AUTONOMOUS, ARMED, AND AMBITIOUS

DARPA AND THE ARMY ENVISION AN UNMANNED COMBAT ARMED ROTORCRAFT THAT FLIES AND FIGHTS AT LOW ALTITUDE WITHOUT PEOPLE IN THE LOOP

By Frank Colucci

Hunting singly or in a team of aircraft with and without pilots, UCAR – the Unmanned Combat Armed Rotorcraft – promises the US Army a lethal scout for its transformational Future Force. The Defense Advanced Research Projects Agency (DARPA) and the Army are funding a four-phase technology program aimed at an operational UCAR around 2012. Phase II now has two industry teams competing for a contract to build Phase III demonstrators by the end of 2006. A winner will be chosen this October based on simulations of prototype software and assessments of full and subscale models of an autonomous, survivable Unmanned Aerial Vehicle (UAV) with integrated sensors and weapons. "We have been developing UAVs like we develop trucks," says DARPA program manager Donald Woodbury. "UCAR is taking a systems perspective."

Day or night, or in adverse weather, the UCAR system with its modular payloads is supposed to find the most difficult targets – dismounted, camouflaged combatants and other targets hidden in ground clutter. A single operator on the ground in the Army's Future Combat System (FCS) or in the air aboard an AH-64D Apache or A2C2S Black Hawk may ultimately command one or more of the unmanned vehicles with a few spoken words. "The goal is that they be commanded using operational orders that are similar to those given to a manned system," explains Mr. Woodbury.

The UCAR concept of operations is very different from that of the Shadow, Predator, and other operational UAVs. Northrop Grumman UCAR program manager Greg Zwernemann explains: "Instead of a person controlling one UAV, you've got a person controlling a team." An operator busy with other duties may issue top-level orders for a collaborative team to reconnoiter a treeline and engage pop-up threats with overlapping fields of fire. The autonomous vehicles allocate tasks and resources within their team, reconfigure the team in a dynamic situation, and ask for authorization to deviate from their orders.

In a network-centric battlespace, the unmanned helicopter might call in fires from manned attack helicopters, tactical jets, or the FCS Non Line Of Sight Launch System. Alternatively, it might perform communications relay, mine countermeasures, or other missions. The K-MAX-inspired UCAR from Northrop Grumman even has a belly hook for cargo. "I'm not necessarily thrilled about the UCAR carrying sling loads," admits Mr. Woodbury, "but when you talk about a multi-role aircraft, you have the capability to provide logistics support as well as the core missions."

The multi-role UCAR will fly dull, dirty, dangerous missions without putting lives at risk. Unlike other UAV users, Army Aviation needs a highly autonomous air vehicle able to find its own way around obstacles at low altitudes and survive a mix of close-in air defense threats. The UCAR concept therefore calls for a Low Observable helicopter smart enough to take spoken orders from human commanders, collaborate in seamless airborne teams, and re-task itself in dynamic situations. That very smart platform will also integrate advanced sensors and weapons to find, identify, and engage enemies. Mr. Woodbury acknowledges, "UCAR was intended from the start to be very ambitious."

The Northrop Grumman UCAR concept uses a Kaman-inspired intermeshing rotor system with a refined rotor system for maximum lift and high cruising speed.

One Phase At A Time

DARPA and the Army began the jointly-funded UCAR program with a Phase I concept development effort. Four teams lead by Boeing, Lockheed Martin, Northrop Grumman, and Sikorsky each performed 40-plus trade studies. Their findings balanced the value of air vehicle attributes such as speed, altitude, payload, survivability, and reliability with cost. The Phase I conceptual design review generated an objective system capability document. It identified key technologies, defined building blocks to mature an operational system, and formulated a risk management and mitigation plan.

When system integrators Lockheed Martin and Northrop Grumman were awarded Phase II contracts for UCAR preliminary design in July 2003, each recruited an experienced industry team. The Lockheed Martin effort now includes four of the company's business units plus Bell Helicopter; Raytheon; Draper Laboratory; Harris Corporation; Whitney, Bradley and Brown; and DRS. With a solid UAV base including the Army Hunter and the FCS Class IV FireScout, Northrop Grumman joined with Kaman, Sikorsky, ASTA, BAE Systems, and L3 Communications for UCAR Phase II.

Phase II calls for demonstrations this year in four key technology areas:

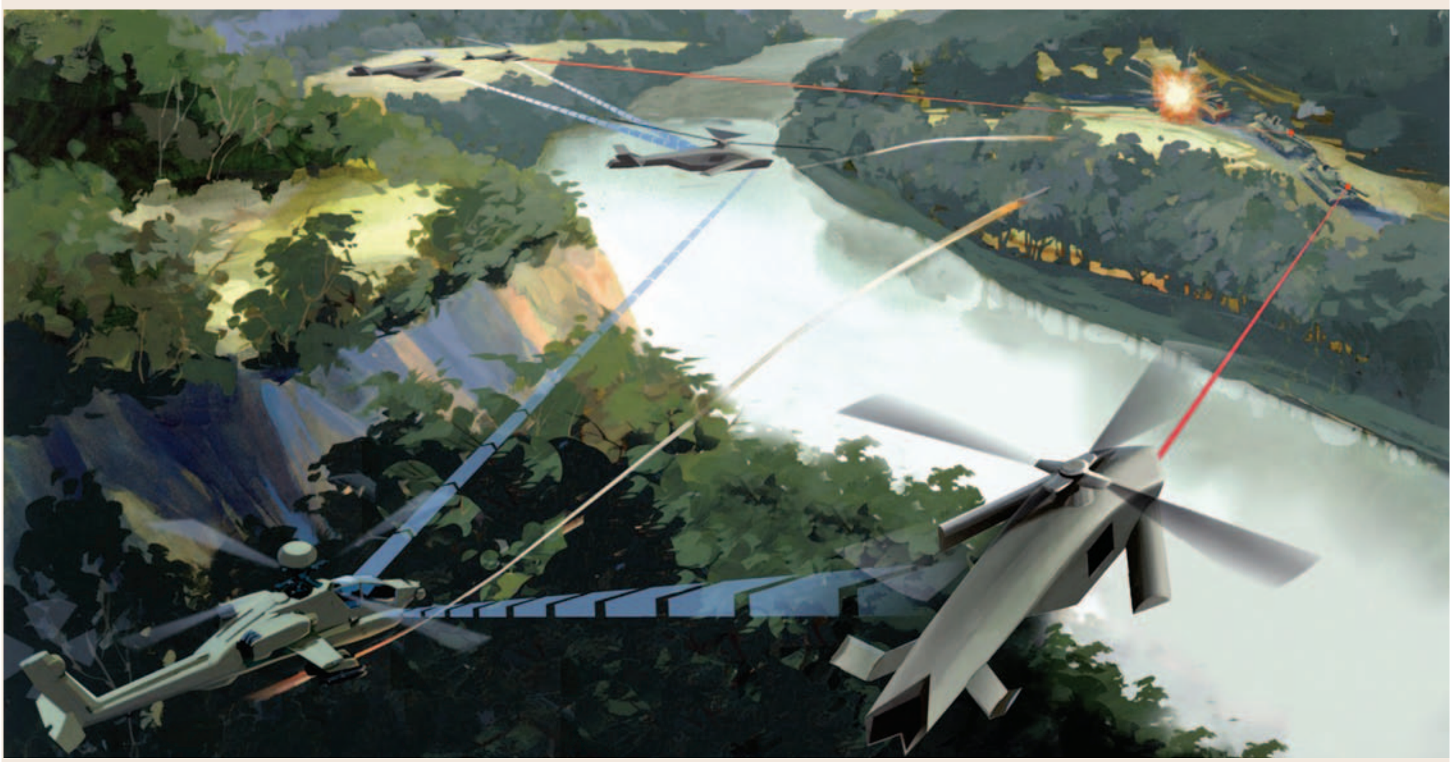
- Autonomous and collaborative operations with manned-unmanned (MUM) teams is being demonstrated in high-fidelity flight simulators.
- See-and-avoid capability for low-altitude autonomous flight is being simulated in Phase II. A brassboard Obstacle Avoidance System built and demonstrated during the next 12 months will fly in Phase III.
- Robust, affordable survivability solutions will be demonstrated with full-scale survivability models and other hardware.
- The performance of surrogate sensors and Automatic Target Recognition algorithms will be demonstrated in simulations and field experiments.

UCAR sensors and weapons come from the existing DARPA and Army technology base, and the competing teams are free to pick and choose promising ideas from government or industry for their Phase II demonstrations. The government provides tailored physics models of advanced sensors for industry simulations. "We're taking these concepts and building them up in surrogate hardware to assess their effectiveness," explains Mr. Woodbury.

Brassboard prototypes demonstrated in Phase II become flying hardware demonstrators in Phase III. If the capabilities ultimately flown in Phase III prove compelling, Phase IV will mature the technologies in flying prototypes with 60 to 80% of the expected operational capability. While UCAR Phases I, II, and III have a DARPA Program Manager with an Army Deputy, the roles reverse mid-way through Phase IV. The goal is a non-expendable vertical-takeoff-and-landing UAV with a flyaway cost of four-to-eight million dollars and operating and support (O&S) costs just 10 to 40% those of the Apache attack helicopter.

Lockheed Martin UCAR program director Dan Rice observes, "The unmanned system offers some unique perspectives on the cost and survivability problems. You don't have a human operator to protect." DARPA's Don Woodbury notes manned and unmanned aircraft differ little in cost per pound. Smaller UAVs also have fewer pounds over which to amortize high-value electronics.

The projected pricetag for the unmanned helicopter flyaway cost is at the high end of what the Army wants to pay, but Mr. Woodbury believes, "You're going to



Lockheed Martin used Bell Helicopter expertise to devise a four-bladed UCAR with a quiet anti-torque thruster.

make up for that cost in unique battlefield capabilities and in greatly reduced O&S costs." O&S costs associated with people, ground stations, replacement parts, and support equipment far exceed the flyaway cost of current UAVs, and UCAR planners aim to reduce manpower requirements and the expensive O&S footprint with a machine that flies itself.

It's The Autonomy, Stupid!

The MQ-1 Predator, so successful in Afghanistan and elsewhere, requires a trained pilot in the loop for most of its mission, and nearly all UAVs require costly Ground Control Stations (GCSs). In contrast, UCAR puts new emphasis on hands-off UAV operations. Few UAVs rank high on the scale of Autonomous Control Levels (ACL) formulated by the Air Force Research Laboratory. The big RQ-4 Global Hawk with an ACL around 3 or 4 takes-off, flies a programmed route, and lands with only keyboard commands. J-UCAS – the stealthy Joint Unmanned Combat Air System – has an ACL around 5 or 6 for groups of UAVs to operate in wide-open skies. By comparison, UCAR must achieve ACLs from 7 to 9 to fly through a far more cluttered environment at low altitudes close to the threat. According to Mr. Woodbury, "The challenging problem is to identify and prosecute targets before they are able to recognize and prosecute friendly forces."

Really, it's about the autonomy because we're taking it to new levels. That's what sets this program apart.

Army Aviation reaches down into the Nap of the Earth (NoE) environment, and UCAR must see-and-avoid in an environment full of trees, wires, and other aircraft. "There really aren't any UAV systems today designed to operate in terrain-flight modes," notes Dan Rice at Lockheed.

DARPA's work with university partners on Software-Enabled Control (SEC) algorithms provided the foundation for high performance UAVs. Advances in commercial microprocessors, meanwhile, afford the computing power for a flying machine that pilots itself. UCAR-style autonomy requires integration of real-time see-and-avoid controls with on-board sensing systems, detailed terrain maps, and aircraft survivability equipment.

See-and-avoid behavior also requires new sensors, but UAV payloads and budgets usually demand lighter, cheaper systems than those carried by manned aircraft. The Army Night Vision and Electronic Sensors Directorate at Fort Belvoir long ago sponsored work on the Fibertek laser-based Obstacle Avoidance System for piloted helicopters. A lighter, more capable derivative now promises UCAR developers a multi-purpose sensor for autonomous navigation and other tasks. The eye-safe, multi-beam, multi-wavelength laser radar (LADAR) provides hemispherical coverage to watch the flight path. With modified software, it interfaces directly with the vehicle flight control system. The brassboard see-and-avoid sensor should be demonstrated by March 2005. Mr. Woodbury notes, "We think we can give the commanders the capability to put UCAR where they need it."

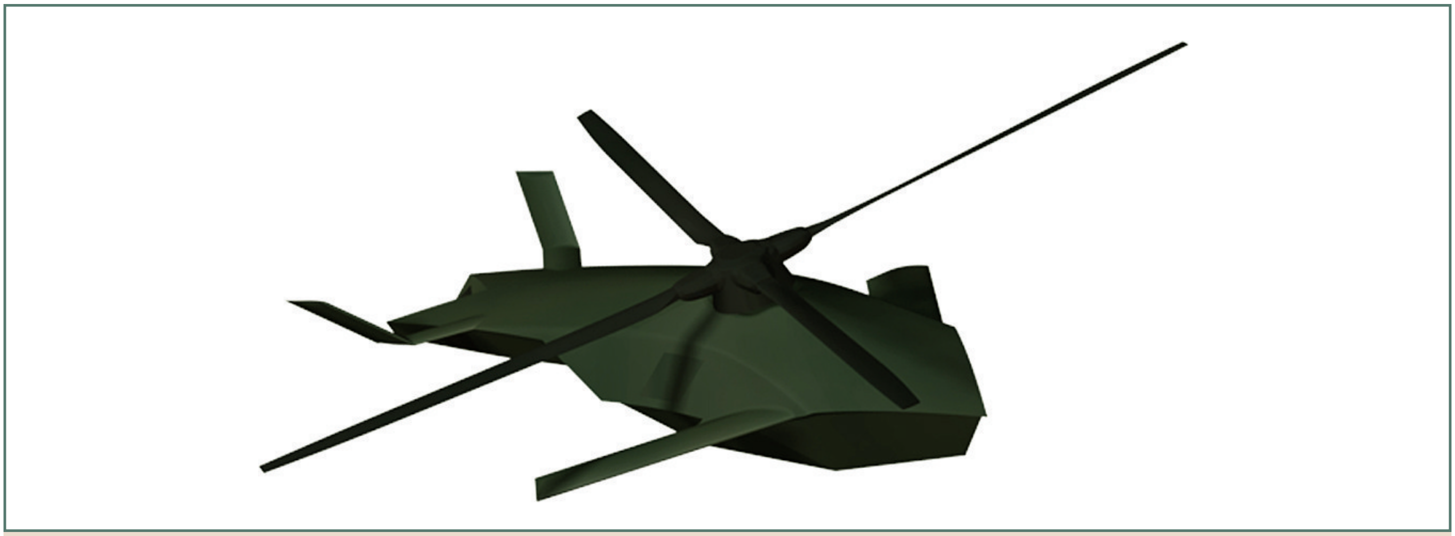
Once in the mission area, UCAR uses sensors optimized for targets in clutter, and software tools that fuse sensors to discriminate combatants from non-combatants. Lockheed Martin and Northrop Grumman both gained experience in assisted target detection/classification on the Comanche and Longbow Apache programs. Lockheed Missiles and Fire Control developed Automatic Target Recognition algorithms for the Air Force Low Cost Autonomous Attack System. Both UCAR teams foresee payloads with electro-optical and infrared sensors, laser rangefinder/designators, multi-mode radars, broadband Electronic Support Measures (ESM), and LADAR.

UCAR plans call for the stealthy, unmanned helicopter to carry a mix of missile, rocket, gun, and non-lethal armament. The Army will have to evolve new tactics, techniques, and procedures for an armed UAV with unprecedented autonomy. "Obviously the UCAR is not intended to make the final weapons release decision on its own," says Dan Rice. "There will always be a human to provide rules of engagement and proper oversight."

Survivable, Supportable, Soldier-Friendly

UCAR Phase II culminates in Preliminary Design Reviews in which both teams must demonstrate key system attributes, such as autonomy, survivability, and cost-effectiveness. "A system solution that's survivable against the range of Army threats is a challenging problem," acknowledges Mr. Woodbury. The unmanned helicopter also needs to keep up with Apaches and Black Hawks, and carry a large payload of sensors and weapons. Trade studies pegged UCAR cruising speed around 160 kt and operating altitudes anywhere from NoE to 20,000 ft.

Details of the competing UCAR concepts are naturally secret, but both UCAR teams use commercial helicopters as starting points, and both have shown Low Observable concepts without noisy, dangerous, inefficient tail rotors. Lockheed Martin teamed with Bell Helicopter to evolve a stealthy unmanned vehicle around Bell 407 dynamics. Northrop Grumman has Kaman at work on a K-MAX-style intermeshing servotab rotor system. Both teams have elected to power their UCARs with the LHTEC T800-LHT-802 turboshaft of the cancelled RAH-66 Comanche.



Like its competition, Lockheed Martin designed a Low Observable UCAR with an internal weapons bay. The removable wings offload the conventional rotor system in high speed and high altitude flight.

Bell derived the Model 407 commercial helicopter from the drivetrain and rotor system of the military OH-58D. Drawings of the Lockheed Martin UCAR consequently show a four-bladed main rotor with an anti-torque tail thruster reminiscent of the SuperTeam LHX proposal. The combination promises cruise speeds to 160 kt, a ceiling greater than 20,000 ft, and range greater than 700 km with a removable wing. Endurance can be up to 9 hours with sensors only or 4 hours with weapons in an internal bay. In the combat configuration, the vehicle will loiter for more than two hours more than 200 km from base.

Northrop Grumman proposes high- and low-altitude UCAR variants differing only in the addition of radar on the high-flying scout. Without a tail rotor or anti-torque thruster, the K-MAX intermeshing rotor system devotes nearly all its power to lift. A new, optimized rotor with low-drag servoflaps buried in the blades was tested in the Ohio State wind tunnel and promises good payload with speeds greater than 160 kt. The conceptual vehicle would have a range up to 2,000 km and endurance greater than 10 hours with auxiliary fuel. Like the intermeshing K-MAX, the UCAR has low disk loading to reduce noise. However, the unmanned vehicle has a smaller split-torque transmission rather than the planetary gears to optimize weight and performance.

Whatever its size and shape, UCAR is also expected to operate alongside manned helicopters and use the same support system. "There was intent from Day One to maximize commonality with the existing fleet," explains Mr. Woodbury. Commonality pays off in reduce operating and support costs for the system. DARPA expects UCAR to return to the same Forward Arming and Refueling Points (FARPs) used by manned aircraft, and it wants the unmanned helicopter maintained by soldiers with existing Military Occupational Specialties.

Both teams look to cut UCAR Operating and Support costs as a way to control systems costs. "The UCAR model we propose has substantial improvements over unmanned systems today," says Mr. Rice. "We focus on UCAR in the Initial Entry package, and we're trying to minimize that….We're looking how to integrate most efficiently with the Future Force aviation element, so there will be no independent logistics stream."

Northrop Grumman takes a similar view. "The Army wants to be on the move," observes Greg Zwernemann. "They don't want to drag around a lot of equipment like ground control systems." Dedicated Ground Control Stations (GCSs) and other support equipment typically cost several times as much as their flying UAVs. UCAR will have no dedicated GCSs. Control software with different levels of authority will run in FCS consoles, Apache cockpits, or the Personal Data Assistants issued individual soldiers.

The sophistication of the unmanned helicopter has positive and negative impact on O&S costs. "Obviously there's a lot of software in this system," acknowledges Mr. Rice. However, unlike human pilots with perishable skills, the pilotless helicopter need not practice to maintain operational readiness. "Not every single UCAR has to fly all the time," observes Mr. Rice.

DARPA expects the autonomy and self-sufficiency of the Unmanned Combat Armed Rotorcraft to someday branch out to other systems in the air, on the ground, and in and under water. However, for an Army focused on near-term aviation solutions, UCAR stands out as an ambitious effort for the future.

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