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In 2001, Congress stated "...that, within 10 years, one-third of U.S. military operational deep strike aircraft would be unmanned, and, within 15 years, one-third of all U.S. military ground combat vehicles would be unmanned." While aggressive and optimistic, this statement demonstrates the determination of our nation's decision makers in supporting unmanned aviation technology. This determination, coupled with recent successes in the Joint Unmanned Combat Air Systems (J-UCAS) demonstration program, makes uninhabited combat aerial vehicles (UCAV) a credible combat force in the near future. Unfortunately, the futuristic air surrounding these accomplishments has led to inaccurate analysis methods for future employment, resulting in outlandish claims or limited expectations. In similar circumstances, other emerging technologies have been rushed into use, without the establishment of joint doctrine, with fatal results. Therefore, in order to exploit UCAV's emerging abilities, military leaders must possess a clear analysis of the unmanned systems undergoing testing, the advantages and limitations of UCAV's, the weapons intended for integration, and the implications of using these unique capabilities under existing doctrinal architecture.

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Future Capabilities and Roles of Uninhabited Combat Aerial Vehicles (UCAV)

By

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A paper submitted to the faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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18 May 2004

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Abstract

In 2001, Congress stated "...that, within 10 years, one-third of U.S. military operational deep strike aircraft would be unmanned, and, within 15 years, one-third of all U.S. military ground combat vehicles would be unmanned." While aggressive and optimistic, this statement demonstrates the determination of our nation's decision makers in supporting unmanned aviation technology. This determination, coupled with recent successes in the Joint Unmanned Combat Air Systems (J-UCAS) demonstration program, makes uninhabited combat aerial vehicles (UCAV) a credible combat force in the near future. Unfortunately, the futuristic air surrounding these accomplishments has led to inaccurate analysis methods for future employment, resulting in outlandish claims or limited expectations. In similar circumstances, other emerging technologies have been rushed into use, without the establishment of joint doctrine, with fatal results. Therefore, in order to exploit UCAV's emerging abilities, military leaders must possess a clear analysis of the unmanned systems undergoing testing, the advantages and limitations of UCAV's, the weapons intended for integration, and the implications of using these unique capabilities under existing doctrinal architecture.

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Introduction

Throughout U.S. military aviation history, unmanned aerial vehicles (UAVs)[i] have been on the outskirts of public awareness and have played little in the operational planning for conflicts. Typically, these vehicles are used in the intelligence, surveillance, and reconnaissance (ISR) role, enabling both the ground and air commanders' ability to locate and target the enemy. However, since Vietnam the U.S. has possessed the ability to use these UAVs in a more offensive role. Specifically, the BGM-34 was designed to act in the suppression of enemy air defenses (SEAD) role, as well as traditional ground attack, becoming the first American Uninhabited Combat Aerial Vehicle (UCAV)[ii]. However, delays in the testing program, limits on capability, and large requirements for support caused the cancellation of this program.[iii] Two decades later, advancements in flight control automation, satellite communication, navigation, and weapon guidance have combined to make this a realistic objective. These prospects, combined with the desire to minimize risk on the battlefield, spurred Congress (2001) to state "…that, within 10 years, one-third of U.S. military operational deep strike aircraft would be unmanned, and, within 15 years, one-third of all U.S. military ground combat vehicles would be unmanned."[iv] This is a strong and significant statement, providing a clear vision of how our military will conduct operations in future conflicts.

Thesis Statement

As we look to the future of military operations with unmanned vehicles, we must ask the question – Is the U.S. military correctly predicting the roles UCAVs will play in future conflicts? The answer is no. Currently, proponents of UCAV focus on the benefits of unmanned aviation, as compared to manned aircraft, in terms of mission areas. This type of analysis leads to a mere subset of available roles and confusing intentions due to ambiguous mission definitions. In order to exploit these technological advances, our leaders must understand the need for such forethought, the systems undergoing testing, the advantages and limitations of unmanned aviation, the weapons intended for integration, and the implications of mixing these unique capabilities into existing doctrinal architecture.

Analysis

The main objective of building a UCAV is to minimize risk and cost without losing the ability to achieve the mission. At the tactical level, risk reduction is inherent while at the strategic level, risk may be a double-edged sword. The lack of risk may reduce the friction, leading to armed conflict, or that lack of risk may prevent the spiraling escalation that often drives a protection force to take offensive preventative measures. Regardless, the primary risk at the operational level, is the consequence of improper integration due to nonexistent joint doctrine or tactics, techniques, and procedures (TTP). For, throughout American military history, new technologies have been repeatedly integrated, prior to establishing joint doctrine or TTPs, with fatal results. In Vietnam, the blind faith in air-to-air missiles, Sparrow and Sidewinder, led to extremely poor kill ratios due to the elimination essential air-to-air training. These numerous losses in the early stages of the war forced a return to basic fighter tactical training, resulting in success by the end of the war and the development of TOPGUN, the Navy's Fighter Weapons School. More recently, the joint direct attack munition (JDAM) made its combat debut in Kosovo during Operation ALLIED FORCE [v] in 1999. During that conflict, JDAM was a scarce commodity and was used only in the predicted fashion. Three years later, the copious supply of JDAM was used in the same manner for the first few days of the Afghani conflict. However, once the preplanned strike missions were complete, combat forces found ingenious ways to employ this capable weapon, in both the armed reconnaissance (AR) and close air support (CAS) missions. Unfortunately, the lack of standardized procedures resulted in multiple friendly fire incidents, because coordinates were either passed incorrectly or misunderstood.[vi] It would not be until the following year that joint doctrine or TTPs would become official.

During this same timeframe, the Air Force modified a Predator UAV and tested the concept in February 2001. The results proved successful, but the Air Force decided not to modify operational vehicles. The CIA, on the other hand, did modify some of their vehicles and operated armed Predators throughout Operation ENDURING FREEDOM (OEF) in Afghanistan. Based on the CIA's success, the Air Force decided to retrofit their Predators and successfully used them during Operation IRAQI FREEDOM (OIF).[vii] To date, three years after testing and two years after initial employment, joint doctrine or TTPs still do not exist. This is not a condemnation of the forces fighting these conflicts, but rather a statement of the American soldier’s predictable determination to use any and all available combat tools in new and inventive ways. For this reason, U.S. military leadership has the responsibility of attempting to integrate these new tools in familiar or doctrinal ways to reduce fatal lessons learned.

History of UCAVs

As early as 1917, the United States dedicated significant resources, over $200,000, to create a remotely piloted flying bomb.[viii] While not officially designated a UAV, this desire to achieve mission success without risk to human life initiated the progression toward today’s UCAVs. The first of which was developed for Israel through the Big Safari management and acquisition program. In an effort to aid the Israelis, in their efforts to destroy SAM and AAA sites along the west bank of the Suez Canal, the armed UAV concept was developed and tested. The results were direct hits on simulated SAM sites in the U.S. The BGM-34A drones were later modified to fire laser-guided Maverick missiles and were used during the Israeli October War. Meanwhile, the U.S. Air Force began a similar program, but found successful employment difficult in the jungles of Vietnam. Shortcomings such as target acquisition, cumbersome communication, and vehicle vulnerability made it difficult for these early UCAVs to overcome the capabilities of manned aircraft. Due to these technological deficiencies as well as reduced funding, the BGM-34C program was cut in 1979.[ix]

Over the next two decades, advancements in computer automation, flight control systems, satellite communications, and weapon systems have enabled unmanned aircraft to demonstrate combat effectiveness similar to today's strike fighter aircraft. In aviation, computer technology has become an integral part of any complex aircraft system. Everything from the built-in-test (BIT) monitoring to the delivery of weapons has been affected and improved by the use of computer efficiency. For example, modern fighter aircraft have computer monitoring systems that not only advise the pilot that a malfunction has occurred, but takes steps to minimize the problem. Additionally, many airline aircraft possess the ability to fly, via autopilot, to a destination, make an approach, land the aircraft, and decelerate on the centerline of the runway before the pilot has to take the controls to taxi to the terminal.[x] The proliferation of communication and global positioning system (GPS) satellites enables UAV travel and refined navigation beyond the horizon. In particular for UCAV, GPS guidance technology has significantly improved combat ability of the weapons intended for use. These abilities are best demonstrated by the Global Hawk's trans-Pacific flight of 2001[xi] and the X-45A's successfully delivery of a small smart bomb, to within feet of the intended target, on 19 April 2004.[xii]

UCAVs in development

In the late nineties, the political risk associated with downed aviators and the escalating costs of advanced strike fighter aircraft forced the military and congress to look for new solutions. This result was today's UCAV programs, possessing two platforms undergoing testing, the X-45A and X-47A. The X-45, manufactured by Boeing, will be tested in concert with the X-47, which is made by Northrop Grumman.[xiii] Both vehicles are test-bed prototypes, with larger versions planned for operational use. Neither version has been designated as the Air Force or Navy prototype, but the X-47 does possess a tailhook and is planned to test carrier suitability by 2008[xiv]. As a point of reference, FA-18 pilots are currently catapulted off of the bow while holding onto a canopy handle, rather than the stick, and the aircraft can, if the pilot so desires, land aboard the carrier hands-free. Like the commercial autopilots, there are other functions the pilot is required to complete, but this example demonstrates the technical feasibility.

The Defense Advanced Research Projects Agency (DARPA) currently runs the joint effort with the mission to demonstrate technical feasibility, military utility, and operational value.[xv] Once DARPA has succeeded in this mission, the decision will then go to the appropriate services to continue operational test and procurement processes.[xvi] While this leaves room for significant changes, recent successes, increased funding from Congress, and technical feasibility make it improbable that both services will abandon the project. As of April 2004, both vehicles have flown and the X-45A has delivered a ballistic weapon as well as the GPS weapon already discussed. [xvii]

Comparison to Strike Fighter aircraft

In an attempt to define the capability of a strike fighter aircraft, most analysts first look at aircraft performance factors such as speed, range, thrust-to-weight ratio, and sustainable G's.

While these characteristics may be critical in a dogfight, weapon delivery systems and survivability make the difference over the target. The systems enabling communication, data or video transfer, navigation, stores management, target acquisition and identification, weapon delivery, and mission recording help define the capabilities of a strike aircraft.[xviii] Additional characteristics such as stealth, electronic protection, and mechanical survivability further define its capability. Since these systems and characteristics can be incorporated onto either weapons delivery platform, they are not accurate factors for comparison except for the unique requirement for certain systems. For instance, UCAVs will require an outstanding communications suite to enable the operator. While there is nothing to preclude similar use on manned aircraft, cost will most likely restrict procurement. Therefore, it is logical to expect UCAVs to have better communications systems (including data or video transfer), fuel economy, and stealth. Using this same deduction method, manned aircraft will not only reap the benefits of an onboard pilot, but will also have superior stores management system (due to a wider variety of weapons), electronic protection, and mechanical survivability.

Advantages of UCAV employment

Cost

Reduced cost has been a major factor in the advertisement of the UCAV and the original estimate claimed stated that the UCAV would be 30-50% the cost of a Joint Strike Fighter (JSF). However, these numbers may change considerably depending on how much our leaders want to invest in the UCAV's future capabilities. As an example, the Global Hawk UAV has recently gone into production and has an estimated cost of $50 million - roughly the same as the U-2 that it is replacing.[xix] While this is not a direct comparison, it does show that UCAVs will suffer from mission and cost creep similar to manned aircraft programs. Currently, most recent estimates have indicated that the unit costs of a UCAV will be upwards of $30 million[xx], less than the anticipated $40-50 million per unit cost expected for JSF[xxi]. Additionally, significant cost savings will occur due to reduced operating, training, and logistical costs as compared to manned aircraft.[xxii] Regardless, this cost will be less than that of manned aircraft, but will force commanders to reevaluate the "expendable" mentality associated with today's less expensive UAVs.

Range, Endurance, and Stealth

UCAV designs enjoy a freedom of design unmatched by manned aircraft. The elimination of a cockpit and the requirement for internal weapons bays allow the engineers to create lift, minimize drag, reduce weight, and streamline inlet air flows, all of which contribute to an extremely efficient flying vehicle possessing a low radar cross section (RCS). Due to these factors, operational versions of UCAV are expected to double the range and endurance of the JSF.[xxiii] The objective combat radius is 1300 nautical miles (nm) and the objective endurance/persistence is 1000nm / 3.5 hrs, with 4,500 lbs of ordnance.[xxiv] Of note, both of these objectives assume no aerial refueling since that ability is untested. Currently, there are ongoing studies attempting to solve this problem for both, boom-receptor and basket-probe[xxv], methods of aerial refueling with the boom-receptor version showing the most promise. While technically feasible, the UCAV's ability to accomplish this task in the future will depend on funding and the success of technical innovations.[xxvi] If, however, this capability becomes a reality, surmountable changes would be required in air traffic control to safely refuel manned aircraft and stealthy unmanned vehicles in close proximity. As for sensor and system performance, the recommendations and predictions vary widely due to the early stages of the program. There are sure to be several variations of mission and weapon requirements between now and initial operational capability (IOC), which could change the sensor requirements. Regardless, the UCAVs will most likely possess some form of target acquisition, ability to self-generate accurate waypoints, and a sensor to record the bomb damage for assessment similar to comparable strike fighter aircraft.

Limitations of UCAVs

With all of the advantages of these UCAVs, military leaders of tomorrow need to understand their limitations as well. Obviously, the difficulty in maintaining situational awareness, on par with an onboard pilot, will be the biggest limiting factor in the UCAV program. In concert with that is the ability to the use of secure communications networks for operator interface. In order to overcome these limitations, current designs use computer automation and weapon technology requiring little operator interface. This way, a vehicle can be sent on a mission or to a holding stack, while the operator interfaces with numerous other vehicles, before the operator consents to weapon release or mission alteration. However, as the compromise shifts from automation to operator interface, bandwidth requirements become a problem.

With all of the technological advances in satellite communications, one would think that this problem is solved. Instead, quite the opposite has occurred. Military leaders, in an attempt to shorten the decision cycle, have established requirements for shared information throughout all facets of our military forces. This need for information has permeated throughout every level of command and has created a grassroots flood of information. Video teleconferences, graphics for briefings, data transfer, and live video feed have overwhelmed bandwidth capacities. Additionally, this shows no sign of receding in the near future. The results have been restricted communication flow and the military's use of unencrypted commercial satellite systems.

Instead, many predict a five or six-fold increase.[xxvii] While increased satellite capability and improved technology, such as laser communications, will help to alleviate this problem, the operations of UCAVs must understand this limitation since this is a critical vulnerability for unmanned operations. The primary method of mitigating this limitation is to rely on automation for operations that do not involve the release of ordnance and minimize the amount of data transferred. If employed in current form, the UCAV will only pass minimal amounts of information. For a pre-planned mission, this could be as little as weapon release consent, given just prior to the vehicle reaching the target.

Weapons

The anticipated weapons for UCAVs are GPS/INS guided[xxviii], to include JDAM and small diameter bombs (SDB)[xxix], offering several advantages and some limitations. First, target acquisition and identification requirements are minimized since the weapon is only guiding toward a three dimensional waypoint, representing the target. This significantly reduces the opportunities for pilot and mechanical (sensor) error. For UCAVs, this allows a significant amount of automation prior to weapon release since the remotely located operator does not have to acquire the target. Secondly, since the weapon does not have to acquire the target, inclement weather and nighttime conditions do not affect the employment or success of the weapon. Lastly, the pilot or operator does not have to support the weapon to the target. The fire and forget nature of these weapons allows for simultaneous attacks on multiple targets, a significant improvement over supported weapons like laser-guided bombs (LGB).[xxx]

The main limitations of current GPS weapons are accuracy and the inability to attack moving targets. Since the weapon simply navigates to a waypoint and does not guide to an acquired target, navigational errors such as target location error (TLE), geometric dilution of precision (GDOP), and GPS timing synchronization will create an inherent reduction of precision.[xxxi] These errors will be reduced with improved systems, but accuracy is not predicted to match that of a terminally guided weapon, especially in a GPS denied (jamming) environment. This is not to say that GPS weapons are ineffective. Obviously, the results, since OAF, are good testimony that the GPS weapon concept is valid and very effective. This limitation in accuracy is only a concern when high levels of precision are required – such as hardened targets or buried bunkers. Moving targets, however, present a major problem for current GPS weapons. For, once employed, current GPS weapons do not possess the ability to update the target waypoint. If the target changes speed, direction, or both, the weapon will continue to the predicted target waypoint. In contrast, LGBs are more precise than GPS weapons and are capable against moving targets.

The implications this has on UCAV development can either be addressed by the mission assignment or the weapon integration. If military planners want the UCAV to possess a precision strike capability, they can use a manned aircraft or incorporate a weapon possessing terminal guidance. Current solutions include LGBs or recently demonstrated technologies, such as automatic target acquisition (ATA).[xxxii] LGBs have a three-meter circular error of probability (CEP), making it the most precise weapon in the current inventory. Additionally, since the weapon does not rely on GPS, it is difficult to jam. Unfortunately, LGBs require clear weather, operating sensors, and proficient operators to be successful. A significant consequence for UCAVs would be the vast amounts of bandwidth required for streaming video and two-way communication. By contrast, ATA (or similar techniques) also significantly improve accuracy, but the autonomous terminal guidance does not require support or streaming video. Bomb damage assessment would be the only requirement for bandwidth and this could be shortened to minimal time. While the scene matching technique requires more in-depth preflight or inflight photographic support, an ATA equipped weapon would not be as limited by weather and be resistant to jamming.[xxxiii] Additionally, since this system compares the scene surrounding the target, instead of the target itself, camouflage is very difficult due to the scale of effort required. The first version of ATA is currently fielded in the Navy's Stand-off Land Attack Missile-Expanded Response (SLAM ER) and the follow-on version has recently demonstrated a 48-inch circular error probability (CEP)[xxxiv], throughout developmental testing, for the unitary Joint Stand-off Weapon (JSOW-C).

Existing Doctrinal architecture

Any time that a weapon is released, fired, or employed, risk is involved. Because of this, our military has gone to extraordinary lengths to train their operators, create rules of engagement (ROE) and joint doctrine, and develop TTPs to reduce the risk of fatal or strategic incidents. For the UCAV, there will be three major areas where it will be integrated – routing, weapon release, and ROE. Routing is already being accomplished with UAVs and will not be significantly different with UCAVs. This is not to say that near mid-airs did not occur during OEF or OIF, instead this implies that lessons learned will benefit UCAVs in the same manner as UAVs.

In accordance with joint doctrine, an operator can release a weapon when directed by higher authority via the Air Tasking Order (ATO) or radio communications, when the ground commander (or terminal controller) authorizes an attack in close air support (CAS), or when the operator believes he can fire based upon the ROE. The first example provides a clean distinction and requires very little situational awareness of the operator. In this case, the UCAV would fly to a target, receive weapon release consent, release the weapon, and return to base for another mission. The second example provides this same level of ease, assuming GPS weapons are used and the terminal controller knows the location of the intended target. Just like a pilot, the operator would reassign the weapon to a new coordinate, in accordance with the terminal controllers instructions.

However, if LGBs or other operator intensive weapons were used, the level of coordination and difficulty across a wide battle space would increase dramatically. Not only would this potentially clog satellite communication, due to streaming video requirements, but also collateral damage and rules of engagement would be more difficult. Normally, visually released weapons imply the need for a collateral damage assessment by the pilot during delivery. However, GPS weapons do not carry this same requirement. For, regardless of where the aircraft is pointed, the weapon will begin to guide toward the designated target coordinate. Instead, the pilot is responsible for deconflicting any new target coordinates with known friendly locations. Since this can be accomplished in a cockpit or at a desk the difference is minimal.

Unfortunately for UCAV proponents, the last example of ROE driven decisions falls into an area where the UCAV's limitations are most conspicuous. Situations like air-to-air escort, where the pilot must make a decision based on incomplete information, regarding hostile intentions, would be difficult to comprehend from a remote ground control station. The same can be said for self-defense actions when a pilot must decide, before being shot down, the intentions of his potential enemy. In war, these decisions can be easy, but military operations other than war (MOOTW) often contain ambiguous direction for tactical operators. Similar rules apply for armed reconnaissance, often referred to as kill box operations, when the pilots must identify targets and decide for themselves the validity of their actions. Currently, technologies designed to automate this function are being researched, with the most notable being automatic target recognition (ATR).[xxxv] While highly touted in numerous articles and web sites, the realistic ability to accurately identify targets will be extremely difficult. For, all the enemy would have to do is change vehicle types or use alternate means to accomplish their mission. This would create a distinct vulnerability. Additionally, integrating an automated weapon release program into existing doctrine would most likely prove ambiguous at best. For these reasons, UCAVs will not be as strong at these missions as a piloted aircraft and should therefore be limited to low intensity conflicts or unique circumstances.

Roles for UCAV

The roles of future UCAVs are anticipated to be a subset of those performed by strike fighter aircraft and UAVs of today. The following table lists the typical strike fighter roles.

Fighter Missions
• Offensive Counter Air (OCA)
• Defensive Counter Air (DCA)
Strike Missions
• Deep Air Strike (DAS)
• Armed Reconnaissance (AR)
• Strike Coordinator for Armed Reconnaissance (SCAR)
• Close Air Support (CAS)
• Forward Air Controller (airborne) FAC(A)
Electronic Warfare
• Suppression of Enemy Air Defenses (SEAD)
Navy specific missions
• Anti-Surface Ship Surveillance and Interdiction
• Offensive Mining

Table 1 –Missions for Strike Fighter Aircraft

While the list of missions is plentiful, the difficultly in determining the appropriate missions for UCAVs is the ambiguous nature of their definitions. For example, Joint Publication (JP) 3-01 defines OCA targets as airfields and bases, aircraft (on deck or in the air), missiles and associated support structure, C4I systems and equipment, naval platforms, air defense systems and enemy forces. Additionally, the OCA mission is further broken down into attack missions, fighter sweep, escort, and SEAD. According to this definition, it would be accurate to state that UCAVs will have the ability to accomplish the OCA mission over Iraq, even though current plans do not possess an air-to-air capability.[xxxvi] Also, the targets listed in OCA can easily fall into most missions, leading to confusion when discussing potential roles or missions of future platforms.

For this reason, it is more accurate to evaluate the UCAV's potential and future use, based upon capabilities and limitations of the system and anticipated weapons. This potential capability should then be used to determine the UCAVs appropriateness for target sets vice missions. In this manner, the military leaders will have a clearer picture of this effective combat tool and be able to control employment through existing doctrine. Simply stated, the leaders of tomorrow should determine the appropriateness of UCAV use based on function rather than the mission, even though the mission will appear on the ATO.

Advantages of a UCAV	Limitations associated with UCAV
Risk Cost Range Endurance Stealth	Limited SA for operator Requires sophisticated communications system Lack of tanking ability[xxxvii]
Advantages of UCAV weapons	**Limitations of UCAV weapons**
Ease of delivery for pre-planned or assigned targets Fit into C2 structure Simultaneous attacks All weather, night capability	Accurate, not precise[xxxviii] Susceptible to jamming Reactive targeting Moving targets No air-to-air weapons planned[xxxix] No HARM missiles[xl]

Table 2 Advantages and limitations of UCAV and GPS weapons

To begin, a review of the limitations can help to narrow the categories. Limited SA, susceptibility to jamming, and limits on reactive targeting make the UCAV a poor choice to perform the air-to-air fighter function, FAC (A) role, or SCAR mission. The lack of HARM or jamming pods will limit the SEAD role to destruction of enemy air defenses. These targets can be treated in similar fashion as other attack missions. Additionally, the absence of mines in the anticipated weapon list may eliminate offensive mining for the Navy. However, if the Navy wanted to pursue this course of action the modifications would not be significant and the UCAV could be an effective tool in this role. Listed as a current limitation, precision will most likely be fixed with off-the-shelf technology or improvements in GPS, allowing UCAV weapons to destroy small, hardened, or buried targets. If this advancement does not occur, then UCAVs would not be able to match the capability of today's strike fighters. The last and most significant limitation is the inability to hit moving targets. Unlike the advancements enabling precision, hitting moving targets is a more challenging task without support from an operator. ATR capability will be difficult to prove and incorporate into existing C2 architecture. Therefore, other weapons need to be added to the UCAV's inventory or the mission should be shifted to another vehicle, specifically manned aircraft or armed Predator.

As for the advantages, the unique advantages will define the highest priorities for mission assignment. Stealth and low risk make the UCAV ideal for defended or dirty[xli] targets in the early stages of a campaign, which is consistent with the Air Force's intended mission – deep precision strike and suppression of enemy air defenses. However, these capabilities will also increase combat flexibility in the following stages of the campaign. For strikes aimed at shaping the battle space, the UCAV will be able to strike known or defended targets, with minimal support aircraft, allowing other platforms to focus their efforts elsewhere. As local air superiority is achieved, the UCAV can then use its abilities in endurance to aid the effort in CAS and AR arenas. However, this is where the doctrinal considerations will determine the appropriate use. As mentioned earlier, UCAVs can easily fit into existing doctrine when targeting information is provided by another source. Difficulty in this task comes when the operator is required to determine target validity based upon ROE. For this reason, UCAVs have potential to thrive in missions where the targets have known locations and create risk when high levels of situational awareness are required.

Conclusions

Throughout the examination of UCAV statistics, the statement can be made that the deficiencies of past projects have been overcome by modern day technology. However, since the project is still in the demonstration phase, much ambiguity will persist for reasons of political support, efforts to gain funding, or differing assumptions for future capabilities. Equally clear is the probability that this emerging technology will be used prior to completed TTPs or Joint Doctrine. Therefore, tomorrow's leaders have the responsibility to consider future employment options. Only then can our military learn form the mistakes of the past to avoid fatal and strategic consequences of improper employment. This is often discussed in terms of missions, but the ambiguity inherent in the definitions and target sets can cause significant misunderstanding. Therefore, the advantages of the vehicle, the anticipated weapons, and the effected doctrine must be used to decide the target validity. If this occurs, tactical forces will retain the freedom of ingenuity to maximize effectiveness while remaining inside the structure of doctrine.

Recommendations

While the future of UCAVs is uncertain, the military leaders of today need to look no further than the Global Hawk and X-45/47 demonstrators. For, these vehicles have clearly overcome the technical deficiencies of the past, proving that a cost effective UCAV is not only an achievable goal, but a future combat tool. However, with these achievements will come limitations, making it a priority for future commanders to understand the initial integration of this technology. The solutions to these limitations will be a combination of improved technology and integrated employment. Leveraging off of technological advancements and appropriating targets to manned and unmanned vehicle will be essential. Specifically for ambiguous situations requiring ROE decisions and moving target prosecution. Finally, the issue of bandwidth shortage can be dealt with through increased capability and decreased use. Since situations requiring persistent operator integration have the ability to overtax the communications network, these types of missions should be reserved for manned aircraft or limited to low intensity conflicts or extenuating circumstances.

As for the roles of UCAV, the advantages and limitations points the leaders of tomorrow into certain directions. First, joint doctrine currently has the required flexibility to accommodate UCAV until autonomous targeting capabilities are proven. Until such time, employment can be emphasized for targets with known locations. These targets can be in any mission area, to include OCA, DAS, AR, CAS, and SEAD.

Regardless of how this technology is used, the need for forethought and clear understanding cannot be overstated. For, “Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.” [xlii]

Notes

[i] A UAV is defined as a self-propelled aircraft that sustains flight through aerodynamic lift. The design is for the vehicle to be used, returned, and reused. This definition excludes flying bombs and guided missiles.

[ii] UCAV is a UAV that is specifically built to possess an offensive combat power. For this reason, Predators carrying missiles are referred to as armed UAVs.

[iii] Richard M. Clark, Uninhabited Combat Aerial Vehicles, The Cadre Papers, no 8, (Air University Press, Maxwell Air Force Base, Alabama, 2000) 23-28.

[iv] Congress, Senate, National Defense Authorization Act for Fiscal Year 2002, 107th Congress, 1st Session, 12 September 2001, <http://www.globalsecurity.org/military/library/congress/2001_rpt/sr062.htm> [2 May 2004].

[v] "Air Force Link – Fact Sheet: Joint Direct Attack Munitions GBU 31/32" Air Force Link, June 2003, <http://www.af.mil/factsheets/factsheet.asp?fsID=108> [10 May 2004].

[vi] Mark Burgess, "Killing Your Own: The Problem of Friendly Fire Durig the Afghan Campaign," CDI Terrorism Project, 12 June 2002, <http://www.cdi.org/terrorism/killing-pr.cfm> [10 May 2004].

[vii] "Predator Unmanned Aerial Vehicle (UAV), USA," The Website for Defense Industries – Air Force, <http://www.airforce-technology.com/projects/predator> 1 May 2004.

[viii] Clark, 8.

[ix] Ibid, 23-28.

[x] In current form, pilots still have to takeoff, manipulate flight surfaces such as flaps and slats, raise and lower the landing gear, and retard the throttles upon touchdown. Once the aircraft has slowed to an appropriate speed, the pilot must take control of the aircraft to taxi to the gate. Steve Kelly, Delta Airlines Commercial Pilot, telephone conversation with author, 8 May 2004.

[xi] "Global Hawk Makes Historic First Unmanned Flight to Australia," Space Daily: Your Portal to Space, 24 April 2001, <http://www.spacedaily.com/news/uav-01d.html> [6 May 2004].

[xii] Jan Walker, "J-UCAS X-45A Destroys Target," Defense Advanced Research Projects Agency News Release, 19 April 2004, <http://www.darpa.mil/j-ucas> [30 April 2004].

[xiii] Jane's, Unmanned Aerial Vehicles and Targets, 20th issue, "Boeing X-45", 220.

[xiv] Glenn Colby, J-UCAS Carrier Suitability IPT Leader, NAVAIR, telephone conversation with author, 10 May 2004.

[xv] Defense Advanced Research Projects Agency, "DARPA J-UCAS Mission Statement," <http://www.darpa.mil/j-ucas/j-ucas.htm> [8 May 2004].

[xvi] Mike Hirschberg, Contractor Joint Unmanned Combat Air Systems (J-UCAS) Office, DARPA, telephone conversation with author, 11 May 2004.

[xvii] Defense Advanced Research Projects Agency , "DARPA J-UCAS Overview," <http://www.darpa.mil/j-ucas/j-ucas.htm> [8 May 2004].

[xviii] The F-14 Tomcat is a great example of how a targeting system can change the capability of the platform. When the LANTIRN pod was first considered for the F-14, the Tomcat were considered air-to-ground capable, but few expected the aging aircraft to participate in combat strike missions due to its multiple shortcomings in weapon delivery. However, within two years the LANTIRN's ability to acquire targets, display accurate delivery information, and record the bomb hit proved superior to the FA-18, making the Tomcat the Navy's premier LGB platform for its remaining years. In contrast, the FA-18s have been superior in delivering more advanced weapons such as JDAM, JSOW, and HARM due to the onboard stores management system.

[xix] Charles Barry and Elihu Zimet, "UCAVs–Techological, Policy, and Operational Challenges," Defense Horizons, October 2001, 5 <http://www.ndu.edu/inss/DefHor/DH3/DH3.htm> [1 May 2004].

[xx] Ibid.

[xxi] United States General Accounting Office, Report on Joint Strike Fighter Acquisition, (Washington, DC: 2000), <http://www.globalsecurity.org/military/library/report/gao/nsiad-00-074.htm> [2 May 2004].

[xxii] Barry and Zimet.

[xxiii] Jane's, 220.

[xxiv] Michael Francis, "J-UCAS Capability Demonstration Program Overview Brief," 11, 20 April 2004, <http://www.darpa.mil/j-ucas/slides/cos/0programoverview-MikeFrancis.pdf> [8 May 2004].

[xxv] Boom-receptor refers to the Air Force style of tanking. In this case, the aircraft to be refueled flies formation directly behind the tanker and the boom operator, inside the tanker, maneuvers the boom into the receptacle on the receiving aircraft. Basket-probe is when a receptacle, with a funnel-like basket attached, is unreeled out of a refueling pod and the pilot is responsible for flying the aircraft probe into the basket. The Navy and certain helicopters use this method.

[xxvi] Colby.

[xxvii] "Pentagon Seeks Bandwidth," JSOnline, Milwaukee Journal Sentinel, 27 March 2003, <http://www.jsonline.com/bym/tech/news/mar03/129030.asp?format=print> [12 May 2004].

[xxviii] JDAM and SDB are unpowered weapons that fall toward the target, guided by INS/GPS information. Before employment, target information is entered into the weapon. Upon release, host platform three-dimensional location and velocities information is transmitted to the weapon. The weapon will then use the INS to guide toward the target while waiting to acquire GPS signals. Once the GPS signals are received, the weapon uses the GPS information to refine the navigation toward the three dimensional waypoint, or the target. If GPS signals are not received, then the weapon continues to use the onboard INS. GPS/INS accuracy is 13 meters and INS-only accuracy is 30 meters assuming the host platform was not denied GPS.

[xxix] Jane's.

[xxx] LGBs are ballistic weapons with terminal guidance. When released from the aircraft, the bomb falls toward the target, receives the encoded laser energy while inflight, and homes in on the reflected laser energy. This terminal guidance eliminates any small navigational errors.

[xxxi] TLE refers to the accuracy of the target designation. This will be improved, as more accurate plotting systems are developed. GDOP is based on the relative position of the four satellites being tracked. The most precise fix would come when the satellites are arranged in an equidistant triangle with the fourth directly overhead. As the satellites shift closer together, the three-dimensional triangulation becomes less precise. This dilution of precision can be predicted based on the satellite almanac information and is often referred to as predicted dilution of precision (PDOP). GPS time synchronization effects accuracy since the system is based on ranging from satellites. If the timing in different satellites is slightly off, the accuracy can be affected.

[xxxii] ATA is a scene matching technology that compares a stored image to the scene observed by the seeker. (The JSOW C currently uses an IR seeker.) Once the lines and shapes (ex. Streets and buildings) that surround the target match the stored image, the weapon guides to the location, within the scene, that has been designated as the target. This capability has some specific requirements for the stored image, but the target does not have to be in the image since the weapon guides to a location relative to the scene.

[xxxiii] ATA is not an all-weather capability, but it can fall through layers of clouds as long as it has clear visibility during the final stage of flight. If ATA were used on a JDAM, or similar weapon, the INS would be sufficiently accurate to match the scene. If using stand-off weapons, the level of accuracy would depend on when the GPS signal was lost since INS accuracy is proportional to the time of flight.

[xxxiv] Sara Hammond, "Raytheon's JSOW Unitary Variant Successfully Completes Developmental Testing," Raytheon News Release, 22 October 2003, <http://www.prnewswire.com/cgi-bin/micro_stories> [8 May 2004].

[xxxv] Automatic Target Recognition (ATR) is designed to locate and identify targets for the purposes of weapon guidance. One of the major problems is the ability to accurately identify friend, civilian and foe. Even if this could be achieved, significant ROE issues would have to be addressed, including responsibility in the event of a mishap.

[xxxvi] Hirschberg.

[xxxvii] Tanking is a limitation right now, but may be proven with developing technologies.

[xxxviii] This is based on current GPS weapon capability. Advancements are possible in the future to make them precise.

[xxxix] Hirschberg.

[xl] Ibid.

[xli] UCAV missions are often referred to as the three D's, dull, dirty and dangerous. Dirty refers to the attacks on nuclear, biological, and chemical targets.

[xlii] Contrails: The Air Force Cadet Handbook, United States Air Force Academy, vol. 28, 1982, 154.

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