Global Hawk in Australia, Tandem Thrust '01.

U.S. Air Force (Jeremy Lock)

Unmanned Combat Aerial Vehicles and Transformation

By JOHN J. KLEIN

Speaking in December 2001, President George Bush noted the changes that are occurring in the Armed Forces as the result of technological innovation: "Now it is clear the military does not have enough unmanned vehicles. We're entering an era in which unmanned vehicles of all kinds will take on greater importance—in space, on land, in the air, and at sea." The need for unmanned combat air vehicles (UCAVs) was illustrated by recent operations in Southwest Asia that employed Predator unmanned aircraft with Hellfire missiles. Although no naval UCAVs currently exist, this shift implies that the sea services must determine their strategic capabilities to avoid using them when manned aircraft or other weapon systems might be more appropriate.

Congress has mandated that a third of deep strike capability be unmanned by 2010. And although the Pentagon indicated that it cannot meet the deadline, significant resources have been earmarked for this purpose. Overall funding is more than $1.1 billion in 2003, and the Navy requested $50 million for its program in 2003, an increase of $8 million over the 2002 budget level.

Several factors have contributed to the anticipated boom in naval UCAVs. The Predator reconnaissance UAV was successfully modified with Hellfire air-to-ground missiles and employed in Afghanistan. Also, technology has advanced to the point where it is feasible to use unmanned vehicles for naval combat operations. Finally,

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naval vehicles have an advantage over land-based counterparts since the Intermediate Range Nuclear Forces Treaty of 1988 prohibited certain land-based cruise missile-like systems but not ship-based systems.

Current Initiatives

The Navy leveraged innovations in unmanned programs by the Air Force and the Defense Advanced Research Projects Agency. Presently, naval requirements address carrier-based UCAVs to suppress enemy air defenses, perform strike missions, and conduct intelligence, surveillance, and reconnaissance (ISR). A notable difference among service requirements is that Navy specifications include such capabilities, while those of the Air Force do not. One reason for this disparity is that the Air Force utilizes other vehicles such as the ISR-proven Predator and Global Hawk.

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The Office of Naval Research and the Defense Advanced Research Projects Agency have selected Boeing and Northrop Grumman to produce the UCAV advanced technology program demonstrator. This program will lead to the development of a system that could become operational by 2015. Requirements call for vehicles with a strike radius of 1,000 nautical miles and payloads of 2,000 pounds (including joint military munitions and new small diameter bombs). Naval guidelines also require UCAVs to perform a 12-hour ISR mission and operate up to altitudes of 35,000 feet. These vehicles will be the same class as F/A–18C aircraft and should have a unit cost one-third that of the joint strike fighter and an operational support cost half that of an F/A–18C squadron.

While the Marine Corps has no current UCAV programs, it has several under development. The requirements call for a family of inexpensive, man-portable vehicles for the battlefield. Dragon Eye, for example, weighs four pounds, has a three-foot wingspan, and is designed to operate at 35 knots with an endurance of one hour. Its one-pound sensor payload can provide day, low light, or night infrared sensor imagery to ground operators. After combat operations in Afghanistan, the Marine Corps sought to use Dragon Eye to support security forces within Kabul, and current plans call for fielding over 300 systems.

Quantifying the Qualitative

Military transformation is a revolutionary or significant improvement in hardware, tactics, or doctrine. In a period of technological breakthroughs, slowly evolving militaries run the risk of being overtaken by enemies that risk all on revolutionary changes. These visionaries seek a force that is lighter, more mobile, and more easily deployed to hotspots around the world. While the military has climbed aboard the transformation bandwagon, the term has been misapplied and even tied to acquisition programs as a way of avoiding criticism and budget cuts. Overuse and misuse have understandably obscured the intended meaning.

Some claim that UCAVs are not transformational but rather the next step in the incremental evolution of aircraft. To prevent pundits from arguing which programs are transformational and to decide if the vehicles have a significantly improved capabilities over manned aircraft, it is desirable to put a stake in the ground and quantify this nebulous claim. Borrowing from engineering and the applied sciences, which routinely perform numerical calculations, the equivalent to transformation is likened to an order of magnitude change, which denotes significant or notable measurable change. Taking the most conservative approach to quantifying transformation, an order of magnitude change with the base 2 numbering system will be used to define transformation, thus denoting a measured doubling or halving.

Applying this thesis, unmanned vehicles are considered transformational if they achieve at least a twofold improvement in cost or capability over manned aircraft. For instance, if UCAVs perform a similar mission for the same price, with twice the endurance as their manned counterparts, they can be considered transformational. In addition, if an unmanned vehicle carries out missions similar to manned aircraft but at half of the cost or less, that could be transformational. An exception occurs when one capability is improved and another is lessened. If a vehicle has twice the endurance as a manned strike aircraft but costs twice as much, this is not transformational since two sequential sorties of the cheaper manned aircraft would provide the same coverage as the longer endurance UCAV. Therefore, improving the performance of unmanned aircraft at any price is not in keeping with the objectives of military transformation.

An exception to quantifying transformation occurs when the novel capability of unmanned vehicles cannot be quantitatively compared to manned aircraft. For example, Dragon Eye is man-portable and uses sensors to accomplish its mission. While there are manned surveillance aircraft with more sophisticated sensors, portability allows this vehicle to provide urban surveillance and operate in a manner manned aircraft cannot; thus it can be considered transformational.

UCAV Attributes

The Navy, Defense Advanced Research Projects Agency, and contractors are designing UCAVs to meet performance specifications based on suppressing enemy air defenses, strike, and ISR missions. Regardless of mission-specific design traits, there are basic capabilities that all naval UCAVs should demonstrate to be operationally viable.

Maintainability and reliability. At a minimum, future vehicles must be readily maintainable and operationally reliable as contemporary manned aircraft. This ensures that they can be repaired and accomplish the missions they were designed to perform. A state-of-the-art unmanned vehicle benefits no one if it is inoperable the majority of the time due to maintenance issues.

Some argue that survivability must be an attribute. While desirable, the ability for UCAVs to survive battle damage should be considered secondary, especially if they have a fractional cost compared to manned aircraft. Designing a vehicle to be highly survivable adds expense and weight; and weight reduces endurance. Also, incorporating inexpensive stealth technology into the design reduces the probability that enemy surface-to-air radar systems will detect vehicles, thus mitigating the need for survivability. Once the technology matures and costs are reduced, minimal combat survivability can be considered acceptable due to the throw-away cost.

Air traffic control standards. UCAVs must be able to operate within the same air traffic control standards as manned aircraft. For the Navy, this means carrier-based vehicles operating within the constraints of the normal operational launch and recovery cycle. Furthermore, carrier-based unmanned vehicles must be able to fly day and night landing patterns within the same timing and airspace requirements as their manned counterparts. Imposing different rules on UCAVs and manned aircraft reduces carrier operational effectiveness and efficiency. Whether or not an aircraft is manned should be transparent when operating within carrier controlled airspace.

Marines guiding Dragon Eye, Enduring Freedom.

1st Marine Division (Kenneth E. Madden)

Organic capability. Naval unmanned vehicles should remain organic to the battle group, which means taking off and landing on board ships. For example, if vehicles are tactically viable in the strike mission or suppressing enemy air defenses, operators who control vehicles must perform required strike planning alongside aircrews flying manned aircraft. All players must understand the mission timeline, aircraft flight routes, and airspace restrictions.

Some may argue that naval unmanned vehicles should operate from nearby foreign airfields when carriers are deployed in-theater. The advantage of land-basing vehicles would be removing the requirements for heavier carrier landing gear, thus increasing aircraft endurance. Nevertheless, land-basing would reduce combat effectiveness because mission planners would not be working alongside air wing strike planners to develop and understand the mission, contingencies, and last minute changes. It is not operationally viable for UCAV mission planners to stay on carriers when unmanned aircraft are based at nearby fields. A case in point is the war in Afghanistan, when Saudi Arabia stipulated that strike aircraft—as opposed to support aircraft such as tankers—could not operate from its airfields. The Navy cannot afford to have foreign governments dictate the use of naval aircraft during wartime operations.

Significant cost or performance advantage. Since the U.S. military is the premier fighting force in the world, deploying naval UCAVs runs the risk of decreasing combat effectiveness. Furthermore, substantial research and development costs are associated with designing future unmanned vehicles, and these funds could be used to build additional combat proven manned aircraft. Therefore, for the Navy and Marine Corps, future vehicles need to provide a significantly improved capability or advantage to offset the risks and costs associated with unmanned programs. Returning to what constitutes transformation, this necessitates that UCAVs demonstrate a twofold improvement over manned aircraft.

Multimission capability. Current manned naval aircraft routinely perform multiple missions during a single sortie and are retaskable once airborne, which commanders have come to anticipate. Future UCAVs should demonstrate this same multimission capacity to provide decisionmakers with real-time options. Moreover, considering that naval vehicles are being designed for endurance up to 12 hours and that tactical priorities can quickly change during combat, unmanned aircraft need to provide mission flexibility. For example, marines might need a reconnaissance capability to detect armor. Once located, they could target it with onboard weapons, and after the enemy is engaged sensors onboard UCAVs could be used to assess bomb damage.

Secure information relay. Finally, UCAVs need a secure and reliable means to transmit tactical information to ground stations, ships, or other aircraft. Naval communication systems must be encrypted to prevent interception and exploitation. If nonencrypted signals are intercepted, enemies can determine whether their mobile assets are being targeted and in turn their forces to expedite movement to a safe area.

Relaying (bouncing) vehicle tactical transmissions is a strategic necessity. Since vehicles are being designed for an over-the-horizon capability, control stations and aircraft would soon reach a relative distance that precluded reception and transmission. However, incorporating the ability to use ground stations, ships, aircraft, or satellites to relay information between UCAVs and control stations would greatly increase the effective range of these vehicles.

Predator UAV landing, Desert Rescue VIII.

DOD (Steven M. Turner)

Getting the Job Done

There are three ways to control unmanned aerial vehicles: by remote piloting, autonomously, and semiautonomously, each with relative advantages and disadvantages.

Manned systems. If unmanned vehicles are such a great innovation, one might ask why the skies over Afghanistan aren't teeming with them? Combat missions often must react to unforeseen circumstances. Critics doubt that computer-brained UCAVs can compete with pilots in taxing situations such as air-to-air combat, when it is necessary to assimilate information and act immediately. Manned aircraft will excel in performing complex multimissions with unplanned contingencies since aviators adapt to evolving situations. While computers can perform certain functions better than aviators, they do not demonstrate the ability to react to unplanned or unprogrammed contingencies.

Notwithstanding their advantages, manned aircraft have disadvantages when compared to their unmanned counterparts. The former are more expensive to operate while one ground operator can monitor and control several unmanned vehicles simultaneously. In addition, in performing missions deep within enemy territory, aviators risk death or capture. Prisoners of war create political and operational concerns because it is necessary to avoid targeting sites where friendly personnel are being held. UCAVs can perform similar missions with only a material loss if shot down.

Remotely piloted systems. Predator unmanned vehicles that engaged targets in Afghanistan used a man-in-the-loop control—that is, they were remotely piloted. In such a system, the vehicle has a communications link with a control station and receives control inputs to dictate flight path and sensor operation. Imagery from sensors is transmitted to the control station, and the manned operator then locates, identifies, and decides when to engage targets. The advantage is that the system is relatively unsophisticated; technology to remotely pilot aircraft has existed for years. The ground station operator can decide and react to the situation and direct the next action for the vehicle. Significantly, the system includes a man-in-the-loop who is responsible for releasing live weapons. Rules of engagement follow a chain of command to determine if circumstances warrant an attack and collateral damage is a concern. This system supports the rules since accountability resides with decisionmakers. The disadvantage is that it depends on a constant communications link, which may be susceptible to jamming or interference. Moreover, a remotely piloted system requires dedicated personnel, which is costly and time consuming during lengthy missions.

Autonomous systems. On the other end of the spectrum is the autonomous control system, which uses an onboard computer to locate, identify, track, and expeditiously attack targets. A control station is only used to receive sensor imagery and aircraft flight information. The foremost advantage of an autonomous system is that it does not require a constant communications link with a control station, and therefore jamming or interference of the aircraft's communications link is not detrimental to the mission. Also, autonomous systems require minimal man-hour support and are thus less expensive to operate.

The disadvantage of the control system is that it has not been combat proven. Autonomous systems have been used for reconnaissance and surveillance, but none has performed in combat. That is due in part to the biggest challenge facing autonomous systems: accountability for making weapons release decisions. Even if technology advances to allow autonomous combat, operational commanders would likely oppose it because if school buses are misidentified as troop carriers, who would be held accountable—the software programmer, UCAV squadron commander, or leader who authorized unmanned aircraft? A purely autonomous system should not be used in combat because of this dilemma.

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Semiautonomous systems. While certain phases of UCAV missions are remotely piloted, others are under autonomous control, blending man-in-the-loop and autonomous operations. For instance, time-consuming tasks such as aircraft station keeping and searching for enemy targets are accomplished autonomously using onboard sensors and computers. Once potential targets are located, decisionmakers verify their identity and ensure conditions exist to release weapons. The advantage is that the most dynamic phase has a man-in-the-loop, increasing the likelihood of success while maintaining rules of engagement and minimizing the chance of misidentification and engagement of noncombatants. The disadvantages are that communications links are susceptible to jamming or interference and that a decisionmaking process involving several people increases the time required to authorize weapons release and engage targets.

Gazing into the Future

From the descriptions of naval UCAVs on the drawing board, it appears likely that these vehicles will incorporate long-range surveillance sensors, electronic surveillance equipment, and precision weapons. Since the Marine Corps has no program underway, it seems doubtful that they will get a dedicated vehicle in the near future; however, it may be possible to modify a land-based Predator for use with close air support and surveillance missions. A near-term plan is in place, but what will naval UCAVs look like in the future?

Minesweeping. While not specifically found on unmanned aircraft, the Defense Advanced Research Projects Agency has used a chemical sniffer to detect buried landmines. With similar technology, a swarm of miniature UCAVs could fly over amphibious landing areas or minefields to locate buried landmines. A single vehicle would lightly land next to the landmine. All of these vehicles would detect individual mines, and once the swarm had detected them all, they would detonate onboard incendiary devices in unison, destroying themselves and the mines. A signal to detonate would come from a single manned control station, precluding unintentional detonation and collateral damage.

Smart grenade. As the Marines employ Dragon Eye for reconnaissance and surveillance, small UCAVs will serve a tactical benefit in the field. Miniaturized variants of Dragon Eye could carry small incendiary devices. Forces on the ground could remotely pilot the aircraft while using onboard sensors to look for enemy troops or ground vehicles. Once a target is detected, a marine could pilot the aerial vehicle, then cause it to detonate. In its simplest form, this miniature aerial vehicle would be used like a grenade that can fly around corners and down passageways.

Air-to-air. The Air Force is considering putting an air-to-air version of the Stinger missile, originally designed as a handheld ground-to-air missile, on the Predator. UCAVs performing air-to-air missions are a logical next step. While personnel aboard command and control aircraft can determine if the hostile identification and rules of engagement are being met using beyond-visual-range criteria, air-to-air UCAVs could easily engage enemy aircraft with their own weapons system. The 24-hour patrols over New York and Washington after September 11 were ended because of reduced threat and expense. The Navy and Air Force flew more than 19,000 combat air patrols over American cities at a cost of $500 million. If the need to reinstate these combat air patrols arises again, air-to-air UCAVs could perform the mission at a substantially reduced cost and free aircrews for other missions.

Amphibious support. Current Navy UCAV plans only cover employment from carriers; however, future vehicles can be housed in artillery shells. Once fired, the vehicles could penetrate defended beachheads, then UCAVs would separate and begin powered flight. Imagery of enemy defenses could be relayed to ships or amphibious units. And when targets are detected, UCAVs would be remotely piloted to detonate on impact. Such vehicles must have a small, inexpensive, and durable design to survive being fired from a naval gun.

Through advancements in technology and increased funding, naval variants of unmanned combat air vehicles will soon be deployed to suppress enemy air defenses and conduct strike and other missions. Moreover, these vehicles promise to conduct some missions more effectively and less expensively than manned aircraft. A result could be fewer joint strike fighters in the near term. Some have even predicted that this fighter might be the last manned strike aircraft built.

As unmanned combat air vehicles become more autonomous, it can be expected that a man-in-the-loop system will be used to preclude misidentification of targets and loss of innocent lives. They must not be employed in combat simply because they are available, but rather because they offer significant advantages over manned aircraft. Since their future application is virtually limitless, unmanned combat air vehicles will help maintain the supremacy of the U.S. military. JFQ