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NEXT-GENERATION NAVAL HELICOPTERS

Fig. 1: Arguably the most promising development in the rotary wing aircraft family, the TiltRotor V-22 OSPREY – bigger, faster, higher, more payload, safer in theory but plagued during the development phase with accidents and failures that repeatedly led to the grounding of the V-22. This view of an OSPREY just landed on HMS "Blundell" clearly shows the enormous size of its propellers. (Photo: Courtesy Bell Helicopter, provided by author)

V-22 ORIGIN AND DEVELOPMENT

Although possessing the undeniable advantage of being flexible and the ability to hover, critically from an operational perspective helicopters still lag fixed-wing aircraft in speed. Helicopters fly with rotors optimised for vertical flight; in forward flight they present only a small inclined area to the oncoming air and so generate only a fraction of the thrust in this direction as they do vertically. If the rotors could be turned to completely face the forward direction the aircraft should theoretically undertake forward flight much more efficiently, in effect fly faster. This principle drove the development of TiltRotor aircraft.

The first aircraft with tilting rotors, the Transcendental Aircraft Model 1G, first flew as a helicopter in July 1954 and converted from forward to horizontal flight that December. The Bell XV-3 flew in August 1955 and converted in December 1958. The more capable 540km/h (348 knots) Bell XV-15 achieved these feats in May 1977 and July 1979 respectively. The V-22 OSPREY first flew in March 1989.

That the V-22 first flew so long ago illustrates the protracted development process. Test aircraft crashed in 1991 and 1992 and twice in 2000. The December 2000 accident resulted from a burst hydraulic line and a flight-control software discrepancy. This resulted in improvement in the design and layout of hydraulic lines and software modification. Earlier in April 2000 a V-22 descended at too high a rate, and its rotor stalled, leading to it crashing and to the deaths of the 19 onboard. These two accidents brought the total to four during development with 30 lives lost. They also led to grounding of the aircraft for 17 months.
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In the first 2000 accident the aircraft experienced vortex ring state (VRS); testing that followed however showed the V-22 no more susceptible to this condition than other rotary-wing aircraft. The developers set the safe rate of descent limit at 245m/s even though VRS only appears after 490m/s. THRR can also recover more easily than conventional helicopters by rotating the nacelles 15° forward for 2s, flying out of the turbulence. Systems will alert the pilot when the aircraft descends at more than 800ft/min with an air speed 74km/h (40 knots) or less. U.S. Marine Corps (USMC) tactics include high-speed fixed-wing descent to prevent the occurrence of rotor stall due to VRS, with reaching 600ft altitude the aircraft conversion to helicopter mode to land. It would use aircraft mode to accelerate out of combat or landing zones.

According to the USMC, the V-22 achieved almost all its performance requirements during the three-month operational test and evaluation (OPEVAL) that began in April 2005. The aircraft fulfilled most maintenance parameters and accomplished operating objectives. It averaged over 23 hours of flight before a maintenance failure, 8 hours better than the USMC requirement. The aircraft required 7.2 maintenance man hours for each flight hour, 13 hours less than the USMC specification. It achieved a mission capability rate of 78 percent, after 10,000 flight hours and should achieve the required 8 percent after 60,000. The aircraft operated at lower cost than the current Boeing CH-46 and Sikorsky CH-53E helicopters. The OPEVAL though revealed that radio software, searing and harness system and the radar warning receiver needed improvements. In September 2005 the U.S. Department of Defense (DoD) approved full rate production.

COMBAT READINESS

The Marines and Bell Boeing encountered smaller issues with the aircraft since then, but resolved each in turn as the type prepares for deployment to Iraq. In March 2006 a V-22 full-authority digital engine control (FADEC) failure led to an unauthorized take-off and hard landing, leading to a software update. Some M/CV-22s were also grounded early this year due to a faulty chip in the flight control computer. In March this year, a hydraulic leak caused an engine nacelle fire. An engine air particle separator (EAPS) bearing failure led to an earlier nacelle fire, in December 2006, EAPS improvements would stop hydraulic leaks and nacelle fires and the EAPS redesigned before V-22s deploy to Iraq. Further 21 V-22s, including three destined for hit, employed fault propeller variable actuator pressure switches, resulting in leaking, with replacement switches required. Other technical modifications before the deployment include improving engine sand filtering. Rolls-Royce further studying coating compressor blades to decrease erosion.

USMC operational preparation included a desert exercise that featured inflight refueling, night flying and assault operations. It also evaluated cooperation with the F/A-18 fighter. The Anil R. Pustum is an independent writer on all and joint power-related issues. He has been published in Germany, the U.S., the U.K., and South Africa and is currently researching for a book on air power doctrine, technology and organisation for small air forces.

The deployment will consist of 10 MV-22B Block 3s of the first operational squadron VMM-263 and continue for 6 months from September 2007. The Block B boats more reliability than the previous Block A and introduces a 3mm gun, hoist and refueling probe. The V-22 enters the theatre a much more survivable aircraft than its theatre and service predecessor, the CH-46 (see figure 2), seven of which the Marines lost in Iraq; the V-22 flies twice as fast (610km/h (275 knots)), at higher altitudes and longer ranges, more quietly and with less IR radiation and equipped with modern missile warning system, laser and radar warning receivers, chaff dispenser and possibly directed infrared countermeasures and armed with a gun.

The aircraft can carry 24 troops or a 2,700kg load to 800km (430km) while its 3,900km (2,100nm) ferry range allows global self-deployment. Two 4,400-kW Rolls-Royce Turboshaft T64-AD-400 turboshafts provide power. The cockpit includes six night-vision-goggle-compatible large-screen displays. The Marines' MV-22 models specialize in combat assault/assault support, with the U.S. Air Force's (USAF) CV-22s focused on special operations and the U.S. Navy's (USN) HV-22s combat SAR/special operations/logistic support. USMC aircraft will fly from LHA/LHD amphibious carriers.

PRODUCTION AND THE FUTURE

The Block B compares to the CV-22 Block 10, which could achieve initial operating capability in 2009. The MV-22 Block C (and CV-22 Block 20) could deploy with a fuselage gun, new radar and modernized environmental control system. MV-22 Block D updates would include a new direct infrared countermeasures package.

Fig. 2: The aircraft the MV-22 replaces, the CH-46 SEA KNIGHT.

The MV-22 provides an improvement in virtually every measure of performance, including speed, range, efficiency, equipment, operating cost, maintenance requirements.

(Print: Courtesy U.S. Marine Corps 050110-M-01447-015 / Sgt. Roman Yuski)
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Fig. 3: The fully maritimeised SUPER LYNX 300 aircraft for South Africa are equipped with a range of advanced sensors including a 360-degree scan search radar, a nose mounted FLIR and an advanced Electronics Support Measures system. The South African Navy Super Lynx 300 aircraft have a high level of South African sourced avionics and mission equipment making it the most advanced version of the Super Lynx 300 helicopter developed and produced so far. (Photo: Courtesy AgustaWestland)

December this year could see the V-22 programme office contract Bell Boeing for 141 MV-22s and 26 CV-22s for delivery over five years from 2008. Production could increase to up to 36 per year. With savings as a result, aircraft cost should also drop from US$72M, having already fallen from US$78M. The CV-22, with more capable electronic warfare systems, notably costs US$89.1M. But Bell Boeing see lowering the cost as important to prevent funding reductions. A second multi-year procurement could follow the first, in account for all of the 360 MV-22s and 50 CV-22s for the USMC and USNAF and including a possible 48 HV-22s for the USN.

The Navy wants to demonstrate the THALES CERBERUS maritime surveillance radar on the V-22. The totally organic sensor system (TOSS) evaluation would prove that the CERBERUS could be made modular and fitted on to the V-22 and other naval aircraft. The service cancelled its plan to replace the Grumman C-2 carrier onboard delivery aircraft with the HV-22 but considers V-22 with the CERBERUS radar for maritime surveillance missions with expeditionary strike groups.

Bell Boeing have promoted the V-22 to Australia, Israel, Japan and the UK, discussing co-production with Japan. This July during a combined exercise a USMC V-22 landed on the UK Royal Navy (RN) aircraft carrier HMS "Illustrious" (see Figure 1). The UK Ministry of Defence could consider the V-22 for its Maritime Airborne Surveillance and Control (MASC) requirement for airborne early warning and control, surface surveillance and battle management. India has also expressed interest in obtaining the V-22, discussing the aircraft with Boeing but its high cost militates against procurement.

**QUAD TILT ROTOR**

Bell and Boeing have developed the TiRotor into a four-rotor design, the Quad Tilt Rotor (QTR). The companies divide work load in a similar way as for the V-22. Version iterations remain under study but with a similar disc loading on the V-22, propeller diameter increases to 15.2m from the V-22's 11.6m. Longoring the rear wing, compared to the forward wing, reduces interference between the proprotors; it will also attach higher on the fuselage. Wind tunnel tests looking at wing air flow found stability similar to a two-rotor TIRotor. The QTR will be bigger than the C-130 fixed-wing transport aircraft, with its fuselage both wider and longer allowing it to carry up to 110 paratroops or 150 passengers.

The QTR contended in the concept design and analysis phase of the U.S. Army Joint Heavy Lift (JHL) future rotorcraft programme among the higher speed options, the aircraft possessing the same top speed as the V-22. Apart from the basic design Bell Boeing offered aircraft with various payloads, ranges and capabilities. The most capable QTR version offered the long range air 108 of heavy payloads and compatibility with the USN's future seaplaning concept. A CVN aircraft carrier could fit eight QTRs on its flight deck, without wing folding, Bell Boeing also designed a larger version with bigger preprotons and longer cargo box. JHL projects could begin development in 2013. The Bell Boeing QTR demonstrator would use the V-22's preprotons and power system.

**MODERN HELICOPTERS**

New naval helicopter models now entering service include the AgustaWestland SUPER LYNX 300, NH Industries NH90 NATO Frigate Helicopter (NFH) and the Sikorsky MH-60S KNIGHT HAWK. Though they retain the decades-old established configuration for helicopters, they include much new avionics and other systems.

The SUPER LYNX 300, which first flew in June 2001, features a glass cockpit, modern avionics, updated airframe and more powerful
LHTEC CTS800-4N engines featuring FADEC (see figure 3).

The first fly-by-wire (FBW) helicopter, the production NH90 (see figure 4) made its maiden flight in May 2004 with NH11 deliveries by late 2009. It uses two Rolls-Royce Turbomeca RTM 322-3L engines with General Electric/Flai/Avio T700/711E1 engines in the Italian aircraft.

Developed from the BLACK HAWK/SEAHAWK, the first production MH-60S flew in January 2013 and entered service with the USN in February 2002. It features the MH-60 Common Cockpit, also destined for the MH-60R SEAHAWK replacement.

Upgraded plans also exist to ensure older in-service designs remain effective for many years. The UK’s Capability Sustainment Programme (CSP) update for its AgustaWestland EH101 MERLIN, introduces new open systems architecture, more capable mission system processing, electrical instead of hydraulic systems, better displays, radar and sensor enhancement. The first modernised aircraft should enter service in 2013, the type envisioned as flying until 2030.

New derivatives of successful established designs may also prove cost effective. So although the original Lynx helicopter first flew in March 1971, the UK Ministry of Defence in March 2005 indicated its interest in replacing today’s RN Lynx HAS.3 and JMA 8 (and British Army Lynx Mk.79) with a development of the Super Lynx 300. AgustaWestland will supply the armed forces with 70 aircraft, with ten more as options, including 30 for the RN. The aircraft should fly by the end of 2009 with deliveries from 2011 for 2015 service with the RN. It will use the same engine as the Super Lynx 300.

In early 2006 the USMC contracted Sikorsky under the CH-53K Heavy Lift Rotorcraft (HLR) programme for the system design and development of a new derivative to succeed its Sikorsky CH-53K SUPER STALLION. Powered by the GE9-11 engine the aircraft will enter service in 2015. Payload increases to 15,300kg, with radius 570km (200nm) and speed 208knots (150 knots). Its 32,000kg gross weight would make it the heaviest U.S. production helicopter (although it could conceivably meet this title to the JHL, should it enter service).

The trends then suggest that future naval helicopters will manifest as evolutions of current models. Programmes underway at Government and corporate research centres suggest likely paths of evolution for helicopter technology: organisations like NASA and the Army Research, Development and Engineering Center in the U.S. focus on speed and performance improvement and noise and vibration reduction, sometimes in partnership with manufacturers like Sikorsky and Boeing, Europe concentrates on similar objectives, with a particular focus on and indeed lead in rotor research.

**COMPOUND HELICOPTER**

Greater speed inspired not only TiltRotor studies (among other benefits) but also other mechanically-simpler helicopter technologies, with foresight among these, compound helicopters. In addition to the rotor that conventional helicopters use for flight in the vertical plane, compound employ a forward propulsor and sometimes a wing for flight forward.

**Fig. 5:** The Piasecki X-49A Speedhawk on its first flight on June 30th, apart from the wings and ducted fan still recognisable in H-60 airframe. Conceptually simple additions, these features substantially boost the performance of helicopters.

(Photos: Courtesy Source: Piasecki Aircraft, provided by author)

Although the AgustaWestland Lynx set the official world speed record for helicopters in August 1986 - 403knots (220 knots), other traditional helicopter designs can normally attain a top speed of about 315km/h (170 knots). But even early compounds substantially surpassed this. Indeed, the Lockheed XH-51A, although achieving a speed of 320knots (175 knots) as a conventional helicopter (first flying in November 1962 in this mode) and after converting to a compound with a Pratt & Whitney J60 turbojet (first flying in September 1964) in 1967 attained 467knots (260 knots), establishing the unofficial helicopter speed record. At a compound helicopter's top speed, nearly all of the engine power drives the propulsor.

Lockheed evolved the AH-56 CHEYENNE attack helicopter, first flying in September 1967, with a turboshaft powering the main and tail rotors and a pusher propeller. Technical issues and cost led to cancellation in 1972. Piasecki developed the ducted-propeller-equipped 16H-1 PATHFINDER and 16H-1A PATHFINDER II, first flown in February 1962 and November 1965.

In 2000 Piasecki began contract development of the YSH-60F derivative of the Sikorsky H-60 with a vectored thrust ducted propeller (VTDP) and wing, also designated X-49A Speedhawk (see figure 3). Supported by the U.S. Army Aviation Applied Technology Directorate and Boeing, the aircraft flew on 30 June this year. The tests included hovering, turns and low-speed forward and sideways flight with the VTDP employed. Two 1208kW G-GE-401C turboshafts provided power but in later tests Piasecki will add a third engine and after aerodynamic refinement, attempt higher speed flight, aiming to reach 370knots (200 knots).

In high speed forward flight the wing provides lift, much more so than the rotor, and by doing so, prevents stalling of the retreating rotor blade. But the wing’s location in the path of the rotor downwash means that in vertical flight the wing impedes this air flow, causing a decrease in the efficiency of hover.

In the 1970s Sikorsky tackled this problem with its Advancing Blade Concept (ABC) helicopter, which used a pair of closely positioned, rigid, coaxial counter-rotating rotors. The advancing blade on each side produces lift decreasing the load on the retreating blades, reducing stall, while not requiring a wing. The XH-59A ABC first flew in July 1973. As a helicopter, the XH-59 produced less noise, hovered more efficiently and displayed better performance at altitude. 1978 saw the installation of two J60 turboshafts, turning it into a compound helicopter, and it attained 338knt, with the rotors autorotating. The aircraft notably featured two
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fuel-gulping turbojets, a complicated transmission system and drag-producing rotor head.

The company, however, sees the ABC in its X2 technology demonstrator. Planned to attain 460km/h (250 knots), the X2 will use an LHTEC T800-801 turboshaft to power its two four-blade counter-rotating coaxial rotors and tail-rotor and blade pusher propeller. The X2 employs FBW flight controls, a more aerodynamic rotor hub and a more efficient transmission system to transfer power between the rotors and propeller. Further, the aircraft introduces transmission-oriented active vibration control, aiming to achieve a similar level of vibration to a conventional helicopter flying at high speed. It would also study future rotor blade concepts. Sikorsky financed the aircraft entirely on its own and included off-the-shelf components. On 4 November 2005 Sikorsky flew a Schweizer 333 with the Honeywell FBW system for the X2; the company will fly the X2 later this year. The X2 could be scaled down or up; the High-Speed Little variant with two propellers contends for JHL.

FANCRAFT

Fancraft or ‘flying jeep’ studies date to the 1950s as an alternative means to achieve vertical flight but control, fuel efficiency and lift capabilities remained unimpressive. Israel-based Urban Aeronautics revamped the concept in its more recent X-Hawk project, revealed by the company and partner Bell Helicopter in mid-2006. The X-Hawk employs two ducted fans, making it better suited than conventional (open rotor) helicopters to operations from confined areas, such as the flight decks on ships. The cabin compares to the Bell UH-1 HUEY but the aircraft boasts a width of 4.3m and length of 8.2m, compared to the current UH-1Y’s 14.9m rotor diameter. The X-Hawk could also be scaled to different sizes. It uses two 1,357kW LHTEC CT780 turboshafts (with two 1,400kW General Electric T700-GE-401C turboshafts in the UH-1Y). They power both shrouded fans and also two rear mounted ducted propellers. Ducts close as the vehicle slows to facilitate the smoothest air flow while vanes enable lateral control. It uses a semi-autonomous flight control system. The developers estimate a 1,260kg load (compared to 3,020kg for the UH-1Y) and 32-hour endurance. Bell sees the challenge in reducing enough weight to allow a reasonable payload and acceptable performance.

Bell undertakes X-Hawk development at its Xworx research centre, the company assisting with systems integration and building. Bell has approached the U.S. Office of Naval Research (ONR) to finance a wind tunnel test of the X-Hawk. Urban Aero and Bell hope to fly a full-size X-Hawk demonstrator by 2010 so that they could launch system development and demonstration of a military model by 2014. They give the U.S. military first preference for the vehicle.

THE NEXT GENERATION?

Promising new technology now under development could offer future rotorcraft substantial gains in capability. A long development process finally results in maturity for the TiltRotor, with the upcoming Iraq operations providing the opportunity for evaluation and the solution of remaining minor issues that may arise. Although more expensive to procure than conventional helicopters of similar weight, they offer much greater flexibility and capability. Of course by operating at speeds twice that of helicopters, TiltRotors will spend considerably less time airborne, so saving on fuel consumption and airframe utilisation.

Proprotors being designed for both vertical and forward flight, as reflected in their unique shape in comparison with both helicopter rotors and fixed-wing aircraft propellers, remain compromised to a degree in each regime. The additional weight and drag due to the tilting mechanisms and the wing partially blocking the rotor downwash in vertical flight also negatively affect efficiency. Still, Boeing claims that the aircraft compares favourably with similarly-sized twin-propeller fixed-wing aircraft in terms of vertical and forward flight. But the aircraft’s vertical and forward flight capabilities combine synergistically, notably unlike helicopters after take-off if it flies in (as explained at the beginning, inherently-more-efficient) fixed-wing mode. The U.S. forces will enjoy the new capabilities the V-22 brings but as a next generation contender, its cost must dampen the optimism of even the better-funded allied Navies; the best foreign prospect exists perhaps with the Royal Navy.

Compound helicopters offer better opportunities for the nearer term. Although still falling short of what the XV-15 achieved, a compound claimed the helicopter world speed record since the inception of the type, revealing the potential the technology harboured. Significantly they offer a low-cost, low-risk means of improving performance, for a wide range of helicopters, although the added weight of the propulsor and the shroud’s hindering of the rotor downwash (in the case of the X-49A) also need to be tolerated in efficiency calculations. The military only provided limited funding for the X-49A programme and none at all for the X2, indicating that it remains not fully convinced with the prospects of these technologies but perhaps flight testing in the coming years will make their potential clearer.

Urban Aero’s new concept and Bell’s and possibly the ONR’s involvement make fancraft topical once again. Technological advances since the early years strengthen their prospects, and they should in particular be easier to control now, but the extent of payload and efficiency improvements will also be of interest; considering too their design suitability for flight deck operations light/ utility missions seem their best fit.

Fig 6: Model of a military X-Hawk when first unveiled, at the 2006 Paris Air Show. Today’s technology could boost the prospects for fancraft.

[Photo: Courtesy Urban Aeronautics, provided by author]