

DARPA's Advanced Rotorcraft Programmes

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Art Morrish is the Director of the Tactical Technology Office (TTO) of the US Defense Advanced Research Projects Agency (DARPA). In this article, he summarises the revolutionary new rotorcraft concepts currently under development at DARPA.

The Defense Advanced Research Projects Agency (DARPA) is the high-risk/high-payoff research and development organisation for the US Department of Defense (DoD). It manages and directs selected basic and applied research and development projects for DoD, and pursues research and technology where risk and payoff are both very high, and where success may provide dramatic advances for traditional military roles and missions. DARPA's Tactical Technology Office (TTO) engages in high-risk, high-payoff advanced technology development of military systems, emphasising the 'system' and 'subsystem' approach to the development of unmanned systems, space systems and tactical multipliers. TTO is currently sponsoring three major efforts concerning rotorcraft: the long endurance A160 Hummingbird; the high speed, stopped rotor X-50 Dragonfly Canard Rotor/Wing (CRW); and the collaborative Unmanned Combat Armed Rotorcraft (UCAR). While all three of these vertical take-off and landing (VTOL) platforms are unmanned, many of the technologies being demonstrated are widely applicable to manned rotorcraft systems as well.

A160 Hummingbird

The A160 Hummingbird unmanned aerial vehicle (UAV) is designed to achieve marked improvements in performance (range, endurance and controllability) as compared to conventional helicopters, through the use of a rigid rotor with variable rpm, lightweight rotor and fuselage structures, a high efficiency

internal combustion engine, large fuel fraction and an advanced semi-autonomous flight control/flight management system. The objective performance is comparable to fixed-wing UAVs with the flexibility of VTOL. The patented Optimum Speed Rotor (OSR) system allows the rotor to operate over a wide band of rpm and enables the A160 rotor blades to operate at the best lift/drag ratio over the full spectrum of flight conditions.

The Hummingbird is designed as a medium-altitude, long-endurance UAV to support the US Army as a surveillance/targeting platform, communications relay platform or VTOL delivery platform. The aircraft will give the Army an 'Eye in the Sky' and an airborne tactical communications network relay. Other roles include the delivery of logistic supplies and deployment of small, unmanned ground sensors, unmanned ground vehicles or even small surveillance UAVs. The A160 is also being evaluated by the Navy for potential shipboard operation.



The A160 Hummingbird UAV.

The goals of the joint DARPA/Army A160 programme are to develop a VTOL UAV that will achieve a 2500nm range at low or medium altitudes and will achieve 32-hour endurance at 15,000ft altitude with a 300lb payload – payloads up to 1000lb can be carried. The speed goal is 140+kt and the flight altitude goals are 15,000ft (hover) and 30,000ft (cruise). The vehicle is also designed to be affordable and easily maintained.

The A160 programme began in February 1998. The autonomous flight control system and swashplate actuators were first demonstrated and flight-developed on a highly modified Robinson R-22 commercial helicopter, which was designated as the Maverick-A, beginning in June 1999. The first forward flight of a 3-bladed A160 was on 29 January 2002. The vehicle was modified in early 2003 to a 4-bladed rotor configuration, which has lower vibration and greater lifting power, and is also quieter. In flight testing, the A160 has achieved 135kt speed, 7.3-hour endurance on an 18% fuel load, and wide variation in rotor rpm. The vehicles have flown at altitudes up to 5000ft above mean sea level (MSL), the altitude being limited to this by the current US Federal Aviation Administration (FAA) approval. As of mid-October, approximately 27 hours of total flight time have been logged in 22 flights by the three A160 demonstrators. Over 400 flight hours have been logged by the Maverick-A, which has a similar flight control system. Vehicle flight development is taking place at the Southern California Logistics Airport in Victorville, California, USA.

Frontier Systems Incorporated of Irvine, California, designed, built and carried out initial flight test of the Maverick-A and the A160 UAVs. In May 2004, Boeing acquired Frontier Systems with the A160 and

Maverick. The Boeing Phantom Works will complete technology development of the A160 and then transfer the programme to Boeing Integrated Defense Systems.

Current efforts are continuing technology development and will mature the aircraft reliability to a technology readiness level sufficient for transition to the Army, as well as demonstrate reduced acoustic and infrared (IR) signatures and carriage of several payloads in Army scenarios. Projected payloads include: electro-optical/infrared (EO/IR) surveillance, laser range finder/designator, synthetic aperture radar (SAR), ground moving target indicator (GMTI) radar, foliage penetration (FOPEN) radar, electronic intelligence (ELINT) systems, communication network relays and satellite communication links.

Canard Rotor/Wing

The Canard Rotor/Wing (CRW) concept combines the VTOL capability of a helicopter with the high-subsonic cruise speed (as high as 400kt) of a fixed-wing aircraft. CRW intends to achieve this by stopping and locking the rotor and using it as a wing to achieve high-speed forward flight; the canard and tail provide additional lifting and control surfaces. For both rotary and fixed-wing flight modes, the CRW is powered by a conventional turbofan engine. Diverter valves are used to direct the thrust to the rotor blade tips to rotate the rotor/wing for vertical flight, or to the aft jet nozzle for fixed-wing cruise. During transition between rotary and fixed-wing flight, the engine thrust is split between the two modes. The thrust-powered rotor system eliminates the need for the traditional mechanical transmission, drive train and anti-torque device.

Under an agreement with DARPA initiated in 1998, Boeing has built two technology demonstrators, designated X-50A and also known as 'Dragonfly', to assess and validate the CRW concept. In 2002, the air vehicles completed a series of ground tests including rotor balancing and spin testing at maximum rotor speed, as well as load testing of the rotor. Hover



The Canard/Rotor Wing Technology Demonstrator.

tests were conducted in December 2003 and March 2004, but a hard landing resulted in significant damage to the first air vehicle. The second X-50 is now being readied to continue the flight testing.

The CRW concept promises fixed-wing jet performance coupled with a true hover capability. Although the CRW demonstrator vehicles are unmanned, the potential exists for development of both manned and unmanned versions of the vehicle. Missions for such a vehicle include reconnaissance, armed escort, tactical air support, communications/data relay and logistics resupply. With such flexibility, operations could originate from small-deck ships or forward bases.

The fundamental CRW layout and technologies also make it inherently scalable to virtually any desired size. Unlike other rotorcraft concepts, tip speed in forward flight does not become a design limiter because the rotor is stopped. This allows much higher maximum cruise speeds than can be achieved by any concept in which the rotor is spinning in forward flight. High-gross weight designs can also be high-speed designs, bringing an entirely new dimension to tactical VTOL and allowing expansion of the operational envelope. An operational CRW would also be able to cruise efficiently at higher altitudes than rotorcraft, translating into longer ranges

for a variety of missions. The combination of high altitudes (above the reach of small arms, medium-calibre anti-aircraft artillery, and even missiles from man-portable air defence systems (MANPADS)) and high speed (limiting time within the lethal envelope of defensive systems) give CRW important survivability advantages over the battlefield.

Unmanned Combat Armed Rotorcraft

The goal of the joint DARPA/US Army UCAR programme is to demonstrate the technical feasibility, military utility, operational value and affordability of a system of intelligent lethal VTOL vehicles as part of the US Army Future Force. The programme is exploring the capability to perform effectively and affordably armed reconnaissance and attack missions within the post-2010 system-of-systems environment.

The UCAR weapons system will transform the future battlespace. The highly survivable systems will penetrate and survive in defended areas, and prosecute high-value targets with relative impunity without placing a pilot in harm's way. The UCAR system is designed to find, identify and attack the most difficult targets: camouflaged and concealed targets hidden in ground clutter, including individual combatants if necessary.



Artist's impression of the UCAR weapon system.

As demonstrated in the ongoing Global War on Terror, it is difficult today to identify these types of targets from high altitudes. Today's manned rotorcraft fly nap-of-the-earth in order to survive, but the terrain that limits the ability of hostile forces to threaten them, also limits their sensor and weapons performance, while the complexity of such low-level flight precludes operations by unmanned systems. UCAR brings the capability to the Joint battlefield to operate and survive in the low- and medium-altitude battlespace necessary for identifying and prosecuting targets in complex and urban environments without the need to operate at terrain flight levels. Furthermore, UCAR is expected to fly faster and with greater endurance than today's combat rotorcraft.

With a revolutionary leap in autonomy and intelligence, UCAR fundamentally changes the command and control relationship between unmanned systems and their managers, enabling effective teaming with manned systems and distributed command and control of unmanned systems. Unlike current unmanned systems, a team of UCARs will be able to be tasked like a human, largely using voice commands, without a dedicated control station. The UCAR commander interfaces with a team leader to provide mission objectives and constraints, implement rules of engagement and provide weapons release authorisation. Experimentation with

Army pilots flying Apache simulators and controlling teams of UCARs has demonstrated compelling performance in Army Future Force simulations. The pilots have demonstrated the potential of Apache-UCAR teams to greatly increase overall effectiveness, without taking the Apache out of the fight.

Contractor teams led by Lockheed Martin and Northrop Grumman have completed preliminary design of their UCAR Demonstration Systems. To reduce risk and increase technical readiness levels, the two teams completed numerous demonstrations of key technologies, processes, and system attributes, including: simulations of autonomous operation and collaborative execution by teams of UCARs; manned/unmanned teaming simulations with Apaches; simulations of an obstacle avoidance system that enables low-altitude autonomous flight; full-scale demonstrations of survivability solutions; characterisation of wind tunnel models; and targeting demonstrations with surrogate sensor suites. In late 2004, one team will be selected to build representative demonstrators, with a first flight expected in 2006.

Summary

DARPA has imagined a future that allows rotorcraft to fly as long as, or as fast as, fixed-wing aircraft, and to fight the wars of tomorrow with greatly increased effectiveness. Through compelling

demonstrations, we are creating a revolution in rotorcraft technologies for the 20th century. The programmes discussed here will allow our forces to field highly capable systems that enable an order of magnitude improvement in military capabilities. ■

Note: Shortly before this article went to press, the US Army informed DARPA that it was unable to contribute its funds to Phase III of the UCAR Programme due to other priorities. Without a service partner, DARPA was forced to cancel the programme. The official statement is as follows. Ed.

'DARPA and the US Army have been working together to develop a revolutionary new capability under the Unmanned Combat Armed Rotorcraft (UCAR) program. The Army has recently decided not to provide additional funding for their portion of the UCAR effort. DARPA is not able to continue the program without a Service partner, and has therefore decided not to proceed with the next phase (Phase III) of UCAR.'

'DARPA is pleased with UCAR progress to date. By the end of Phase II, the program had clearly demonstrated that the objective capabilities desired for UCAR are within grasp. In addition, the program realized incremental capabilities that go beyond anything currently being pursued within DoD's science and technology community. The UCAR government/industry team developed an effective partnership, and demonstrated an innovative system development process that holds great promise for future acquisition programs.'

'"The Lockheed Martin and Northrop Grumman teams should be commended for the outstanding progress that has been made in the UCAR program. Both teams delivered results that exceeded our expectations," said Don Woodbury, UCAR program manager.'

'DARPA remains committed to the development of the next generation of autonomous systems and to technologies that will enable US forces to dominate on the battlefields of the future.'