Civilian Research Project

# The Need for High Speed in Next Generation Rotorcraft

by

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DOD and Defense Contractors are now seeking the next level of rotorcraft development. The increase in helicopter airspeed is now being considered as one of the important next-generation rotorcraft improvements. The challenge is to build a helicopter that can hover under load, move the required payload and fly faster than current helicopter platforms. All of these improvements will allow greater service ranges, provide faster response times and provide needed future cost reductions.
This paper will address the history and evolution of high-speed rotorcraft capabilities, typical roles and missions, and the advantages and disadvantages of the U.S. Army developing and procuring high-speed helicopters. The analysis will attempt to answer the following: 1) Are these types of aircraft practical for use in the Army inventory? 2) What is the timeline associated with development? 3) Will the DOD be able to afford the capability?

**15. SUBJECT TERMS**
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# THE NEED FOR HIGH SPEED IN NEXT GENERATION ROTORCRAFT

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# ABSTRACT

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THE NEED FOR HIGH SPEED IN NEXT GENERATION ROTORCRAFT

From the earliest thought of manned flight the helicopter was considered as a viable option to satisfy the requirement for flight. Leonardo Da Vinci first dreamed of the helicopter flight concept in the year 1480. His adaption of the flying machine, named the "Helical Air Screw," used the theory of compressing air in order to obtain lift and perform flight. Plans were drawn, but without adequate technology required to build the machine, his theory never reached reality.[1] This theory was very similar to production helicopters of modern day. Much innovation has occurred since Da Vinci's early idea and many improvements continue to make helicopters more useable, stable and efficient. The military role and mission continually guide modern helicopter development to this day.

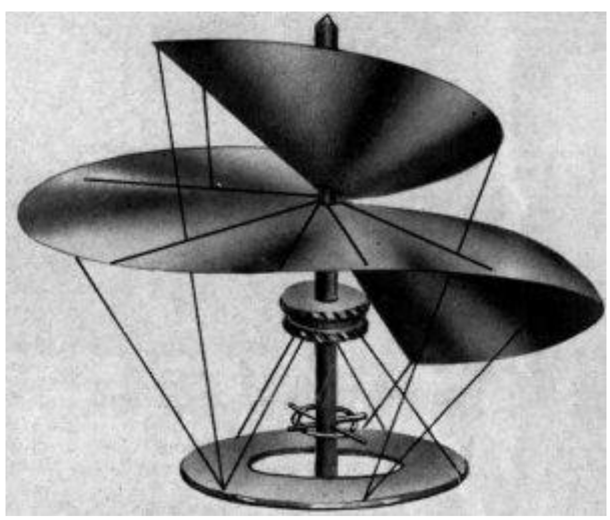

Figure 1, Da Vinci's Helical Air Screw

Helicopter flight and the basic concept were both proven by the late 1940s. Several aircraft were in production and numerous helicopter manufacturers entered the business. Design engineers set their sights on many improvement aspects for the flying machine; the most important was to extend the helicopter's speed envelope.[2] This is one area, today, that continues to interest military commanders and leaders as they perform various peacetime and combat missions. The need for greater airspeed grows each year with ever-increasing demands on Army Aviation assets. Convertiplane rotorcraft were the initial concept derived to extend the speed envelope.

By early 1950, numerous convertiplane helicopter configurations were proposed by industry partners. Convertiplane configurations combined the vertical take-off features of a helicopter and the forward flight and range characteristics of fixed-wing aircraft.[3] Initial designs were created for reconnaissance and observation mission utilization, to include applying the principle to larger aircraft for cargo support missions. In 1950 a joint Air Force and Army design competition was conducted to explore the feasibility of flight principles behind the convertiplane concept.[4] Specifically, they looked at designs that provide effective conversion from the hovering helicopter flight to forward flight like that of a fixed winged aircraft.

Mission requirements during the 1950s included significant hover duration, low speed maneuvering and agility, and a speed and range greater than current helicopter capabilities.[5] The challenge of finding an aircraft type that met both the hover and cruise-mode performance criteria, while also meeting other operational, economic and environmental requirements was the major task encountered by Vertical Takeoff and Landing (VTOL) developers. Determining the requirements was the first step in assembling the design and test approach the Army desired. The next step was to comb the field of available defense contractors and solicit initial concepts for exploration.

Three initial concepts were selected from three different industry partners: McDonnell Aircraft Corporation's unloaded rotor principal (XV-1), the tilting rotor configuration (X-3) constructed by Bell Aircraft Corporation, and the single-bladed, fully retractable rotor (XV-2) built by Sikorsky Aircraft Division. Of the three concepts, two were chosen to continue development. The single-bladed rotor proposed by Sikorsky was considered to require further rotor-systems development and was dropped from the competitive study.[6] These chosen initial designs led to further development and study by both industry and military engineers.

Figure 2, McDonnell Aircraft Corporation, XV-1, Unloaded Rotor Principal

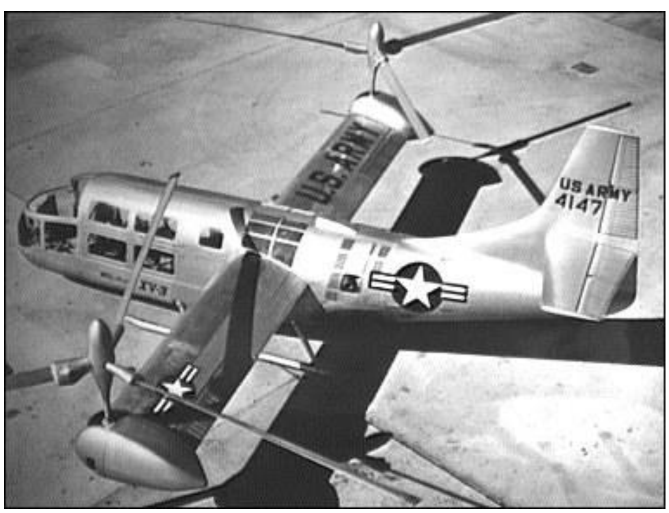


Figure 3, Bell Aircraft Corporation, XV-3, Tilting Rotor Configuration

Although there were great advancements in the 1950s focusing on convertiplane creation, this early work was severely hampered by limited gas turbine technology since both the characteristics and availability of the turbines in the early 1950s were unfavorable.[7] Several new wind tunnel design models did emerge during this period, containing invaluable convertiplane data. The most important technical challenge centered on the rotor system during the conversion phase. In the late 1950s, many convertiplane development contracts were cancelled and the ideas shelved for later efforts. The U.S. Government became focused on space exploration and funding for the development of space and missile programs took priority.

Work and further study on convertiplane and composite aircraft design did occur into the 1960s. The original convertiplane idea paved the way for a new design concept named “composite aircraft design”. This concept represented the next generation of rotary wing research. Composite aircraft design aimed at providing the technical base for helicopters having speed capabilities in the 300 to 350 knot speed range.[8] In order to obtain the desired speed, the rotor drag in high-speed flight had to be reduced or eliminated by altering the mode of operation of the rotor. Possible solutions for this issue were:

a. Tilting the rotor forward to act as a large propeller in forward flight.

b. Stopping the rotor and using the rotor blades as fixed-wing systems. This would involve providing the forward thrust by diverting the power for the rotor system to thrust producers mounted to the fuselage.

c. Stopping the rotor, folding the blades aft, retracting the rotor system into the fuselage and diverting the rotor power to thrust producers.[9]

Like the initial convertiplane concept, the composite aircraft design concept combined into one aircraft the hover efficiency and low downwash velocities of the helicopter and the high-speed efficiency of fixed-wing type aircraft. Initial contracts were awarded in November 1965 to Bell Helicopter Company, Hughes Tool Company and Lockheed-California Company. Bell was to study the tilt rotor/prop concept, Hughes to study the jet-powered hot-cycle rotor/wing concept, and Lockheed was to study the stopped/stowed rotor concept.[10] Specific objectives by all three contractors were the following:

a. Performance and propulsion area

b. Stability, control and flying qualities area

c. Structures area

d. Productivity and productivity per dollar[11]

Design goals in the 1960s were very similar to those of today's aviation community. We must learn from history and capitalize on the work already accomplished to continue modern development. The importance of laying out past objectives, development and requirements is paramount to understanding the issues around the high-speed helicopter flight concept. Certain flight objectives and test results of the high-speed flight progress were shelved only to be resurrected again for later development. Developmental engineers built upon past advancements and through modern technological improvements the early ideas have become a reality. Objectives described below correspond with current concerns and requirements.

Performance and propulsion objectives included helicopter-type capabilities such as vertical takeoff and landing with a useful load of 6,000 lbs, low disc loading and the ability to hover out of ground effect at 6,000 feet on a 95 degree Fahrenheit (F) day. The hover out of ground effect requirement remains the same today on new rotorcraft developments. In the airplane mode, objectives were a forward speed of 300 knots (with 400 knots desired) for all aircraft design configurations. All internal compartments were to be of the same size in order to have a common reference point between the different contractors and a single reference point for aircraft design.[12] No restriction on engine type was passed to the contractors; they were merely restricted to the current existing engines available at the time.

Stability, control and flying quality objectives were oriented towards a fail-safe airplane that would be statically stable when all sources of augmentation were turned off; have sufficient mechanical advantage in the pilot's primary controls to preclude excessive control forces when control boost was off; and be able to accomplish a safe landing if all power was lost. Control boost provides a computer-augmented assistance to the pilot increasing flight control effectiveness and response. Also there could be no major problems in stability and control characteristics during transition/conversion from helicopter mode to the cruise-type fixed wing mode and vice versa.[13]

The weight of the helicopter as influenced by aerodynamic loads was a concern. Banking a helicopter while maintaining a constant altitude, pulling through a high speed dive or pitching the nose down in high speed flight causes increases or decreases in "g" load factor readings. Structures objectives were to adhere to military specifications that limited structural design flight and ground handling loads to factors of +3.0g and -0.5g. In the fixed wing mode the flight structural design limit load factors were to be +4.5g up to maximum speed and a negative load factor of -1.0g to maximum level flight varying linearly to zero g at dive speed. Landing gear was to be designed for applicable VTOL conditions according to prescribed military specifications. The aircraft was to also have the capability for emergency landing in the fixed wing mode on a standard runway.[14]

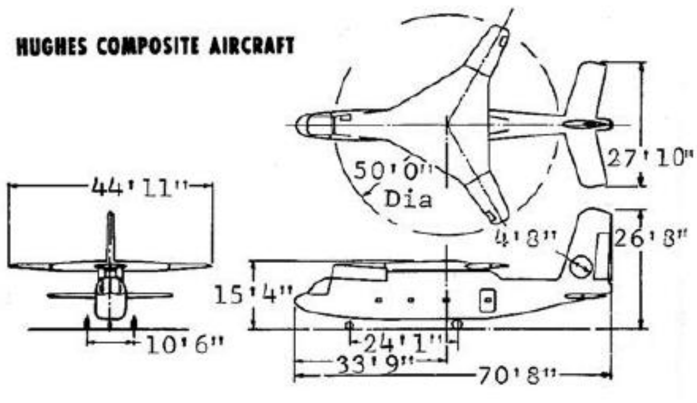


Figure 4, Hughes Composite Design, Three-View Design Drawing

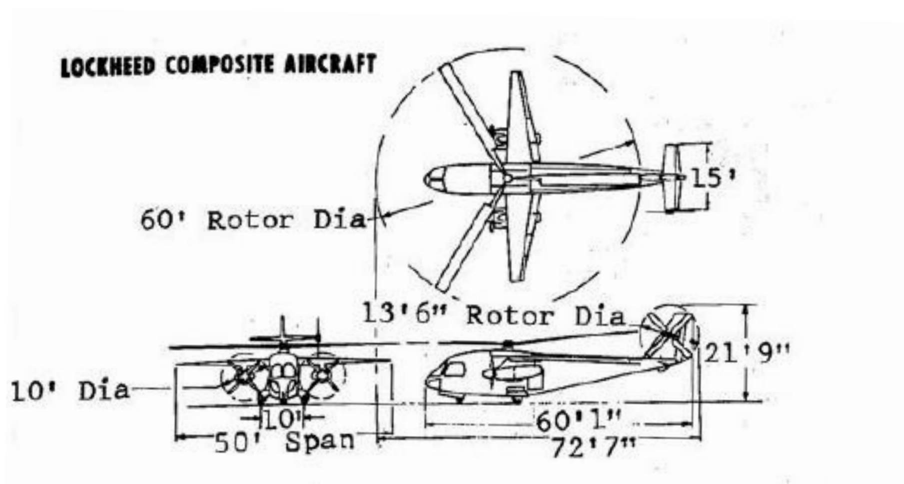


Figure 5, Lockheed Composite Design, Three-View Design Drawing

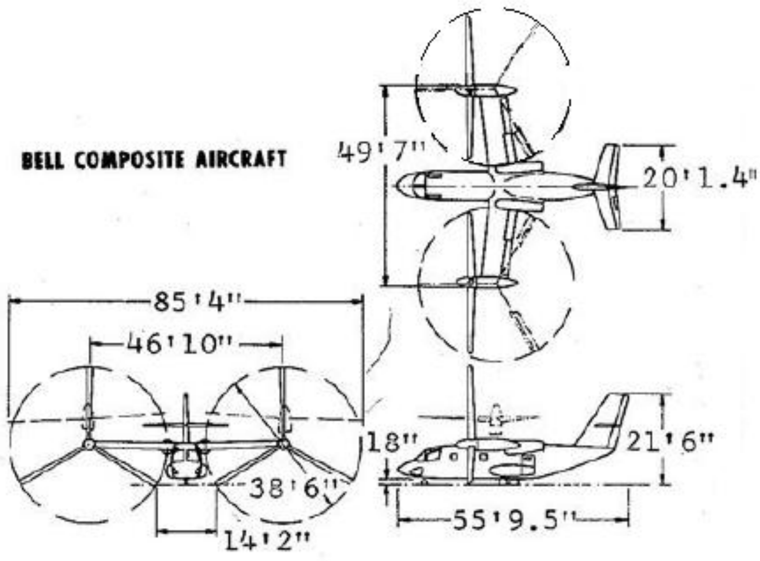


Figure 6, Bell composite design, Three-View Design Drawing

Productivity and Productivity per dollar were important Army considerations. A basic 200-mile sea level mission was used to baseline all aircraft configurations. Productivity did increase as the speed increased, even though higher airspeed demanded higher power and fuel consumption rates. Comparing concept results, the standard helicopter excels up to about 180 knots, the compound is best between 180 and 250 knots and the composites and tilt-wing concepts shine in the 250 to 350 knot speed range. Composite aircraft do suffer a 30 to 35 percent decrease in productivity per dollar if they are required to operate solely at helicopter mission speeds (e.g. from hover to 100 knots forward airspeed).[15]

Final conclusions from the concepts study:

a. The combining of both hover efficiencies of a helicopter and the high-speed flight of a fixed wing aircraft is feasible. State of the art technology will later offer significant potential to the concept.

b. Composite aircraft can provide the desired increase in airspeed up to 100 knots over helicopter capabilities with no sacrifice to productivity or to productivity per dollar due to higher airspeeds.

c. Composite aircraft, when operating at higher speeds, can provide up to a 20 percent increase in productivity and the same productivity per dollar as compared to helicopters.

d. As composite technology is refined, a substantial improvement in ton-miles per dollar over that for the tilt wing may be expected.[16]

Upon conclusion of this study, it was determined that only the tilt rotor/prop efforts would continue forward for further research. Detailed designs, manufacturing processes and flight testing would advance. The developmental vehicle would then be turned over to the Army or another DOD organization to determine the operational potential of the concept for future military missions. Of the three composite concepts discussed, only the Bell tilting rotor/prop received approval for further development. Bell continued to develop their tilt-wing technology with their experimental XV-3 program. The XV-3 program went through a series of downturns which ultimately resulted in the canceling of this program in 1965.[17] Further study did reemerge during the late 1960s on the tilt rotor concept, which expanded upon the Bell's initial design.

After nearly 20 years of development and testing that began with the XV-3 program, extensive experimental work ultimately resulted in a breakthrough that solved the tilt rotor design’s high-speed stability problems. Further experimental work focused on previous poor performance and handling qualities that were noted in early testing. Following a partnership between NASA and the U.S. Army in the late 1960s, the joint team applied several methodology developments to the tilt rotor design. Each major design problem was addressed and solved by a planned series of experimental and analytical investigations.[18] Due to these extensive efforts the tilt rotor development continued through the 1970s and into the 1980s.

In the late 1960s and early 1970s, NASA worked extensively on theoretical and wind tunnel tests of various rotor configurations. Two companies directly involved in this research and design were Bell Helicopter and Boeing-Vertol. Their focus was tilt rotor pods and the integration of the tilting rotors with wings on the aircraft fuselage. This testing and research led to the official XV-15 project launch in 1971 at the NASA Ames Research Center. After initial work was completed, a brief competition was held, and research contracts were awarded to Bell Helicopter and Boeing-Vertol in 1972. Design proposals followed and were delivered to the DOD in 1973.

The Bell tilt rotor design led to the development of the Short Takeoff and Landing (STOL)  and Vertical Takeoff and Landing (VTOL) capabilities in use today. The tilt rotor concept became the basis for United States Department of Defense Joint-Service Vertical Take-off/Landing Experimental (JVX) aircraft program which started in 1981. The team of Bell Helicopter and Boeing Helicopters was awarded a development contract in 1983 for the tilt rotor aircraft. The Bell/Boeing team jointly produced the aircraft which first flew in 1989, and began flight testing and design alterations shortly thereafter.[19] The current production V-22 Osprey aircraft is the fruit of the continued development and refinement of the original Bell design.

Further improvements in the quest for high speed helicopter flight continued to emerge. Continuing these historical advancements does shed light on the growth path to newer technological advancements of today. In addition to the convertiplane and composite aircraft designs there were other concepts developed. Additional concepts of interest include:

a. Compound helicopters; these aircraft added auxiliary lift and forward propulsion devices to otherwise conventional helicopters.

b. Advancing Blade Concept (ABC); this idea eliminated the problem of retreating blade stall by using two counter-rotating rotors so that there were advancing blades on both sides of the aircraft.

c. X2 Technology, which expands upon the advancing blade concept but with advanced airfoils, active vibration control and other modifications. Very similar to ABC design, but different enough to qualify as a separate category.

Compound helicopters did not require the advanced levels of technology and technology invention as convertiplane concepts. The initial design approaches envisioned speeds in the 210 to 250 knot range, which were compared to 125 to 175 knots for current production helicopters.[20] I will cover three specific compound designs developed by Sikorsky Aircraft and the Lockheed-California Company:

a. The Sikorsky S-66 Advanced Aerial Fire Support System (AAFSS).

b. The Lockheed XH-51A.

c. The Sikorsky S-67 Blackhawk, not to be confused with the UH-60 Black Hawk medium lift helicopter currently in production.

The Sikorsky AAFSS and the Lockheed XH-51A were both chosen by the Army from a design study performed in the 1960s. These two aircraft were chosen from a group of 12 draft proposals to proceed with preliminary design and formal proposals.

The Sikorsky S-66 AAFSS was envisioned to replace the Bell UH-1 “Hueys” that were currently being used in the Vietnam conflict as troop transports and armed aerial platforms. The AAFSS design speed was 260 knots as compared to the less than 100 knot airspeed for the UH-1.[21] The AAFSS focused on a compound design due to it being lighter, simpler, lower risk and was more agile and stable at all airspeeds. The design was a conventional articulated rotor with a tandem two-man cockpit, and forward propulsion was provided by a pusher propeller. The Sikorsky S-61F was determined to be the final demonstrator designation for the AAFSS technology. The AAFSS used a "Rotoprop" device, where the tail rotor swiveled 90 degrees to become the pusher propeller in cruise flight.

Lockheed proposed its "rigid" rotor which was already flying on the XH-51A experimental compound aircraft.[22] The XH-51A had previously achieved airspeeds of 235 knots and demonstrated high levels of maneuverability. Lockheed received much publicity on the ability of the XH-51A to perform both loops and rolls.[23] The acrobatic demonstration was aimed at proving that a rigid rotor design was superior to an articulated rotor system. The loops and rolls were pure marketing, however, since the Army did not require loops and rolls for production aircraft. The Army’s focus was on new technology that could be put into production to meet the speed and other mission requirements.

At the end of the preliminary design competition, the Lockheed design was chosen over the Sikorsky AAFSS. The Lockheed design later became the AH-56A Cheyenne. The Cheyenne did offer promising results but there were overall deficiencies in the design. First the aircraft was too large, the systems were outdated and ever-increasing cost growth ultimately caused the cancellation of the Cheyenne program in 1972. Although cancelled, the Cheyenne program jump-started the Army's Advanced Attack Helicopter (AAH) which later produced the AH-64 Apache helicopter that is currently in service around the world today.[24]


Figure 7, Lockheed AH-56A Cheyenne

The third compound aircraft design of interest is the Sikorsky S-67 Blackhawk. Around the same timeframe that the Cheyenne continued development, Sikorsky still proceeded to internally work their opportunity to compete in the gunship market. The S-67 aircraft was completed in a remarkably short period of time and consisted of a new type of tandem, two-person fuselage. This improvement combined with the dynamic method of helicopter production included wing and drag brakes, but did not include auxiliary propulsion. The Blackhawk was fast, highly maneuverable and set a 1970 speed record for helicopters without auxiliary propulsion at 221 knots.[25] The Blackhawk never made it into production. It was deemed too large for a two-pilot attack aircraft. The Blackhawk did provide the test fuselage for Sikorsky's "fan-in-fin" anti-torque system. This "fan-in-fin" system was chosen as the tail rotor for the RAH-66 "Comanche", developed years later as a joint Boeing and Sikorsky program.

Figure 8, S-67 Fan-in-Fin Demonstrator

The second additional concept of interest is the Advancing Blade Concept (ABC). ABC eliminated the retreating blade stall problem that plagues the common helicopter. Retreating blades do not have to produce lift at high advance ratios during high speed flight conditions. Two rigid coaxial counter-rotating rotors designed to carry large rolling moments maximize the lift capabilities of the advancing blades.[26] The two counter-rotating rotors also remove the need for a tail rotor providing “anti-torque” for the aircraft, removing weight and additional moving components from the aft of the fuselage.

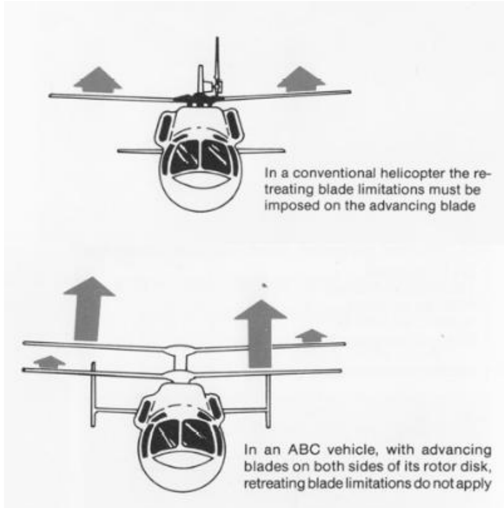


Figure 9, The Advancing Blade Concept, ABC Helicopter

The primary advantage of ABC is that rotor lift increases with both airspeed and altitude similar to a fixed wing aircraft. The threat of retreating blade stall restricts the maximum speed of conventional helicopters. Retreating blade stall is a very dangerous flight condition where the rotor blade rotating away from the direction of flight stalls causing the retreating side of the aircraft to descend rapidly. This concept was conceived by Igor Sikorsky prior to World War II; at that time it was called the coaxial configuration. Technology at the time did not allow the aircraft to proceed into test or production. It is important to note that the ABC rotor system also has the capability of canceling certain vibration inputs by the phasing of the rotors.[27] Increased vibration levels are also a major concern for helicopters where the vibrations can lead to "in-flight" component and structure failure events.

Sikorsky's X2 concept bridges the gap between history and current compound aircraft design for Sikorsky Aviation. The Advancing Blade Concept was reintroduced and is currently being used in Sikorsky's X2 concept development aircraft. Sikorsky began their X2 preliminary design activities in 2004.[28] Initial designs of Sikorsky's XH-

59A program paved the way for the X2 program and attained 240 knots maximum airspeed at altitude. The X2 is very similar to the XH-59A but it has advanced airfoils, active vibration control and other key modifications applied to the platform. The primary goal of the X2 technology demonstrator is to address many of the issues that emerged during testing of the XH-59A, especially the vibration problems. Determined to continue development and to provide possible future aircraft capabilities, Sikorsky worked to improve the X2 design.

Key technologies explored on the X2 include improvements in the efficiency of the rotor system through advances in blade and hub design, integration of the aircraft drive system, lift and auxiliary propulsion systems and the achievement of VIP-transport vibration levels at high forward speeds through application of active vibration control.[29] The active vibration control system is very similar to the one used on the Army's UH-60M helicopter. The total rotor blade count was increased by two, using two four-bladed rotor systems on the aircraft. Adding the extra blades did increase the designer's challenge to achieve the “flapwise stiffness” of the blade needed to maintain tip clearance.[30] The updated auxiliary propulsion system (pusher-prop) consisted of an improved six-bladed design that Sikorsky specifically produced for the X2 demonstrator. The lift and propulsion power is produced by a single turbine engine, unlike the XH-59A which had separate lift and propulsion engines.

Sikorsky recently achieved a major milestone with the X2 technology demonstrator. The X2 broke an old speed class record by flying 250 knots in November of 2010. The X2 is roughly twice as fast as Sikorsky's famed UH-60 Blackhawk. The X2 features fly-by-wire controls, hub drag reduction, active vibration control, and an integrated auxiliary propulsion system and can maintain superlative low speed handling, efficient hovering, autorotation safety, and a seamless and simple transition to high speed.[31] Sikorsky engineers are transitioning the X2 technology to a new helicopter, the S-97 Raider. The S-97 has an estimated first flight set for the year 2014 and is expected to be the company’s entry into competition for the U.S. Army’s next generation armed scout. The Kiowa Warrior replacement will feature twin coaxial counter-rotating rotors and is predicted to fly at speeds over 250 knots.

Figure 10, Sikorsky X2 Technology Demonstrator

Historical VTOL/STOL aircraft demonstration testing proved out many design improvements and paved the way for future efforts. These efforts proved fruitful to military purposes and I will turn the focus to current needs and aspirations. This paper focuses on the Army's needs and requirements but these aircraft were well-suited to meet the requirements of other services as well. Examples of typical roles and missions include vertical assault (Marines), rescue and logistics (Navy), and long-range special operations (Air Force). The Army found the aircraft capability useful for medical evacuation, long range combat, logistical support and combat air assault support missions.[32] I will also address the impact of speed as it directly relates to the various Army missions.

During the late 1980s Army Aviation development was focused on the RAH-66 Comanche Helicopter. While the other services continued development and exploration of various compound rotorcraft, the Army was interested in producing a world-class reconnaissance and attack platform. Developing the avionics, weapons and systems required for the Comanche Helicopter pushed VTOL and STOL capabilities to the bottom of the Aviation priority list. The Comanche provided increased speed and agility over the existing fleet of Army reconnaissance and attack aircraft. The Comanche did attain a "dash speed" of 172 knots with a 162 knot cruise airspeed. Multiple configurations of the Comanche were envisioned to fulfill several future roles and missions.

Typical roles and missions derived from historical operations are: medical evacuation, long-range combat, logistical support and combat air assault support missions. I will briefly discuss these typical missions and the impact of high-speed helicopter flight. Medical or Medical Evacuation (MEDEVAC) missions are defined as the timely, efficient movement and en route care provided by medical personnel to the wounded evacuee. Medical Evacuation aircraft typically cruise at speeds of 130 to 150 knots. The emphasis on time is a critical measure directly associated with MEDEVAC operations. The speed with which medical evacuation is initiated is extremely important in reducing morbidity, mortality and disability.[33] Increasing the speed for future aircraft will create a larger footprint, and thus extend the total area for which one MEDEVAC unit can effectively provide support. An increased footprint also correlates to potential cost savings due to a reduction in total aircraft, fuel supplies and support equipment required within a given area.

Attack helicopters provide a highly mobile and lethal armor, personnel, and materiel destruction capability during the day, night and adverse weather conditions. The typical missions are attack, reconnaissance and security operations complementing other maneuver forces.[34] The increase in speed provides mission utility where aircraft might be called to attack urgent or time-sensitive targets. When aircraft are deployed from ground alert to launch, the increase in speed allows for the servicing of more targets. Apache AH-64D aircraft cruise at speeds in excess of 140 knots. Increasing this speed will decrease travel time to the target allowing the commander to reduce the number of assets required to cover the same battlefield area. The increase in range also comes without increasing the support infrastructure such as supply routes, Forward Arming and Refueling Points (FARP) and additional troops to provide the required maintenance and security. Speed does increase responsiveness and the overall tactical agility of the operation when introduced to attack helicopter platforms.[35]

Logistical support missions are typically resupply operations to troops in combat for FARPs and remotely located units. Numbers of aircraft to support required missions are determined by amount of supplies to haul and distance to supply locations. The longer the distance or the larger the amount of supply, the more aircraft required to complete the operation. In the area of logistical resupply, speed is normally deemed to be less critical to mission utility than the aircraft payload capability. Although CH-47 Chinook and UH-60 Blackhawk aircraft can both sustain cruise speeds of over 140 knots, future requirements will demand faster aircraft. Because of the scheduled aspect of a resupply mission, the response time is not as critical since times are planned and scheduled in advance. The payload has a greater impact on ability to accomplish the resupply operation for the amount of cargo carried.[36] Although speed is certainly helpful the desired benefit is dependent entirely on current mission requirements. The desired future speed requirement, as set by DoD planners, is a maximum cruise speed from 170 to 300 knots at max continuous operational power.[37]

Combat Air Assault missions fully integrate Army ground units with other members of the combined arms team to form powerful and flexible air assault task forces that can project combat power with little regard for terrain barriers.[38]Increases in speed and/or payload reduce closure time as projected in a step function, where fewer "lifts" of the aviation force are needed to meet the ground force closure requirements. Providing the ground force a faster time to target allows the aviation force to conduct more turns within the allotted mission timeframe. Each turn of aviation assets will carry a predetermined number of troops to the drop location. This will provide additional forces in a quicker manner, thus allowing the ground force to reach full strength in a quicker time. Speed is certainly important in the air assault and other Army missions. The question that needs to be answered is, “just how fast does the Army want to fly?” Current planning figures are in the area of 130 knots cruise speed for air assault operations. Future planners should focus on exceeding this cruise speed for maximum effectiveness.

The Army and selected partners are working to determine speed required for future missions and to develop the associated requirements. Simply put, the value of speed is reflected in time. Time to the commander on the ground or humanitarian assistance manager can be deemed critical. Increased speed saves lives, saves precious time and moves sensitive cargo to positions when they are needed. The saved time translates into either greater combat mission effectiveness with the same number of assets or fewer assets required to achieve the same effectiveness. Factors to consider for high-speed flight are the amount of time the aircraft spends at high speed, the criticality or urgency of the mission and time spent in the hostile environment or supported area. Exceeding the current fleet's capabilities is certainly a good starting point to determine how fast the Army wants to fly.

Army Combat developers and Capability Managers within the Army's Training and Doctrine (TRADOC) Command are working with the Office of the Secretary of Defense (OSD), the Joint community and research facilities to define system attributes. These organizations along with other engineering commands and defense contractor team members are in the early stages of the science and technology effort to engineer, design, build and deliver the next generation high-speed rotorcraft.[39] Future Vertical Lift (FVL) and Joint Mulit-Role (JMR) are the two primary initiatives guiding the Army. Working together, the OSD FVL Working Group (WG) and the JMR Program Office are defining the family or classes of aircraft to be slated for development.

The JMR Helicopter is a concept to develop a family of helicopters for the United States Armed Forces. Family variants are envisioned in four different size classes that will be designed and developed sequentially. They are envisioned to share common hardware such as composite materials, sensors, avionics, engines, and electronic countermeasures. The JMR size classes are planned to range from the light, medium, and heavy-lift to an ultra-class category. The ultra-class category will include a new fleet of super-heavy-lift aircraft.[40] The first three classes are envisioned to be part of the Army and other DOD services, but the ultra-lift class is to be an Air Force-led program. Initial focus is upon building the medium-lift capability class.

| JMR Study Performance Ranges | | | | |
|---|---|---|---|---|
| | Light | Medium | Heavy | Ultra |
| Speed | >170-300+ kts | >170-300+ kts | >170-300+ kts | 300+ kts |
| Combat Radius | ~424 km | ~424 km | ~424 km | ~462 km |
| Payload (Int) | ~2k - 4.5k lbs | ~6k - 20k lbs | ~20-30k lbs | ~40-72k lbs |
| Payload (Ext) | ~2k - 4.5k lbs | ~10k - 20k lbs | ~16-30k lbs | ~40-72k lbs |
| Passengers* | ~4-6 | ~11-24 | ~33-44 | ~100-120 |

Figure 11, Joint Multi-Role Emerging Attributes[41]

The U.S. Army has been considering the FVL concept since 2004 and since October 2010 has been planning a technology demonstration to take place in the near future. The purpose of the program is to develop a replacement for the Army's aging UH-60 Black Hawk, AH-64 Apache, OH-58 Kiowa Warrior and CH-47 Chinook helicopter fleets.[42] The JMR Program Office and associated organizations are developing the capabilities documents to define the high-speed requirements to meet the Army's and DOD's needs. The Initial Capabilities Document or ICD is created to document the need for a materiel acquisition approach to address specific capability gaps that currently exist. The capabilities required of the DOD future rotorcraft fleet cannot be achieved through upgrades to the current fleet.

Capabilities discussed are to build aircraft to sustain speeds in excess of 170 knots, have a combat range greater than 800 kilometers and hover with a full combat load under high/hot conditions.[43] The high/hot conditions match many other platform requirements where the requirement is to specially meet mission at altitudes of 6,000 feet and at a 95 degree F day. Sufficient speed to perform required operations is derived from several mission requirements. Examples include special operations missions under the period of darkness; the required speed to close the force in a more timely manner; and speed to enable timely MEDEVAC and Air-Assault operations.

Speed can best be achieved through the application of new technologies within new aircraft designs. Joint Forces (JFOR) must be capable of both rapid response and decisive action operations over extended distances and cover expanded areas in an increased range of environmental conditions and sustained operations. As a result, FVL platforms will enhance the commander's ability to exercise the functions of mission command, by improving situational awareness (SA) and situational understanding (SU) through reconnaissance, surveillance, and targeting. Future Joint force operations will rely on increased air delivery and increased speed to maneuver forces across distributed environments and over hostile territory.[44] Minimum requirements must exceed the current fleet's capability of approximately 130 to 150 knots maximum cruise speed.

Next-generation solutions encompass areas such as propulsion, airframe materials, rotor system types, engine technology and mission systems. The initial timeline developed by the JMR program office is to design several "demonstrator" aircraft by 2013 and conduct first flight in 2017.[45] This will be only the first step in identifying what is possible for future aircraft solutions. The DOD plans to begin fielding the new fleet of next-generation helicopters by 2030 with a lifecycle extending beyond 2040.

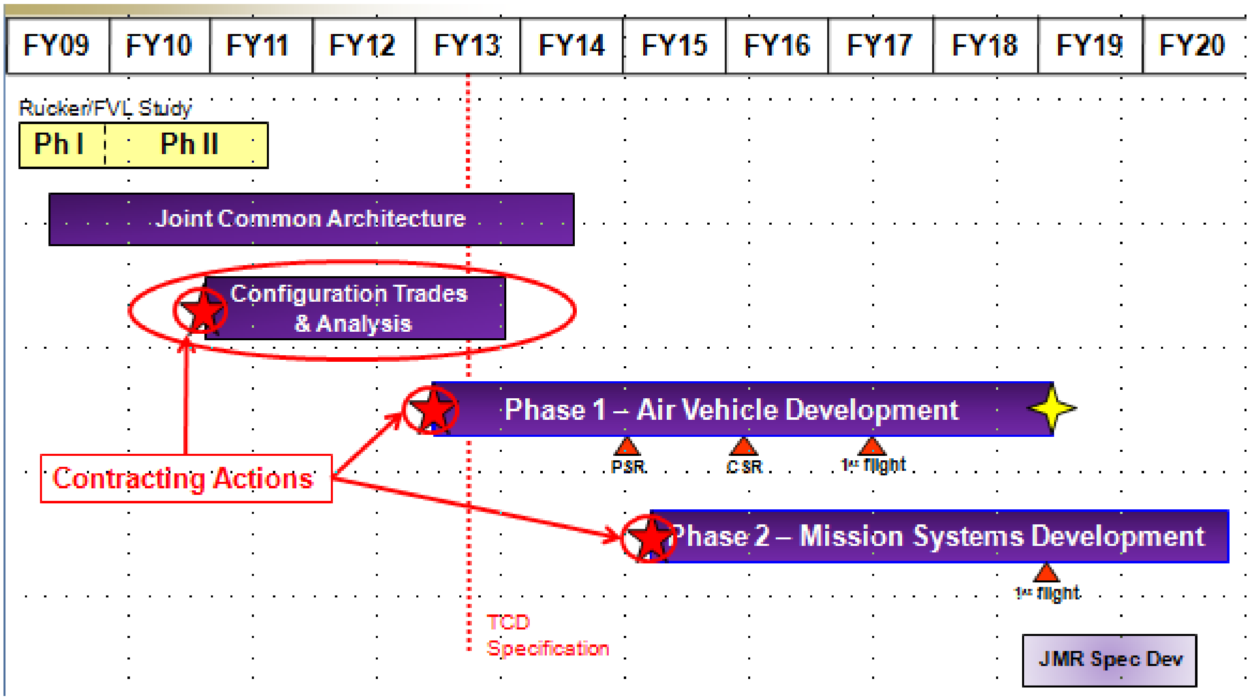


Figure 12, Joint Multi-Role, Acquisition Schedule as of June 2011

The future aircraft requirements will consider the logistical support required. Two key tenets for FVL development are program affordability and aircraft sustainability. If the aircraft or technology required to perform high-speed flight is too expensive, the DOD may move the capability requirement further into the future. The next-generation aircraft must be less expensive to operate than the current fleet. Ideas to achieve the DOD's affordability objectives include improving reliability, capitalizing on large quantity parts purchases and shortening the supply chain.[46] Having significant commonality between platforms across DOD will simplify supply chain logistics and reduce parts replacement costs. Developing parts with high reliability by actively monitoring component life will assist with overall reliability resulting in increased aircraft availability times to conduct operations.

Affordability is the top priority with the JMR program and development effort. The vision is to develop ideas that will drive down future acquisition costs. Future upgrades that are easier and more cost effective to perform will further improve operating expenses.[47] Spreading the costs, the component order quantities and development across all services will be of major benefit to the DOD. As for an operations and support costs (O&S) planning estimate, the Marine Corps' V-22's cost per flight hour today is over $11,000, more than double the initial targeted estimate.[48] The cost benefits of future replacements for lift, attack and reconnaissance helicopter platforms can be multiplied if all services adopt like aircraft to perform these missions. "Spreading the wealth," so to speak, will improve the chances for DOD approval.

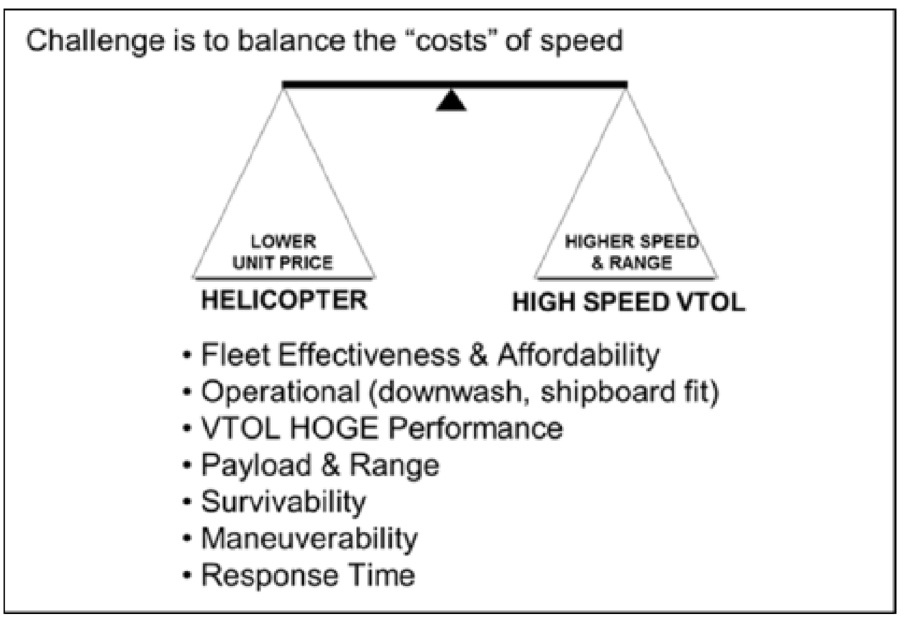


Figure 13, Balancing the Cost of Speed[49]

Possessing a family of aircraft that provides the materiel solution for all DOD services will require applicable missions designed to meet their future capabilities. Potential missions for the FVL aircraft fleet:[50]

- Close Air Support
- Air Reconnaissance
- Air Assault
- Air Delivery
- MEDEVAC
- Aerial Escort
- Special Operations
- Security Operations
- Combat Search and Rescue
- Counter Sea Operations
- Homeland Security Operations
- Recovery Operations

Although there are potentially other missions to be added to list above, the FVL capability will bring a total package to DOD. The total package will be delivered in phases, and the four aircraft categories discussed earlier will be designed to accomplish multiple missions. Mission configurations depend on the type of operation to be flown and the combat or operational situation at the time. Missions can be of varied combat types or operations within the continental United States such as humanitarian or homeland security missions. The mission applicability following the advent of FVL aircraft will differ due to the configuration-change ability these aircraft will possess. I will discuss potential advantages and disadvantages of building high-airspeed capability into next-generation helicopters.

Advantages for the next generation helicopters with a high-speed flight capability:

- Reduced time to target, improved top speed
- Greater range, increased battlefield footprint
- Greater endurance to cover large areas, time on station
- Increased responsiveness for remotely dispersed forces
- Potential life savings with reduced medical travel time
- More agility to support simultaneous operations
- Reduced logistics footprint
- Effect on mission planning, time management increase
- Reduced acquisition costs when shared by multiple DOD services
- Certain configurations reduce retreating blade stall conditions
- Disadvantages for the next generation helicopters with a high-speed flight capability are:
- Potential increase in maintenance assets required
- High acquisition costs if not shared by multiple DOD services
- Development time to design, build and test all JMR aircraft classes
- Possible increased fuel consumption costs
- Approval channel delays for joint program activities
- Need for major engine design and/or improvements
- Services must agree on final configurations

Comparing the various advantages and disadvantages, the aviation community looks to current aviation leaders for their vision on what the Army will do next to extend Army Aviation's role and capabilities. Future needs must be met with a lighter, smaller force that is affordable, sustainable and adaptable to mission requirements. We seek guidance from such sources as the Commander of U.S. Army Aviation Center of Excellence at Fort Rucker, Alabama, the Program Executive Officer for Aviation at Redstone Arsenal, Alabama and the Commander of the Aviation and Missile Command at Redstone Arsenal. Each of these influential leaders agree: We, the aviation community, cannot continue to rely on upgrades and improvements to meet the requirements of tomorrow. We must create new aircraft that meet several needs to include the high-speed requirement.

Affordability is a key element in the puzzle to build, field and sustain a new aircraft fleet. Innovating and improving key components, sharing costs across multiple military services, building in sustainability, improving reliability and planning for future support will have to be considered. Current acquisition planners have a variety of Industry partners to choose from. Choosing a prime contractor and building an effective team is the first step. Working together to make the program affordable must be the next step. Affordability from design through the final production phase is a difficult task that needs to be prioritized high in the program to obtain success.

The program can remain affordable if planning includes service cost sharing, reliability improvements and adequate sustainment planning as major program goals. Taking the required time to choose the correct contractor or contractor team is paramount to success. Working the design and functionality in a government/contractor team setting through the acquisition process must be a daily focus during the life of the program. For when the team fails, we all fail. If we cannot develop this new family of aircraft to replace the existing helicopter fleet, manned flight within the U.S. Army may disappear. In reference to the unsustainability of never-ending upgrades to the existing fleet, Major General Anthony Crutchfield, the present U.S. Army Aviation Center of Excellence (USAACE) Commander has said, "We should not plan for the Apache Block 40."[51]

If we continue to upgrade the current fleet of UH-60, AH-64, OH-58 and CH-47 aircraft we will simply continue to improve old systems. All of these aircraft have been and are wonderful machines that perform their respective jobs extremely well. There will be a day when our current Army Aviation fleet's technology is outdated, no longer upgradable and sustainment costs grow to extraordinary heights. When that time comes we need to be ready to adapt and survive with new manned aircraft that meet mission requirements. I have attempted to show through this paper that history shares vast knowledge we can utilize today. Building upon the past success of compound, tilt rotor and improved helicopter designs and their potential benefit, I show many desirable improvements that have been and are yet to be explored.

There are several advantages and disadvantages that will be weighed along the development process. Capitalizing on the advantages to bring a new fleet into the reach of DOD organizations is the direction to proceed. Not only can this new capability be affordable, it can also streamline maintenance, supportability and logistics functions. The next generation of rotorcraft must leverage resources across DOD and address the aging helicopter fleet. Decisions made today will impact helicopter operations for the next half century. The Army and DOD both need to strive to meet this goal.

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