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F-16 UNINHABITED AIR COMBAT VEHICLES

by

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Disclaimer

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Abstract

The U.S. Air Force is actively pursuing unmanned aerial vehicle (UAV) programs for surveillance and reconnaissance missions. However, the Air Force has not funded any substantial research into bomb or missile carrying "lethal" UAVs, also called uninhabited combat aerial vehicles (UCAVs), despite the recommendations of the USAF scientific board's *New World Vistas*, DARPA, and the *Air Force 2025* project. With budget constraints and a reluctance to transition to an unmanned combat force, new advanced technology UCAVs are decades from operational status.

In the meantime, the U.S. needs to quickly field an interim UCAV program for political, economic and military reasons. An interim UCAV will provide another unmanned military option for U.S. leadership that currently relies on cruise missiles to deal with conflicts where the loss of American lives is politically unacceptable. Economically, a reusable UCAV is more cost effective in the long run than a one shot million dollar plus cruise missile. Militarily, cruise missiles have ordnance and target limitations that are overcome by the variety of weapons employed by a UCAV and its "man in the loop" capability. An interim UCAV is needed now to provide U.S. leadership with another unmanned military option.

By modifying the multi-role F-16 fighter into an unmanned aircraft, the USAF can quickly provide a cost-effective interim UCAV. Lockheed Martin has suggested the modification of "boneyard" non-flying F-16 A-models into UCAVs. An investigation of

this idea yielded several limitations and concerns that led to the formulation of an alternative F-16 UCAV proposal.

Many of the limitations, concerns and costs associated with the Lockheed Martin F-16A proposal are eliminated or reduced by modifying currently flying block 40 and 50 F-16Cs in operational squadrons. With the addition of remote control equipment, a few squadron jets are converted into “dual role” aircraft. The selected dual role F-16Cs can continue to fly as normal “manned” aircraft or, if needed, as unmanned remotely piloted UCAVs. Converting a few block 40 LANTIRN laser targeting pod equipped and block 50 HARM targeting system equipped F-16Cs in operational squadrons to dual role UCAVs will quickly provide a cost effective and capable interim unmanned military option.

With low modification costs, no new infrastructure requirements, and no need for additional pilots or support personnel, the USAF should immediately start the development, testing and conversion of a few F-16Cs into dual role UCAVs. As an interim unmanned military option, the F-16C UCAV will provide valuable insights and lessons for future advanced technology UCAV development and operations. In addition, a successful interim F-16C UCAV program will help the psychological transition to unmanned combat aircraft operations for the “white scarf” Air Force.

Chapter 1

Introduction

> *New World Vistas also "got too focused" on high-performance unmanned fighters. I think UAVs are moving in the right direction—that is, initially, we'll use them for intelligence, surveillance, reconnaissance and hopefully for longer dwell, greater survivability kinds of things. In the longer term, though, we'll have to look at whether a "smart" UAV is really the way to deliver weapons.*
>
> —General Ronald Fogleman, USAF Chief of Staff[1]

> The first wave of inexpensive unmanned aerial vehicles (UAVs) with radar reflectors flew north drawing the attention of enemy AAA and SAM acquisition and fire control radars. A few miles behind them were more UAVs carrying small explosive charges that detected the enemy radar frequencies and guided towards the emitters destroying them on impact. With the radars destroyed, waves of manned fighters and bombers flew virtually undetected into enemy territory without the loss of a single aircraft. This scenario sounds like the beginning of a Tom Clancy novel or the dreams of a current Air Force SEAD planner. However, this is exactly what happened in 1982 when the Israelis successfully used Scout and Mastiff UAVs against the Syrian air defense system[2].

Current U.S. Position on UAVs

Prompted by Israeli UAV successes in 1973 and 1982 and more recently, the remarkable performance of the Israeli built Pioneer UAV flown by the U.S. military in Desert Storm, the Department of Defense is actively pursuing military UAV systems. Starting with sub-scale drones in Vietnam, the DOD effort has focused primarily on surveillance, reconnaissance and suppression of enemy aircraft defense (SEAD) missions for UAVs. A major step for UAV programs occurred two years ago when the USAF started its first UAV operational squadron in Las Vegas, Nevada flying the medium altitude Predator surveillance and reconnaissance platform.

Figure 1. Predator Medium Altitude UAV

The USAF is researching future ideas for UAVs using a "battlelab" at Eglin AFB, Florida. However, the Department of Defense, in particular the USAF, has not funded any substantial research into a bomb or missile carrying unmanned air vehicle or lethal UAV. The USAF scientific advisory board's *New World Vistas* report, the Defense Advanced Research Projects (DARPA) office, and the *Air Force 2025* project have all called for the rapid development of lethal UAVs or uninhabited air combat vehicles (UCAVs). Military planners, industry experts and scientists all agree that "off the shelf" technology is adequate to field an effective lethal UAV platform. Yet, USAF leadership is reluctant to trust an unmanned remote control aircraft with the responsibility of dropping bombs or shooting missiles. Along with defense budget cuts and competition from the manned F-22 Raptor and Joint Strike Fighter (JSF) programs, the operational fielding of new technology UCAVs is decades away. Last year, both USAF Chief of Staff, Gen. Ronald Fogleman and Eglin UAV Battlelab Commander, Col. Joe Grasso, stated that lethal UAVs would not fly for at least 25 years.[3]

In the meantime, U.S. military and political leadership must rely on cruise missiles to deal with conflicts where the potential loss of American lives is unacceptable. Today, sea and air launched cruise missiles are the only offensive military instruments of power (IOPs) guaranteed not to produce U.S. casualties or POWs. However, cruise missiles have ordnance limitations that restrict them to attacking only "soft" targets such as radar antenna dishes or aircraft on a runway. Current cruise missiles cannot destroy important "hardened" military targets such as concrete bunkers, underground facilities, bridges, runways or armored vehicles. In addition, the 1.2 million-dollar expendable cruise missile is unable to hit mobile targets because its accuracy depends on the programming of correct target coordinates before launch.

Because of cruise missile target restrictions and the high costs associated with a "one-shot" delivery platform, U.S. leaders need another unmanned military option today that can destroy most potential enemy targets and is reusable for cost effectiveness. UCAVs can provide this additional unmanned military option to cruise missiles. Yet, as previously stated, new advanced technology UCAVs are decades from operational fielding. Can the USAF quickly provide a cost effective UCAV option to U.S. leadership in the interim?

Research Thesis and Overview

The USAF can quickly provide a cost effective unmanned military option by modifying some F-16C fighters into dual-role UCAVs. The multi-role F-16 is a combat proven air to air and air to ground fighter platform that can perform all air power missions with its capability to carry almost all of the USAF bomb and missile inventory. Slightly modifying an F-16C for unmanned flight while maintaining its manned flight capability gives the USAF most of the advantages of UCAV operations and reduces or eliminates many unmanned flight concerns. A remotely piloted dual role F-16C UCAV can quickly provide a politically safe, cost effective, and flexible unmanned military option for U.S. leadership.

An important prerequisite for this thesis is proving the U.S. now needs an additional unmanned military option to cruise missiles. Therefore, this paper will present arguments on why U.S. leadership quickly needs an interim UCAV option before exploring the F-16C UCAV proposal. The objectives of this paper are to 1) provide UAV background with advantages and concerns related to unmanned flight, 2) explain why the U.S. needs an interim UCAV military option, 3) compare two F-16 UCAV proposals, and 4) recommend the dual role F-16C UCAV. In summary, this paper addresses two important issues. First, the U.S. needs an interim UCAV option to overcome cruise missile limitations as soon as possible and second, a dual role F-16C UCAV can quickly and effectively fulfill the requirements for this interim unmanned military option.

Review of Related Literature

Those unfamiliar with unmanned aircraft can become quickly confused with the numerous terms and acronyms for remotely piloted aircraft such as drones, unmanned aerial vehicles (UAVs), unmanned tactical aircraft (UTAs) and uninhabited combat air vehicles (UCAVs). Drones, such as the full-scale QF-106 and the sub-scale BQM-74, are normally considered practice targets for air to air missile training or testing. UAVs, such as the Predator, Global Hawk or Darkstar, conduct medium to long range surveillance and reconnaissance. For low altitude, short-range "tactical" surveillance and reconnaissance, the Army and Marine Corp use UTAs such as Pioneer and Pointer. This paper is primarily concerned with UCAVs or "lethal" UAVs that carry offensive bombs or missiles.

History of UAVs

Unmanned aircraft are often thought of as relatively new inventions relying on advanced technology. However, the Sperry Company built two unmanned aircraft in the spring of 1918 that during test runs could accurately hit a target within 300 feet up to 40 miles away. To launch the "Bug" with its 300 pounds of explosive, the operator would point the aircraft with wind corrections towards a target and set the necessary engine revolutions required to fly the aircraft the proper distance. When the engine revolution timer stopped, hopefully over the target, the wings would fold up and 300 pounds of explosives would detonate on impact.[4] Over twenty years later during WWII, an improved version of the "Bug" became the first unmanned aircraft to use radio control guidance with a range of over 200 miles.[5]

Starting in the middle 1960s, the Ryan 147 series sub-scale drones flew over 3400 photo-reconnaissance missions over Vietnam with an impressive 84% success rate.[6] Due to its UAV achievements in Vietnam, the USAF started its Compass Cope project with Teledyne Ryan and Boeing competing to build a high altitude, long endurance UAV reconnaissance aircraft. Even though the 81-foot wingspan Teledyne Ryan UAV could carry a 750-pound payload at 55,000 feet for over 30 hours, the program was canceled in 1976 due to cutbacks in a downsizing post-Vietnam military.

Prompted by Israeli UAV successes in the 1973 war, the U.S. Army started its Aquila UTA program in 1974. After millions of dollars and 13 years of testing the 300 pound 13 foot wide unmanned tactical reconnaissance aircraft, the program was cancelled in a series of budget cuts in 1987.[7] Also impressed by the Israeli UAV results, the U.S. Navy, in 1985, selected the Israeli built Pioneer UAV for use as an over the horizon targeting system for its battleships. In 1989, both the U.S. Army and Marines were so impressed by the Navy's Pioneer UAV that they ordered several additional systems just in time for Desert Storm. Not one Pioneer was shot down in more than 300 Desert Storm missions that provided invaluable real-time intelligence on Iraqi positions. In addition, the Pioneer made headlines as the world watched camera footage of several Iraqi soldiers surrendering to the unarmed UAV.[8]

Figure 2. U.S. Navy Pioneer UAV Launch

Current Military UAVs

After the cancellation of the Army's expensive Aquila program, DOD set up the UAV Joint Project Office (JPO) in 1988 to consolidate UAV acquisition and development by the different military services. The UAV JPO helped write Joint Publication 3-55.1, Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles, to consolidate DOD service language and training. However, after spending more than three billion dollars and developing only one operational system, Predator, Congress terminated the UAV JPO in 1996 and UAV development programs transferred to the Defense Airborne Reconnaissance Office (DARO)[9].

Currently, there are no lethal UCAV prototypes flying and the DOD has funded few initial contractor proposals. Today, the sole mission for military UAVs is surveillance and reconnaissance with the USAF flying the Predator medium altitude UAV and the Army, Navy and Marine Corp still primarily using the Pioneer low altitude tactical UAV. To replace the aging Pioneer, two new UTA programs, Hunter and Outrider, are currently competing for DOD funding. The Army and Marine Corp have also acquired a few small hand-launched Pointer UAVs to supplement the Pioneer but its future funding is uncertain.

The USAF is funding research and development in the high altitude endurance (HAE) UAV area. Boeing has flown the stealthy Darkstar but a recent crash caused by a landing gear problem has put the program behind schedule. Teledyne Ryan has conducted successful taxi tests and is preparing to fly the Global Hawk in the spring of 1998. Table 1 on the next page is a program comparison between the Darkstar and Global Hawk HAE UAVs.

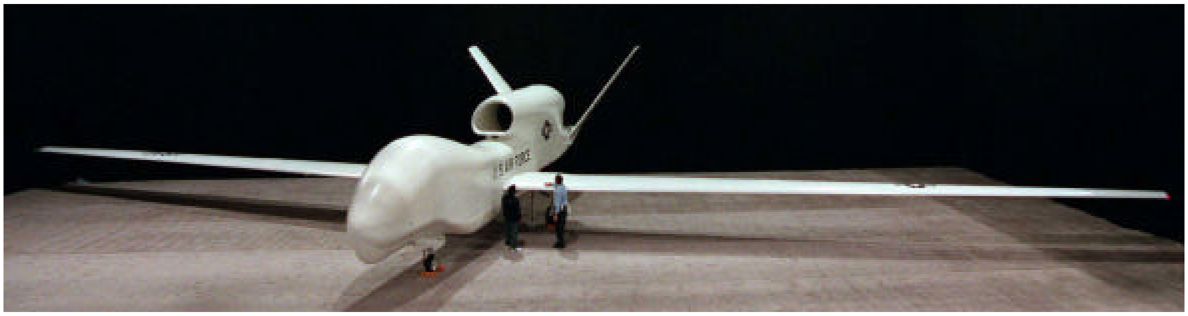

Figure 3. Global Hawk High Altitude and Endurance UAV

Table 1. HAE UAV Program Comparison[10]

Characteristic	Global Hawk	Darkstar
Mission Range and Endurance	3000 NM with 24 hours on station	Over 500 NM with 8 hours on station
Airspeed and Altitude	300-400 knots at 65,000 feet	250 knots at 45,000 feet
Sensors (all with SATCOM datalink)	Simultaneous use of radar (1 ft resolution), IR and Visual	Single use of either radar (1 ft resolution), IR or Visual
Payload Weight	750 lbs. (including sensors)	Same
Cost	$10 million (FY94)	Same

Figure 4. Darkstar High Altitude Endurance UAV

Some studies have suggested putting small lethal bomb payloads on either the Darkstar or Global Hawk UAVs to make them potential UCAVs. Yet even with the B-2 stealth technology of the Darkstar and the 65,000-foot orbit of the Global Hawk to provide protection, their lethal impact is limited by small payload capability that now permits just one 500-pound bomb. However, future plans for smaller 100 to 300 pound

GPS guided weapons may give these prototype UAVs a potential for 24 hour "air occupation" over enemy territory.

Future UCAVs

Figure 5. Northrup-Grumman's Future Concept UCAV

Prompted by the USAF scientific advisory board's recommendations in *New World Vistas*, DARPA research grants, and UCAV interest in the *Air Force 2025* project, several U.S. aerospace companies including Teledyne Ryan, Boeing, Northrop, and Lockheed Martin have started preliminary designs on advanced technology UCAVs. Both Great Britain and Germany are also studying a UCAV replacement for their air to ground Tornado. Interestingly, the development and research phase of the Joint Strike Fighter (JSF) now has four versions, USAF, USN, USMC *and a UCAV*. USAF Chief Scientist, Dr. Gene McCall, predicts that the last JSFs to roll off the factory line will be UCAVs.[11]

Figure 6. Artist Conception of Joint Strike Fighter

Advancing technology, politics, and most importantly, smaller military budgets will eventually persuade the USAF to operate unmanned lethal aircraft for most combat missions. Primarily because UCAV "operators" conduct routine training in simulators, DARPA and other aerospace companies have suggested UCAVs will save 55% to 80% in daily flight operations and support costs compared to manned systems.[12] Lower maintenance, training and operation costs are only some of the advantages of UCAVs over traditional manned aircraft. Table 2 on the next page lists some UCAV advantages over manned aircraft. Table 3 on the next page presents some concerns engineers and military officials must address for future UCAV operations.

Table 2. Advantages of Future UCAVs over Manned Aircraft

Vehicle Cost	Cheaper to build since pilot requirements such as cockpit controls and gauges, ejection seat, oxygen system, canopy, and cabin pressurization are unnecessary. Saves about 10% on overall vehicle cost.
Range & Endurance	Longer flight times and ranges due to less drag and better engine placement without the canopy and cockpit. No human limits on flight endurance time. Some UCAVs may fly for days over enemy territory.
No Crew Risk	No political risk from casualties or POWs. Can employ non-lethal weapons to put an enemy to sleep such as acoustic or brain wave manipulation. Can operate aircraft in a nuclear, biological or chemical environment with no risk to the pilot.
Survivability	Unmanned design without canopy makes aircraft smaller and lowers radar cross section. No human limits to high 10G+ turns, which helps survival in missile avoidance maneuvers.
Training	Most training for UCAV operators done in simulators. No dependence on weather or maintenance ready aircraft. Periodic major exercise participation such as Red Flags to test unmanned doctrine alone or its interface with manned aircraft.
Training & Support Costs	With only periodic flight training and little to no maintenance on the majority of "stored" UCAVs, there is an order of magnitude reduction in peacetime training, fuel and maintenance support costs.
Personnel	Fewer pilots and support personnel needed. UCAV operators can fly numerous UCAV sorties sequentially or at the same time. With few training flights, less maintenance personnel and equipment is required.

Table 3. Future UCAV Concerns

Datalink Communications	1. Loss of control due to enemy jamming or signal manipulation 2. Long connectivity lapses due to distance, satellite location, or friendly mutual interference 3. Limited amount of frequency bandwidths to accommodate large numbers of secure links for multiple UCAV operations
Air Refueling	1. Transoceanic deployment distances and communications 2. Risk to KC-135 or KC-10 high value assets 3. Tanker join-up and multi-aircraft air refueling
Operator Situational Awareness	1. Number of aircraft per operator *or* operator per aircraft 2. ATC and enemy airspace deconfliction from other aircraft 3. Threat reactions, especially visual-only AAA or IR SAMs
Emergencies	1. Aircraft problems due to engine failure 2. No emergency mutual support or visual "battle damage checks" 3. Hung live ordnance procedures and recovery 4. UAV capable alternate airfield recovery due to fuel or weather

The USAF can overcome many UCAV concerns with experience and development of safe procedures and doctrine. Some, especially the protection of the critical UCAV command and control links, may require new emerging technologies in communications such as data compression and data burst transmissions. The USAF's vision of the capabilities expected from future UCAVs is expressed in the following excerpt from the *Air Force 2025* Strikestar executive summary.

> In 2025, a stealthy UAV, we refer to as "Strikestar," will be able to loiter over an area of operations for 24 hours at a range of 3700 miles from launch base while carrying a payload of all-weather, precision weapons capable of various effects. Holding a target area at continuous risk from attack could result in the possibility of "air occupation." Alternatively, by reducing loiter time, targets within 8500 miles of the launch and recovery base could be struck, thus minimizing overseas basing needs.[13]

Notes

[1] Evers, Stacey. "Interview with General Ronald Fogleman." *Janes Defence Weekly*. 18 Dec 96. p. 26.

[2] Green, John K. *Lethal Unmanned Air Vehicle Feasibility Study*. Monterey, CA, Sep 95. (Naval Postgraduate School Thesis) Doc. call no.: M-U 42525 G7961L. p. 9.

[3] Walsh, Mark. "Battlelab of Drones That Can Kill." *Air Force Times*. 28 Jul 97. p. 27.

[4] Builder, Carl H. *The Icarus Syndrome*. New Brunswick, ME, Transaction Publishers, 1994. p. 158.

[5] Ibid., *The Icarus Syndrome*. p. 159.

[6] Ibid., *Lethal Unmanned Air Vehicle Feasibility Study*. p. 5.

[7] Ibid., *Lethal Unmanned Air Vehicle Feasibility Study*. p. 8.

[8] Ibid., *Lethal Unmanned Air Vehicle Feasibility Study*. p. 11.

[9] Finkelstein, Dr. Robert. *Unmanned Aerial Vehicles Seminar Study Guide*. San Diego, CA, Technology Training Corporation, (UAV Seminar in Washington D.C., 17-18 Nov 97).

[10] Ibid., *Unmanned Aerial Vehicles Seminar Study Guide*.

[11] Fulghum, David A. "Groom Lake Tests Stealth." *Aviation Week*. 5 Feb 96. p. 27.

[12] Francis, Col. Michael. *Advanced Unmanned Vehicle Systems.* Advanced Research Projects Agency (slide presentation with notes). 1996. http://www.arpa.mil/ARPATech-96/slides/francis/100/1.gif. p. 7.

[13] Carmichael, Col. Bruce W., DeVine, Maj. Troy E., Kaufman, Maj. Robert J., Pence, Maj. Patrick E., Wilcox, Maj. Richard S. *Strikestar 2025.* A Research Paper Presented to Air Force 2025. 1996. Volume 3, Chapter 13 Executive Summary. http://www.au.af.mil/au/2025/volume3/chap13/v3c13-1.htm.

Chapter 2

Reasons for an Interim UCAV

Clinton White House Orders Missile Attack on Iraq

—Newspaper Headline on 3 Sep 96[1]

Figure 7. Tomahawk Cruise Missile

Iraq continues to restrict access to UN weapons inspectors. A recent high-ranking Iraqi defector has confirmed CIA suspicions that chemical weapons are currently stored in a large underground bunker 30 miles east of Baghdad. President Clinton is not willing to risk an American life or give Saddam Hussein any chance to capture a POW. Remembering the missile attack he ordered two years ago, The President asks the Joint Chiefs of Staff Chairman, General Shelton, "how many cruise missiles will it take to destroy this chemical storage facility?" Unfortunately, General Shelton must tell the President that cruise missiles are unable to destroy hardened or underground facilities. Planned upgrades to give cruise missiles a penetration capability are just beginning testing and are at least three years away from operational status. New advanced standoff rocket propelled or glide GPS bombs are also in testing but still put the delivering aircraft deep into Iraqi territory. The only sure way to destroy

> that chemical storage bunker today is to risk lives using manned aircraft with steel cased laser guided weapons.

As previously stated, it will take the USAF decades to put advanced technology UCAVs into operational status. So why spend money on an interim UCAV? Cruise missile advocates argue that improvements to the sea launched Tomahawk and the air launched AGM-86 can handle high-risk missions for the next 20 years. However, air and sea launched cruise missiles have important ordnance and target limitations. Air Force planners point out that new "stand-off" launch and leave rocket propelled or glide bombs can destroy targets without risking lives. Although these expensive and untested "stand-off" weapons do put the aircrew further from the target area at release, they have some target limitations similar to cruise missiles and they may still expose the aircrew to enemy threats outside the target area.

This chapter will present political, economic, and military reasons why the U.S. should immediately take steps to reap the advantages of UCAVs over manned aircraft. Although political advantages are inherent to both UCAVs and cruise missiles, the economic and military sections will specifically address how UCAVs overcome some cruise missiles limitations.

Political

UCAVs provide U.S. political leadership another military instrument of power option that will not risk American lives. In smaller scale conflicts, the threat of a losing a pilot and even worse politically, the enemy holding a POW, has motivated President Clinton to rely primarily on cruise missiles in standoffs against Iraq after Desert Storm. The overwhelming national response to the Scott O'Grady shootdown and the size and complexity of his rescue has re-enforced the value of a single human life in military missions to the President and Congress. For example, the *Washington Post* ran a front-page story for three straight days after the O'Grady shootdown. Yet, two months later when two Predator UAVs were lost over Bosnia, the same newspaper devoted only one small back page article.[2]

Trying to plan effective and efficient military missions with zero loss of life is the almost impossible task given to military planners today. Not only do UCAVs give war planners more options, the capabilities of UCAVs to strike hardened or underground targets without loss of life is an important deterrent to U.S. enemies. A combination of UCAVs and cruise missiles will better enforce United Nations resolutions against tyrants such as Saddam Hussein or Bosnian Serb Commander, Gen. Ratko Mladic who remarked that "the Western countries have learned they cannot recruit their own children to realize goals outside their homelands."[3]

Reliance on basing rights in foreign host nations will become an increasing political concern for all U.S. military forces. Many UCAV critics argue that money spent on future military projects must address this issue through increased combat range to operate from the U.S. or close ally territories such as Guam or Diego Garcia. One possible solution is to use Navy carrier assets for UCAV operations to avoid basing problems. However, a small mistake by one unmanned F-18 landing or "trap" may have devastating consequences on the populated deck of a carrier versus an F-16 "mistake" on an empty 10,000 foot runway. While the U.S. Navy should investigate an F-18 UCAV carrier option, it is doubtful that the Navy can quickly conduct research, development and carrier concept of operations to implement a UCAV program in just a few years. An interim

UCAV based on the modification of a current aircraft may have a small increase in combat range due to weight reductions or additional fuel areas with removal of cockpit equipment. Even with a small increase in range, interim UCAVs will still rely on forward basing. Future UCAVs with long range and high endurance capabilities similar to Global Hawk will reduce the political problems of forward basing in other countries such as Saudi Arabia.

Economic

Reusability is one of the key advantages of UCAVs over expendable cruise missiles. Tomahawk cruise missiles today cost between 1.1 and 1.2 million dollars per shot with over 250 launched in the first week of Desert Storm alone.[4] In contrast, a 20 million-dollar "used" F-16 converted into a UCAV would become more cost effective than a cruise missile in about 25 flights adding a conservative five million dollars for bombs, fuel and one year of maintenance support. Therefore, it is important that a UCAV is survivable for repeated missions or it quickly becomes a very expensive cruise missile. Non-stealth UCAVs may need SEAD to survive a high threat area with numerous SAMs or they may require air escort protection in areas without air superiority.

By modifying existing or retired fighter or bomber airframes into unmanned remotely piloted aircraft, an interim UCAV program saves the expensive research and development costs associated with a new aircraft. New technology is not needed to modify an existing airframe into an interim UCAV, only inexpensive "off the shelf" systems. The USAF will realize additional cost savings at the end of the interim UCAV program since Tyndall AFB can use the retired UCAVs for air to air missile testing and training versus the expensive conversion of "boneyard" fighters into target drones.

With unmanned aircraft, another economic benefit is the elimination of or reduced requirement for combat search and rescue (CSAR) resources. Not only high operational costs but also a high TDY rate affecting quality of life issues are continuous USAF concerns in maintaining a CSAR alert force for the conflicts in Iraq and Bosnia.

Military

Long range sea and air launched cruise missiles will always remain an important capability for the U.S. military because of survivability and no requirements for forward basing. However, cruise missiles currently have ordnance limitations that restrict them to attacking only fixed position "soft" targets. Another limitation due to the cruise missile's full automation is the lack of "man in the loop" target identification and consent for release of weapons. On the other hand, an interim UCAV can carry a variety of ordnance to destroy most enemy targets and with "semi-autonomous" flight, a human operator can identify the target area and consent to ordnance release. In addition to increased target selection and "man in the loop" target verification, other important military reasons to operate an interim UCAV include mission success in high threat environments, improved transition to an unmanned Air Force, and the technology dilemma.

Target Selection

One of the major advantages of a UCAV over current and future cruise missile designs is its ability to deliver a variety of ordnance. Currently, cruise missiles can only carry a 1000-pound explosive or about 600 baseball sized "grenades." These ordnance loads restrict military planners to "soft" enemy targets such as radar dishes or unsheltered aircraft. Because the cruise missile's low altitude flight profile limits ordnance delivery to explosions just above a target area, there is no current capability for warhead penetration and delayed explosions needed to destroy hardened or underground facilities. Cruise missiles have little to no effect on critical enemy targets such as bunkers, bridges, runways and armored vehicles.

Air Force Systems Command is aware of the soft target limitation and is planning to test AGM-86C cruise missiles with a 1000-pound penetrating warhead in hopes of providing this capability in two to three years.[5] However, the success of this program is questionable since cruise missiles are not as accurate as laser or TV guided bombs. A successful attack on a small hardened bunker or underground facility requires a 3 meter or less CEP for "air vent accuracy" and may require more bomb weight for deeply buried targets. Even with penetrating warhead capability, many targets such as underground command bunkers, bridges, or runways currently require multiple 2000 pound bombs for destruction, much more than a cruise missile's single 1000 pound warhead.

Figure 8. Iraqi Bunker Destroyed by an LGB

On the other hand, a UCAV modified F-16C can fly the necessary altitudes, airspeeds and dive angles to deliver the right ordnance to destroy most enemy target types for example, the target penetrating 2000-pound steel encased GBU-24I laser guided bomb. Reprogramming target coordinates in the air with the new JDAM GPS guided bombs give a future interim UCAV the ability to destroy targets in any weather condition.

A mobile SCUD missile launcher, SA-6 SAM site or columns of tanks are not viable targets for a cruise missile because its accuracy depends on the programming of correct target coordinates before launch. However, an F-16C UCAV could use its Global Positioning System (GPS), radar Ground Moving Target (GMT) mode, and Targeting Pod laser to find moving vehicles to drop 500 pound LGBs or shoot Maverick missiles. In Desert Storm, a moving vehicle was the easiest to find and destroy since it was not buried in sand for protection or camouflaged to prevent identification. An unmanned F-16C carrying GBU-12s can work with JSTARS for real-time target position updates to quickly destroy up to six moving vehicles.

“Man in the Loop” Target Verification

Even with terrain updates and target photo matching, a cruise missile does not always find the correct target. Mechanical errors such as a drifting inertial navigation system (INS) or human errors in entering the wrong target coordinates always puts some doubt in the launcher’s mind. Without real-time target validation just prior to bomb release, many potential targets located near politically unacceptable areas such as hospitals or residential neighborhoods may remain untouched. An interim UCAV, however, with “man in the loop” semi-autonomous flight control can identify the target area and consent to ordnance release. The ground remote control operator receives real-time optical, infrared or radar mapping pictures of the target area and sends back, if needed, target position updates or corrections. When the human operator verifies the unmanned aircraft is attacking the correct target, consent to release weapons is sent to the UCAV.

Even manned systems with enemy target identification technology are not 100% reliable. For example, in Desert Storm an errant HARM from an F-4G guided towards the tail of a B-52 and the U.S. Navy fired on one of their own aircraft. Until the U.S. military is comfortable that artificial intelligence weapon systems will not kill or fratricide friendly troops, “man in the loop” control will allow unmanned systems in the interim more flexibility in combat missions. Unlike cruise missiles with one mission, strategic attack, UCAVs carrying a variety of ordnance with “man in the loop” control can conceivably fly SEAD, battlefield air interdiction (BAI), and offensive counter air (OCA) missions. Later, with more interim UCAV experience and acceptance, the USAF may allow missions to expand to close air support (CAS) and defensive counter air (DCA).

One more consideration for a UCAV “man in the loop” control system is its ability to defend itself if attacked. Although cruise missiles rely on small size and radar cross-section to survive to the target area, slow subsonic speeds and better radar technology are becoming survival concerns to the USAF. Since NORAD air defense exercises routinely practice F-16 and F-15 air to air engagements of simulated enemy cruise missiles, the U.S. military must believe that other modern aircraft such as the SU-27 Flanker or the Mirage 2000 can do the same against defenseless U.S. cruise missiles. An interim

UCAV fighter, however, can carry AMRAAMs for protection and use "man in the loop" control to help prevent fratricide. With enemy aircraft confirmation from AWACS or Rivet Joint aircraft, a future war may produce the first ground station remote control operator "aces."

Mission Success in High Threat Environments

Figure 9. F-16s Attacking Heavily Defended Target

The USAF can increase mission success in "high threat" environments with UCAVs. In addition to the dangerous SEAD mission, low cloud ceilings will force aircraft for target identification to fly into the lethal AAA and IR SAM envelope that caused thousands of aircraft losses in Vietnam. Also, many missions are aborted or mission effectiveness is decreased by the numerous aircrew distractions found in a high threat environment, especially at night with lack of visual depth perception. Tense pilots flying in known high threat areas instinctively react to ground explosions or missile launches even if there is no threat to their aircraft. For example, during Desert Storm, many aircraft just prior to ordnance release violently turned in response to friendly F-4G

HARM shots that contrailed upwards and were mistaken as SAMs. Numerous night fighter formations at high altitude were temporarily disrupted by meteor showers. With a relaxed UCAV operator sitting in a quiet air-conditioned room, the aircraft need only to react to actual threats as indicated on the Radar Warning Receiver (RWR) or an IR missile detector. With automatic threat response, the aircraft would instinctively operate defensive systems such as chaff, flares, ECM pods, and towed decoys.

Transition to the "Pilot-less" Air Force

Even with the "white scarf" mentality prevalent in the USAF today, technological advances and political pressures will eventually force most aircraft that fly over enemy territory to be pilot-less by the mid 21st century. An interim UCAV program will help ease this transition by exposing pilots now to the distinct advantages of unmanned flight and more importantly, by working out many of the "bugs" for implementation of advanced technology UCAV systems. For example, the FAA has been avoiding control and deconfliction of UAVs and civilian air traffic for years. The operational fielding of the Predator and its peacetime training requirements in U.S. airspace has forced the FAA to begin seriously working unmanned aircraft issues.[6]

Technology Dilemma

The employment of expensive advanced technology weapon systems creates an interesting dilemma for a military commander. Especially in minor conflicts, the military advantage of using a weapons system must be weighed against the risk of losing an expensive aircraft or passing advanced technology to the enemy. For example, the B-1 bomber can carry more ordnance and deliver it with higher accuracy than the aging B-52, but the U.S. did not fly any B-1s in Desert Storm. The risk of giving Iraq and eventually

Russia advanced electronic warfare technology from the shootdown of an expensive B-1 was too much for the U.S. to take. Will the U.S. be willing to risk the B-2 stealth technology and advanced sensors now used on the Boeing Darkstar UAV from a simple engine or datalink failure over enemy territory? Low unit costs and a lack of sensitive technology on current fighters will keep military leaders from having reservations on employing them as interim UCAVs.

Notes

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Chapter 3

F-16 UCAV Proposals

I could very easily go out and put a smart bomb on an unmanned aerial vehicle tomorrow.

—Col. Joe Grasso
Commander USAF UAV Battlelab[1]

With years of experience turning mothballed fighters into full-scale target drones, remote control engineers can easily convert any of the U.S. military's aircraft for unmanned flight. So why is the F-16 the best candidate for an interim UCAV? Because the F-16 is a multi-role fighter, it performs all USAF missions such as SEAD, DCA, OCA, killer scout, deep strike, interdiction and CAS. No other current aircraft in the U.S. military can explore unmanned doctrine in so many areas of air combat. Not only is the F-16 a comparatively inexpensive aircraft weapons systems to procure and operate, F-16s are more numerous than all other interim UCAV candidates including the A-10, F-15E, F-117, B-1 and B-52 combined. This would help the F-16 community better "absorb" an initial testing or operational mission loss versus a more expensive and less numerous high value asset such as an F-117 or F-15E. The small size and superior maneuverability of the F-16 also increase its survivability over larger bombers such as the B-1 or B-52.

Because of these advantages, this chapter will present two F-16 proposals for an interim UCAV. The first proposal from Lockheed-Martin Tactical Aircraft Systems

(LMTAS) suggests the modification of “retired” F-16 A-model fighters into UCAVs. Out of a detailed study of this proposal and its limitations comes the second interim UCAV proposal of converting a small percentage of current F-16Cs into dual role aircraft.

LMTAS F-16 A-Model UCAV

An interesting interim UCAV solution offered by Lockheed-Martin is to modify older F-16A jets baking in the Arizona sun at the Davis-Monthan AFB “boneyard” into remotely piloted UCAVs.

Figure 10. F-16 A-Models in Storage at the Tucson, Arizona “Boneyard”

In addition to UCAV operations and support cost advantages, LMTAS proposes to solve another potential USAF problem, a fighter aircraft shortfall in the 2005-2015 timeframe.[2] To meet global force requirements with fewer resources, the USAF would store most of the UCAV converted F-16 A-models at worldwide strategic locations. When needed, a UCAV rapid response team would deploy with maintenance equipment, support personnel, and several small computer workstations for the simulator trained operators to “fly” their UCAVs.

Design Modifications

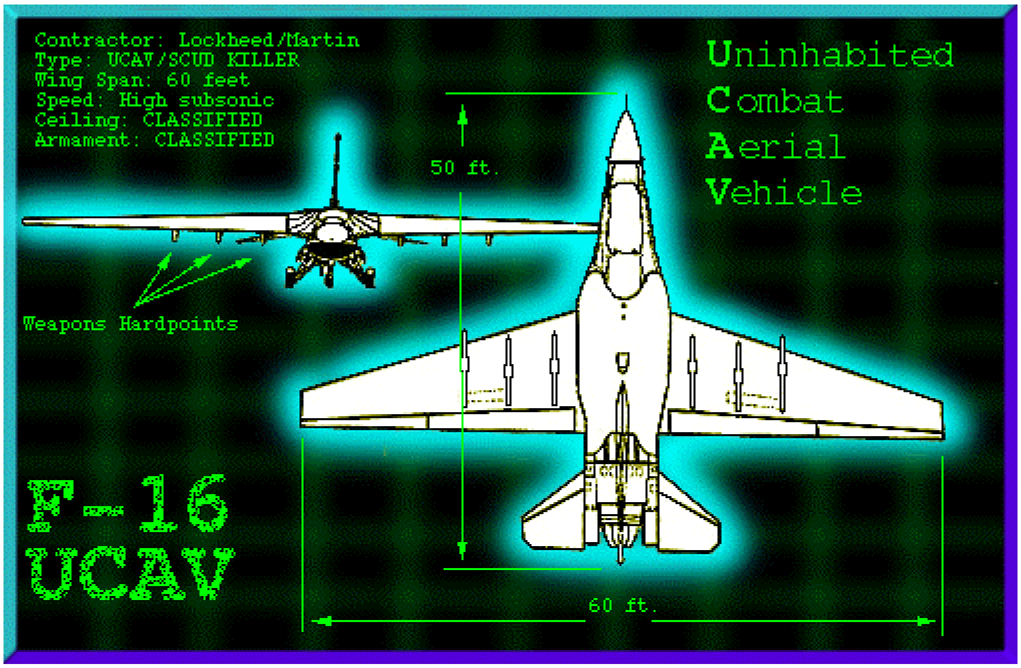

Figure 11. Lockheed Martin F-16A UCAV

The only major structural modification for the F-16A UCAV is replacing the current low aspect wing with a 60-foot long thick high aspect wing similar to an A-10. Better aerodynamics and almost 22,000 pounds of fuel would potentially increase combat endurance up to 8 hours or at least three times the current F-16 design.[3] Other design modifications include the removal of the canopy, seat, and cockpit displays and possibly adding an additional 2300-pound fuel tank into the now empty cockpit area. In addition, the unneeded gun and ammo drum would be removed to make room for additional data link and communications equipment. To complete the conversion to a UCAV, off-the-shelf automatic landing flight controls and throttle systems would be added to the basic F-16A avionics.[4]

According to LMTAS, FY95 research and development cost estimates for the F-16A Long Endurance Defender run between 60 to 90 million dollars and conversion estimates run from 3 to 5 million per jet. Without the 60-foot wing replacement, the R & D cost lowers to 25 - 35 million with UCAV conversion costs of 1 to 2 million per jet. These LMTAS conversion estimates for the F-16A without the new wing compare closely with the current USAF target drone QF-4 program. The QF-4 contractor delivered 10 prototype QF-4s in FY1996 with a $40 million dollar R & D budget.[5] Thereafter, with an average of 42 aircraft per year for 9 years, the QF-4 drone conversion cost runs about $200,000 per jet. For unrestricted or "dual-role" manned flight capable QF-4s, the cost is about $600,000 per aircraft.[6] The additional UCAV conversion costs for the F-16A include SATCOM and other communications datalink equipment and antennas not found on the QF-4.

Concept Development

LMTAS believes that the USAF must move quickly on this UCAV concept given the possibility of a tactical fighter shortfall as early as 2005. However, before any full-scale conversion program is initiated, the USAF needs to develop and evaluate many UCAV concerns and concept of operations (CONOPS) such as air traffic control interface, datalink connectivity, air refueling and manned/unmanned aircraft interface. The USAF Research Laboratory has just initiated a program to evaluate issues common to both manned fighters and UCAVs, which could culminate in a new unmanned vehicle demonstrator[7]. In New World Vistas, the USAF Scientific Advisory Board has already recommended that data link equipped manned fighters be used as imitation UCAVs for demonstration and evaluation purposes.[8] With a pilot initially in the cockpit for safety reasons, these remote controlled fighters can establish technical and operational feasibility and pursue risk reduction for the overall UCAV system concept. Once initial

UCAV testing is complete, LMTAS views their F-16A UCAV as an important CONOPS stepping stone for contributions to their own and other future advanced technology stealth UCAV programs.

Figure 12. LMTAS F-16A Long Range Defender UCAV[9]

F-16A UCAV Proposal Concerns

Although the LMTAS F-16A proposal offers many interim UCAV advantages for the USAF, two major areas of concern are the limitations of the F-16 A-model and the ability of the USAF to integrate this program into its force structure. Because of the additional costs, equipment and personnel required to overcome these concerns, the USAF may not have enough additional resources to quickly implement the F-16A UCAV.

Even though it is difficult to visually distinguish an F-16A from an F-16C, there is over 20 years of technological difference on the inside. Compared to the F-16 C-model, F-16 A-model limitations include ordnance, avionics, and maintenance.

Figure 13. F-16C Dropping Laser Guided Bomb

The most severe F-16A UCAV constraint is that its only air to ground precision ordnance capability is the tank killing AGM-65 Maverick missile. A fighter aircraft operating in the 21st century must have the ability to drop laser-guided weapons, such as the block 40 F-16C, for a direct hit to penetrate underground or hardened targets. Without FLIR target identification or GPS aided navigation, an F-16A relies on INS computer bombing and is ineffective for night operations. In addition, F-16A models cannot perform package protection SEAD missions since they have no HARM or HTS capability similar to block 50 F-16Cs.

The second limitation of the F-16A concerns antiquated avionics. The LMTAS proposal leaves most of the 1970s technology F-16A computer and avionics hardware and software systems unchanged except for small additions to accommodate remote control communication links. While this avionics package can handle normal F-16A systems, additional weapon systems upgrades to handle F-16C ordnance may overload the wiring, hardware and software. Attaching modern F-16C systems such as GPS, datalink, HTS, HARM, FLIR and LANTIRN may take years to test and incorporate in the F-16A. Except for some Air National Guard jets, most F-16As are not modified to fire the AMRAAM. Not only is the F-16 A-model radar range and target limited in the air to air role, it does not have many of the needed air to ground modes widely used in the F-16C such as Ground Moving Target (GMT) and Doppler Beam Sharpening II (DBS II). This limits F-16A all-weather capability to radar identify target areas and prevents aircraft radar acquisition of moving targets.

The final F-16A limitation deals with aircraft maintenance. Almost all maintenance officers agree that a constantly flying aircraft maintains a "Code 1" mission ready status much better than the rarely flown "hangar queen." The nearly 20 year old F-16A will certainly encounter aging problems such as wire chaffing, hydraulic leaks and metal fatigue. Aging aircraft primarily kept in inactive storage will undoubtedly experience much lower mission capable rates than currently flying F-16Cs. In addition, the big wing F-16A with 22,000 pounds of fuel and just 4000 pounds of ordnance exceeds current max gross weight limits. High F-16A gross weights may lead to more blown tires or landing gear stress problems.

To resolve F-16A ordnance and avionics limitations, LMTAS provided rough cost estimates for this paper to add F-16C capabilities to the F-16A UCAV. The upgrades were divided into small, medium or large tasks with recurring unit costs running 3 to 5% of the development costs. Costs for small tasks were thrown into the initial $25 to 35 million F-16A UCAV research and development. Medium tasks would add another $5 million and large tasks would add $20 million to R & D. Listed in Table 4 are the needed upgrades to give an F-16A without the 60-foot wing modification laser guided bomb or HARM targeting system (HTS) capabilities.

Table 4. F-16A Research and Development Upgrade Costs[10]

F-16 Block 40 with TGP (no LANTIRN)		F-16 Block 50 with HTS	
Targeting Pod	Medium (5)	Harm Targeting System	Large (20)
LGBs	Small	HARMs	Medium (5)
AMRAAMs	Small	AMRAAMs	Small
Towed Decoys	Medium (5)	Towed Decoys	Medium (5)
GPS navigation	Medium (5)	GPS navigation	Medium (5)
Datalink	Medium (5)	Datalink	Medium (5)
Original R&D	$30 million	Original R&D	$30 million
TOTAL R&D	**$50 million**	**TOTAL R&D**	**$70 million**
Each Jet	**$2-3 million**	**Each Jet**	**$3-4 million**

In addition to F-16A limitations, a quick and smooth integration of the LMTAS UCAV idea into the USAF force structure is a concern. Even though LMTAS believes that the USAF can receive its first F-16A UCAVs in just two years, the implementation of any new program involves expensive infrastructure startup costs and impacts USAF personnel and resources.

Because most UCAV training is done in simulators, studies show that the daily peacetime flight operations and maintenance support costs for a UCAV squadron are from 50 to 80% less than a manned fighter squadron. However, unless the UCAV squadron is replacing a manned fighter squadron, the cost to operate this UCAV squadron is still an addition to the DOD budget. Along with day to day operating costs, millions of dollars are spent on initial squadron buildup of maintenance and administration equipment, work areas and training of personnel. Normally, only 15% of a weapon system program cost is the vehicle itself. The other 85% of the cost includes research, development, testing, infrastructure, maintenance, and operations costs.[11]

Along with initial program startup costs, the USAF must find new operators and train them in F-16 UCAVs. Until UCAVs demonstrate reliability and a safety record equal to or better than manned aircraft, the USAF and the U.S. public will probably not accept “non-rated” operators. Obviously, the initial UCAV operators should be qualified F-16 pilots. Yet, with the current USAF fighter pilot shortage projected to continue into the 21st century, the opening of a new UCAV squadron in the near future will create an additional burden on the Air Force Personnel Center (AFPC). AFPC usually sends pilots to “fly” in the new Predator UAV squadron in a non-volunteer status. Predator squadron morale is low, even in a location as desirable as Las Vegas, due to numerous TDYs and the “grounding” of pilot operators.

Currently, due to budget constraints, the USAF is experiencing a shortage of LANTIRN Targeting Pods and Harm Targeting System (HTS) Pods in testing and training squadrons. Additional UCAV aircraft added to the USAF inventory will require one of these pods to be an effective weapons platform. With each pod costing about one million dollars, for 100 F-16As in storage, this is an additional $100 million cost if each UCAV is assigned an HTS or laser targeting pod.

In summary, the LMTAS F-16A interim UCAV proposal must overcome problems with F-16A ordnance, avionics and maintenance limitations and the cost, personnel, and resource constraints of implementing a new weapons system into the USAF inventory.

F-16 C-Model Dual-Role UCAV

To avoid many of the problems and costs associated with the LMTAS F-16A UCAV proposal, another F-16 UCAV option is to modify currently flying block 40 and 50 F-16s into "dual-role" manned and UCAV aircraft. A dual-role F-16 will retain all of its original manned fighter capability with the addition of a few hundred pounds of remote control and communications equipment. If called upon to perform its unmanned role, the UCAV aircraft is immediately available with no additional maintenance. Initially, the USAF should convert only four to six jets in selected operational LANTIRN and SEAD F-16C squadrons into dual-role UCAV aircraft. This will reduce initial program costs and ease the transition to unmanned aircraft operations by training only a few pilots and maintenance personnel in "dual-role" operations and support. As unmanned flight operations and support become more routine, additional squadron aircraft can convert to dual role status and more pilots and maintenance personnel can cross-train into the program.

Design Modifications

Permanent design modifications for dual-role F-16C UCAV aircraft are similar to the LMTAS F-16A proposal without the 60 foot wing addition except for placement of the remote control and communications equipment. Since the manned F-16 would require the 20mm gun system, alternative locations for this equipment include the empty space already in the avionics bay area or in the vertical fin base originally designed to house internal ECM equipment. Rough estimates from QF-4 conversion experts put basic F-16 UCAV flight control and auto-landing costs at $300-400,000[12]. Adding SATCOM and additional secure data links and antennas would add $200-300,000.

If the UCAV mission required additional combat range, maintenance can remove the seat and replace it with a 2300-pound cockpit fuel tank in a matter of hours. If future unmanned missions require F-16C UCAV air refueling, one proposal is to add a small camera near the HUD at a lookup angle so the remote ground or tanker based operator could fly off the refueling position lights mounted on the tanker bottom.

Figure 14. Block 40 F-16C Air Refueling in Saudi Arabia

Benefits of the F-16C UCAV

The F-16C UCAV proposal is the best candidate to quickly and effectively fulfill the requirements for an interim UCAV because of low program cost and small impact on USAF integration. Additional dual-role F-16C benefits include increased survivability, high combat readiness rates, and a better global response capability.

The most important part of any new weapons system program is cost. The F-16C dual role UCAV keeps costs low by modifying existing operational aircraft and by using the current world-wide billion dollar F-16C infrastructure. Slightly modifying currently flying F-16Cs into dual-role UCAVs will be less expensive than the millions of dollars required to return to flight status “mothballed” F-16A aircraft. Since the F-16C is compatible with most current weapon systems, research, development and testing would save money by focusing only on remote control interface and UCAV concept of operations. Sharing the current operational F-16C infrastructure will provide substantial savings compared to the normal start up costs of a new weapons program, including block 40 laser targeting pods and block 50 HARM targeting pods. Current manned F-16 operations budgets would absorb most UCAV costs involved with daily peacetime training, flight operations and maintenance support. By using the current F-16C aircraft and its support infrastructure, the dual role F-16C is a cost-effective interim UCAV.

In addition to cost effectiveness, a UCAV program utilizing the current F-16C infrastructure greatly reduces the impact on the USAF in manning and combat readiness issues. During a pilot shortage, the USAF cannot afford to transfer combat qualified F-16 pilots to a new UCAV squadron. By initially converting just four to six F-16Cs into dual role aircraft, current squadrons can maintain combat readiness status since they need to train only a few pilots and maintenance personnel in UCAV operations. Over time, with increased experienced and more confidence in unmanned operations, if needed, the USAF can convert more F-16C aircraft into dual role UCAVs. In addition to manning and combat readiness, “hiding” UCAVs in the current F-16C infrastructure is the best way to have fighter and bomber pilots mentally accept lethal unmanned combat operations. Once F-16C UCAV flight operations become routine, the rated Air Force will see the advantages of remote control flight and better accept the eventual transition of the USAF from a manned to unmanned combat force.

In addition to cost effectiveness and USAF impact, the dual-role F-16C benefits from increased survivability, high combat readiness rates, and a better global response capability. Survivability is the key to reusability, which make UCAVs more cost effective than cruise missiles. With a more capable radar, AMRAAMs, a better threat warning receiver, more countermeasures dispensers, and other classified protection capabilities, the F-16C is a more survivable aircraft than the F-16A. High combat readiness rates for the UCAV will automatically mirror the manned F-16C combat force with “code 1” maintenance ready rates the highest among fighters in the USAF. Another benefit of the F-16C UCAV over F-16As “stored” in worldwide locations is the ability to rapidly respond to any global crisis. The F-16C would avoid current UCAV air refueling, diplomatic clearance and ATC problems by flying across the ocean as a manned aircraft. After landing, no maintenance is necessary for the aircraft to immediately fly an unmanned mission, if needed.

Figure 15. F-16C Firing AMRAAM

F-16C UCAV Concerns

The primary concern for an F-16C UCAV program that LMTAS addressed with its F-16A UCAV with the 60 foot wing modification is limited combat range without air refueling. Manned F-16s can bomb targets thousands of miles away on missions with pre and post-strike air refueling. Most UCAV supporters, including LMTAS, believe that unmanned air refueling is feasible with today's technology either controlled from the ground or by the tanker boom operator. However, manned F-16 air refueling requires numerous rapid flight control corrections and is considered a difficult pilot task, especially at night or in poor weather conditions such as clouds or turbulence. In addition, air refueling puts unmanned aircraft within a few feet of a U.S. high value asset with no room for error. Therefore, even with advanced technology, many years of testing and more importantly, KC-135 and KC-10 manned tanker acceptance is needed for UCAV remote control air refueling.

To extend combat range without air refueling, the F-16C UCAV can increase fuel load using the 2300 pound cockpit fuel tank previously mentioned or 600 gallon wing fuel tanks. However, F-16 pilots prefer the standard 370-gallon wing fuel tanks because the 600-gallon wing tanks severely limit aircraft performance. Table 5 below shows the combat radius for a block 42 F-16C carrying two 2000 pound LGBs and for a block 52 F-16C carrying two HARM missiles. The F-16C computer flight planning system (CFPS) version 2.0 computed both aircraft flying at .85 Mach carrying wingtip AMRAAMs and a centerline ALQ-184 ECM pod.

Table 5. F-16C Combat Radius

Fuel Tanks (Internal fuel 6900 lbs.)	**F-16C Block 42** (NVP + TGP) (2) GB-10C Cruise 25,000'	**F-16C Block 52** (HTS) (2)HARM Cruise 30,000'
Current 370 Wing tanks	450 NM	525 NM
370 Wing + cockpit tank	550 NM	650 NM
600 Wing tanks	600 NM	700 NM
600 Wing + cockpit tank	700 NM	800 NM

For the LANTIRN and HTS F-16C UCAVs, the use of 600-gallon wing tanks and the cockpit fuel tank gives about a 50% increase in combat range without air refueling over the standard 370-gallon wing tank configuration. However, with this increase in range, the UCAV suffers in combat maneuverability that may lower survival chances in high threat areas.

Other F-16C UCAV proposal concerns are the same as for future advanced technology UCAV aircraft previously mentioned in Table 3 in the review of related literature located in chapter one. The use of automation in the F-16C UCAV command and control loop will prevent aircraft mishaps due to data link termination. If data link is lost, the F-16C UCAV will return to the launch base and execute an automatic landing. As previously mentioned, flight testing of manned aircraft with remote control interface will alleviate many of the concerns listed in Table 3 and build USAF confidence in UCAV operations.

Notes

[1] Walsh, Mark. "Battlelab of Drones That Can Kill." *Air Force Times*. 28 Jul 97. p. 27.

[2] Chaput, Dr. Armand J. *Design Considerations for Future Uninhabited Combat Air Vehicles.* Lockheed Martin Tactical Aircraft Systems, Ft. Worth, TX. p. 4.

[3] Ibid. *Design Considerations for Future Uninhabited Combat Air Vehicles.* p. 8.

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[5] *Full Scale Aerial Target Acquisition and Logistics Support Planning.* Air Force Audit Agency Report 96064030, 1 Sep 97. p. 2.

[6] Ibid. *Full Scale Aerial Target Acquisition and Logistics Support Planning.* p. 2.

[7] Ibid. " Design Considerations for Future Uninhabited Combat Air Vehicles." p. 4.

[8] McCall, Dr. Eugene. *New World Vistas*. USAF Scientific Advisory Board Report to the Secretary of the Air Force. Dec 95. Section 5.1.1.

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[12] Ibid. *Full Scale Aerial Target Acquisition and Logistics Support Planning.* p. 2

Chapter 4

Recommendations

> *For the price of one B-17 with a bomb load of 6000 pounds, we could have sent 500 of these little (radio controlled pilot-less) Bugs over enemy territory, each carrying about 800 pounds of explosives. Much more important than any monetary factor was the possible saving in human life.*
>
> —General Henry "Hap" Arnold[1]

The USAF should continue to fund preliminary research for the Lockheed Martin "boneyard" F-16 A-model UCAV proposal as a solution to a possible severe U.S. tactical aircraft shortfall in the 2005 to 2015 period. However, with low modification costs, no new infrastructure and minimal training, the USAF should immediately start planning for the development, testing and modification of F-16C aircraft into "dual-role" LANTIRN and HTS capable UCAVs.

Implementation of the F-16C UCAV

To quickly field an F-16C UCAV program, the USAF must prioritize with increased funding UCAV research in three critical areas, 1) the F-16C aircraft modification, 2) the remote control ground station, and 3) CONOPS development.

F-16 Aircraft Modification

The modification of the F-16C into a dual role manned and unmanned capable fighter requires the addition of "off the shelf" SATCOM and datalink communications equipment and antennas. DARPA is currently planning with LMTAS the modification of the Advanced Fighter Technology Integration (AFTI) F-16 as a UCAV technology demonstrator.[2] With additional information on remote control equipment and operations from the QF-4 aerial drone squadron at Tyndall AFB, LMTAS can quickly design plans for the USAF to modify at least one Block 42 LANTIRN and one Block 52 HTS F-16C as unmanned flight demonstrators.

As previously mentioned, initial flight testing of remote control interface with pilots having override authority in the cockpits will alleviate many unmanned operation concerns. Pilots from the 422 Test and Evaluation Squadron should initially fly the demonstrator F-16Cs at Tyndall AFB to utilize the existing remote control facilities and the drone runway. More advanced "battlefield" testing for weapons and communications jamming should occur at the Nevada Ranges from either Nellis AFB or from Indian Springs AAF using Predator ground station facilities.

Ground Station Design

Ground station remote control "cockpit" design must start just prior to aircraft testing. The large and expensive F-16 visual simulators used to train new pilots are not practically deployable. A smaller procedures task trainer (PTT) similar to the ones currently used by F-16 ANG units should be the baseline for a UCAV ground station. These small cockpit PTT simulators with their associated computers and TV monitors can easily fit onto one airlift cargo pallet.

Does every switch and light in this PTT simulator need to work? Should the pilot look at the current 4x4 inch F-16 multi-function display (MFD) or at 27 inch TVs around the cockpit? LMTAS may have the answers to some of these questions from several years of testing in its F-16 UCAV simulator in Ft. Worth, Texas. Additional human factors engineering testing with LMTAS and F-16 pilots will provide the optimal compromise between mission effectiveness and a small, cost effective and deployable ground station design.

Concept of Operations

The USAF should form a working group with personnel from the Predator squadron at Indian Springs AAF, the QF-4 drone squadron at Tyndall AFB, the Eglin AFB UAV battlelab, LMTAS and Weapons School instructors at Nellis AFB to develop F-16C UCAV concept of operations. Concept of operations or CONOPS development will initially attempt to answer many of the concerns in operating an unmanned F-16 such as air traffic control interaction and if the F-16 UCAV should carry AMRAAMs. CONOPS development will define which mission areas require direct operator control, semi-autonomous control or UCAV fully autonomous control. The use of more autonomous and semi-autonomous control of UCAVs will minimize communications bandwidth availability problems and reduce enemy EW detection. Appendix A contains an example UCAV block 40 LGB mission from taxi to landing with control categories for each phase.

If the USAF provides the necessary funding then simultaneous research, development and testing of the aircraft, ground station and concept of operations can put F-16C dual role UCAVs into operational squadrons in just a few years. The F-16C UCAV idea will require a small budget investment compared to normal Pentagon acquisition programs and the interim F-16C UCAV is a low risk investment. Even if the program suffers setbacks or is cancelled, the USAF retains its manned F-16 infrastructure and modified aircraft are easily returned to a “manned-only” status. If an unexpected aircraft mishap occurs, the USAF will not lose a pilot and the large F-16 community can best absorb an aircraft loss.

Future F-16C UCAV Missions

U.S. leadership and military planners will use aircrew risk and target type as two key considerations for the decision of whether to use cruise missiles, UCAVs or manned aircraft to attack a target. Aircrew risk is the combination of political and military risk. Even if the military risk due to enemy threats and good weather is small; the political consequences may be too high. Likewise, in major conflicts with lower political risk for aircrew death or capture, advanced SAMs, lack of air superiority, or poor weather may drive the military risk too high for manned flight. If the combination of political and military risk is high, target type will dictate the use of cruise missiles or UCAVs. Table 6 below lists the most cost effective weapons platform depending on risk and target size and type.

Table 6. Weapon System Selection

Target Type	**Military + Political RISK**		
	High	**Medium**	**Low**
Soft	Cruise missiles	Cruise/UCAVs	Manned aircraft
Large Hardened	Cruise missiles*	Cruise*/UCAVs	Manned aircraft
Small Hardened	UCAVs**	Manned/UCAVs	Manned aircraft
Bridges/Armor	UCAVs**	Manned/UCAVs	Manned aircraft
Mobile	UCAVs**	Manned/UCAVs	Manned aircraft

*If proposed hard target penetration capability is available, otherwise, UCAV with LGBs
**Block 50 HTS UCAV SEAD may be needed for survival of Block 40 UCAVs

USAF planners should use manned aircraft for all low threat missions because they are the most cost effective and capable air power tool. Because of cruise missile CEP accuracy, UCAVs or manned aircraft with penetration LGBs are best for smaller hardened targets where the bombs need to "go down the air vent." An interim F-16C UCAV is the weapon system of choice if the political or military risk is high and the target is not cruise missile capable. Because of the need for SEAD in military high risk areas, F-16C UCAV CONOPs must address the coordination of both Block 40 LGB and Block 50 HARM unmanned aircraft.

Notes

[1] Builder, Carl H. *The Icarus Syndrome***.** New Brunswick, ME, Transaction Publishers, 1994. p. 159.

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Chapter 5

Conclusions

> *Just the names of today's UAV models—Hunter, Raptor, Talon, Predator, Darkstar, and so forth—are good clues that, even unmanned, the UAV is meant to fight rather than just see.*
>
> —Col. Richard Szafranski[1]

Technology is taking the human out of the fight. In the near future, unmanned Army tanks, Navy ships and Air Force aircraft will conduct battles controlled by operators hundreds or even thousands of miles out of harms way. Advancing technology, smaller post Cold War budgets, and political pressures have convinced many scientists and military planners to push for research and development of unmanned systems despite the resistance to change from some leaders in the Pentagon. Because of past success stories and the current dependence of military commanders on the valuable battlefield information provided by systems such as Pioneer and Predator, the future funding of new UAV surveillance and reconnaissance platforms is assured. However, budget competition from the manned F-22 Raptor and Joint Strike Fighter programs has severely limited research and development funding and Pentagon enthusiasm for lethal UCAVs. Current estimates put the operational fielding of an advanced technology UCAV system decades away.

In addition to cruise missiles, does the U.S. now need another unmanned lethal military option? Yes, the political, economic and military benefits of quickly fielding an interim UCAV system are worth the additional funding. Similar to the important political advantages of cruise missiles, interim UCAVs do not expose U.S. aircrews to the risk of death or capture which also eliminates the need for CSAR resources. Unlike cruise missiles, however, reusable UCAVs may provide a more economical military IOP in certain situations than a one shot million dollar plus Tomahawk. Militarily, an interim UCAV provides much more ordnance and target capabilities than cruise missiles, especially against smaller hardened structures, bridges and mobile targets. UCAVs also provide the military with a "man in the loop" capability to identify target areas and give consent prior to ordnance release. Compared to manned aircraft in high threat mission scenarios, UCAVs may increase combat effectiveness through better task management of cockpit inputs and resources without the numerous distractions and mental stresses of combat. In addition, the important CONOPS "lessons learned" and the resolution of other future unmanned flight concerns will greatly ease the transition of the USAF into an advanced technology unmanned combat force in the 21st century. A successful interim UCAV program will be an important stepping stone for the transition from a manned to unmanned combat Air Force. For these political, economic and military reasons, the U.S. needs an interim UCAV capability until advanced technology unmanned combat forces are operational.

Can the USAF provide a quickly fielded, cost effective and capable interim UCAV? Yes, a "dual-role" F-16C UCAV is the answer. Converting four to six block 40 LANTIRN or block 50 HTS aircraft in current operational squadrons to dual role manned and unmanned F-16Cs will provide a cost effective and capable UCAV option that the USAF could quickly field. The F-16C UCAV is cost effective not only because the simple aircraft modification is the addition of “off the shelf” communications and remote control equipment, more importantly, it uses the existing F-16 infrastructure. Using the current F-16C airframe, support and operations facilities and maintenance plus pilot “operator” workforce eliminates expensive new weapon system start-up costs including the training of additional personnel.

The F-16C Block 40 and 50 dual-role UCAV is a “can’t lose” proposition. With a small program investment and limited risk, there is a huge potential payoff. The USAF should immediately start funding research and development for the operational fielding of F-16C UCAVs.

Notes

[1]Szafranski, Col. Richard and Libicki, Dr. Martin. “…Or Go Down in Flame? Toward an Airpower Manifesto for the 21st Century”. *Airpower Journal*. Fall 1996. P. 70.

Appendix A

UCAV Mission Profile

Stages of an example F-16C Block 40 UCAV LANTIRN laser guided bomb (LGB) mission are listed below.

Taxi	Crew chief tows UCAV to the arming area at the end of the runway
Start	Crew chief starts engine, aligns the INS and tests communications and data links with the remote operator
Arming	Crew chief leaves cockpit, removes engine inlet protection and arms aircraft. Final system checks done with direct control by remote operator
Takeoff	Direct control by remote operator upon permission from the tower
Climb	Direct control by remote operator responding to calls by ATC
Air Refueling	Direct control by ground remote operator or control temporarily given to the KC-10/KC-135 boom operator
Cruise	High altitude autonomous or semi-autonomous operation. Automatic ground threat detection and reaction. AWACS communications interface with remote operator for air threats and deconfliction
Attack	Direct control by remote operator in TGP operations only. Autonomous navigation and threat reaction control by UCAV. Target detection, laser pointing and release consent by remote operator
RTB Cruise	High altitude autonomous or semi-autonomous operation. Automatic ground threat detection and reaction. AWACS interface with remote operator for air threats and deconfliction
Descent	Direct control by remote operator responding to calls by ATC

Landing	Direct control by remote operator responding to calls by ATC to line up on ILS final. Autonomous control with an ILS based auto-land and braking system similar to those found on airliners and Navy jets today
Dearm	Remote operator taxis off runway and stops jet in EOR for dearm. Remote operator shuts down aircraft engine or crew chief shuts down engine using fuel master switch outside control panel
Taxi/Park	Crew chief will tow the aircraft back to parking for refueling and ordnance reloading

Glossary

AAA	Anti-aircraft artillery
AAF	Auxiliary Air Field
ACSC	Air Command and Staff College
AFB	Air Force base
AFTI	Advanced fighter technology integration
AMRAAM	Advanced medium range air to air missile
ANG	Air National Guard
ATC	Air traffic control
AU	Air University
CAS	Close air support
CFPS	Computer flight planning system
CIA	Central Intelligence Agency
CONOPS	Concept of operations
CSAR	Combat search and rescue
DARO	Defense Airborne Reconnaissance Office
DARPA	Defense Advanced Research Projects Agency
DBS	Doppler beam sharpening
DCA	Defensive counter air
DMPI	Desired mean point of impact
DOD	Department of Defense
ECM	Electronic counter measures
EOR	End of runway
FAA	Federal Aviation Administration
FLIR	Forward looking infra-red
FY	Fiscal year
GMT	Ground moving target
GMTR	Ground moving target radar
GPS	Global Positioning System
HAE	High altitude endurance
HARM	High-speed anti-radiation missile
HTS	Harm targeting system
HUD	Heads up display

IADS	Integrated air defense system
INS	Inertial navigation system
IOP	Instrument of power
IR	Infra-red
JPO	Joint Project Office
JSTARS	Joint surveillance and targeting system
JSF	Joint Strike Fighter
LANTIRN	Low altitude night targeting for infra-red navigation
LGB	Laser guided bomb
LMTAS	Lockheed Martin Tactical Aircraft Systems
OCA	Offensive counter air
POW	Prisoners of war
PTT	Part task trainer
R&D	Research and development
RWR	Radar warning receiver
SAM	Surface to air missile
SATCOM	Satellite communications
SEAD	Suppression of enemy air defense
TGP	Targeting Pod
TDY	Temporary Duty
UAV	Unmanned aerial vehicle
UCAV	Uninhabited combat air vehicle
UN	United Nations
U.S.	United States
USAF	United States Air Force
USMC	United States Marine Corp
USN	United States Navy
UTA	Unmanned tactical aircraft or Uninhabited tactical aircraft

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