

Unmanned Combat Aerial Vehicles: Transformation of the USAF

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Unmanned Combat Aerial Vehicles: Transformation of the USAF

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Executive Summary

Title: Unmanned Combat Aerial Vehicles: Transformation of the USAF

Thesis: *The United States military should explore multiple types of Unmanned combat Air Vehicles (UCAVs) to deal with the realities of casualty aversion and increasing battlefield lethality, but should procure simple and expendable platforms now while developing more sophisticated, high technology unmanned strike aircraft for the future.*

Discussion: There are several reasons to adopt unmanned attack aircraft. Casualty aversion and increasing lethality of ground based air defense are the most prevalent. There is a strong requirement for all services to address these issues as they develop new technologies and look to the lessons of Desert Storm, and Kosovo. Emerging design technology coupled with a proliferation of real time intelligence information is making manned attack aircraft obsolete and too expensive.

Of course, there are arguments against UCAVs; they may be technologically unworkable, decrease operational flexibility, increase fratricide risk and may be unnecessary given other similar weapons or even space based weaponry.

Conclusion: The arguments for UCAVs outweigh the ones against; however, we must ensure that tactical, expendable UCAVs are developed in conjunction with other manned weapons systems and new munitions. The USAF should pioneer the eventual development of a sophisticated long range UCAV, while all services pursue less expensive unmanned platforms to meet service requirements.

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The United States military should explore multiple types of Unmanned Combat Air Vehicles (UCAVs) to deal with the realities of casualty aversion and increasing battlefield lethality, but should procure simple and expendable platforms now while developing more sophisticated, high technology unmanned strike aircraft for the future.

A UCAV is a self-propelled aircraft that sustains flight through aerodynamic lift, is *re-useable*, unmanned, and capable of delivering lethal force. A UCAV differs from an Unmanned Aerial Vehicle (UAV) as a UCAV is a lethal weapons system, and a UAV is not. Currently all branches of the armed forces fly UAVs as reconnaissance aircraft, but future wars may see a great increase in armed unmanned aircraft.

There are many reasons to pursue this technology. Certainly, Americans are extremely casualty averse. Surface to air missiles (SAM) are also becoming more lethal, and there is a need to quickly locate, identify, decide and kill significant targets protected by these SAMs, These factors, along with other emerging technologies, also make UCAVs appealing to all branches of the armed forces. Various weapons, like cruise missiles, have already removed humans from the "tip of the spear" and in some cases humans slow the engagement process. Similarly, manned aircraft are approaching their performance limits, as human physiology limits the flight envelope. Finally, UCAVs are potentially less expensive than manned aircraft and other current weapons. In the national interest, the Department of Defense (DoD) should take steps to keep the United States at the forefront of UCAV technology—and some lawmakers are pushing this. Recently, Congress proposed House Resolution 4205, which directs the DoD to "achieve the fielding of unmanned, remotely controlled technology such that by 2010, one third of the aircraft in the operational deep strike force fleet are unmanned and by 2015 one third of

the operational ground combat vehicles are unmanned."¹ The Air Force, as the service with ownership of the "deep strike force aircraft," should work at fielding viable UCAV technology, and there are many reasons to support this position.

The arguments favoring UCAV technology are strong and start at the national level. In today's conflicts, an American serviceman's loss or capture focuses the nation's attention to an amazing degree—military action in the information era entails considerable political risk. Casualty aversion is a big issue in Washington, and even the Senate Armed Services Committee stated, "The American people are coming to expect that military operations are *casualty free*."² By illustration, when an SA-6 SAM shot down USAF Captain Scott O'Grady over Bosnia in 1995, Americans anxiously awaited news of the downed flyer, and networks cut to special bulletins when Marines rescued him. Two months later, the Serbs shot down a Predator UAV in the same area, and the incident escaped the notice of the majority of Americans.³ Socio-political arguments aside, there are strong military reasons that favor UCAVs.

First, something is needed to counter the increasing ground based threat—and UCAVs may be part of the solution. The airspace over the modern battlefield has never been more lethal, with the historic trend favoring the attacker (aircraft) swinging back to the defender (air defense). There is an ongoing proliferation of increasingly lethal Surface to Air Missiles (the SA-10, SA-12, SA-18 and Roland⁴) protecting the enemy's most lucrative targets. These weapons can create "no fly" areas for manned aircraft on the first day of combat. Some of them are so sophisticated and lethal that they must be attacked by 1.4 million dollar⁵ cruise missiles rather than manned aircraft. Elaborate strike packages consisting of electronic jammers and other "wild weasel" Suppression of

Enemy Air Defense (SEAD) aircraft, all designed to neutralize or destroy the SAM threat, can suppress less sophisticated SAMs. However, hand held SAMs and simple gunfire can have a great impact on low flying aircraft. Certainly, Stinger missiles challenged Soviet air supremacy over Afghanistan and lessened the impact of helicopter gunships. The enemy's mobile weapons, particularly the sophisticated PATRIOT equivalent Russian systems, create "wild card" threats that can decimate incoming strikers, transports, or helicopters, and make hitting unplanned, high payoff targets risky.

The armed forces of the future must be able to quickly locate, identify, decide, and destroy unplanned targets of opportunity, and UCAVs can play a key role in shortening this engagement cycle. Theoretically, a UCAV can conduct "killer scout" missions and strike with impunity targets it detects or receives from offboard sources, such as JSTARS. Manned aircraft can do the same thing, but require more intelligence to locate ground threats and electronic support to suppress them—this is simple prudent mission planning and execution for a package commander. On the other hand, a UCAV should be able to move in and kill a target in a much riskier situation, dashing into a high threat area at low altitude, potentially into the heart of an unlocated SAM envelope. UCAVs should interest the other services as well.

In general, the UCAV mission is of interest to all ground forces. During Desert Storm, coalition pilots flew with a floor of 10,000 feet before the ground campaign to avoid the teeth of enemy SAM and AAA defenses. From two miles up aircrews had difficulty locating tanks and mobile ground targets, and because target coordinates were sometimes derived from old intelligence photography, aircraft were occasionally sent to kill ground forces which had long since redeployed.⁶ During the 1999 air campaign in Kosovo, the

Joint Force Air Component Commander, Lieutenant General Michael C. Short, told of an incident in which a low flying Predator detected tanks hidden under trees and air operations center personnel tried unsuccessfully to vector a flight of A-10s to the target. The story could have been different had the Predator been armed.⁷ The acquisition of new DoD weapons systems will create new challenges for planners of all services.

The Marines are acquiring the V-22 Osprey, an airframe which allows rapid, operational level assault of targets deep inside hostile territory. Such assaults will often be time critical and intelligence sparse, with a substantial but unlocated ground to air threat. A ship borne UCAV will allow an armed reconnaissance into enemy territory, with imagery sent back to the assault force. UCAVs could destroy SAMS and other high payoff targets along the Osprey ingress route while providing battlefield imagery to the assault force. The idea of a naval UCAV should appeal to the Navy.

Naval aviators as well as surface warfare officers should consider UCAV development as a way of enhancing power projection. Small UCAVs on a carrier could allow more punch for the airwing by consuming less deck and hanger space and reducing the requirement for specialized reconnaissance and attack aircraft. Cruisers and destroyers could utilize tactical UCAVs to conduct a variety of anti shipping and littoral attack missions. While others services will benefit from UCAV research, it is the USAF that is most aggressively pursuing this emerging technology to perform deep strike missions. Specific UCAV proposals attempt to address these requirements.

For example, Boeing is designing a UCAV prototype (designated the X-45) with on-board sensors, such as sidelooking airborne radar and sensitive electronic gear to detect both threat weapons and targets of opportunity. As X-45 project manager, Colonel

William Leahy (USAF) stated, "[This particular] UCAV can operate much closer to its targets because of its reduced signature. This will allow for better target acquisition, (than manned aircraft or cruise missiles) and it will compress the time between the moment the decision is made to destroy the target and the moment the target is actually destroyed."⁸ Because of their potential to operate in high threat environments, UCAVs may be more flexible than current air vehicles.

A well- designed UCAV should adapt to all levels of conflict. At the low end of the conflict spectrum, as stated earlier, the National Command Authority is reticent to risk high profile American casualties and prisoners as a result of limited, one time strikes. At the high end of the spectrum, major theater war, the Air Force is rapidly moving toward a "system of systems" air war where technology is leaving the single pilot in the cockpit behind. To illustrate, consider that Link 16⁹ is going to transmit so much information over a 4X4 inch display that it will overwhelm a pilot whose priorities are aviate, navigate, and communicate. A ground based flight team may have higher situational awareness of the overall campaign, and thus be better modern warfighters. Several USAF documents support this concept.

Specifically, several years ago the USAF wrote its requirements to prospective bidders for a UCAV prototype. The original requirement called for the operator in a ground based mission control station to have an unbelievable amount of situational awareness, much more than a pilot in a single seat strike aircraft. Here is a sample of the original requirements document from the DoD's Defense Advanced Research Projects Agency (DARPA)¹⁰ to prospective civilian contractors¹¹:

"The control station should provide the appropriate levels of system, tactical, operational, and strategic levels of information. An extensive amount of information will be available to present the maximum amount of relevant intelligence in an intuitive format which permits accurate and timely

team and individual decisions, It shall have an interface with the JFACC via the command and control network for ATOs, realtime mission updates, and target folders. It should provide team members with real time situational awareness, tasking, targeting and threat ID through real time intelligence sources or operational links within the projected 2010 C4I infrastructure"

By implication, it seems the Air Force is admitting that ground based operators could be much more effective than single seat aircraft, at least in terms of processing copious digital information. But what of the accountability issue when weapons are fired?

Some airmen and military commentators argue that the man in the loop is crucial to weapons release, that "machines cannot be held accountable for collateral damage and fratricide." However, current and proposed weapons systems, and USAF decisions, may have effectively taken decision makers out of the loop already. Today's cruise missiles, once launched, are autonomous and non-recallable during hundreds of miles of flight to the target. Proposed munitions like the Low Cost Autonomous Attack System (LOCAAS) are small (one meter long), inexpensive and autonomous attack aircraft that search, detect, identify and destroy a variety of targets from SAMs to tanks and other ground mobile targets.¹² In other words, the man in the loop argument is specious—at least according to the pro-UCAV school. Similarly, there are many technological arguments that favor UCAVs.

Technology may give UCAVs the ability to leave manned aircraft behind, at least for some missions. Modern fighter aircraft are driven by a major design constraint: they must have a cockpit which allows 360 degree visibility, so it must be placed high on the airframe with a large bubble canopy. This in turn drives engine placement, the need for large vertical stabilizers, and increases the minimum aircraft size.¹³ Simply, manned

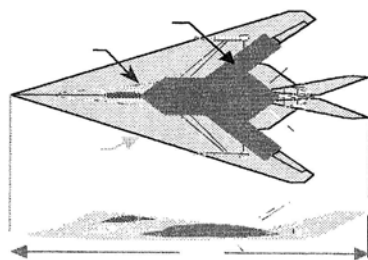


Figure 1: X-45 Size Comparison

Overlay showing the X-45 in bold, the F-16 and the F-117 around the perimeter

aircraft are difficult to make non-angular and thereby stealthy. The Boeing X-45 is two thirds the size of the F-16 and much more difficult to detect (See Figure 1), and almost all conceptual UCAVs are tailless, which makes them less reflective to radar with less use of expensive and sensitive Radar Absorbant Material (RAM).

Another capability that makes unmanned vehicles more survivable is maneuverability; manned airframes are limited to 9 G's by human tolerance, and unmanned are comparatively unlimited. In designing a UCAV, Lockheed Martin reports that they could make the aircraft pull 20Gs, while remaining stealthier and 40% smaller than a conventional aircraft of equal performance.¹⁴ Their conceptual UCAV would evade the enemy using a combination of low observable technology and violent maneuverability. In summary, technology may favor the UCAV depending on desired mission. Integral to this argument is the cost factor; UCAVs are less expensive.

Several factors could make UCAVs more economical than competing weapons. First, manned strike fighters require a massive support infrastructure of counterair, surveillance and SEAD aircraft as well as search and rescue forces. Indeed, a huge percentage of the Air Force's Tactics, Techniques and Procedures Manual that deals with Combat employment¹⁵ discusses protection of a strike package, and combat search and rescue. Conversely, UCAVs are unmanned and thus should be expendable in combat.

Expendability is inversely related to cost. One interesting possibility involves the recent test pairing of the Predator UAV with the AGM-114 Hellfire antitank missile. The combination destroyed a stationary target in benign circumstances (low altitude, perfect weather, no opposition) in early 2001. Predator is a proven, if slow and vulnerable, potential UCAV platform that is cheaper, thus more expendable than either an A-10 or AH-64.¹⁶ Costs of pilots could be reduced as well.

Pilots of unmanned aircraft can use simulators to train, thereby decreasing operations and maintenance costs associated with maintaining flying proficiency. Due to this decreased training requirement, UCAVs could be "cold stored" and the pilots trained on simulators. When needed, strategic airlift could haul UCAVs to the appropriate theater. For of these reasons, designers tout the X-45 as costing one-third the flyaway cost of the JSF¹⁷. More conservative officers propose simpler alternatives.

Some USAF officers have proposed modifying "retired" A-10 and F-16 airframes (from the Davis-Monthan AFB storage yard) and creating dual-use manned / unmanned attack aircraft.¹⁸ After considering this concept, one company in Texas drafted a concept for "unmanning" A-10s and developing comparatively low cost UCAVs, and Lockheed Martin has stated they can convert F-16s to dual use manned / unmanned aircraft for less than \$600,000 per aircraft.¹⁹ Institutionally, the USAF does not seem interested in this approach, although it does offer the promise of inexpensive UCAVs which come with maintainers, ordnance troops, and pilots. Building a dual use aircraft also solves the safety issue involving UCAV operations in the United States (discussed in the next section), and allows for manned deployment of the aircraft to theater using existing bases and tankers. There are some who say that this approach is a threat to the concept of

manned flight and may not be an acceptable option; indeed, many question the validity of the UCAV concept.

There are valid arguments against the arming UAVs. For example, there are operational and technical issues associated with UCAVs that may be insurmountable. First, the operational issues alone may be difficult to overcome. Specialized aircraft such as UCAVs may be the antithesis of flexibility. Today's attack aircraft can fight their way to a target with medium range air- to-air missiles, make snap engagement decisions, drop ordinance, and egress based on a changing threat environment. A UCAV would be hard pressed to flex from a strategic attack mission to a Close Air Support (CAS) mission based on a distress call from a special operations forces team, as happened during Desert Storm. It cannot render assistance using hand signals to an aircraft that has had its communications shot out, or electronically identify and kill a "get through" MiG at 10 miles. There are also safety issues.

The safety concerns with UAVs and UCAVs are considerable; integrating high flying, high speed deep attack UCAVs with manned aircraft in a strike package will prove extremely difficult, with midair collisions a significant concern. "Putting a TV camera" in the UCAV may not be the ideal solution unless the datalink to the ground station is secure and completely reliable, the flight control inputs quick, and the communications bandwidth available, The Federal Aviation Administration (FAA) has placed many restrictions on UAVs because they cannot reliably "see and avoid" large, non-maneuvering civilian airliners²⁰--at least not yet. Similarly, some argue human judgment at the point of attack is indispensable.

Another concern is obvious, and that is a man on the scene is the best decision maker in a dynamic tactical situation, namely the "fog" of war. Humans can assimilate visual, auditory, and electronic data and determine a course of action in accordance with commander's intent, all while injured and functioning at less than full capacity.

A human decision maker is arguably the best one to decide whether or not to employ lethal force, and the one who is accountable for such action, particularly when troops are in close proximity. Weaponizing the Predator creates Joint issues—is the Predator pilot accountable for fratricide in a Close Air Support (CAS) situation, and does he have the situational awareness to hold him accountable? Some officers at the UAV Battlelab²¹ conclude that the answer to the above questions is "yes"²², but what happens during a deep attack UCAV mission when positive control (telemetric guidance which ensures the aircraft does as directed) is lost? One author who has written extensively on the subject of UCAVs concluded that, "[they] should operate in a semiautonomous mode; there must be a man in the loop to authorize weapons delivery (due to the risk of fratricide),"²³ Interestingly, the X-45 Concept of Operations calls for a limited and even *full autonomous* capability for the UCAV in the event datalink with the ground is lost²⁴.

There are numerous technical challenges to fielding an effective UCAV. First, there are the conflicting needs for positive command and control, and the requirement for autonomous operations—the two concepts are inversely related. Positive control of a UAV requires a sophisticated datalink. At a minimum, a UCAV must be receptive to change in target, a veto of weapons release, reactive to unanticipated threats and able to avoid collision with other aircraft. Naturally, datalinks create vulnerabilities, as the link is susceptible to jamming, deception, and simple failure brought on by the harsh airborne

environment (extreme temperature differences, moisture, battle damage, vibration, speeds and G forces). Satellite datalinks will be vulnerable to attack as will ground control stations. Thus, designers must reconcile the need for positive control with the reality that the datalink tether, the enabler of such control, may be a critical vulnerability. Another serious problem is flight path deconfliction. The UAV Battlelab is working to incorporate Link 16 reception into the UCAV in order to ensure that it will in effect "see and avoid" other friendly and potentially unknown aircraft.²⁵ However, currently only a few fighters (some F-15C, F-14D and British GR-1) and command and control aircraft (E-3, E-8, E-2) are Link 16 capable, and again, this link is susceptible to failure, time delays, and simple human errors in loading crypto.

These are just some of the potential technical problems with UCAVs; others include possible problems with satellite communications, frequency allocation, flight control, etc. In the past, UCAVs have always shown great potential, but the technology was not available. In WWII, the United States Army Air Forces experimented with radio controlled B-17 Flying Fortress bombers which were guided to target. All of them were shot down, crashed, or hit the wrong targets due to inaccurate navigation.²⁶ In the end, technology was unable to fulfill the vision. Besides the technical problems, there are those who question the necessity for UCAVs, given alternative technologies. Current and emerging weapons may make UCAVs unnecessary. For example, they may have to compete with the cruise missile. The cruise missile has the obvious advantage of being a fire and forget weapon that can kill almost any "soft" target (SAM radar, troops, ballistic missile, building. etc.) from existing aircraft. A flight of four B-52's armed with penetrating-warhead Conventional Air Launched Cruise Missiles

(CALCMs)²⁷ would be able to react to external cueing from the JFACC to kill targets quickly and from a safe distance. Similarly, standoff weapons such as the Joint Standoff Weapon and the Joint Air to Surface Standoff missile are deliverable from current aircraft, Other rocket assisted bombs, like the AGM-130 are accurate, very deep penetrating, guided by a bombardier, have a range greater than 25 miles and have been used extensively in combat. One emerging technology that may offer the most promise is space based weaponry. Given the historical enthusiasm for space based strategic defense displayed by the current Secretary of Defense, Donald H. Rumsfeld, it seems logical that weaponization of space is a logical next step. Certainly, space based weaponry can render SAMs obsolete. Finally, Congressional pressure to purchase JSF may make UCAVs politically undesirable. The JSF meets many of the concerns raised in this section, and its acquisition will surely please Congressional constituents. Why, then should the Air Force pursue UCAV technology, and become a UCAV centric service?

In debating UCAV utility, it is useful to ask several questions. First, what is the vision for the USAF of the future? Second, what does the service want to achieve using UCAVs, and what UCAV technology is available to help achieve that objective? Third, what are the strengths and weaknesses in relation to the objective? With answers to these questions, recommendations then can be made on if and how to proceed.

The USAF must keep in mind that it needs to remain at the forefront of aeronautical innovation in the nation's interest, even if the solutions favor "grounding" aviators. A former Air Force Chief of Staff stated in 1997 that "lethal UAVs will not fly for at least 25 years"²⁸. Recent Predator / Hellfire demonstrations proved him wrong, and UCAV technology is an issue today. The question is, what does the service want UCAVs to do?

In assessing UCAV proposals, the Air Force should ask what it wishes to achieve. If it wishes to use them for low end "punitive" missions against non-hardened specialized targets (terrorist camps, WMD facilities), they potentially compete with cruise missiles, which means collateral damage avoidance along with overall cost may be the greatest measures of merit. Certainly, if commanders can retarget cruise missiles in flight and arm them with a variety of munitions, including penetrating warheads, the UCAV as defined may be unnecessary. If the USAF wants to use UCAVs in more intense support roles, such as knocking out key command centers and SAM sites, the technology becomes more challenging. These missions, "force enablers", augment the manned force on high risk missions and place the UCAV in competition with aircraft such as the F-117 and perhaps the F-16CJ SEAD aircraft. This role is more demanding and requires the service to think about an adaptive enemy who will jam and deny the C2 datalink to the UCAV. The most challenging UCAV mission would be to act as a replacement or alternative strike aircraft, which could be tasked for a variety of missions across the spectrum of conflict, and anywhere on the battlefield. Here, UCAV might compete with the Joint Strike Fighter. Then again, simple and relatively unsophisticated UCAVs might be seen as complementary to existing and proposed weapons systems. Perhaps the simplest and most appropriate for the UCAV is an armed tactical reconnaissance aircraft—a simple and expendable support platform that can employ a variety of weapons from anti personnel munitions, to antitank missiles, to LOCAAS type smart weapons. Such platforms, although not as prestigious as the proposed X-45, can be developed with today's technology.

There are several characteristics of UCAVs that merit discussion. The first one is expendability. The lack of a pilot allows the JFACC to place a UCAV into high risk situations; a Predator with a Hellfire falls into this category. Of course, the more survivable a platform, the less expendable it may become. A high tech, multimillion dollar, UCAV coated with the latest RAM, with a sophisticated countermeasures suite and artificial intelligence software may be highly survivable, but cannot be written off easily as the cost of doing business. The F-117 lost in Kosovo was 'just one aircraft', but the technology transfer to the Russians and Chinese damaged America's greatest asset, our technological edge.

Closely related to the "expendable / survivable" paradigm is cost—Congress wants a less expensive yet more capable platform. The JFC should expend UCAVs as needed to accomplish the mission without losing valuable national assets; on the other hand, a cheaply built platform is probably not survivable in a high threat environment.

Another related concern is centralized versus decentralized control. With centralized control, the risk of fratricide or collateral damage is reduced, and both are concerns with unmanned aircraft. With decentralized control, the risk of midair collision, fratricide, and erroneous targeting all increase, but the critical C2 datalink vulnerabilities diminish as well. The above discussion is summarized in figure 2.

According to this continuum, the Predator / Hellfire (or any purpose built CAS UCAV) would fall to the left, and the X-45 would fall to the right. The left end of the spectrum is the evolutionary school of thought, the right end revolutionary. The USAF should take the conservative course of action as a step toward a revolution.

In summary, the Air Force needs UCAV technology to adapt to the political and military realities of the future battlefield. First, this technology should include tight and constant control for flight safety and fratricide prevention reasons. Next, the USAF's first operational UCAV be expendable, not so sophisticated that it cannot be risked—why else build one? Third, the UCAV should be simple, an initial stepping off point into a larger unmanned force; it should complement rather than threaten to replace fighter and attack aircraft currently under development. The reasons for this are twofold; the USAF does not want to pay the price of an extremely ambitious but unfeasible failure (potentially the X-45) and needs an interim UCAV to perform armed reconnaissance missions today. Fourth, the UCAV needs to be compatible with manned aircraft if it is to be a force enabler.

There should be no doubt that the DoD should continue to develop UCAVS. UCAVs answer the increasing threats of SAMs and casualty aversion. They are less expensive and potentially offer higher performance than manned aircraft. The USAF and all the services should all look to maximizing the use of unmanned technology across the UCAV continuum, and avoid the temptation to make a "bold leap of technology" and attempt to field a overly ambitious X-45. Tactical Predator UCAVs, reprogrammable cruise missiles, LOCAAS, and stand off weapons should be fielded in parallel with development of sophisticated unmanned strike aircraft. All of the above weapons are needed on the future battlefield and should not compete with each other. In fact, because all services have a need for UCAVs, all should pursue inexpensive tactical technology separately, but the USAF should take the lead on the replacement strike aircraft of the future, as the owner of the "deep strike" mission.

ENDNOTES

¹ United States. House of Representatives. *Unmanned Advanced Capability Combat Aircraft and Ground Vehicles*. HR. 4205, 2000, No reasons were cited for the "one third" figure.

² Sherman, 14

³ Clark, 1

⁴ These SAMS are mobile, difficult to detect and suppress. The fact that they are mobile makes them difficult to detect, and they can appear at anyplace on the battlefield. The SA-10 and 12 are Russian made, long range weapons comparable to PATRIOT, where the Roland is a short range system built by the French and Germans. Fortunately, only the Roland has been widely exported. The best counter for the SA-10 and 12 may be to avoid it, thus achieving the missile's sole purpose, target defense,

⁵ Nick Cook, "Leaving the Pilot on the Ground" *Jane's Defense Weekly*, 3 July 1996, 34

⁶ Tom Clancy with Gen. Chuck Homer, "Every Man a Tiger", 416

⁷ Lt Gen Short relayed this story at Air Command and Staff College in the year 2000.

⁸ Clark, 55

⁹ Link 16 is a secure, jam resistant time share datalink that transmits the tactical picture. Track locations are actively transmitted by the actual aircraft in question, or sent out based on radar returns, for example from AWACS.

¹⁰ DARPA, or Defense Research Project Agency, is a DoD run organization that manages research and development of innovative, high risk ideas that go well beyond the normal evolutionary developmental approach.

¹¹ UCAV System Capability Document. (9 March 1998). (On line). Appendix A, 7. File www.arpa.mil/tto/ucav/ucavappen.html

¹² Clark, 49

¹³ Cook, 34

¹⁴ Cook, 35

¹⁵ AFTTP3-1, Volume I.

¹⁶ Major "Duke" Odom, project officer at UAV Battlelab, interviewed by author, 15 Mar 2001.

¹⁷ No side by side "flyoff" between the X-45 and JSF has been performed. Leahy, 10 Jan 2001

¹⁸ Major Kenneth Thompson, *F-16 Uninhabited Combat Air Vehicles*, 1998. Unpublished manuscript, Air University

¹⁹ Thompson, 27

²⁰ Damian Kemp, "Low Profile UAVs Set Air Traffic Riddle" *Jane's Defense Weekly*, 16 July 1997, 28

²¹ The UAV Battlelab is located at Eglin AFB, Florida, and was created in 1997 to look at ways of integrating UAVs into the Air Force.

²² Odom, 15 March 2001.

²³ Clark, 73

²⁴ Colonel Michael Leahy, Project Officer for UCAV at DARPA, interviewed by author, 10 January 2001

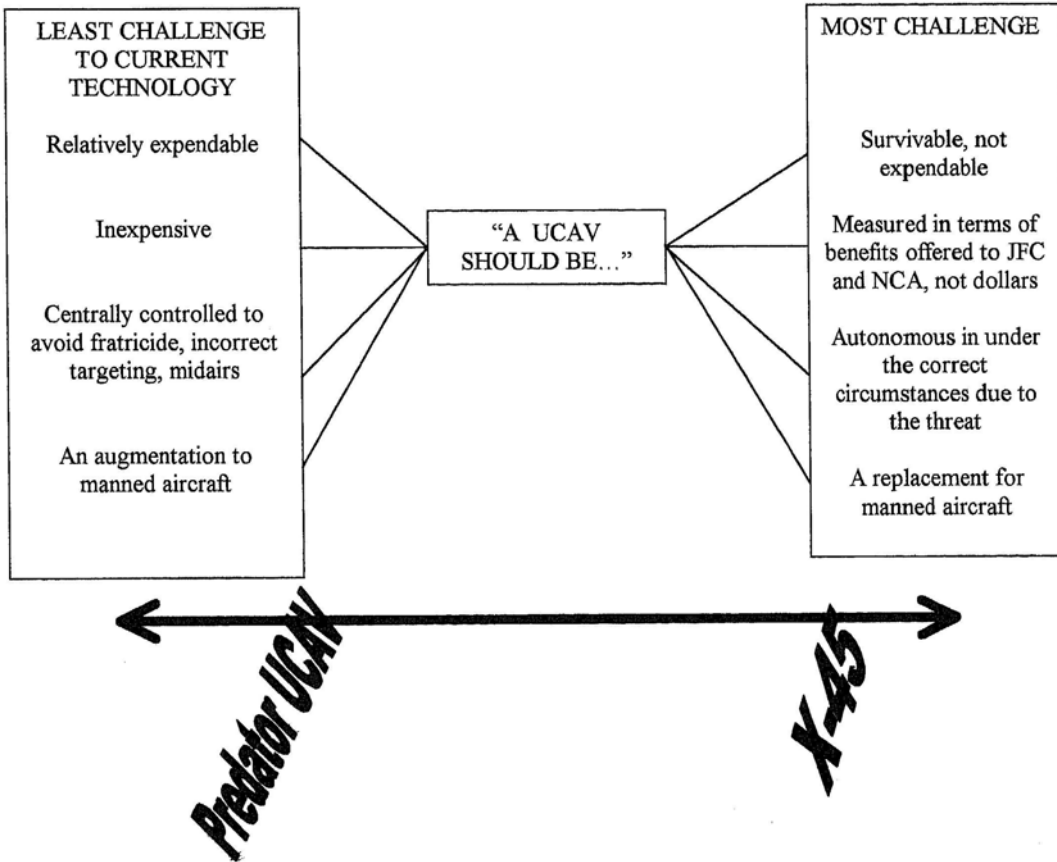
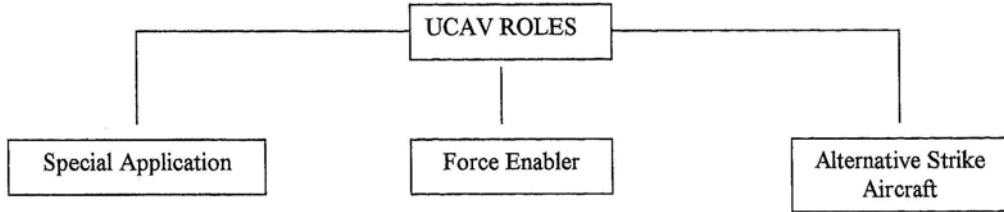
²⁵ Major Grilly, Action Officer at UAV Battlelab, interviewed by author, 15 March 2001

²⁶ Clark, 10

²⁷ CALCMS are currently capable of killing soft targets only—they airburst.

²⁸ Mark Walsh, "Battlelab of Drones That Can Kill" *Air Force Times*, 28 July 1997, 27

Figure 2: UCAV Continuum



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