for each aircraft. However, interesting cost comparisons are presented in the following sub-sections of the thesis.

1. UNIT ACQUISITION COST

Acquisition cost includes the airframe, mounted engines, installed avionics, other hardware, non recurring expenditures test and demonstration, and in the case of the V-22, research and development. Table 3 shows the cost of each aircraft in then year dollars and compares the cost of each aircraft in 1990 dollars (GNP deflator used).

TABLE 3 AIRCRAFT UNIT ACQUISITION COSTS

	HH-65A	HH-60J	HU-25A	HC-130H	V-22
Unit Acquisition Cost	$3,500,000 ($ 1984)	$11,722,000 ($ 1990)	$4,996,000 ($ 1981)	$23,000,000 ($ 1989)	$30,000,000 ($ 1986)[1]
FY 1990 Adjusted Unit Acquisition Costs	$4,325,400	$11,722,000	$7,074,124	$24,569,021	$34,691,573[2]

Notes

Unit Acquisition Costs includes airframe, mounted engines, installed avionics, test and demonstrative.

Sources:

HH 65, HU-25, HC-130: Commandant, USCG (G-OAV)

HH-60J: Commandant, USCG (G-AMR)

V-22: Joint Services Advanced Vertical Lift Program Selected Acquisition Report dated 12-31-88.

1. Other weapons systems costs, military construction costs, and initial spares were excluded from unit cost for comparison with Coast Guard aircraft. Cost escalation information provided in the SAR was included in unit cost. When weapons system costs, military construction, and initial spares are considered, unit cost approaches $39,000,000.

2. Given sufficient orders, Bell-Boeing marketing material indicates that unit costs could approach $16,000,000. If weapon system and construction costs parallel DOD, unit cost could approach $45,000,000.

Although the acquisition price represents only a small portion of life cycle costs, the V-22 calls for a substantial up front outlay of at least $34 million. However, Table 3 probably understates the acquisition costs associated with the HH-65A and the HU-25A. Both aircraft continue to experience engine, supply and maintainability problems that increase costs.[25] Nor does Table 3 reflect airframe upgrades made over time. Lastly, HH-65A and the HU-25A configurations differ significantly from their civilian counterparts; therefore, costs associated with reopening production lines would probably result in higher acquisition prices than those reflected in Table 3.

Yet, the economic reality of sunk costs likely favors the existing air assets. If current aircraft remain in production, and the Coast Guard considers replacements in kind, the existing support base (spare parts, tools, test equipment, ground service equipment, etc.) would probably represent a significant advantage for aircraft already in the field.

A concept related to *marginal* costing applies as well. If the V-22 is considered as a replacement for current aircraft, acquisition cost would be a marginal concern for the tilt rotor, but unless additional purchases are planned, it would be an irrelevant cost factor for the existing air assets (investment in the existing resources has already taken place; consequently, acquisition cost would not be a marginal cost).

The V-22 is not an airplane or a helicopter. Therefore, familiar measures may not adequately address its costs or potential. However, managers must sometimes compare dissimilar objects. In fairness to the V-22, the unit acquisition cost reflects several design features not found in current Coast Guard airframes. Some of these attributes include:

[25]The ATF-3 engine on the HU-25A has not been a commercial success. Compressor, hot section, bearing and turbine problems with the HH-65A's LTS-101 engine caused the Coast Guard to consider completely re-engining the aircraft.

- An airframe fabricated almost entirely of composite materials. Only 1,000 pounds of metal are used.
- An automatic blade folding and wing stowing system. The V-22 is the first aircraft whose wings can be rotated parallel to the fuselage for compact storage.
- The first fixed wing aircraft to use "cross-connected" propulsion systems that ensure balanced thrust with one engine inoperative.
- Digital fly-by-wire control system.
- Digital flight management system.
- A single airframe with the capability to carry a 15,000 pound payload externally or a 10,000 pound payload internally.
- Ballistic tolerance.
- A completely hands off forward looking infrared (FLIR) sensor that responds to the pilot's head and projects the FLIR image on the pilot's visor.
- An on board inert gas generating system (OBIGGS) which replaces spent fuel with nitrogen to purge explosive fumes and improve crash survivability (Thornborough, 1990, p. 25).
- Built-in diagnostic systems with self test capabilities.
- Longer intervals between airframe overhauls (*The Case for the V-22 Osprey Program*, 1990, p. 8).
- A vertical takeoff and landing capability combined with the forward speed of a turboprop airplane.
- A terrain storage system with a multi-mode terrain radar (Thornborough, 1990, p. 18-23).
- An AN/ALE-39 missile warning set with chaff, flair and decoy dispensers (Thornborough, 1990, p. 25).
- Fire detection/halon filled suppressor units in the wing to increase crash survivability and reduce the effectiveness of 30mm ammunition. (*The Bell-Boeing V-22 Osprey Tilt Rotor Aircraft Program*, 1990, pp. 1-30)

2. INITIAL PROVISIONING

Initial provisioning consists of both spare parts and repair parts used for maintenance and replacement purposes. Table 4 compares V-22 provisioning costs with those of the HH-60J (extensive archive research beyond the scope of the thesis would be necessary to determine the initial provisioning costs of the HH-65A, the HH-60J and the HC-130H). In this case, the V-22's initial provisioning costs appear to be slightly less than those associated with the HH-60J. But, expenditures on the HH-60J are sunk costs. Therefore, provisioning cost advantages alone probably do not justify V-22 procurement.

TABLE 4 INITIAL PROVISIONING AND SPARES PER AIRCRAFT

	HH-65A	HH-60J	HU-25A	HC-130H	V-22
Initial Spares per Aircraft	[1]	$2,910,000	[2]	[3]	$1,850,000

Sources: HH-60J: Budget Plans for the HH-60J.
V-22: Selected Acquisition Report, 12-31-88.

Notes:

1. Due to warranty programs, changes in contractor recommended spares list, and LTS 101 engine performance disputes, additional archive research is required to determine cost of initial provisioning.

2. Due to warranty programs, changes in contractor recommended spares list, and ATF3 engine contracting, additional archive research is required to determine cost of initial provisioning.

3. Due to procurement of 1500 series in 1972, 1600 series in 1978, and 1700 series aircraft in 1989, additional archive research is required to determine cost of initial provisioning.

3. ANNUAL PROGRAM FLIGHT HOURS

Table 5 displays annual program flight hours, funded allowance, fleet wide program hours and fleet size. As the table indicates, the number of program flight hours vary by aircraft type. The table represents the annual flying time scheduled for each operational Coast Guard air resource. Once established, an aircraft type's program flight hours usually remain fairly constant during the resource's service life.[26] In essence, program flight hours define on an individual airframe basis the amount of flying time available for training and operational missions. For example, a Coast Guard air station consisting of three HH-65A helicopters would plan a total of 1,935 flight hours for the entire year.

TABLE 5 AIRCRAFT PROGRAM INFORMATION

	HH-65A	HH-60J	HU-25A	HC-130H
Program Flight Hours (hrs/yr)	645	700	800	800
Funded Allowance (# of aircraft)	80	32[1]	32	26
Fleet Wide Program Hours (hrs/yr)	49,855[2]	22,400	25,600	20,400[3]
Actual Fleet Size	96	32	41	30

Notes:

1. The Coast Guard is replacing HH-3F's with HH-60J's. This number represents the eventual fleet size.

2. HH-65A:

   74 funded at 645 flight hours per year
   4 funded at 325 flight hours per year
   3 funded at 275 flight hours per year

3. HC-130H:

   25 funded at 800 flight hours per year
   1 funded at 400 flight hours per year

The funded allowance refers to the number of Coast Guard aircraft operating in the field. The funded allowance differs from overall fleet size because aircraft are periodically withdrawn from service and overhauled at depot level maintenance facilities.

When program hours for a particular aircraft type are multiplied by the funded allowance, the total number of fleet wide program flight

[26]From time to time adjustments are made to account for changes in mission demands, aircraft age, reliability or logistics support.

hours can be determined. This figure represents the total number of flight hours a particular fleet will accumulate in any particular fiscal year. Fleet wide program hours embody the total number of flight hours available to perform training and to fly operational missions on a fleet wide basis.

Fleet size accounts for the total number of aircraft in the service's inventory. It represents the total sum of all Coast Guard air assets of a particular type including aircraft assigned to field units, those in overhaul and attrition spares.

For the sake of comparison, the Marine Corps is planning to operate each of their V-22's for 35 hours per month (Thombs, telephone conversation, October 25, 1991). Although the Marine Corps and Coast Guard flying environments are different, the Marine Corps' plan calls for each V-22 to fly 420 hours per year. However, all the Coast Guard's current aircraft operate at a higher program rate than 420 flight hours per year. Depending on which resource the V-22 replaces, mission demand levels might require a Coast Guard version of the tilt rotor to operate at program levels approaching 800 flight hours per year.

Finally, program flight hours are important because they help establish Coast Guard aviation's operating and budgeting baseline. In terms of hypothetically formulating a V-22 fleet size for the Coast Guard, the concept of program flight hours becomes a key assumption in determining the number of tilt rotor aircraft necessary to replace an existing resource.

4. ANNUAL FIELD LEVEL MAINTENANCE COSTS PER AIRFRAME

Marine Corps estimates regarding V-22 field level maintenance costs are being reviewed, thus they are not currently available (Thombs, telephone conversation, October 24, 1991). Table 6 contains field level maintenance costs for the current fleet of Coast Guard aircraft. If the V-22 enters production and becomes a viable alternative for the Coast Guard, tilt rotor field level maintenance costs would be evaluated against the field level maintenance costs of existing Coast Guard resources. Although these costs will increase with inflation and probably rise as existing resources age, Table 6 provides a near term measuring stick for the V-22.

TABLE 6 FIELD LEVEL MAINTENANCE COSTS

	HH-65A	HH-60J	HU-25A	HC-130H
Budget per flight hour (OG-30)[1]	$93.19	$211.00	$74.99	$119.98
Annual Field Level Maintenance per Airframe[2]	$60,108	$147,700	$59,992	$95,984

Notes:

1. Source: Commandant USCG (G-OAV).
2. Computed by multiplying hourly budget rate and program flight hours.

Bell and Boeing claim that the V-22 is two times more maintainable than CH-46 or H-3 generation helicopters (Magee, telephone conversation, October 25, 1991). But, the Coast Guard's current aircraft are a generation younger than the CH-46 or the H-3. Since the V-22 incorporates newer technology than the current assets, the tilt rotor may offer a maintenance advantage over current air assets. But, the savings would probably be less than that projected for the Marine Corps.[27] Although various estimating techniques can be used to predict V-22 field level maintenance costs, a high degree of certainty may not be available until the V-22 actually enters service with a Department of Defense component.

[27]According to the Institute for Defense Analysis, a highly respected Washington D.C. think tank, the V-22 is 1.3 to 2.2 times more cost effective for Marine Corps operations than a mix of UH-60 and CH-53 helicopters (Flight International, July 3. 1990, p. 16).

5. **ANNUAL DEPOT LEVEL MAINTENANCE COSTS PER AIRFRAME**

Marine Corps estimates regarding V-22 depot level maintenance costs were under review and thus not available (Thombs, telephone conversation, October 24, 1991). Table 7 outlines depot level maintenance costs for existing aircraft types in Coast Guard service. Again, these figures represent bench mark targets that would be compared with V-22 depot level maintenance costs.

TABLE 7 DEPOT LEVEL MAINTENANCE

	HH-65A	HH-60J	HU-25A	HC-130H
Budget per flight hour (OG-41)[1]	$1,039.35	$954.00	$1236.15	$994.25
Annual Depot Level Maintenance per Airframe[2]	$670,381	$667,800	$988,920	$795,400

Notes:

1. Source: Commandant, USCG (G-OAV).
2. Computed by multiplying hourly budget rate and program flight hours

Bell and Boeing claim that the interval between fixed overhauls for the all composite V-22 airframe is much greater than the period for conventional aluminum aircraft (*The Case for the V-22 Osprey Program*, 1990, p. 8). Although the need for overhauls is not completely eliminated, this requirement is significantly reduced. It represents a major marginal benefit over existing Coast Guard air assets.

6. **SUPPORTABILITY**

The V-22 is includes several features that enhance supportability and reliability. Some are listed below:

- An all composite airframe designed to resist corrosion in a salt water operating environment.[28]
- Solid state digital avionics and four multi-function color display tubes in the cockpit.
- Engines incorporating 39 easy to change field replaceable units.
- A diagnostic engine monitoring system.

With the recent exceptions of the HH-65A and the HU-25A, the Coast Guard has traditionally favored aircraft types being operated by at least one other branch of the armed forces. Provided the V-22 is fielded by a Department of Defense component and subsequently acquired by the Coast Guard, all parties could conceivably benefit from larger replacement parts orders that would tend to reduce costs. Additionally, the Coast Guard might be able to take advantage of Department of Defense depot level test and maintenance facilities. In this regard, the Osprey offers advantages similar to those provided by the Coast Guard's HH-60J and HC-130H.[29]

In terms of supportability, the Coast Guard learned some valuable lessons from its HH-65A and HU-25A acquisitions. Since both aircraft were primarily designed for commercial applications, parts reliability under Coast Guard operating conditions was untested. Therefore, some component failure rates tended to be higher than expected and parts shortages were not uncommon. Unfortunately, the Coast Guard experienced the other extreme as well. Since Coast Guard inventory modeling capabilities were limited, the service significantly over estimated other component failure rates. Also, the Coast Guard was unable to adequately validate inventory stocking levels recommended by the contractors. Today, a $95 million

[28]More than 70% of the Osprey is fabricated from composites. The wing is made primarily from Hercules IM-6 graphite/epoxy solid laminate. The fuselage and empennage incorporate additional AS4 graphite fiber materials.

[29]Various models of the HH-60 and C-130 are flown within the Department of Defense.

overstock situation can be directly attributed to the service's poor inventory estimates early in the HH-65A and HU-25A programs.[30] (Halvorson, telephone conversation, October 17, 1991)

Although these lessons learned represent sunk costs, they highlight an interesting point. Demand forecasting is easy to do in theory, but much harder to do in practice. If the V-22 first enters service with the Department of Defense, then the Coast Guard could receive access to actual tilt rotor support and maintenance costs.

The V-22 conceivably offers a supportability advantage over the HH-65A and the HU-25A. Since both the HH-65A and the HU-25A are produced in France, long lead times are sometimes necessary to ensure adequate parts supplies. With these two aircraft, the Coast Guard is committed to a foreign sole source manufacturer whose lead times result in higher inventory costs (Halvorson, telephone conversation, October 17, 1991). The V-22 could offer lead times comparable to those affiliated with the HH-60J and HC-130H, rather than those affiliated with the HH-65A and the HU-25A.

Lastly, the V-22 program involves two prime contractors, Bell and Boeing. Although both contractors are working closely to develop the tilt rotor, plans eventually call for Bell and Boeing to compete against each other on future production runs. Therefore, the competitive nature of the V-22 program might eliminate or greatly reduce the problems accompanying sole source procurements similar to the HH-65A and the HU-25A.

7. MANPOWER

Table 8 outlines the direct work billets associated with the service's aircraft types. They represent targets which the V-22 would have to match or beat. In the simplest terms, direct work billets account for those personnel that would accompany an individual air asset to a Coast Guard air station. However, direct work billets are not an all

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[30]The inventory value is $600 million.

inclusive measure of manpower because they do not account for command and control or support billets.

TABLE 8 DIRECT WORK BILLETS PER AIRFRAME

Billets	HH-65A	HH-60J	HU-25A	HC-130H	V-22
Pilots	2	3	2	3	2.3
Enlisted Personnel	10	17	11	22	15.8
Source	1	1	1	1	2

Source: 1: Commandant, USCG (G-OAV)
2: Commandant, USMC

In the Marine Corps, the V-22 appears to decrease manpower requirements compared to conventional helicopters. Today, the Marine Corps has 4,500 uniformed people involved in direct medium lift support. It is expected that the Osprey will reduce manpower requirements by approximately 750 people. (*Placing V-22 Costs in Perspective, Executive Summary*, July 30, 1990 p. 7)

The Marine Corps approaches aircraft maintenance differently than the Coast Guard. The Marines use three maintenance levels, while the Coast Guard uses two. The Marine's maintenance strategy involves a line level, an intermediate level and depot level facilities. The following list addresses the work performed at each maintenance level:

- Line level - General maintenance, phase inspections, quality assurance, corrosion control, hydraulic, airframe and power plant maintenance.
- Intermediate level - Component repairs.
- Depot level - Major airframe overhauls.

In comparison, the Coast Guard uses a line level, which is capable of performing some component repairs, and depot level facilities.

Although Coast Guard and Marine Corps maintenance strategies are different, the proposed structure of a V-22 squadron provides some insight into the direct support necessary to maintain the Osprey. Plans call for V-22 squadron's to be made up of 12 aircraft. Squadron personnel would consist of 32 officers, 28 of whom would be pilots, and 190 enlisted members. The enlisted force is divided so that 134 members would be in line maintenance and 56 members would be in intermediate level maintenance. (Kiley, telephone conversation, October 23, 1991)

Taking a straight average that includes the line and intermediate maintenance levels, a single Marine Corps' V-22 is supported by 2.3 pilots and 15.8 enlisted people. Provided V-22 program hours within the Coast Guard and the service's aviation environment were similar to the operating conditions in the Marine Corps, the Coast Guard could use approximately the same number of pilots and enlisted members for its version of the tilt rotor. If the different maintenance structures in the two services are taken into account, with half the Marine Corps intermediate maintenance level being considered depot level activity in the Coast Guard, then each V-22 assigned to a Coast Guard air station could potentially be supported by 2.3 pilots and 13.5 enlisted members. Roughly speaking, the averages suggest that the Osprey requires slightly less manpower support than the Coast Guard's medium range recovery resource, the HH-60J.

8. CREW

Plans call for the Navy's combat search and rescue version of the V-22 to be operated by a crew of five, two pilots and three enlisted aircrew members. A five member crew, possibly a pilot, copilot, load master, hoist operator and scanner, seems sufficient for the Coast Guard version as well.

9. COST SUMMARY

As discussed in Chapter III, many opinions exist about the cost effectiveness of the V-22. The cost information gathered in this chapter was primarily used to provide a first look at the V-22 in comparison to existing Coast Guard air assets. Although this cost information does not meet the rigid standards of a formal cost benefit analysis, it does highlight three important areas: acquisition cost, field level maintenance and depot level maintenance.

At $34 to $45 million each, the V-22 unit acquisition cost is much greater than the acquisition cost of a HC-130H. The V-22 would probably be difficult for the Coast Guard to justify. However, if sufficient quantities are produced so that unit acquisition costs approach $16 million, the tilt rotor begins to become much more cost effective.

The second and third major issues focus on field level and depot level maintenance costs. Since projected Marine Corps costs are still under review, the degree of maintenance cost uncertainty associated with the V-22 remains high. Interestingly, this assessment is shared by commercial airline operators. At Rotor and Wing International's Civil Tilt Rotor Symposium in June of 1990, civil airline operators indicated that as long as the Osprey's operating costs were greater than equivalent capacity turboprops, it would be unwise to purchase the V-22 (Snyder, personal interview, September 3, 1991).

Several cost issues would be intimately tied to the number of tilt rotors purchased and the employment strategies adopted by the Coast Guard. The V-22 could potentially allow the Coast Guard to perform its air related missions with fewer aircraft than currently employed. This potentiality could be a significant marginal benefit in favor of the V-22. Another possibility involves replacing more than one existing air resource with the tilt rotor. This action could also lead to cost savings directly attributable to the V-22. Under both scenarios, training costs might decline making the case stronger for the V-22. Lastly, given the V-22's speed advantage over conventional helicopters, fixed costs could potentially be reduced through air station closures. However, extensive analysis of these issues turned out to be beyond the scope of the thesis.

If the V-22 is produced, it creates a complex Coast Guard acquisition decision. However, the sunk costs and relatively young age associated with the service's existing aircraft are strong economic arguments to retain the use of these assets. Among the Coast Guard's current aircraft, the HU-25A will be the first to reach the end of its useful service (2001). Therefore, the Coast Guard has sufficient time to evaluate the cost factors related to the V-22.

C. A MEASUREMENT FOR A FLEET WIDE COMPARISON

To determine the number of V-22's that would be required to replace each existing aircraft fleet, three potential measures were considered. These measures were equal cost, equal lift and equal range. Since Coast Guard aircraft operations involve rescue, surveillance and interdiction, equal range was selected as a means to compare fleet sizes. Equal lift was ruled out because it did not seem to capture the essence of Coast Guard flight operations. Equal cost was rejected because the cost data in the previous section was incomplete. Again, after reviewing the mission requirements previously discussed in Chapter IV, range seemed to be the most appropriate measure for fleet wide comparisons.

Based on established program rates discussed earlier in the chapter and listed in Appendix G, Table 9 provides the annual range of a single aircraft of each particular type, the fleet wide range of existing resources, a V-22 range equivalent fleet size and the funded allowance currently in the field. Annual fleet wide range was obtained by multiplying the funded allowance by the annual range of a individual aircraft of each type.

Assuming that a single V-22 could be programmed to fly 750 flight hours per year (more than the HH-60J helicopter but less than a HU-25A jet), a single V-22 could theoretically fly 187,500 nautical miles in one year. Dividing current annual fleet wide total ranges by 187,500 nautical miles yielded the V-22 range equivalent fleet size. However, no allowance was made for attrition spares or aircraft being rotated through overhaul.

As expected, fewer V-22's (approximately 40% as many aircraft) are required to fly the same distance as the HH-65A fleet. The same

TABLE 9 FLEET SIZE EQUIVALENT RANGE MEASUREMENT

	HH-65A	HH 60J	HU-25A	HC-130H
Single Aircraft Annual Range at Cruise Airspeed (NM)	80,625	87,500	328,000	232,000
Annual Fleet Wide Total Range (NM)	6,231,875[1]	2,800,000	10,496,000	5,916,000[2]
Funded Allowance	80	32	41	30
V-22 Range Equivalent Fleet Size at Cruise Airspeed[3]	33	15	56	32

Notes:

1. Calculated with 4 HH-65A's at 325 hrs/yr and 3 at 275 hrs/yr.
2. Calculated with 1 HC-130 at 400 hrs/yr.
3. Assumes that the V-22 was programmed to fly 750 flight hours per year.

observation holds true for the HH-60J fleet (approximately 50% as many aircraft). But, a V-22 fleet intended to replace the HU-25A or the HC-130H would have to contain more aircraft than currently employed in either case.

D. CHAPTER SUMMARY

Performance characteristics indicate that the tilt rotor has several advantages over the Coast Guard's conventional helicopters. However, when compared to the service's fixed wing assets, the V-22's advantages are less clear. Substituting the V-22 would mean foregoing the speed of the HU-25A or the lift capacity of the HC-130H. On the other hand, the V-22 would provide a recovery capability not offered in the current mix of aircraft as well as the ability to transport relatively heavy loads to remote sites.

As far as costs are concerned, more research is required. Added capabilities aside, the initial acquisition cost of the V-22 represents a big hurdle during times of federal fiscal constraints. But, the tilt rotor offers potential cost savings that could enhance its affordability. As additional cost information becomes available, a clearer case could be made for or against the V-22. In any event, the sunk costs associated with the Coast Guard's existing aircraft probably makes them very attractive, at least until they reach the end of their useful service life.

Nevertheless, the V-22 could potentially bring several desirable features to the service's aviation environment. Therefore, the next chapter proposes possible V-22 employment strategies to assimilate the tilt rotor into Coast Guard aviation.

VII. ASSIMILATING THE V-22 INTO THE COAST GUARD

Since a favorable V-22 production decision remains possible, this chapter takes a subjective look at potential tilt rotor employment strategies the Coast Guard could adopt. If the V-22 is produced at an affordable price, the tilt rotor has the potential to become an integral part of the Coast Guard's aviation resources.

This chapter looks at three broad employment schemes or strategies that take advantage of the tilt rotor's capabilities to meet the mission needs discussed in chapter four. These strategies include:

- Using the V-22 as the service's primary recovery resource.
- Using the V-22 as a medium range recovery and/or surveillance resource.
- Using the V-22 to fill gaps not covered by current air assets.

Since the Marine Corps is still reviewing the V-22's operating and maintenance costs, the chapter approaches each potential strategy in a general manner. Political considerations could make some strategies more appealing than others. Quantitative marginal benefits and marginal costs could favor others. In any case, the situation will be clearer as more accurate cost data becomes available.

Although some cost information is incomplete, this chapter reviews the strengths and weaknesses associated with the each employment strategy. This chapter's goal is to establish a valid picture of the hurdles the tilt rotor must overcome to become an operational Coast Guard aircraft.

A. THE V-22 AS THE SERVICE'S PRIMARY RECOVERY RESOURCE

Under the terms of this strategy, the V-22 would become Coast Guard's primary air recovery vehicle. In essence, the strategy consolidates the mission needs embodied by the short range and medium range recovery resources. However, the strategy faces one major operational drawback.

The tilt rotor cannot deploy or operate from existing Coast Guard flight decks. Since the service is unlikely to forego this capability, a small contingent of HH-65A's, HH-60J's or some other rotary wing resource would still be required to meet deployment commitments. Although this strategy fails to totally eliminate the need for short range recovery resources, the strategy has merit.

At first glance, the idea of significantly reducing the role of the HH-65A or replacing this 8,900 pound helicopter with a 60,000 pound tilt rotor seems like "gold plating". Even if the V-22's mission included medium range recovery, V-22 benefits would have to be significant for the strategy to be worthwhile. Both the HH-65A and the HH-60J currently satisfy the service's mission requirements. Additionally, both helicopters are relatively young. The HH-65A entered Coast Guard service in 1985 and the HH-60J became operational in 1991. Therefore, the HH-65A and the HH-60J have respectfully 14 years and 20 years of useful service life remaining.[3]

However, a viable tilt rotor would offer several advantages worthy of a cost/benefit analysis. As indicated in the previous chapter, 48 V-22's could potentially replace 80 HH-65A's and 32 HH-60J's. While the size of the V-22 fleet might have to be increased to account for the likelihood of simultaneous responses, the number of V-22's required to perform the short and medium range recovery missions should be significantly less than the number of helicopters used today. Furthermore, fewer aircraft could mean much lower training, maintenance, supply and manpower costs.

Other cost savings could be achieved through air station closures. For example, the map in Appendix H locates current air stations. Although the distance between these facilities varies, the average separation in

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[3]Since entering Coast Guard service, the HH-65A has been a maintenance intensive helicopter. It has experienced engine problems and suffered inter-granular corrosion in the composite airframe. A telephone conversation with Lieutenant Palmquist, Coast Guard Aeronautical Engineering Branch, indicated that decision makers were looking for alternatives to the HH-65A.

the continental United States is approximately 203 nautical miles (eight air stations are separated by less than 180 nautical miles). The average half way point between air stations is just over 100 nautical miles. At HH-65A and HH-60J cruise airspeeds the mid point between air stations is reached in 48 minutes. In the same time, the V-22 traverses 202 nautical miles. Therefore, tilt rotor air stations could be positioned further apart than today's rotary wing facilities. However, this relocation would increase geographic areas of responsibility for the air stations remaining open, which could offset the benefits of the V-22's speed advantage over the HH-65A and the HH-60J.

While fixed cost reductions associated with air station closures are appealin , other factors could make this an extremely unattractive option. Rescue service, law enforcement and environmental response capabilities would decline near the closed facility. This decreased responsiveness could generate adverse public opinion and a backlash political reaction.

Politically, it could be difficult to phase out certain facilities, especially those with long established histories and those that are integral parts of relatively small communities. Large metropolitan areas are not likely to give up adjacent Coast Guard air stations either. Over the past decade, the Coast Guard has repeatedly tried to close Air Station Chicago.

Indeed, obtaining Congressional approval to close air stations due to the V-22 introduction could turn out to be politically impossible. From a parochial perspective, air station closures may not be in the best long term interest of the Coast Guard As air stations are closed, the Coast Guard could find itself with decreasing Congressional support.

Finally, the strategy carries a certain element of risk. Since only a minimal number of conventional helicopters would be set aside for shipboard deployment operations, recovery efforts would primarily fall on the tilt rotor. A fleet wide tilt rotor maintenance or supply problem could adversely impact aircraft availability. Operations could suffer significantly. In comparison, today's strategy of using two types of recovery resources mitigates the effect of problems in either community.

B. THE V-22 IN THE MEDIUM RANGE RECOVERY AND/OR SURVEILLANCE ROLES

Of the four mission areas described in chapter four, the medium range recovery and surveillance missions offer the best fit for the tilt rotor. The V-22 could easily fill both roles, if slower speeds could be tolerated for the medium range surveillance mission and shipboard compatibility foregone in the medium range recovery mission. Again, the result could be fewer aircraft and a corresponding reduction in support costs.

A tilt rotor offers several advantages over the two aircraft now in place. In search and rescue operations, the V-22 has significant speed and range advantages over the HH-65A and the HH-60J. Just as importantly, the V-22 eliminates the need for fixed wing aircraft to fly long searches and helicopters to recover survivors. (Goward, 1990, p. 83-85). The tilt rotor performs both tasks while extending the recovery zone well beyond that reachable with the HH-60J.

For law enforcement the V-22 offers interesting tactical capabilities not available in either the HH-60J or the HU-25A. In the Southeastern United States and the Bahamas, the V-22 could be used instead of the HU-25A to intercept, identify and, if appropriate, shadow aerial smugglers as well as carry the apprehension team.[17] Even though the HU-25A has a marked speed advantage over the V-22, many of the aircraft used by smugglers are relatively slow so that they can use small airports or unimproved fields. Consequently, the V-22's decrease in performance should not be overly detrimental to mission accomplishment. In fact, the option to carry the apprehension team aboard the intercepting aircraft could enhance law enforcement operations by eliminating the need for a

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[17]When a suspect aircraft is detected, current doctrine calls for a HU-25A to be launched to make an identification and if necessary follow the aircraft. A helicopter carrying an apprehension team then rendezvous with the HU-25A and waits for the suspect aircraft to land.

cumbersome rendezvous at the smuggler's landing site.[13] (Goward, 1990, pp. 83-85)

The V-22 brings several other important advantages to law enforcement. It could be used to patrol larger areas than the HH-60J and thereby increase the service's law enforcement presence. The tilt rotor's ability to hover and its slow flight capability would also allow it to easily make detailed identifications. Fixed wing aircraft on the other hand, must remain above stall speeds.

Three areas of interest are relevant to logistics missions, where the V-22's volume and cargo capacity could be more advantageous than that associated with the HH-60J and the HU-25A. First, the HU-25A is not a cargo aircraft, while the V-22 provides greater cargo capacity (Saylor, telephone conversation, September 17, 1991). The V-22 could carry sensor suits currently installed aboard the HU-25A while still retaining the ability to perform logistics missions.

Second, Alaska air stations, which are scheduled to replace their HH-3F's with HH-60J's in the spring of 1992, are already concerned that the HH-60J does not have the internal capacity to support aids to navigation missions or other logistics activities.[14] In contrast, the V-22 has the volume capacity to handle these missions.

Third, a Bell and Boeing study concluded that the V-22 was a excellent platform for transporting environmental clean up equipment to isolated pollution sites (Samouce, 1990, pp. 1-12). Although the HH-60J can deliver material to remote locations, it does not offer the total range and payload capacity of the V-22. The HU-25A is also out classed. It has

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[13]A Bell and Boeing study indicates that the V-22 is large enough to perform the Coast Guard's law enforcement mission. According to Bell and Boeing the tilt rotor can carry a sophisticated avionics suit, including the APG-66 radar and infrared sensors, the apprehension team and airframe mounted weapons for protection (V-22 Military Studies and Analysis, Executive Summary, 1990, pp. 7-1 to 7-5).

[14]If the Coast Guard begins using standardized containers (CONEX boxes) on HH-60J external load missions, this issue may be resolved.

a very limited cargo capacity and it must land and takeoff from prepared surfaces.

However, an interesting dilemma develops when the V-22 is considered solely for the medium range surveillance mission. Here, the HU-25A maintains some advantages over the tilt rotor.

While tilt rotor advocates claim that the V-22's speed is sufficient, there are times when faster is better. In maritime search and rescue, law enforcement, environmental protection and national defense, speed can be important. In rescue situations it shortens enroute time, in law enforcement cases it decreases intercept times and in pollution response efforts, like the Exxon Valdez grounding and the Persian Gulf, it reduces pollution response and mapping times.[35]

The HU-25A also gives a commander the ability to dispatch an aircraft and quickly obtain on scene information. In several scenarios, this information could critically influence further Coast Guard responses or significantly enhance prospects for a successful operation. Yet, after arriving on scene, the HU-25A operates at speeds comparable to those of the V-22.

Lastly, a Coast Guard version of the Osprey would be compatible with V-22's in the Department of Defense. The potential for mutual maintenance and support arrangements could lower costs for all parties and undoubtedly facilitate interoperability.

Although not an identical replacement for the HU-25A, the V-22 meets most of the medium range surveillance mission requirements. Since the HU-25A nears the end of its service life at the turn of the century, it could represent the first opportunity for the tilt rotor to enter Coast Guard service. If the slower speed of the V-22 can be accepted, then the Coast Guard could gain an aircraft with greater versatility than the Falcon jet.

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[35]Two HU-25B "Aireye" Falcon's with the APS-131 side looking aerial radar were used to map the Persian Gulf oil spill.

The Coast Guard's newest helicopter, the HH-60J, creates a problem. The sunk costs associated with the helicopter give it a tremendous edge over the V-22. That advantage means that the V-22 might not be able to replace the HH-60J outright. The HH-60 series has proven to be reliable and maintainable; consequently, it would be unreasonable to retire this helicopter before the end of its 20 year service life. Besides, this rotary wing series is widely used by Department of Defense components and the Coast Guard; therefore, it should be supportable for several years.

However, the HH-65A's poor maintenance and availability track record raises a significant question. The HH-60J could be shifted to the short range and recovery mission to make room for the tilt rotor. This action would again give the Coast Guard a mix of primary air assets that were common to the Department of Defense (the HH-60J, the V-22 and the HC-130). Of course, the service would have to accept reductions in deployability and increase the size of flight decks on future cutter designs to more easily accommodate the larger helicopter.[36]

The operational risk associated with using the V-22 in one or both of the medium range capacities would be less than making the tilt rotor the service's sole recovery resource. If fleet wide maintenance of supply problems developed, a short range recovery resource and a long range surveillance resource would still be in place to substitute for the tilt rotor.

As a final thought, three mission gaps exist with the service's current mix of aircraft, law enforcement, limited mid range logistics capabilities and Alaskan operations. While these gaps are not major shortcomings, they could represent an opportunity for the tilt rotor to

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[36]These shipboard design changes represent substantial marginal costs that could make it uneconomical to phase out the HH-65A. Not only would larger flight decks be desirable, but shipboard support systems, such as JP-5 fuel tanks and fresh water wash holding tanks, would also have to be modified to meet the higher demands associated with the HH-60J.

prove itself in the Coast Guard aviation environment. However, a more diversified mix of aircraft could result in higher overall aviation costs.

In the final analysis, the V-22 could become an extremely capable medium range recovery and/or surveillance resource. But, the HH-60J and the HU-25A are both effective resources currently operating in the field. Therefore, the Osprey could have a difficult time replacing either resource.

C. SUMMARY

In essence, three tilt rotor assimilation strategies appear possible. These include making the V-22 the service's primary recovery aircraft, moving the V-22 into the medium range recovery and surveillance missions or using the V-22 to fill operational gaps in the existing asset base.

However, each strategy has unique attractions and distinct risks that involve several operational, economic and political issues. While the primary recovery resource strategy could offer lower costs through air station closures and reductions to the number of aircraft now in service, it still requires that a small helicopter be retained for shipboard operations. Fewer air stations could also mean less Congressional support. In addition, eliminating both helicopters reduces the redundancy inherent in the dual recovery system.

The medium range recovery and surveillance missions probably offer the best operational fit for the Osprey. Since the HU-25A has a recovery capability, possible options include replacing the HH-60J, the HU-25A or both current assets. The V-22 out performs the HH-60J and it reasonably approaches HU-25A performance. But, the HH-60J is brand new and the HU-25A is more efficient (lower costs, less fuel consumption and greater speed) than the V-22 in a pure surveillance role. However, the V-22 has greater cargo capacity than the HU-25A and it reduces the need for dual (fixed wing and rotary wing) rescue and law enforcement responses. Additionally, the strategy carries less operational risk than using the tilt rotor as the service's primary recovery aircraft. A mix including a short range recovery helicopter, tilt rotor and long range surveillance aircraft offers some redundancy not available with the primary recovery resource option. Air station closures are also not as strongly tied to this approach; therefore, the political atmosphere could be much more receptive to the medium recovery and surveillance strategy.

Finally, the V-22 could fill operational gaps not covered by the service's current air assets. However, federal budget constraints would probably make this strategy very difficult to implement.

In the final analysis, the V-22 could significantly enhance the Coast Guard's operational capabilities. However, it must be affordable before it is assimilated into the Coast Guard aviation inventory.

VIII. CONCLUSIONS

This chapter is divided into two sections: the first section answers the studies primary research questions and the last section outlines areas for further research.

A. CONCLUSIONS

The thesis tried to answer the following questions about the V-22 tilt rotor aircraft:

- What is the history of tilt rotor development?
- What are the major economic arguments shaping the tilt rotor debate?
- What are the potential implications on the Coast Guard's current mix of aircraft of a favorable Department of Defense or a Congressionally mandated decision to produce the V-22?
- In terms of cost and performance, how does the V-22 compare with the four major aircraft types already in Coast Guard service?
- Is there an affordable role for the V-22 in Coast Guard aviation?

While the study did not reveal a definitive answer to each research question, the thesis outlines several economic and political issues that are shaping the tilt rotor production decision.

The following sub-sections discuss the major conclusions yielded by the research. The conclusions fall into five broad areas consistent with the primary research questions.

1. HISTORICAL DEVELOPMENT

The V-22 embodies over 55 years of combined Bell and Boeing tilt rotor experience. This experience includes 9,000 hours of wind tunnel tests and 1,000 hours of flight simulator development. The first four V-22 prototypes have also accumulated more than 500 flight hours during more than 400 flights since the first V-22 made its maiden flight on March 19, 1989. Flight test milestones include:

- Successful conversions from vertical takeoff mode to fixed wing turboprop and back.
- A top speed of 349 knots in a 12,000 foot-per-minute dive.
- Level fight speeds up to 283 knots.
- Flight up to 21,500 feet.
- Flight maneuvers up to 2.3 "G" loads.
- A cross country flight of 1210 nautical miles from Wilmington, Delaware to Dallas, Texas.
- Simulated instrument flight. (Harvey, August 1991, p. 26)

Furthermore, the V-22 technology base stems from 40 years of research and development extending from the XV-3 aircraft through the Army and NASA XV-15 proof of concept aircraft.

While early hybrid helicopter/airplane designs showed that an aircraft could be converted from helicopter mode to airplane mode in flight, performance penalties and reliability issues restricted their usefulness. None ever entered production. However, the XV-15 and the V-22 seem to have validated the technical feasibility of the tilt rotor design. While the research suggested some concern over the recent crash of prototype number five, the tilt rotor remains technologically viable. In fact, Bell and Boeing officials insist that the V-22 is an extremely reliable and maintainable aircraft.

2. A REVIEW OF THE MAJOR ECONOMIC ISSUES SURROUNDING THE V-22

While the technological issues surrounding the tilt rotor appear resolved, questions about the cost effectiveness of the design persist to this day. While several independent studies indicate that the V-22 is the most cost effective resource for meeting Marine Corps medium lift requirements, the issue is not as clear when it comes to Department of Defense priorities or national public policy concerns.

Currently, the Marine Corps and the Office of the Secretary of Defense dispute the need for the V-22. The Marine Corps favors it, but Secretary Cheney believes it is too expensive. While there are some indications that the Secretary of Defense may reverse his V-22 cancellation decision, such action is not assured.

With major V-22 contractors in Pennsylvania, Texas and Indiana and other contractors dispersed across 45 states, the tilt rotor enjoys considerable support on Capital Hill. A Tilt Rotor Technology Coalition, headed by U.S. Representative Curt Weldon (Republican - Pennsylvania), views the tilt rotor as vital to the nation's commerce (Harvey, June 1990, p. 34).[37] But, the aircraft remains controversial as Congressional decision makers and the Bush administration look to reduce defense spending.

While politics could decide the V-22, several economic arguments are being used to foster tilt rotor support. These arguments, explained in more detail in Chapter III, include:

- Potential V-22 commercial applications.
- Positive externalities.
- Opportunity to improve the trade balance.
- Reductions in Unemployment.
- A means to maintain the national defense industrial base.
- Improved contractor relations.

While the value of reducing unemployment through V-22 production is debatable, the other arguments appear to have merit. However, their benefits are extremely difficult to quantify. Similarly, there is no assurance that the V-22 will be marketable in the private sector. There are commercial concerns that the tilt rotor could be more expensive to operate than existing turboprops and capital expenditures are necessary to implement "vertiport" service. Therefore, job creation and commercial applications should not be used as the primary justification for a V-22 production decision. While the idea of federally supported "spin off"

[37]The Tilt Rotor Technology Coalition includes approximately 100 bipartisan members of Congress and industry leaders.

technologies sounds like a good acquisition strategy, it is a questionable near term economic activity. Although one could argue that private and public sector support was appropriate for the long term research and development necessary to produce V-22 prototypes, continued support would isolate the tilt rotor from the near term market signals that will determine whether or not it is a commercial success (Gates, 1988, p. 40.) Rather, Congress should only authorize V-22 production if there is a legitimate national defense need that justifies tilt rotor costs. The medium lift requirement of the Marine Corps seems to warrant the expense.

3. IMPLICATIONS OF A FAVORABLE V-22 PRODUCTION DECISION

The thesis research indicates that the V-22 must clear several hurdles before it can significantly alter the composition of the Coast Guard's existing mix of aircraft. Unless Bell and Boeing change their stance about requiring a Pentagon commitment before continuing V-22 development, the first and foremost obstacle is a favorable production decision by the Department of Defense or Congress. While this decision is possible, it would be impossible to predict with certainty the outcome of the tilt rotor debate. However, Rear Admiral Milligan, the Chief Budget Officer for the Navy, hinted, during a lecture at the Naval Postgraduate School, that a favorable tilt rotor production decision was still feasible and that a Marine Corps tilt rotor squadron could be activated by 1997.

Therefore, the immediate implications of a favorable V-22 production decision on the Coast Guard are two fold. First, the Coast Guard would need to flight test the aircraft to validate performance in the service's aviation environment. Although technical aerodynamic issues were outside the scope of the thesis, the V-22's disc loading of 20 pounds per square foot (high by helicopter standards) generates a downwash that approaches 80 knots (Prouty, June 1990, p. 43). While a neutral area exists directly beneath the V-22, the Coast Guard must ensure that the tilt rotor's downwash permits operations near people in the water, small pleasure boats and commercial fishing vessels.

Provided the tilt rotor received a favorable operational evaluation, the next step would be for the Coast Guard to formally evaluate tilt rotor employment strategies to determine if marginal benefits exceed their marginal costs. Assuming that these evaluations showed that the V-22 was cost effective, the tilt rotor could alter the Coast Guard's current mix of aircraft.

Although the V-22 is not an identical replacement for any of the service's current aviation assets, it possesses characteristics that would allow it to function as a medium range recovery resource or medium range surveillance resource. Indeed, if the service can accept a slower dash speed than that of the HU-25A, the V-22 could function in both capacities, eliminating the need for two aircraft.

Alternatively, the V-22 could evolve into the Coast Guard's primary recovery resource replacing both the short range recovery and medium range recovery resources.[18] While using the V-22 in the short range and recovery role initially seems excessive, the strategy potentially could reduce fixed costs through facility closures, commonality of equipment, reductions in manpower and lower training costs. However, the strategy eliminates the two helicopter system[19] and increases risks by lowering recovery system redundancy. Lastly, this employment scheme may not be politically viable or even in the best political interests of the service.

4. PERFORMANCE AND COST COMPARISON SUMMARY

Generally, the V-22 out performs the Coast Guard's conventional helicopters, the HH-65A and the HH-60J. The tilt rotor flies twice as fast as these helicopters while maintaining the recovery capability essential to Coast Guard flight operations. The V-22 also offers longer

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[18] A contingent of conventional helicopters would be required for deployment purposes.

[19] The use of a short range recovery helicopter and a long range recovery helicopter.

range and greater cargo capacity than the helicopters now in service. As discussed in Chapter VI, these advantages offer potential dividends in search and rescue, law enforcement, environmental protection and national defense. But, the HH-65A consistently deploys aboard the service's flight deck equipped cutters and the HH-60J must be compatible with 270 and 378 class cutters. The V-22 is too large and too heavy to deploy on Coast Guard ships.

The HU-25A and the V-22 pose an interesting dilemma. The HU-25A is much faster and more efficient as a surveillance platform. On the other hand, the V-22 can make recoveries. If a slower speed is acceptable (410 knots verses 250 knots), the tilt rotor reduces the need for joint fixed wing and helicopter rescue responses. No longer would fixed wing assets fly long searches and vector helicopters to the scene to perform recoveries. The V-22 could perform both functions.

The speed differential means tradeoffs in other areas as well. In law enforcement, the HH-25A has the speed to rapidly close targets. Although the V-22 may be fast enough, it will not make the intercept as quickly as the HU-25A. Nor will the V-22 map pollution spills or deliver an on scene observer as fast as the Falcon jet.

But the V-22 is much more flexible than the HU-25A. In law enforcement endeavors, such as the Operations Bahamas, Turk and Caicos Island Task Force, HU-25As intercept and follow suspicious aircraft and helicopters transport the apprehension team to the landing site. Again, the V-22 could eliminate the need for two resources because the apprehension team could be carried aboard the tilt rotor. While the V-22 has multiple logistics applications, the HU-25A is not a cargo aircraft at all.

The research suggests that the V-22 is not a suitable replacement for the Coast Guard's long range surveillance resource. While a V-22 carrying four internal fuel tanks is self deployable to most areas of the world, it does not match the overall surveillance, logistics or transcontinental capabilities of the HC-130H. However, the V-22 could complement the HC-130H. For example, in a pollution response scenario HC-130H's could transport people, equipment and material to the nearest airfield. Tilt rotors could then deliver the goods to clean up sites.

While the V-22 offers more than conventional helicopters, it also costs more. In fact, V-22 unit acquisition costs were significantly higher than any of the aircraft now in Coast Guard service (twice that of a HC-130H, currently the Coast Guard's most expensive aircraft). However, projected V-22 initial provisioning costs were similar to the those associated with the HH-60J. Although the Marine Corps uses a different maintenance strategy than the Coast Guard, the research suggests that the V-22 could be supported and flown under existing manpower constraints (more research is required to determine the specific technical specialties necessary to maintain the V-22). Unfortunately, the unavailability of V-22 operating and maintenance costs limited the cost comparison section of the thesis. While the composite airframe, in line replaceable units and 35 hour maintenance cycle associated with the V-22 could render savings over existing aircraft, a definitive answer was not forthcoming. Until more conclusive data is available, the matter is open for debate.

5. AFFORDABILITY

V-22 affordability depends on several issues: those inherent to the V-22 and those related to how the tilt rotor is employed. Whether the V-22 is considered a replacement for one aircraft, a combination of aircraft or acquired to fill gaps not covered by current air assets, the V-22 will only be affordable if the marginal benefits derived from the tilt rotor exceed the marginal costs. More succinctly, the tilt rotor must offer an incremental improvement in mission performance that justifies the cost of acquiring and operating the aircraft over its life cycle. Even if the V-22 is judged to be a more capable platform than a current aviation asset or combination of assets, that factor alone does not necessarily merit tilt rotor acquisition. The V-22 could be more capable and commensurately more costly. The result could be a poor public policy decision as federal outlays were diverted from other worthy Coast Guard programs to support the service's V-22 variant.

While the cost comparison section of the thesis was inconclusive, there are reasons to be concerned about tilt rotor costs. For one, the V-22 Program Finance Officer indicated that a Coast Guard order of 30 to 50 tilt rotors would not appreciably effect unit acquisition costs, as long as other markets outside the Department of Defense failed to opened up (Metts, telephone conversation, September 3, 1991) Therefore, depending on Coast Guard options for weapons systems, construction and initial spares, the service would be looking at unit costs approaching $34 to $45 million. Arguments about life cycle costs and tilt rotor's advantages aside, Coast Guard decision makers would probably find it extremely difficult to procure an aircraft that could cost twice the price of a HC-130H. Furthermore, 30 tilt rotors would cost between $1.0 and $1.4 billion in 1990 dollars or just a little more than one third of the Coast Guard's entire 1990 operating budget (*Coast Guard, 200 Years of Service, Overview 1989-1990*, September 1989, p. 16).

Concerns over operating and maintenance costs also remain. At a recent national tilt rotor symposium, commercial airline operators questioned whether or not the V-22 was cost competitive with existing turboprop aircraft (Personnel interview, Lieutenant Commander Snyder, June 3, 1991). Finally, the Coast Guard is in a different position than the Marine Corp. Its aviation assets are relatively young and are not in need of immediate replacement. Therefore, sunk costs would make it difficult for the V-22 to be more economical than resources already in the field.

Admittedly, there are also reasons to be optimistic about tilt rotor costs. While the HH-65A and HU-25A are flown exclusively by the Coast Guard, the V-22 would be compatible with Department of Defense needs. All the services could benefit from mutual support and the economic savings from larger spare parts orders. If the tilt rotor is commercially successful, unit cost could fall to $16 million, making the aircraft much more attractive. In addition, some of the employment schemes presented in chapter seven suggest possible ways to reduce fixed costs. Fewer V-22's could potentially replace the larger number of aircraft in service today. The result could be a net savings.

While these possibilities deserve serious attention, more accurate V-22 cost information is needed before these employment strategies can be evaluated in detail. Even if the V-22 is affordable, political realities could prevent some of the more ambitious plans from being accepted by the Coast Guard, the Department of Transportation or the Congress.

A favorable V-22 production decision is a key signal for Coast Guard managers. With it, the V-22 becomes an alternative resource and its potential Coast Guard applications should be formally evaluated.[40] Without a Department of Defense or Congressional production decision, the Bell and Boeing tilt rotor may never be built.

An affordable tilt rotor could have major ramifications on the Coast Guard's mix of aircraft and its aviation resource employment strategies. Provided marginal benefits exceeded marginal costs, the two employment strategies listed below seemed the most likely ways for the V-22 to enter Coast Guard service.

- Use the V-22 to fill gaps not covered by existing Coast Guard aircraft.
- Use the V-22 to replace the HU-25A.

While the gap filling strategy adds another aircraft type to the inventory, it increases recovery range for rescue operations, potentially reduces the need for joint response resources, provides a logistics

[40]This study drew on information applicable to the Marine Corps and the Navy versions of the V-22. A formal analysis would involve working with Bell and Boeing to develop a tilt rotor derivative to meet the service's particular needs.

capability to move pollution clean up equipment to remote locations and introduces a law enforcement platform that could simultaneously carry an apprehension team and perform intercept missions. Similar to the way helicopters were slowly but steadily integrated into the service following World War II, the gap filling strategy offers the chance to introduce the tilt rotor to Coast Guard aviation.

The first opportunity for the V-22 to replace an existing asset will probably occur when the HU-25A approaches the end of its useful service life, near the end of the century. Of course, the V-22's slower speed will have to be acceptable and V-22 costs will have to be attractive.

The Coast Guard's current position on the V-22 appears sound. Decision makers in the Coast Guard Office of Aviation Programs believe that the tilt rotor's capabilities are attractive; but, the service is not in a position to acquire the V-22 unless the aircraft is first procured by a Department of Defense component. Even then, costs will have to be examined very closely and weighed against some unique benefits. In essence, the management challenge may be to create a realistic vision that takes advantage of the tilt rotor's uncommon capabilities while simultaneously remaining within legitimate budget constraints.

B. AREAS FOR FURTHER RESEARCH

Provided the V-22 enters production, several areas must be addressed before the tilt rotor can enter Coast Guard service. These areas include:

- Formulating a mission need statement.
- Establishing the hardware requirements for a Coast Guard version of the Osprey.
- Developing a basing strategy for the tilt rotor.
- Conducting a formal cost benefit analysis.

Besides the tilt rotor, the thesis suggested two other aviation related issues which also need to be examined:

- Historical cost information is not accessible to decision makers in aviation management offices.
- The Coast Guard's budget allocation process does not ensure that aviation program funds reach the service's air stations. Therefore, it is difficult to validate aviation costs against the program budget.

Historical costs associated with the service's various types of aircraft are dispersed across several offices at Headquarters (Aviation Program Office, the Aeronautical Engineering Office, the Office of Acquisition and the Chief of Staffs Office) and the Aviation Repair and Supply Center in Elizabeth City, North Carolina. The documents containing this data are archived and retrieval efforts would have exceeded the scope of this thesis. A good management information system is needed to link these offices so that decision makers have ready access to historical cost data. For example, to determine HH-65A original spares levels, subsequent alterations in stocking levels and the cost of HH-65A airframe modifications (since acquisition), it would be necessary to review original contracts warehoused in North Carolina. While the information is available, it is not very accessible. Although not every document should be saved, a data base needs to be established to provide historical aviation cost information in a timely manner. This information would also be readily available for cost analysis improvement efforts.

Secondly, the Coast Guard aviation budget is filtered through 10 district offices before it reaches the service's 27 air stations. While this study used data derived from the aviation program budget to approximate costs, there is no guarantee that program rates are actually allocated to each air station. Therefore, any effort to compare budgeted aviation dollars with actual expenditures is somewhat diluted because district offices have the option of shifting aviation funds to other areas. While district commanders want budget flexibility, the budget allocation process makes it difficult to assess the potential impact that major aviation resource changes could have on overall aviation costs.

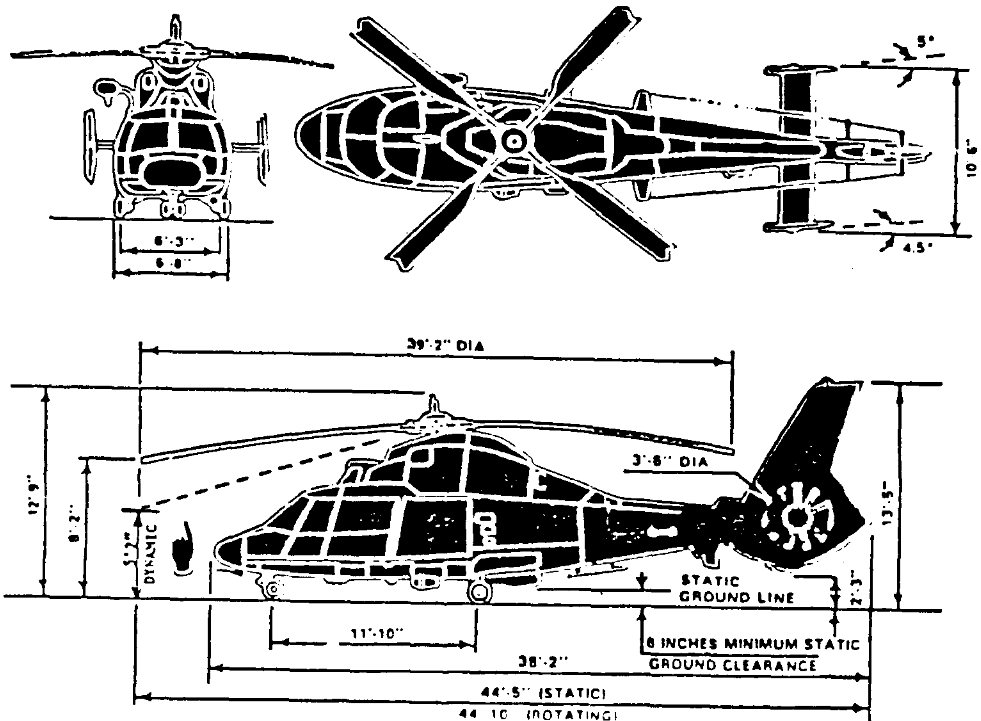
Therefore, the budget allocation process needs to be reviewed with an eye toward planning for actual aviation expenditures. The objectives would be to develop a more accurate budget process that provides a clearer picturer of Coast Guard aviation's fixed and variable costs.[41]

[41] In the long run, all costs are variable costs.

APPENDIX A

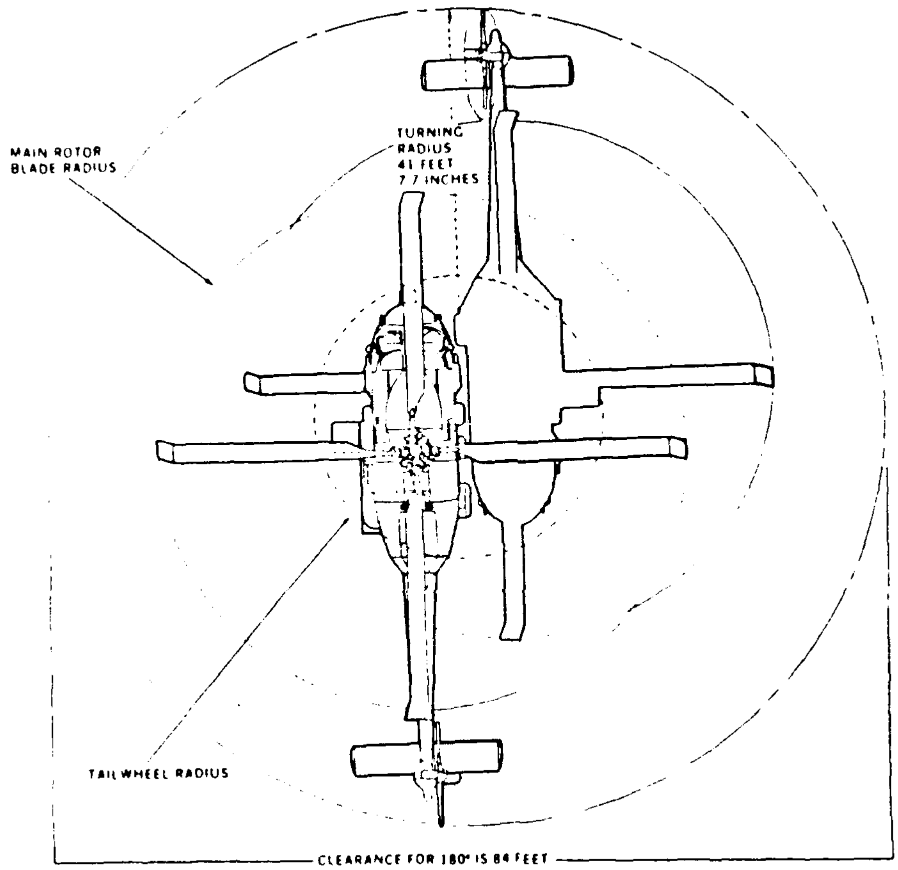
AIRCRAFT DIAGRAMS

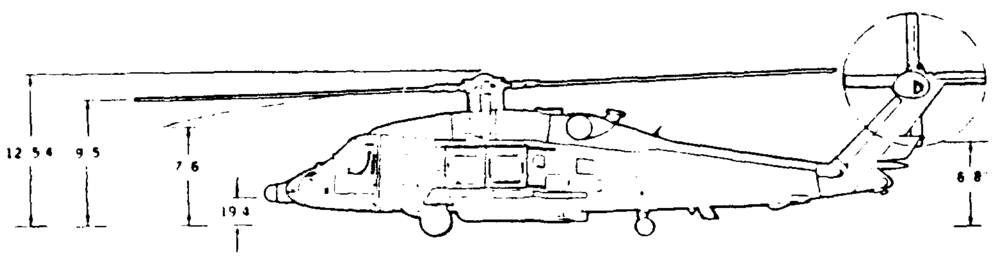
The HH-65A Short Range and Recovery Helicopter



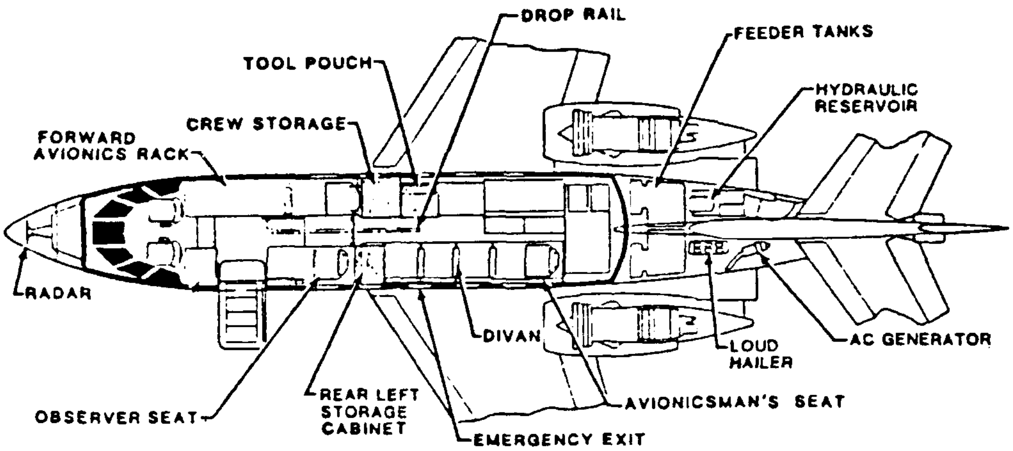
AIRCRAFT DIMENSIONS	
ROTOR DIAMETER	39 feet - 2 inches
OVERALL LENGTH (STATIC)	44 feet - 5 inches
HEIGHT TO TOP OF ROTOR HEAD	12 feet - 9 inches
HEIGHT TO TOP OF FIN	13 feet - 5 inches
MAIN LANDING GEAR TRACK	6 feet - 3 inches
WHEEL BASE	11 feet - 10 inches
MINIMUM GROUND CLEARANCE WITH CYCLIC DISPLACED TO LIMIT LIGHT ILLUMINATION (100% NR)	7 feet 7.2 inches
MINIMUM STATIC GROUND CLEARANCE (BLADE AT 12 O'CLOCK)	8 feet - 2 inches
GROUND CLEARANCE (UNDER FUSELAGE)	8 inches
TAIL ROTOR DIAMETER	3 feet - 6 inches
CYCLIC FULL FOWARD, DYNAMIC	5 feet - 2 inches
AIRCRAFT WITH BLADES FOLDED	
LENGTH	38 feet - 2 inches
WIDTH (AT STABILIZER)	10 feet - 6 inches
AIRCRAFT DISASSEMBLED FOR SHIPMENT	
LENGTH	21 feet - 8 inches
WIDTH (STABILIZER REMOVED	6 feet - 8 inches
HEIGHT (ROTOR HEAD AND LANDING GEAR REMOVED	8 feet - 4 inches

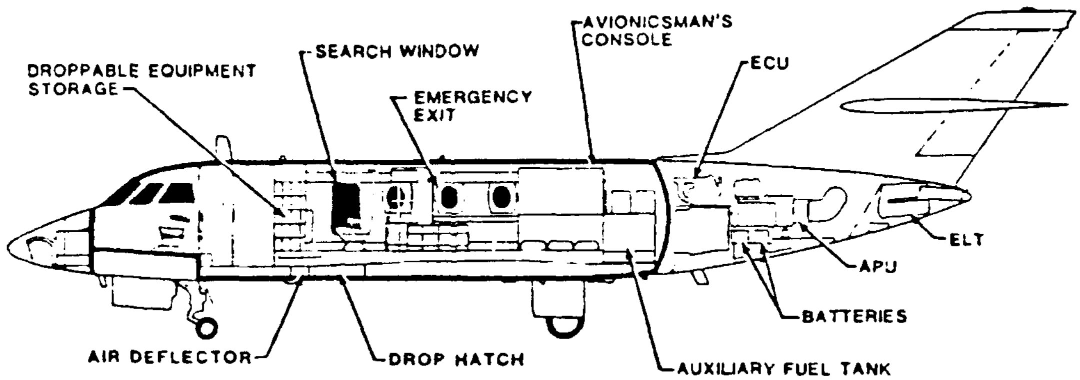
The HH-60J Medium Range and Recovery Helicopter



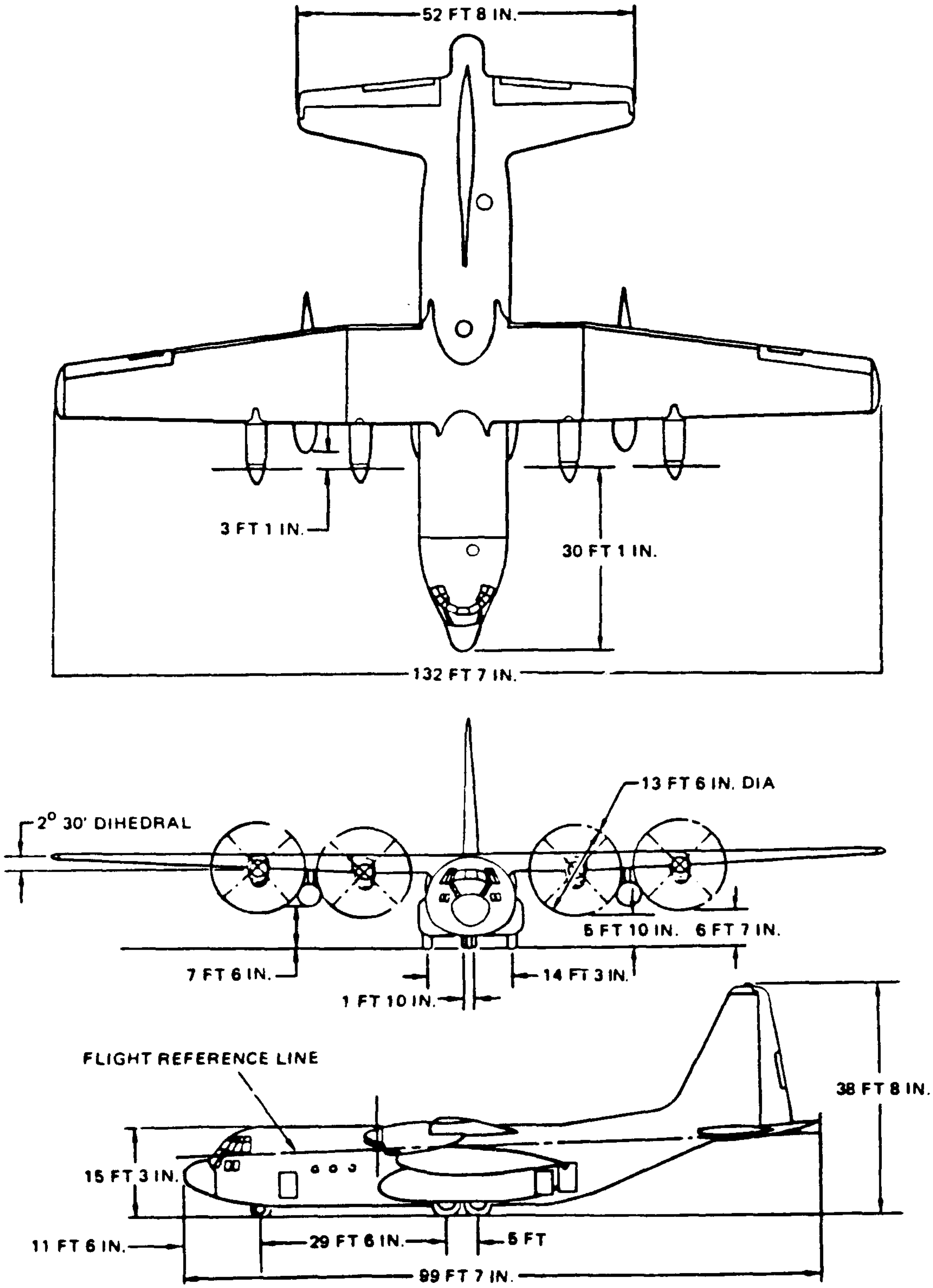


The HU-25A Medium Range and Surveillance Aircraft

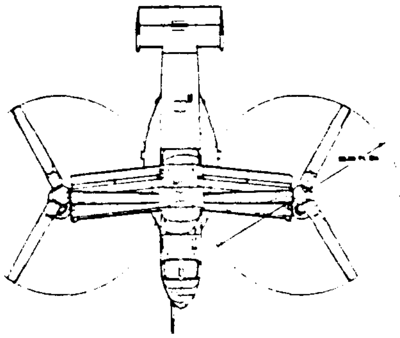




The HC-130H Long Range Surveillance Aircraft

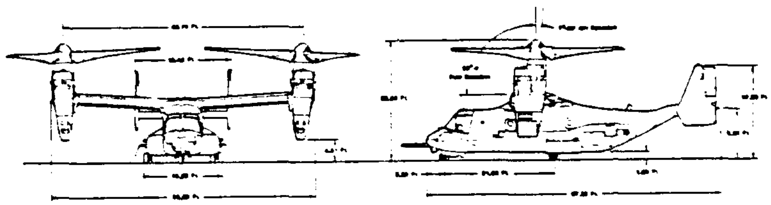


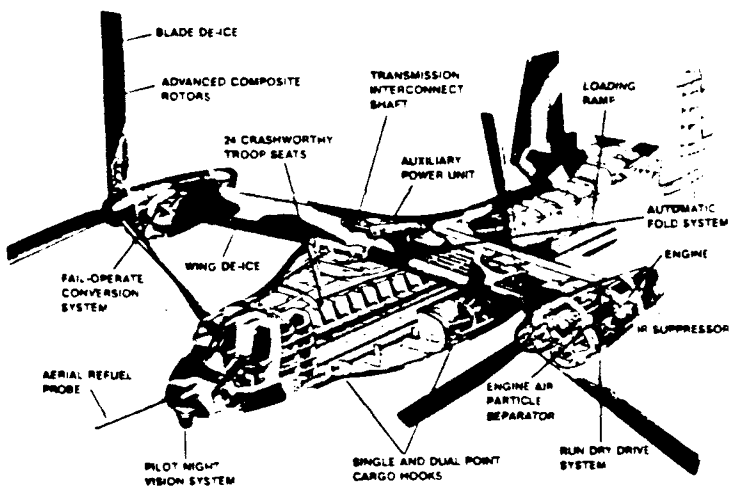
The V-22 Tilt Rotor Aircraft (diagrams extracted from V-22 Program Office and Bell-Boeing tilt rotor publications)



Aircraft Characteristics

Spread	
Length	57' 4"
Width	84' 7"
Height	22' 7"
Folded	
Length	62' 7"
Width	18' 5"
Height	18' 1"
Take-Off Weights	
VTOL/STOL	55,000 lb
Self Deploy STOL	60,500 lb
Fuel Capacity	2015 gal





APPENDIX B

EXCERPT FROM THE V-22 JOINT SERVICES ADVANCED VERTICAL LIFT AIRCRAFT SELECTED ACQUISITION REPORT DATED DECEMBER 31, 1988

Cost	Development Estimate	Approved Baseline	Current Estimate
Development (RDT&E)	2443.7	2471.0	2471.0
Procurement	20493.1	17425.5	17425.5
Airframe	(11013.0)	(10272.1)	(10272.1)
Engine	(1519.8)	(1289.7)	(1289.7)
Avionics	(1293.5)	(1015.0)	(1015.0)
Other Hardware	(493.7)	(379.7)	(379.7)
Non Recurring	(1197.1)	(973.9)	(973.9)
Total Flyaway	(15517.1)	(13930.4)	(13930.4)
Other Wpn Sys Cost	(3299.6)	(2288.7)	(2288.7)
Initial Spares	(1676.4)	(1206.4)	(1206.4)
Construction (MILCON)	136.2	134.4	134.4
Total FY86 Base-Year $	23073.0	20030.9	20030.9
Escalation	6589.3	5824.5	5824.5
Development (RDT&E)	(181.5)	(189.5)	(189.5)
Procurement	(6371.1)	(5595.4)	(5595.4)
Construction (MILCON)	(36.7)	(39.9)	(39.6)
Total Then-Year $	29662.3	25855.4	25855.4

Quantities	Development Estimate	Approved Baseline	Current Estimate
Development (RDT&R)	6	6	6
Procurement	913	657	657
Total	919	663	663

APPENDIX C

RESCUE CASE INFORMATION BY DISTANCE OFFSHORE, FY86-FY90

	0 - 150			151 - 300			300 +			TOTAL		
FYR	CASES	LS	POA	CASES	LS	POA	CASES	LS	POA	CASES	LS	POA
86	57789	6765	134,272	216	77	491	254	160	641	58259	7002	135,404
87	55508	5540	130,356	229	117	401	242	131	738	55979	5788	131,495
88	53864	4181	127,726	147	63	252	176	68	395	54187	4312	128,373
89	52346	3652	116,568	182	67	294	208	242	678	52736	3961	117,540
90	52555	4138	115,510	183	180	656	161	60	832	52899	4378	116,998

LS = Lives Saved
POA = Other Persons Assisted

APPENDIX D

FY89 AVIATION RESOURCE SEARCH AND RESCUE STATISTICS

Aircraft Type	Cases	No. of Sorties	Time on Sortie	Lives Lost After
HC-130H	516	775	3,979.1	80
HU-25A	781	1,022	2,379.6	41
HH-52A[1]	204	256	354.4	24
HH-65A	3,192	4,181	7,242.1	121
HH-3F[2]	1,434	1,781	4,448.6	75
Other	3	3	5.6	0

Aircraft Type	Lives Saved	Person Otherwise Assisted	Property Lost ($000)
HC-130	366	1,051	77,583
HU-25A	315	893	23,977
HH-52A	139	122	1,411
HH-65A	847	3,250	118,534
HH-3F	467	1,154	83,172
Other	0	17	0

Aircraft Type	Property Assisted ($000)	Property Loss Prevented ($000)
HC-130H	48,506	45,625
HU-25A	12,773	8,645
HH-52A	8,247	3,957
HH-65A	49,685	35,840
HH-3F	12,799	10,043
Other	95	75

[1] These cases represent short range and recovery responses. The HH-52A has been retired in favor of the HH-65A.

[2] The Coast Guard's HH-3F helicopters are being replaced with HH-60J helicopters.

APPENDIX E

ESTIMATED WEIGHT INFORMATION FOR A V-22 CONFIGURED FOR SEARCH AND RESCUE (provided by the Bell-Boeing Joint Program Office)

EST PILOT PRODUCTION WEIGHTS		(lbs) VTO	(lbs) STO
MGTOW (SL/90 F, 20 kts W.O.D.): (Note 1)		55,876	60,400
HV-22 WEIGHT EMPTY		34,023	34,023
REMOVE 16 TROOP SEATS		-177	-177
REMOVE CARGO ROLLER RAILS		-81	-81
CREW (5)		1,100	1,100
CREW EQUIP		150	150
DATA TRANSFER CARTRIDGE		3	3
REFUELER PROBE KIT		63	63
ANTI-EXPOSURE SUITS		90	90
LIFE RAFTS		200	200
SAR KIT:		447	447
MEDIVAC KIT	94		
FOREST PENETRATOR	25		
MISC EQUIP	130		
OXYGEN RESUSCITATION	50		
PARARESCUE KIT	25		
PYROTECHNIC BOX	60		
SCUBA TANK	50		
STOKES LITTER	13		
TOTAL	447		
OPERATING WEIGHT:		35,818	35,818
NORMAL NAVY CONFIG FUEL LOAD (MAX INTERNAL):		13,700	13,700
NORMAL SAR MISSION WEIGHT:		49,518	49,518
EXCESS CAPACITY:		6,358	10,882

CABIN AUX FUEL TANKS: 602 GAL CAPACITY EA. (USEABLE)
4093 LBS. FUEL CAPACITY EA. (USEABLE)

CABIN AUX TANK WT EMPTY: 415 LBS. EA.

MAX CABIN CAPACITY: 4 TANKS

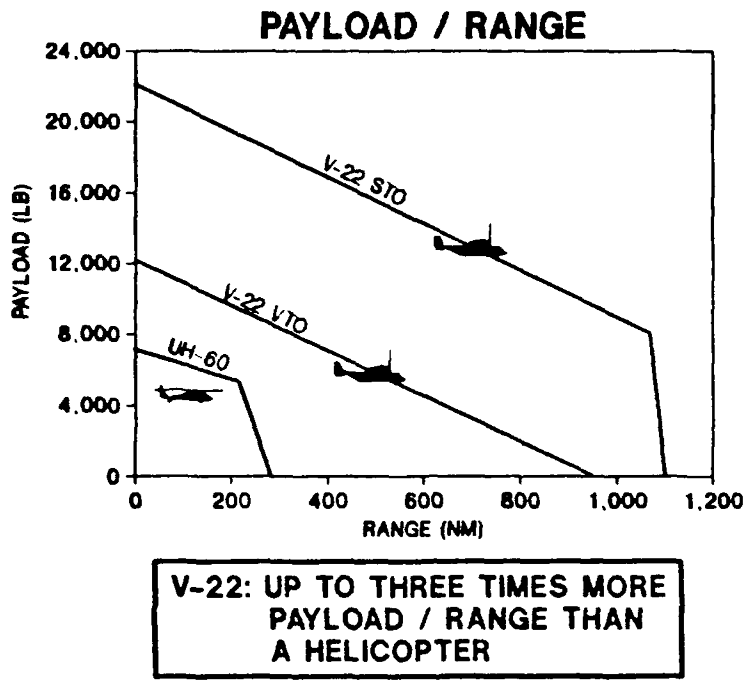
Note 1: No wind MGTOW VTO weight is: 51,773

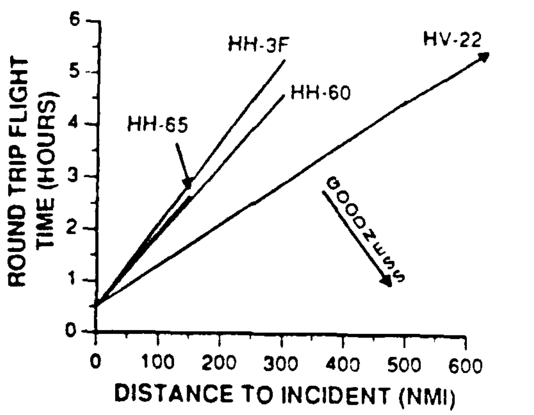
- NORMAL SAR MISSION WT: (49,518)

No wind VTO Excess Capacity: 2,255

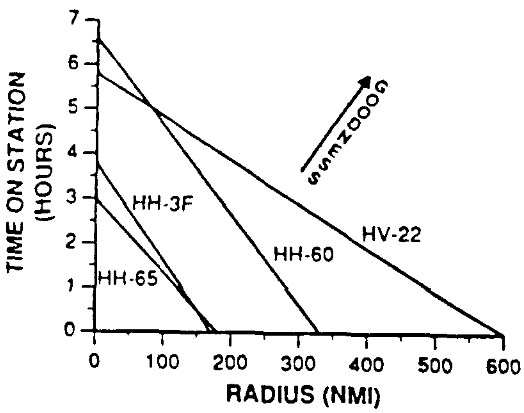
APPENDIX F

GRAPHIC MEASURES OF V-22 VERSATILITY





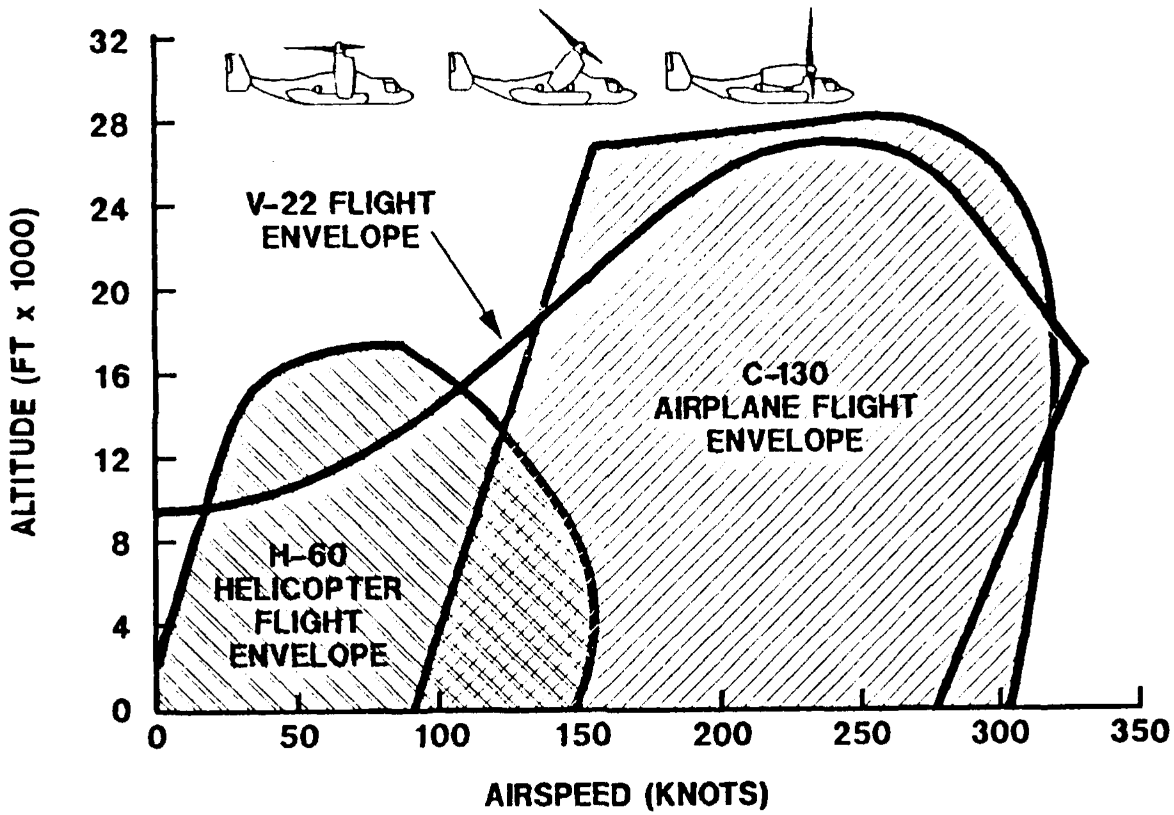
The Responsiveness of the HV-22 Far Exceeds That of the Helicopter Alternatives



The HV-22 Provides Superior Time on Station for SAR Missions

V-22 OSPREY: THE BEST OF BOTH WORLDS

THE HELICOPTER AND AIRPLANE HYBRID



V-22 OSPREY:

SPEED AND EFFICIENCY OF AN AIRPLANE
LANDING FLEXIBILITY OF A HELICOPTER

APPENDIX G

AVIATION PROGRAM RATES

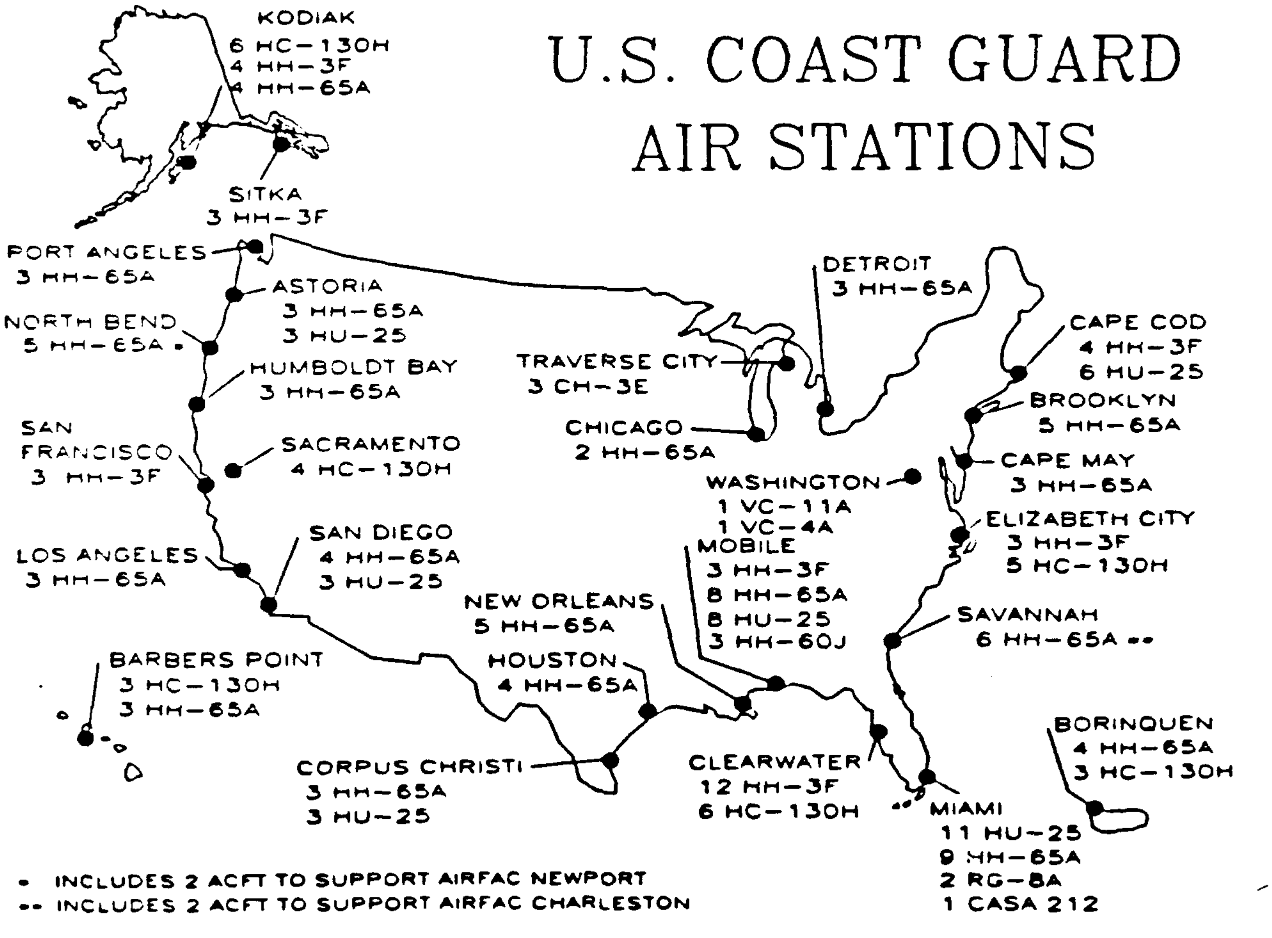
PROGRAM MEASURE	AIRCRAFT HH-65A	HH-60J	HU-25A	HC-130H
Rate (flight hrs/yr)	645	700	800	800
Fuel Consumption (gal/hr)	94	154	310	870
Fuel Expense ($/hr)[1]	94.00	154.00	310.00	870.00
Unit Level Maintenance ($/flight hr)	93.19	211.00	74.99	119.98
Depot Level Maintenance ($/flight hr)	1,039.35	954.00	1,236.15	994.25
Measured Work Billets[2]	2+0+10	3+0+17	2+0+11	3+0+22

[1]Based on a federal contract price of $1.00 per gallon.

[2]The first value is for pilots, the second for warrant officers and the third for enlisted maintenance personnel.

APPENDIX H

MAP OF COAST GUARD AIR STATIONS



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