Part II

UAVs in 2010: Lean and Lethal

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Unmanned Combat Aerial Vehicles:

SEAD and EW for the Future

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CHAPTER 5
UNMANNED COMBAT AERIAL VEHICLES: SEAD & EW FOR THE FUTURE

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I. Introduction and History: UAVs Make Their Mark

> *They (UAVs) offer expanding opportunities for new and unique capabilities, and they offer an invaluable advantage, the ability to perform necessary missions without putting warfighters into harm's way.*[1]
>
> --Dr. James G. Roche, Secretary of the Air Force

The two radio calls that the leader of a strike package wants to hear during his ingress are "Viper 21, Magnum SA-3" and "Prowler 33, Music on." They mean the SEAD (suppression of enemy air defenses) F-16CJs and the EW (electronic warfare) EA-6Bs are doing their job in locating the enemy surface-to-air-missiles (SAM) systems and keeping them from threatening the strike package. What isn't reassuring is that these systems are in short supply. The availability and ability to sufficiently accomplish the mission in the near future may be jeopardized due to more capable enemy integrated air defense systems (IADS). The question is whether a UCAV should do this "dangerous and dirty but certainly not dull mission."

UAVs have been in the spotlight over the past few years with successful intelligence, surveillance, and reconnaissance operations in Allied Force, Enduring Freedom, and Iraqi Freedom. With the weaponization of the Predator UAV and its successful use in Afghanistan, the Air Force has taken the first steps toward the transformation of UAVs to UCAVs. In fact, Major General David A. Deptula, Air Force national defense review director, told Congress in March 2003 that UCAVs would be one of "four platforms that will define the stealthy Air Force of 2020," alongside the F-22 fighter, B-2 bomber, and Joint Strike Fighter.[2] Technological advances in warfare are normally offset by a counter-advance soon thereafter by an enemy trying to negate that advantage. Such is the case with countering the proliferation of advanced SAM systems available to any country willing to pay for them. Even pilots of our stealthiest aircraft are reluctant to challenge these systems and rely extensively on the SEAD and EW support. With SEAD and EW assets limited and aging, the U.S. is postured for a fundamental shift, possibly from manned to unmanned air vehicles to accomplish these very dangerous missions.

While there may be some resistance from the "white scarf-wearing pilots" concerning UAVs, the real test of whether an unmanned vehicle should accomplish a mission will be whether it lowers risk or cost. The risk to human lives has been an ever-increasing factor in conflicts the U.S. has been involved in over the past 20 years. The loss of life during any of these conflicts sent shock waves throughout the media and the military operations. Compare that with the lack of drama involved in the loss of Predator UAVs, as summed up by a senior Pentagon official: "Thus far, we've had no missing-man flybys, no funerals, no Arlington burials—and no excitement in the E-ring over the loss of a Predator."[3]

Unmanned air vehicles did not begin with the current Predator, as it would appear to the lay public. The reality is that UAVs have been around longer than manned flight. The first sustained powered flight was a UAV. Less than nine years after the U.S. Army Signal Corps awarded the Wright brothers a contract for the Army's first manned aircraft, Charles F. Kettering of General Motors was awarded a contract for the Army's first unmanned aircraft.[4] His "Bug" could carry 180 pounds of explosives and cruise at 55 miles per hour with a range of about 40 miles. It was guided to its target by preset controls and had jettisonable biplane wings.[5] Alas, the system suffered catapult problems, along with guidance errors, that made it too unreliable for the project to be continued. These early attempts at constructing a UAV were marked by some of the same problems that plagued the early years of manned flight. That is, aerodynamic principles were not yet fully understood and the mechanical requirements of flight for things like engines and guidance systems were still in a very rudimentary level of development.

While multiple projects came and went from World War I until after the Second World War, U.S. involvement in UAVs didn't mature until the early variants of the Ryan Firebee Q-2 first appeared in 1948. The Q-2 started life as a target for aerial gunners but soon developed into a whole family of unmanned aircraft that would see use for multiple decades and usher in the age of the UAV.[6] By the early 1960s, Ryan Aeronautical won a classified contract to modify standard Firebees into reconnaissance UAVs designated as the 147A Firefly but later renamed as the Lightning Bug.[7] The basic structure of the Lightning Bug was enlarged to make room for sensors and more fuel while the wings were more than doubled in length to carry the extra weight.[8] These improvements helped set the stage for its successful use in the war in Vietnam.

The Lightning Bug was successful in many variants during the Vietnam War, proving itself in the reconnaissance role it was originally modified for, but more importantly, being modified to help it survive over the battlefield. Known as Operation Chicken, "this project provided the UAVs with artificial intelligence so they could maneuver out of harm's way when threatened."[9] "In all, with the ability to maneuver out of harm's way, the birds out-guessed eight MiG intercepts, three air-to-air missile launches and nine ground-to-air launches. Smart drones were finally out-smarting the smart missiles!"[10] The world situation in the Middle East would drive the development of the next derivative of the Bug, one that would be capable of finding and attacking targets on its own.

This variant, known as the BGM-34A, would become the first true unmanned combat air vehicle (UCAV). The Israelis needed help from the United States in destroying Arab anti-aircraft artillery (AAA) batteries and SAM sites along the banks of the Suez Canal.[11] At the end of 1971, a successful test of the SEAD capability of the drone to find a site and then attack it with a guided air-to-surface missile prompted the Air Force to try get as many of the missile carrying UAVs to Southeast Asia as possible.[12] "The philosophy of Tactical Air Command (TAC) was to use them to go in on the first wave and soften up the target so that the manned aircraft, F-4 Phantoms and F-105s, could go in and finish the job with the human eye."[13] While the Israelis used the BGM-34A against the Egyptian missile sites and armored vehicles with great success, it was never used in Vietnam "because it did not have the technology necessary to perform better than manned aircraft."[14] The assessment was that USAF UAVs would not be any better at finding camouflaged SAM sites, so there would be no advantage to employing them for that task.[15] As a result, in the Vietnam War UAVs had multiple successes in the reconnaissance role, but utilization in the UCAV role would have to wait on further development.

That development didn't take long, with two more variants of the BGM-34, the B and C, successfully tested during the 1970s. While the B-version was a larger version of the A-model, capable of finding and destroying targets, the C-variant "could accomplish three major missions: strike, reconnaissance, and electronic warfare."[16] All three missions were successfully tested, and the Air Force nearly placed initial orders. However, the end of the Vietnam War, placing all UAV programs under TAC, and competing programs for scarce funds meant that choices had to be made. Sadly, all existing UAV programs were shelved. "In 1979 more than 60 UAVs in various configurations were sent to the mothball fleet.

Military use of UAVs would lay dormant for the next decade, waiting for the need to arise again for their development and use."[17]

The past decade has seen an exponential proliferation of the number of different types of UAVs on the world market. The two most prominent are reconnaissance UAVs. The Predator is in high demand in any theater due to its sterling performance in Kosovo, Afghanistan, and Iraq. The technology in this slow-moving UAV is rather old but has been refined to improve both reliability and capability. The biggest jump in capability came when a Hellfire missile was fitted to a wing pylon on the Predator and successfully fired at a target the Predator had acquired. This shortened the time required to find, fix, target, track, engage, and assess (F2T2EA) down to almost nothing; a very useful capability that proved itself multiple times during Operation Iraqi Freedom (OIF). Dr. Roche, Secretary of the Air Force, relays a great example of this capability:

> So, on this day, an F-15E pilot, call sign "Ivana," and her system operator were tasked to employ a predator to take out the antenna system [of Baghdad Bob]. She flew her aircraft into downtown Baghdad very slowly as to be very quiet, and hits the antenna and its generator and structure with a Hellfire missile. They not only took out the dish, but Fox News [antenna less than 150 feet away] kept on broadcasting uninterrupted, and the nearby Mosque was left unscathed. This is just one of many Predator stories from Iraq.[18]

The newest large UAV, Global Hawk, has been seeing action in conflicts around the world even though it is still in the development phase. At over 25,000 pounds it is not a small vehicle, and its capability to carry a myriad of modern reconnaissance sensors makes it a high-demand asset. "Global Hawk is a high-altitude, unmanned aerial reconnaissance system that operates autonomously from takeoff to landing. Flying at an altitude of 65,000 feet and with an endurance of more than 30 hours, the Global Hawk provides intelligence, reconnaissance, and surveillance information to the warfighter in near real-time."[19] "Our experience in Operation Iraqi Freedom really validated the Air Force's confidence in the Global Hawk system. It demonstrated the UAV's potential to transform the way wars are fought in the future," observed Colonel Scott Coale, director of the Global Hawk program office at Wright Patterson AFB.[20]

Most doubt that the military's recent emphasis on UAV use will be another short-lived experiment. UAV technology has caught up with inventors' imaginations, and most technical problems that could not be solved in the past to make UAVs a viable military weapon have been overcome. Whether the services take advantage of this leveraging capability remains to be seen.

II. Current SEAD and EW Capabilities

> *Since 1996, the US military services have tried to restore suppression capabilities lost through retirement of the EF-111 and F-4G aircraft but the approach has been limited and piecemeal.*[21]
>
> --GAO report on EW in DOD

Getting the mission done is what really matters and to that end, some manned systems require tactics that are not optimal for mission accomplishment. For instance, the Navy EA-6B Prowler EW aircraft typically stays at an inconvenient distance from the sites it seeks to jam because it cannot defend itself at close range to the threat due to its slow speed. Furthermore, the EA-6B can't keep up with ingressing strike aircraft, which diminished its jamming effectiveness in Kosovo.[22] Jamming is essential for aircraft to reach their target in a high-threat environment.

The USAF F-16CJ, the current SEAD platform, is faster and can maneuver better than the Prowler but still operates at a greater than optimal range from known threat areas to facilitate survival and to provide more time to analyze the current electronic order of battle (EOB). This standoff range adds to fly-out time of the current SEAD weapon, the high-speed anti-radiation missile (HARM). Also, according to Colonel Daniel J. Darnell, then commander of the Air Force's 20th Fighter Wing during Kosovo, the lack of HARM targeting system (HTS) pods (a key system on the F-16CJ) may have reduced the Air Force's ability to generate SEAD sorties: "In Allied Force, there were more F-16 aircraft capable of carrying the pod than there were pods to go around."[23] Since it is a single seat aircraft, attention sharing must occur between basic stick-and-rudder flying, clearing the formation for threats and wingman's position, and operating the sensors and weapons to accomplish the SEAD mission. Just having time to understand what the HTS pod is seeing is tough enough; deciding to fire a HARM at it takes that much more time looking inside the cockpit, not an activity conducive to survival in a high-threat environment.

In a typical tactical scenario the F-16CJs will use their HTS pods and other off-board sensors to look for radars that can track friendly aircraft or a guided surface-to-air missile being fired. When one is detected and determined to be a threat, a HARM missile will be fired at it. The reactive mode of this tactic, and the fact that most SAMs enjoy about a 3-to-1-speed advantage over the HARM, makes this a tough battle to win, especially when the SAM is shooting at striker aircraft that are close by and the HARM is being shot from further away. The HARM missile relies on the radar of the adversary's missile site to guide it to the target, but SAM radar operators have learned that leaving their radars on means they will be targeted. Instead, they only turn the radar on long enough to guide their surface-to-air missile when it is close to hitting the airborne target. This decreases the likelihood that the enemy radar will still be emitting when the HARM "opens its eyes" to acquire the site. "Perhaps a greater SEAD concern [in] Kosovo was the great difficulty US forces had detecting, tracking, and destroying Serbian SAMs that minimized their radar emissions or used 'shoot and scoot' tactics. Part of the challenge is that the primary SEAD weapon, the HARM, quickly loses its guidance once an adversary turns off his radar, even for a short period of time."[24] The missile relies on a relatively unsophisticated guidance system that will drift off course unless it receives electronic signals from the site it is targeting. Long missile time of flight and wise enemy tactics degrade mission accomplishment due to concern for protecting the "man in the machine."

The Prowler can carry the HARM missile as well but in doing so it gives up the capability to carry other jammers, forcing a tradeoff in the capabilities it brings to the battle.

> The Prowler's main mission is to intercept and jam enemy electronic emissions by means of its primary "weapon," the tactical jamming system (TJS). The TJS consists of an onboard electronic system (OES) and externally mounted jammer pods. The OES is capable of monitoring the electronic environment and displaying it to the electronic countermeasures officer (ECMO). When a threat is detected, action is taken to tune and direct the jammer pod antennae to the hostile radar frequency.[25]

The Prowler has started to receive an upgrade to its jamming capability under the "improved capabilities (ICAP) III" system. At the heart of ICAP III is the installation of the digital LR-700 receiver. "This will make it possible to evaluate enemy signals far more accurately and to provide "reactive" jamming, i.e. no longer will energy simply be radiated over a broad spectrum, instead only the relevant frequencies will be jammed. Thus, the new system can keep up with the frequency hopping employed on many radars."[26]

Current EW and SEAD platforms were intended as stopgap measures until the next generation of platforms and sensors could be fielded. Unfortunately, not many systems are available and minimal replacements are being developed and fielded for these assets. The follow-on for the F-16CJ may be the F-22 but that has not been addressed beyond discussions, and until that time there will likely still be a shortage of HTS pods to go around for the F-16CJs. The Prowler's intended replacement, the Boeing F/A-18 "Growler," now designated the EA-18G, is a version of the two-seat F/A-18F, with anywhere from 120 to 150 aircraft proposed to replace the EA-6B. These would be jointly crewed by the Navy and the Air Force as the Prowler is today. "By 2008/2009 it is likely that there will no longer be enough Prowlers to keep all the squadrons operational. In fact, the Navy recently grounded 19 of its 119 Prowlers due to fatigue levels in the wings and then announced that another 24 would be taken out of service for repairs for the same reason."[27] These issues are getting more attention, as attested to in this statement by Representative Joe Pitts: "Congress and [the Defense Department] must be diligent in ensuring a seamless transition from the Prowler to the follow-on support jamming aircraft, or our military will be faced with a capabilities gap that will hamper our ability to obtain and maintain air superiority."[28] The EA-18G is really only an incremental improvement on the Prowler. However, since it uses the EA-6B's jamming pods with a newer airframe, development of a successor is essential, yet no clear solution is planned.[29]

III. Defining the Problem

> *This is accompanied by a growing threat in the surface-to-air missile business. Every air force that doesn't like our country is out there trying to figure out how to beat U.S. air power -- the United States Air Force, Navy, Marine Corps and Army aviation. They're trying to figure out how to beat it.*[30]
>
> --General John P. Jumper, USAF Chief of Staff

The former Air Force Chief of Staff, General John Jumper, is not so much interested in what is used to suppress and destroy an adversary's IADS as he is in how we can achieve that result.[31] The options need to be examined with a critical eye, focusing on what future conflicts will look like. Most visions of future SEAD warfare see either evolutionary manned systems of what is currently being used or a UCAV that gets the job done without fear of loss of life. What is needed is the remainder of this vision, like a host of capabilities to deal with radars that may or may not emit in a potentially very hostile environment. Further, SEAD and EW platforms need to arrive before any strikers and loiter during the strike/egress of the package to provide protection. Ideally, they should continuously loiter to catch enemy radar sites off-guard while they are relocating or doing maintenance.

Beyond simply staying over a battlefield for longer times, the next platform has to accomplish the mission better. During Operation Allied Force (OAF), "the soft kill nature of SEAD assets meant that enemy air defenses were a threat throughout the conflict."[32] According to the Defense Intelligence Agency, during all of OAF the U.S. forces never succeeded in entirely closing down the Yugoslav air defenses.[33] Further, Serb missile operators had learned from the Iraqis about how to minimize radar use and utilize "shoot and move" tactics to avoid being targeted by the HARM missiles.[34] "Again, radar and missile launchers are becoming more mobile. If the various radars and other sensors can be networked, the result is a better situational display. This in turn means that individual radars do not need to be switched on for so long, making them harder to detect."[35] Adversaries are adapting for survival and it's working.

The realization that the enemy may not always "cooperate" during war has brought about another challenge in prosecuting an enemy IADS, that is, having to find the SAM sites without having them emit or emit for only a short time. This new category, termed destruction of enemy air defenses (DEAD), probably needs even more attention than SEAD in future technology developments. The situation of threats being suppressed temporarily but not removed from the enemy's usable weapons is of concern today more than ever with the refinement of the Russian S-300 and S-400 SAMs (also known as SA-10 and SA-12). SA-10s and SA-12s are lethal out to a slant range of 80 nautical miles—five times the killing reach of the earlier-generation SA-3.[36] "One SA-10/12 site in Belgrade and one in Pristina could have provided defensive coverage over all of Serbia and Kosovo. They also could have threatened Rivet Joint, Compass Call, and other key allied aircraft such as the airborne command and control center and the Navy's E-2C operating well outside enemy airspace."[37] It will take a coordinated effort to get in close to these long-range lethal systems. If it's worth jamming or suppressing it, it's worth eliminating it.

Even current SAM systems like the highly exported SA-2 and SA-3 still pose a formidable threat as they are continuously upgraded to improve range, jam-resistance, mobility, and lethality. The speed and range of these upgraded missiles present new challenges in getting close enough to the threat to affect it without being shot down. To combat these threats requires a weapon that will allow aircraft to stay outside the huge lethality envelope of these missiles and still attack their primary targets, but no such weapon exists in the current or planned inventory. Further, the higher speed of the newer missiles allows them to have more energy for maneuvering at the time of intercept. This negates the advantage previously held by fighters of doing a last-ditch maneuver to increase the missile's miss distance when it detonates. Anytime any of these threats are left to radiate and shoot another day is another chance a U.S. or coalition aircraft will be shot down. Airpower should eliminate these threats vice just suppressing them for a short duration. Suppression for a single strike requires escorting that strike mission again to suppress it once more. DEAD allows the commander to redirect SEAD and EW assets to strike or other missions once the threat is removed, thereby leveraging the limited assets.

IV. The Next Generation: Many Possibilities

> *But here is where we offer a word of caution. The more these systems work, the more people jump to the extreme conclusion that we should take crews out of all of our cockpits and make all aircraft unmanned.*[38]
>
> --Dr. James G. Roche, Secretary of the Air Force

What are the alternatives? Some propose UCAVs for performing SEAD and EW roles but that vision needs refinement. For instance, plans to put HARM missiles on the X-45 UCAV for SEAD are akin to strapping the aging Prowler jamming pods on the EA-18, just a stopgap solution that will not significantly impact survivability and lethality. Moreover, some proffer use of cruise missiles as a way to improve hard-kill capability. The problems with this solution are many. First, the cost of a cruise missile like a $1.4M Tomahawk is fairly high compared with other alternatives.[39] Second, most modern air defense systems are designed to be mobile; a cruise missile requires time to program in the target and its route of flight, giving the threat lots of time to move before the missile can reach it. Even the once traditional "fixed-site" systems like SA-2s and –3s became pseudo-mobile in Iraq. While aircraft like the B-2 offer quicker response time than cruise missiles in terms of targeting munitions, they depend on long search times to find the sites with their radar or they require off-board cueing from another system.

The greatest problem, however, lies in having a costly manned aircraft like the B-2 flying in a high-threat area while searching for pinpoint targets. The fleet is limited in size and the payoff in timeliness may not be substantiated when balanced with the risk. The long-term solution lies in first defining the capability needed to solve the problem of taking out an enemy's air defenses and then figuring out how best to get that capability to the fight. That solution may or may not be a UCAV (specifically the X-45), at least not for the time being. The current Air Force Secretary and USAF Chief of Staff have both been quoted as saying: "We have a debate going on today about the Unmanned Combat Air Vehicle. We frequently ask the question: 'If it weren't for the novelty of not having an aircrew or pilot in it, would we even be thinking about this vehicle?' The answer for some designs is no."[40]

The Vehicle

Assuming that the best way to use a weapon or sensor is with a UAV, there is still the question of the type of environment in which you plan to employ it. For instance, a high-threat environment with an active air defense system will require some element of stealth to get past the acquisition and targeting radars. A stealthy, low-observable (LO) vehicle is less efficient in terms of lift, drag, and weight—all things that detract from a vehicle's ability to loiter over the battlefield or go long distances. Integrating weapons and sensors into an LO vehicle is more difficult in design as well as in upkeep because of the meticulous and time consuming care required to maintain the LO surface. As General Jumper puts it:

> The great thing about unmanned vehicles is, …., their persistence. They can stay airborne for long periods of time in ways that human beings cannot. If you want to combine that persistence with a stealthy platform, then the stealthy platforms are not very aerodynamically smooth and they don't stay airborne very long. [41]

The possibility of high-threat environments is more realistic given the proliferation of air defense systems sold by Russia, China, North Korea, and other nations. Rather than building a totally stealth aircraft, giving it some LO attributes while not seriously impacting flight characteristics and costs may be sufficient. Fortunately, LO capabilities have evolved rapidly in the last decade and can be an integral part of the vehicle from inception. There is, however, still a tradeoff in design and cost for making LO a primary design factor, highlighted in the DOD UAV roadmap:

> Examining the Global Hawk and DarkStar programs provides insight into this tradeoff. Both were built to the same mission (high altitude endurance reconnaissance) and cost objective ($10 million flyaway price); one (DarkStar) was to be more highly survivable by stealth, the other only moderately survivable. Performance could be traded to meet the cost objective. The resulting designs therefore traded only performance for survivability. The low observable DarkStar emerged as one-third the size (8,600 versus 25,600 lbs) and had one-third the performance (9 hrs at 500 nm versus 24 hrs at 1200 nm) of its conventional stablemate, Global Hawk. It was canceled for reasons that included its performance shortfall outweighing the perceived value of its enhanced survivability.[42]

Beyond the decision concerning the amount of stealth the vehicle should have is the speed that it needs to accomplish the mission. There is a tradeoff between maneuverability associated with higher speed and being an easier target for enemy defenses at slower speed. Further, higher speed means that sensor inputs and decisions need to happen at a faster pace to keep up with the vehicle, necessitating that much better command and control (C2) capability or more automation. Speed, however, does not always translate to survivability as witnessed by the faster, jet-powered UAVs, such as the German CL-289 deployed over Yugoslavia that proved to be even more vulnerable and less effective than the slow moving Predator.[43]

So how do we get there from here? First, the notion that a "one size fits all" UCAV will offer the flexibility required is probably over-optimistic. The radars, emitter acquisition systems, and jamming systems will require differing amounts of space and energy to power them. Further, some systems must be armed, like the SEAD UCAV vehicle, potentially carrying a mixture of guided missiles and bombs, while the jammer vehicle may not require any weapons. Systems that must approach closer to the threat would be more suited to a stealthy UCAV while standoff jammers would be better suited to a larger platform capable of producing the required energy for jamming across a broad spectrum. To that end, stealth technology is wonderful until a weapons bay is opened to drop a weapon, whereupon the aircraft immediately highlights itself to any radars looking that way. This also limits the stealth platform from loitering over an area in close proximity to threats after it has "exposed" itself by attacking the first time. This problem requires serious development and tactics to find the answer while not compromising the mission. The current design concept for the X-45 calls for thirty minutes of loiter capability at a range of 650 miles from the launch base.[44] This range may be fine for the typical escort mission when tied to a strike package but falls short of supporting the Global Task Force concept. More importantly, it fails to provide the persistent battlefield presence so well suited to UAVs. One of the reasons to shift to unmanned vehicles is their ability to loiter for long periods of time to take advantage of any opportunity the enemy may present in terms of testing missile systems or exposing equipment that may have been camouflaged during friendly strikes. UCAV is required to have future capability for in-flight refueling. One thing leads to another, and in this case it is the current lease brokering for the KC-135 replacement. If the Air Force wants to have UCAV refueling with the new tankers, the future technology requirements should be engineered into the new tankers for system compatibility. However, the question should be asked whether this is a capability that really needs to be developed, especially if the cost per vehicle is to be kept to a palatable level. More importantly, if a different design is capable of long loiter times without in-flight refueling then that might be a more prudent course to follow.

The Sensors

Determining the right type of vehicle to accomplish the mission is important, but there is a wave of thinking in the defense industry that believes one should design the sensors and weapons first and then design the vehicle around it. To that end, getting the sensor capabilities right from the start is crucial. For SEAD that probably doesn't mean just an improved version of the HTS pod or a Prowler pod with a new coat of paint and a faster processor for EW. New technologies emerge rapidly so they must be quickly evaluated for the battlefield of tomorrow.

Jamming enemy radar can be as effective at suppressing it as shooting a HARM missile at it, but one must get close enough to do either one. Unfortunately, the speed and range of the newer SAMs forces current manned aircraft to operate that much further from the threat, reducing their effectiveness. Thus, one must either increase the output power of the jammer or move the jammer closer to the threat radar. The Prowler is not capable of getting closer to the threat without unacceptable risk to the aircrew, and it lacks the speed to stay with the strike package for imbedded support. The Growler will have the speed to stay with a strike package but will still be at high risk if it leads a package deep into enemy radar coverage, since it lacks any stealth capability. Further, since the EA-18 will use jammers from the Prowler, long-range standoff capability will not be substantially improved. Hopefully, newer and more capable versions of the selective frequency jammer from the Prowler's ICAP III upgrade and a follow-on to its communication jammer, called the communications countermeasures receiver, will be part of the Growler's arsenal to attack electrons.[45] These improvements will add marginal capability for near-future EW but still force less than optimum employment tactics to protect the aircrews.

Real-time jamming will be necessary for the foreseeable future but whether it needs to be brought to the battlefield in a manned platform that lacks the capability to loiter for long periods of time remains to be seen. One benefit of persistence is the ability to mask the activities of friendly forces for long periods of time, allowing a much broader range of attack options. According to General Jumper, that capability might be brought to bear by loading empty pylons on a B-52 with jammers and keeping it loitering for long periods of time.[46] While this effectively uses an existing platform for an expanded role, it fails to account for the need to jam in high threat areas. The real solution may lie in a combination of platforms, using the B-52 as a standoff jammer to allow an expendable UCAV tactical jammer to escort and protect the strike package in close to the target area.

Many other issues need attention and face bigger technological challenges. First is the development of sensors that can effectively locate, target, and enable an attack against targets. A key lies in the ability of these sensors to talk to other UAVs, the controller at the ground station, and other command and control platforms. One program seeking to solve that issue is the Defense Advanced Research Project Agency's (DARPA) advanced tactical targeting technology (AT3). The technology seeks to exploit time and travel information from multiple cooperating platforms to attain threat position to an accuracy of 50 meters.[47] Three problems surface with this direction. First, multiple vehicles are required to fly to an area of high risk. Second, an accuracy of 50 meters is not adequate for delivering inertially guided munitions, especially low-yield weapons. Finally, this strategy relies on a willing adversary, one that will turn on his radars so the sensors can detect them, thereby allowing the sensors to triangulate the radar's position. Based on our experiences with well-developed and tactically savvy IADS in Kosovo and OIF, it is doubtful that will happen. To avoid their relatively easy destruction by coalition SEAD aircraft, Iraqi forces refused to give SEAD forces what they look for—radar emissions.[48]

What is needed is a mix of sensors that can accurately detect radar emissions and find enemy missile sites using other methods that will lead to a true weapons quality solution for attacking the site. One such capability is automatic target recognition software used in conjunction with a laser-radar that can scan large areas and detect an object that it is programmed to look for.[49] Field-testing of these two technologies is well under way and proving to be very accurate. The major technical challenge is the development of robust algorithms that are needed to contend with the target signature variations due to target configuration or camouflaging. Once accomplished, this will further enhance a UCAV's reliability in correctly detecting targets, and operations will evolve from someone on the ground deciding to employ a weapon against that target to the UCAV being capable of autonomous operations.

Another capability well along in development is actually a sensor that turns itself into a weapon once a target is found. Known as LOCAAS (low cost autonomous attack system), this small, 100-pound vehicle uses a LADAR (laser acquisition detection and ranging) seeker to detect and identify the correct target and guide the LOCAAS to a warhead-detonation point.[50] While having a limited range of about 100 miles, it is easily carried by a number of aircraft and can loiter in an area for 15-30 minutes while looking for a preprogrammed target.[51] After a live fire test, Colonel Michael Ruff, an Air Force Research Laboratory munitions director, noted:

> Equipped with a multi-mode warhead, the LOCAAS system — with no outside control — successfully located, attacked and fired a warhead at a target for the first time. This test represents a significant step in demonstrating an autonomous wide area search miniature munition capability for the warfighter. In this test, experts released LOCAAS from a test aircraft over the Eglin range. After flying under its own power, LOCAAS used its on-board Global Navigation System and Inertial Navigation System to navigate to two waypoints before searching for the target — a relocatable surface-to-air missile launcher. The

> LOCAAS acquired and correctly identified the target, tracked it, and detonated the warhead above the target at the appropriate time and location. Fragments from the warhead impacted and penetrated the SAM transporter, launcher and radar system. All flight test objectives were met.[52]

Unfortunately, this sensor is essentially a smart missile and is not recoverable. However, it is being modified with an override to keep a man-in-the-loop for final targeting decisions, if required. With a multi-mode warhead that can attack a variety of targets and do so with minimal collateral damage and relatively low cost, it is a capability that can help shape the battlefield.

The Weapons

The current SEAD weapon, the HARM, is losing ground to newer enemy SAMs. It lacks the speed required to win the "first shot, first kill" battle against those SAMs and requires a cooperative enemy willing to have his radars emit so that the HARMs can guide to them. At close range, the Air Force's small diameter bomb (SDB), with the first hardware deliveries due in the 2006 timeframe, would contribute greatly to accomplishing the SEAD mission, especially when smarter future variants are fielded.[53] The complement to the SDB might be a follow-on to the HARM for the reactive SEAD mission. This missile would require a dramatic speed improvement and, more importantly, capability to track a site if it shuts down after missile acquisition. The addition of a GPS-aided guidance system like that found on weapons such as the Joint Direct Attack Munitions (JDAM) would help to solve that problem. Alternatively, a microwave system that could "reach out and touch" the sites almost instantly would alleviate the problem of radars that stop emitting before the weapon can reach it. A high-powered microwave uses a short burst of microwave energy and can be lethal. Research is progressing in SDB and microwaves but has not reached the maturity required for battlefield use.

Going further, a possible solution to the need to quickly kill an emitter, especially during reactive SEAD, would lead to using laser weapons. The low-collateral damage aspect of the technology makes high-power microwave weapons useful in a wide variety of missions where avoiding civilian casualties is a major concern.[54] The drawback with this type of weapon is that it doesn't necessarily destroy the weapons themselves, just the radars, potentially allowing an adversary to rapidly repair and resume operations. Further, because of the microwave's power and line-of-sight requirements to the target, the short ranges required between the two make it a potentially risky mission.

Another alternative is the use of low cost UAVs like the Israeli-made "Harpy." Much like the LOCAAS, the Harpy is a "fire and forget" lethal UAV, designed to autonomously attack radar emitters.[55] While Turkey has already taken delivery of some of these vehicles, they have not been embraced by the U.S. Air Force due to legal concerns regarding the Harpy's lack of communications capability to override or veto the machine's decision to employ weapons on a potential threat. The U.S. Navy is currently working the follow-on to Harpy known as Cutlass, which will allow data link capability.[56] The biggest detractor from Harpy's otherwise glowing appeal, much like LOCAAS, is that it is a one-way weapon; if it fails to acquire and attack a target it is programmed to self-destruct before it runs out of fuel. This not only makes for a somewhat costly missile but, more importantly, it cannot compensate for an enemy that chooses to not turn on his radars, possibly rendering the Harpy a futile expenditure in a cost-limited acquisition era. Thus, LOCAAS has an advantage in that it doesn't require radar transmissions to acquire the target, relying instead on its radar and automatic target recognition software. While not a stand-alone solution, either of these two systems might be incorporated into the USAF arsenal to offer an alternative to manned or more expensive UCAV systems.

Command and Control

While sensor technology is evolving quickly, communication capabilities, especially the man-machine interface (MMI), needs a definitive direction for development. While the ultimate goal may be to have the UCAVs operating autonomously from takeoff to landing, for the foreseeable future there will need to be a "man-in-the-loop" to make targeting decisions, act as a backup until reliability has been proven, and coordinate with the manned aircraft in the airspace. Most of the flight can and should be pre-programmed, requiring less "stick and rudder" time by the operator, thereby allowing a single operator to perhaps control four to six vehicles at a time in the near future. The ability to establish secure, robust, over-the-horizon communications is crucial if UCAV is to succeed.[57] The quicker the UCAV can get targeting information to and from the ground stations, the more the F2T2EA kill chain can be compressed and the more effective they will be in shaping the battlefield.

"Fighters and UCAVs may fly together, with the unmanned platforms serving as 'scouts,' anti-air defense 'wild weasels,' jammers or first-wave strikers. Manned aircraft in the strike package might be UCAV control nodes, with crewmembers making on-scene decisions when human intervention is required."[58] The road to achieving that integrated force of manned and unmanned vehicles won't be easy for many reasons, including the way in which UAV operators are currently assigned. Pilots taken from the cockpit to operate UAVs have not been thrilled about it. As one pilot said, "I didn't grow up dreaming about flying model airplanes from inside a shipping container," referring to the ground stations that house Predator operations.[59]

Studies have shown the skills needed to successfully operate a UAV are universal. Extensive amounts of manned aircraft pilot experience are not required. The skill sets required to operate current and future UAVs have less to do with stick-and-rudder movements and more to do with keystrokes on a computer. The cost and time required to train a UAV operator currently includes the many years and enormous amounts of money to train pilots to fly in manned aircraft. Those costs include the entire support base of aircraft, maintenance, and instructors to get the pilots to their required proficiency level. The current pilot shortage is not forecasted to go away, so avoiding siphoning pilots out of manned systems to fly UAVs might help the problem. Keeping pilots in the cockpits further abates the pilot retention issues associated with UAV assignments.

While some weapon employment decisions would come more naturally to an experienced pilot, concentrated simulator training could bring UAV operators up to the same level of ability. The U.S. Army successfully utilizes motivated enlisted personnel to operate their battlefield UAVs, as do the Marines. There is no reason that as UAV automation and simulator training continue to improve that the Air Force could not follow this same course of action. A better way of selecting future UAV operators will have to be found to avoid a rift between manned and unmanned systems developing and hurting both communities. The current perceived need for a pilot to operate a UAV will be removed with the acceptance of flight automation and a progressive training program for the next generation of UAV operators.

V. The Future: A Road with Many Forks

> *Those are the balances that we have to think about before we jump to tactical level conclusions and start reciting bumper stickers that sound good in the abstract and fail in execution.*[60]
>
> --General John. P. Jumper, USAF Chief of Staff

The idea of using a UCAV for SEAD, DEAD, and EW is not new, but DOD needs a strategy to ensure it has the right platforms, sensors, and weapons along with the vision for controlling those assets. "The unsettling SEAD experience of Allied Force sent a much-needed wake-up call to the Air Force's EW community."[61] It's reasonable to expect more of the same as potential future opponents continue to monitor U.S. SEAD capabilities and operating procedures, adapting their countertactics accordingly.

Some improvements in electronic countermeasures have been introduced in the last decade. The use of active towed decoys by aircraft like the B-1, F-16, and other fighters has improved a pilot's chance of defeating a missile in the air but still requires him to visually acquire the missile and maneuver his aircraft to ensure survivability. Software reprogramming of radar warning receivers and electronic countermeasures pods can only do so much to help increase survivability in a dense threat environment and do nothing towards eliminating that threat. The bottom line is that aircrews are still at risk if the radar sites can see their aircraft and shoot at them.

In a tactical scenario with weapons like lasers and microwaves, more possibilities arise for different employment. For instance, the notion of using one platform as the sensor, another for weapons, and a third for jamming would allow less complexity for each platform while maximizing effect. A sensor/target suite that can be installed or removed quickly from the baseline UCAV will ensure maximum flexibility as the battlefield changes and the UCAV's mission balance or focus changes. To reduce the effect of losing a single sensor vehicle, one could have multiple vehicles of each configuration working the area with each one capable of interacting with the other.

So what might be the vision for the future of SEAD and EW? Here are two: the first concerns the next 10-15 years, where these missions will be shared by manned and unmanned systems. Then there is the long-term phase or iteration of SEAD and EW that is accomplished almost entirely by unmanned aircraft that would have a full complement of automatic target recognition (ATR) capability, multiple sensor platforms that utilize electronic, radar, and electro-optical (EO) signals to find and strike a vast array of targets. Not every platform will carry all of the sensors and the mission payload will be capable of being altered to the changing battlefield situation, depending on the electronic order of battle (EOB) and the loiter time required. The level of man-machine interface will decrease as technology evolves and leadership's trust in proven capabilities increases. The requirement for stealth will be proportional to the distance the platform needs to be from the threat. For instance, a jamming platform that seeks to jam a specific frequency of a radar site may need to be in close while a high-powered band-jamming system can afford to be less stealthy as it maintains a longer range from the threats and jams larger spectrums of bandwidth.

The DOD and the Air Force are pouring a lot of money into UCAV development; it is critical that the result of those efforts isn't simply a stealthy platform with marginally improved ability to find and destroy targets. Concerning EW, the EA-18 Growler may be a good stopgap for the aging Prowler but the question remains of whether it is the right EW capability for the future. A fresh start is needed to allow future growth of coherent, doctrinally sound tactics, techniques, and procedures with a platform, sensors, and weapons that will react in seconds, not minutes, and will find targets regardless of whether they emit or not.

Some have argued that the shift to unmanned systems is inevitable based on escalating costs of manned systems and the technology leveraging that gives unmanned systems the potential to outperform manned systems in the near future. Discussion on UCAV development involves talk of stealth and the tradeoff in performance in terms of loiter time, complexity, and cost. The first step should be to go back to General Jumper's edict to "turn the system upside down. We need to start with CONOPS (concept of operations) first and then we go into the programs."[62] While examples of this working in the past are hard to find, the next few examples show nonetheless that the mandate is not being followed. In a recent interview General Hornburg, commander of Air Combat Command, made a few comments concerning the requirements for UAVs: "The Air Force needs UAVs that can fly in tight formations, as do manned fighter aircraft. Without that capability, the service cannot achieve the necessary "strike package density."[63] The notion of flying in tight formations was conceived to provide visual lookout, something not required for a UAV. "Strike package density" is only one-way of achieving the desired target area effect. Swarming with multiple platforms from multiple directions can achieve the same effect. In the same article, General Jumper said that the future UAV "has to be able to defend itself…[and] be able to air refuel in order to get that persistence."[64] If the cost is kept down with less LO and the design emphasizes efficiency, then self-defense and in-flight refueling isn't required. The CONOPS for a UCAV must be realistic, but more importantly, it must first be clearly defined if it is going to be successful. Based on these and other leaders' comments, it's hard to tell just what the CONOPS for UCAV is and that needs to change.

A well-defined CONOPS would necessarily narrow the scope of missions and capability that is currently being envisioned for the UCAV. According to the Chief, the most difficult task we face is the "anti-access problem; the countries that have the competence to keep us from going in where we need to go in."[65] Most of the capabilities needed for that CONOPS involve a limited number of stealthy platforms with standoff capability that can also penetrate capable defenses. One must ask the question of whether we need a UCAV for that mission vice the F/A-22 as well as the B-2 and F-117 that all possess the required capabilities for this CONOPS.

Taking this view returns one to a more traditional air campaign where persistence over the battlefield and being able to detect and shoot quickly will carry the day. Here stealth will be less important than loiter time, and sensor and weapons capability will matter more than platform shape. This is also where larger quantities of platforms will be required for coverage and attrition during combat. A natural conclusion from this baseline CONOPS discussion would lead to a UCAV that sounds more like the Predator-B than the Boeing UCAV. Baseline cost estimates for the MQ-9 Predator-B are $8M for each unit, while the UCAV-C is currently estimated at $25M apiece.[66] Therefore, one can afford to build a Predator-B type UCAV in the quantities required and with the sensors and weapons required for the mission for which it is designed. Moreover, one can gain loiter time without adding the need for in-flight air refueling.

The single unit cost of weapon systems is usually secondary to ensuring we have the right capability to get the job done on the battlefield. The trend in aircraft acquisition has been for less quantity, partially based on capabilities increases and partly due to the higher cost of advancing technologies. Fewer numbers of aircraft available to the combatant commander in the future may very well drive his campaign strategy. He may not be able to undertake the mission, and just as importantly, if he loses only a few aircraft, he may fail once he has started. The capability of dropping 80 GPS-guided bombs on as many targets from one B-2 is great technology, but if that one B-2 is lost one forfeits a potentially crippling amount of capability.

The survivability of Predator on the battlefields of Kosovo, Afghanistan, and Iraq has been admirable. True, many have been lost but very few to enemy fire. While not possessing much stealth technology, its size, quiet engine, and medium altitude flight profile gives it a reasonable degree of inherent survivability. Thus, the logical question is why a stealthy platform and its inherent cost and complexity are required. In fact, speaking on the development of future UAVs, Generals Jumper and Hornburg both echoed the reality that, with all of the requirements heaped on UCAV, we must now be more careful with it. The Chief said the UCAV is "no longer a razor blade that we consider disposable. It is now a Norelco, and it costs a lot of money," and General Hornburg added, "They're not going to be expendable."[67]

"That inflation means the Pentagon has lost sight of its goal," warns DARPA's Joint UCAV program manager, Michael Francis. The UCAV as originally conceived, he says, "was designed to get us out of the death spiral—the term for the trend in which each generation of military airplanes costs more and is built in smaller numbers than the one that came before it."[68] "UCAVs must make unique contributions to the fight but do so without being overburdened by a requirements creep that threatens to make the systems too valuable to risk on high-threat missions."[69] While that statement was written about UCAVs, it applies to all weapons systems. Unless the USAF recognizes that it doesn't need, nor can it afford, the entire force to be stealthy, we may one day find ourselves in a conflict without enough capability in quantity, not quality.

Beyond funding and the level of stealth required, the question remains as to whether a UCAV is really necessary or whether a manned platform couldn't get the job done just as well. The strongest argument for having the UCAV, that it can loiter much longer than a manned platform and maintain the same level of performance throughout, is not the only one. Another prime reason for having UCAVs is the ability to penetrate formidable enemy air defenses without concern for loss of lives. With or without stealth technology, a small radar signature UCAV like a LOCAAS has a better chance of getting in close enough to kill the most capable SAMs in the world. For risk mitigation during Kosovo even the stealthy F-117 could not go into known enemy air defenses without the escort of an EW platform and pre-emptive HARM shots from SEAD platforms. One must then ask if a B-2 or F-22 will be sent in to take down a more advanced system like an SA-10 by itself? If not, then is an expensive stealthy UCAV required or can multiple expendable LOCAAS have the same effect?

So is the UCAV inevitable for our future fighting force? The leap in technologies it is capable of employing, along with the ability to go where the USAF hesitates to send manned aircraft, clearly signals that there is a need. While the Air Force leadership makes clear their point of not having blind devotion to unmanned systems, General Jumper, during testimony on the 2004 defense budget, told the senators the MQ-9 Predator B will provide "great leverage" on the battlefield.[70] In 2004 alone the budget has the USAF buying 10 of the larger Predators that, according to DOD's "Unmanned Aerial Vehicles Roadmap," will be able to carry up to 10 missiles and loiter above a combat zone for 30 hours.[71] With combatant commanders clamoring for platforms with the persistence and firepower capabilities of the Predator, it would appear the answer is a resounding affirmative that UCAVs are an inevitability for DOD's future viability.

VI. Conclusion: Where Do We Go from Here?

> *Our vision is one of a fully integrated force of manned, unmanned and space assets that communicate at the machine-to-machine level, and deliver a capability to conduct near-instantaneous global attack against a range of threats and targets.*[72]
>
> --Dr. James G. Roche, Secretary of the Air Force

The on-again, off-again relationship of UAV development in this country has been directly tied to warfighter's needs during conflict and limited budgets during peacetime. For the first time this cycle appears to have changed. Development gathered momentum in the years leading up to Desert Storm and has been rapidly accelerating since the end of Operation Allied Freedom in 1999. Does this mean UAVs will continue to garner the necessary attention and funding to become a first-string player? One can hope so. The issue of complexity and cost may cause them to come under fire if a more concise and realistic CONOPS is not spelled out quickly.

For the near future, a mix of manned and unmanned systems will work in concert to accomplish the mission, but within 10-15 years the UCAV should be capable of undertaking multiple missions with minimal approval from a ground or airborne monitoring station. The mission will be done with multiple platforms sharing targeting data, working coordinated attacks on both known sites and targets of opportunities. The desire for persistent coverage and quick reaction time for targeting mandates long loiter times, necessitating the requirement for ultra-endurance but not necessarily in-flight refueling capability, if the "need" for a stealthy platform is relaxed.

Most of these missions fall under the dull, dirty, and dangerous category, which should re-emphasize the desire to keep the cost down, but not by trading off required capabilities. Future UCAV development needs to strongly emphasize the sensors and weapons vice the platform that carries them. The desire is to be able to find the target or air defenses and then destroy or neutralize it long enough to ensure the safe passage of a strike package. Concentrating efforts on making synthetic aperture radar that works reliably with automatic target software to find and identify targets will be key in reducing the bandwidth required for controller inputs. The payoff in continued emphasis on laser and microwave weapons will mean a near instantaneous precise kill capability, whether onboard the UCAV that finds the target or is cued from another nearby vehicle.

The need to migrate some missions to UAVs and UCAVs appears clear for cost, mission effectiveness, and risk mitigation. What isn't clear is whether the current DOD path will get us there. In reality, technology is available today to begin migrating missions like SEAD and EW to a UCAV, with the caveat that manned platforms will still be required as a supplement for the near future. However, the military must not allow requirements creep to price UCAVs out of business. The fear is that a good design will become so overloaded with sensors, weapons, and missions that it will become too expensive to build or too valuable to use and risk losing in combat.[73] Keeping cost down is a critical issue for UCAV, not just in terms of how many can be purchased, but whether they'll be allowed to operate in the environment they're designed for fear of losing one.

The recent proliferation of UAVs on the battlefield is in direct response to the requirements of the commanders for capabilities that aren't available or done as well with manned platforms. The large increase in funding allocated to these combat systems will help accelerate their development in the hope that they can take on some of the more dangerous missions. SEAD and EW missions are a great jumping off point for UCAV, since they can be made autonomous more easily than others while reducing the risk to aircrews. A SEAD and EW UCAV holds great promise for helping gain and maintain air superiority while ensuring that the strike packages can do their mission without distraction. The trick is to set future systems up for success by more closely defining what is needed for the mission and not overload a single vehicle with every mission and capability.

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