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The Future of Unmanned Aerial Vehicles in U.S. Military Operations

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International Security and Economic Policy Specialization Project
May 2000

Executive Summary

Unmanned aerial vehicles (UAVs), remotely or automatically piloted aircraft, have been pursued by militaries for several decades as an alternative to risking the lives of military pilots. The U.S. military is currently in the latter stages of UAV development for intelligence gathering missions, and has begun to explore UAVs for other missions as well. As the Defense Department modernizes its airpower capability in the next two decades, spending an estimated $60 billion per year, UAVs must be considered as a possible alternative to other systems.

Potential baskets of missions for UAVs include intelligence gathering, communications, and force application. Manned aircraft, spacecraft and standoff weapons offer alternatives to UAVs in these mission baskets. In analyzing alternatives, system cost, capability at performing the mission and reliability to complete it satisfactorily must be considered.

UAVs appear ideally suited to take a leading role in the intelligence gathering mission basket. They may be able to serve in a backup role in communications, and support force application through jamming enemy communications and providing target acquisition and designation to other U.S. aircraft. Manned aircraft will continue to perform operations that combine multiple missions on one aircraft. Spacecraft will continue to play a leading role in communications missions. Standoff weapons show great potential to keep U.S. military personnel safe as they attack enemy targets.

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This paper does not necessarily represent the views of the Defense Department or the United States Air Force.

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Introduction

Theorists writing about the "revolution in military affairs," a fundamental change in the way conflict is carried out due to the proliferation of advanced information technologies, usually place unmanned aerial vehicles high on their list of emerging technologies. In their view of the future battlespace, UAVs will be a critical part of the new high-tech armed forces, collecting more intelligence than ever before, relaying information instantly between command authorities and warfighters, and delivering lethal force without risking casualties.

While there are few detractors for UAVs within the military (aside from perhaps a small group of pilots opposed on principle to anything that may cost them jobs), there seem to be few strong supporters of pursuing the technology. The military services have made other modernization efforts a higher priority. The air force in particular has made it abundantly clear that the F-22 (manned) air superiority fighter is its highest priority acquisition effort.[i] Tactical fighter acquisition, including the F-22, currently receives 25 times more funding than UAV programs.[ii] After maintaining a joint UAV program office for some years, the Defense Department has returned UAV acquisitions to the services, which will fit them in among their other research and development efforts and Congressional budget requests.

The current broad planning document in the Department of Defense, Joint Vision 2010, identifies four main operational concepts. *Dominant manuever* requires the ability to apply force quickly at any point on the globe and within specific theaters to be more flexible and agile than adversaries. These two goals work together to support *precision engagement*, the actual application of force. The military seeks to minimize the amount of explosives and the number of delivery systems needed to attack specific targets. It also involves reduced collateral damage. *Full-dimension protection* means keeping U.S. soldiers, sailors, airmen and marines as safe as possible. The final objective is *focused logistics*, the ability to sustain operations anywhere in the world. To make each of these four objectives possible, *information superiority* is necessary. This involves collecting and processing the maximum amount of intelligence and providing it to the lowest possible levels of command.

Unmanned aerial vehicles inherently serve to enhance full-dimension protection, because they do not require a living individual in the cockpit. While focused logistics do not seem to apply to UAVs, different types of UAVs show potential to assist the U.S. military in each of the other Joint Vision 2010 objectives as well, along with the overarching goal of information superiority.

Background

Unmanned aerial vehicles can mean many different things. Missiles that "fly" to their target are sometimes considered UAVs. UAVs have been used most extensively as target drones for air-to-air and surface-to-air munitions. This use of UAVs will undoubtedly continue, but this paper focuses instead on the operational use of UAVs and all future use of the term refers only to this subset of unmanned aerial vehicles. The standard NATO definition is as follows:

> A UAV is an uninhabited, reusable aircraft that is controlled remotely, autonomously by pre-programmed on-board equipment, or a combination of both methods. A UAV system, in addition to air vehicles, includes: remote flight and mission control equipment, modular mission payloads, communication devices for uplink and downlink and launch and recover systems. UAVs do not include cruise missiles, fire-and-forget weapons or other guided missiles.[iii]

The Israelis have been the most aggressive users of unmanned aerial vehicles. The most commonly cited use of UAVs in combat is the 1982 strike on Syrian missile batteries in the Bekaa Valley, where the Israelis used UAVs for surveillance to gather information on surface-to-air missiles prior to attacks and as a distracting device while manned fighters dropped bombs. The technique was highly successful, although the Israelis also had the advantage of inadequate tactics and camouflage by the Syrians and a good understanding of the terrain.[iv]

While UAVs are currently more a matter of speculation for the theorists of future war, the United States has pursued UAV technology for many years. The table below shows

the major operational UAV programs that the U.S. military has pursued during the past four decades.

U.S. Unmanned Aerial Vehicle Programs

Program	Period	Description	Status
Lighting Bug	1964-1979	Reconnaissance drone first used by Air Force during the Vietnam War	retired
Aquila	1979-1987	Tactical UAV for Army commanders	cancelled
Amber	1984-1990	Classified endurance UAV	cancelled
Pioneer	1986-present	UAV originally acquired to assess battle damage by naval gunfire	deployed
Medium range	1987-1993	Tactical UAV for the Air Force and Navy	cancelled
Hunter	1988-1996	Joint tactical UAV	cancelled
Gnat-750	1988-present	Long-endurance UAV developed with CIA funding; exported commercially	used for training
Predator	1994-present	Long-endurance UAV for theater commanders; based on Gnat-750	initial production
Darkstar	1994-1998	Stealthy endurance UAV for high-threat environments	cancelled
Global Hawk	1994-present	High-altitude, long-range endurance UAV	in development
Outrider	1994-1998	Joint tactical UAV	cancelled

SOURCE: Congressional Budget Office

As the table indicates, the U.S. has had a great number of cancellations of UAV programs that showed great promise early, but failed to live up to expectations. The General Accounting Office has been regularly critical of Defense Department UAV programs.

Currently, three U.S. UAV programs are in various stages of development. In December 1999, the U.S. Army selected the Shadow 200, built by AAI as the successor to the cancelled Outrider tactical UAV. If it survives the full acquisitions process it will serve as a tactical intelligence gathering UAV. Predator, which has been used operationally in southeast Europe, is still not fully tested, but will be fully operational within a year or two. Global Hawk, which will be operational sometime in the next decade, flies at a higher altitude than Predator, and is designed to be used for strategic intelligence gathering. In the earliest research stages is a combat UAV, which will be involved in the direct delivery of force, rather than the supporting role of intelligence gathering that has characterized UAV development to date.[v]

Unmanned aerial vehicles, in a continuing attempt to remain low cost, rely on small size and unconventional flight profiles to survive hostile situations.[vi] It is not clear if increased use of UAVs will make them more vulnerable as enemy air defense forces look for them more carefully.

Analysis Methodology

Unmanned aerial vehicles appear to be an option for performing several categories of military air missions. UAVs have potential in intelligence gathering, communications, and force application. Currently these missions are primarily assigned to manned aircraft.

Alternatives to UAVs include an increased dependence on space-based assets, continuing to use manned aircraft within the atmosphere, and, for force application, the use of standoff weapons.

Three criteria will be used to determine the appropriate system for each of the air missions. Cost includes both development and operational expenditures. It does not include the potential loss of human life. Capability is a measure of the ability of a particular system (UAV or alternative) to successfully perform a mission. It includes both speed and accuracy. Reliability measures the redundancy that must be built into planning because of the rate at which a particular system will fail. It also includes the flexibility that a particular system brings to be able to perform missions on short notice.

The matrix below shows the structure of this analysis, indicating the mission needs, the alternative systems, and the criteria for assessment.

		System Alternatives			
		Manned aircraft	**Spacecraft**	**Standoff weapons**	**UAVs**
Airpower Missions	**Intelligence gathering**	Cost Capability Reliability	Cost Capability Reliability	---	Cost Capability Reliability
	Communications	Cost Capability Reliability	Cost Capability Reliability	---	Cost Capability Reliability
	Force Application	Cost Capability Reliability	---	Cost Capability Reliability	Cost Capability Reliability

Potential Missions for Unmanned Aerial Vehicles

While ultimately UAVs may perform all of the dozens of different military air missions, in the foreseeable future the potential of UAVs lies in three major mission categories. These include both peacetime and wartime missions. Each of these "mission baskets" corresponds to one of the objectives in Joint Vision 2010. As indicated earlier, all UAVs offer maximum protection to U.S. military personnel, who do not need to enter the battlespace. This meets Joint Vision 2010's fourth goal of full-dimension protection. Intelligence gathering corresponds to information superiority. Communications corresponds with dominant manuever. Force application corresponds with precision engagement.

Some airpower missions seem clearly unsuited to unmanned vehicles. Strategic airlift, for example, generally operates in a low-threat environment, and often involves the transport of personnel. If there are human beings in the back of the aircraft, there is

little to be gained by eliminating the human in the cockpit. A less obvious example is the counter-air mission. The complexity of air-to-air combat with its requirement for multiple instantaneous decisions and maximum situational awareness make it an unlikely candidate for unmanned vehicles, which will not have the combination of computers and sensors capable of matching a pilot's abilities in the near future.[vii] Finally, extremely long-term, low-resolution reconnaissance, such as weather monitoring, is not suited to aerial vehicles nearly as well as orbiting satellites.

Intelligence Gathering Missions

Intelligence gathering is the basket of missions for which UAV technology is the farthest advanced. UAVs equipped for intelligence gathering would carry electro-optical (video), infrared or radar sensors. These missions include surveillance and reconnaissance missions, which have both peacetime and wartime components, as well as battle-damage assessment and detection of biological and chemical weapons, which are only necessary during conflict.

Reconnaissance. Although sometimes used interchangeably with surveillance, reconnaissance specifically involves gathering information about resources, activities, and characteristics of a potential adversary at a particular point of time. It includes collecting information about weather and geography. It can be tactical, with use limited to a local commander, or strategic, with relevance to an entire conflict or the nation. Reconnaissance missions are currently performed with low-altitude satellites, manned fighter aircraft and high altitude manned aircraft designed specifically for this mission.

Surveillance. In contrast with reconnaissance, surveillance involves watching a specific location for an extended period of time in order to gain information about the activities that occur there. Like reconnaissance, it can include both tactical and strategic components. Because it provides more information than reconnaissance, surveillance appears to be increasing in significance.[viii] Surveillance is currently performed by high altitude manned aircraft.

Battle-damage assessment. Following the delivery of force, military planners need to know the effectiveness of their attack. This mission can include information about the accuracy of munitions delivery and the remaining capability of targets not completely destroyed. This can be a time consuming process, as complete damage is not often known by either side immediately following an attack. No current air or spacecraft is specifically tasked with battle damage assessment, so aircraft involved with other surveillance or reconnaissance missions generally performs the mission.

Biological and chemical detection. The threat of biological and chemical weapons use remains a significant concern for the U.S. military. Forces must be able to detect the use of biological and chemical weapons before moving soldiers into a contaminated environment. If biological or chemical weapons use is detected, planners need to know the potential lethality in order to deal effectively with the situation. There is no current air capability for a biological or chemical detection mission.

Communications Missions

Communications forms the second basket of missions with potential for UAVs. Communications relays, gathering electronic intelligence, and jamming are each, respectively, more dangerous and intrusive uses of military airpower.

Communications relay. Line-of-sight communications are not always possible because of geographical barriers or distance that requires communication over the horizon. The unique physical arrangements of urban environments can pose special challenges to communications activities. An asset placed at a relatively high altitude between the two sources of information can serve to relay information between the two. Currently, most communications relay is done by satellites.

Signals intelligence. Gathering electronic emissions from the enemy communications and radar equipment is often the first step in outmanuevering the enemy. Gathering information on enemy warning and air defense radars allows military planners to deal effectively with these threats before turning their focus to more strategic targets.

Jamming. Jamming involves confusing or disrupting enemy communications or preventing radar equipment from noticing or locking on (in order to fire a missile).

Force Application Missions

Some future military thinkers have suggested that UAVs can fundamentally alter war because of how intrusive they could become. Theorists imagine machines entering a building and determining which specific individual to attack. This kind of technology is not available now, and this report focuses on traditional force application missions with the potential of UAV use. For the foreseeable future these missions will remain with us and will have to be performed by some air system.

Suppression of enemy air defenses. To establish the air superiority necessary for both tactical and strategic attack on ground targets, one of the first priorities of U.S. air forces is the elimination or crippling of the warning and tracking radars, missile launchers, and anti-aircraft artillery of the enemy's air defense system. This is an extremely dangerous mission, because it not only involves flying into the teeth of the defenses, but often relies on incomplete intelligence, requiring searching for the defensive systems first.

Target acquisition and designation. The increasing use of precision guided munitions allows U.S. forces to pick very specific targets for attack. Target acquisition involves discovering or confirming the precise location of a potential target and relaying that information to the aircraft that will perform the actual attack. Although most critical for mobile targets, such as enemy tanks, stationary targets still require longitude and latitude measurements. Related to target acquisition, this mission involves "illuminating" a target with a laser to allow a missile or other munition to follow a path to its target.

Close air support. Ground troops generally require airpower to support their operations against enemy ground forces. Close air support often involves attacks on enemy tanks and other armored or hardened positions. It involves low-altitude flying, putting the aircraft in a very dangerous position to surface-to-air missiles and artillery.

Interdiction and strategic attack. The ultimate goal of applying airpower, strike missions involve placing bombs on targets of both military and strategic value. Increasingly, strikes are carried out with precision guided munitions that limit the number of bombs that must be dropped to guarantee success and limit the collateral damage caused by attacks.

Combat air patrol. After the U.S. and its allies have established air superiority, combat air patrols are typically round-the-clock missions to maintain it. They provide early warning intelligence. These can also be missions to enforce no-fly zones, such as in Iraq and Bosnia.

Alternatives to Unmanned Aerial Vehicles

Manned Aircraft

The oldest and most traditional use of airpower, manned aircraft are used for all current missions that could be moved to UAVs. Manned aircraft are generally larger, more expensive to acquire and to operate and less maneuverable than unmanned aircraft.

Inherent advantages of manned aircraft. Having a trained, intelligent individual on the scene who can make decisions and seek the appropriate information is invaluable. Manned aircraft traditionally use performance technology (including stealth) and agility as the means of survival in a combat environment.[ix] Multiple capabilities, such as gathering intelligence and delivering force, are generally possible only in manned aircraft.

Inherent disadvantages of manned aircraft. Manned aircraft place U.S. military personnel at the greatest risk. This can have political as well as military limitations on mission planning. The human body can physically withstand only a limited amount of stress. Having pilots in aircraft limits their ability to maneuver, because humans can only withstand 8 or 9 g-forces (and only for a limited amount of time). It also limits the amount of time an aircraft can stay on location.

Spacecraft

The United States military has used satellites for military use for nearly four decades. Space has been used as a means of gathering and transmitting information, though space has not been used for weapons.

Inherent advantages of spacecraft. Spacecraft, with the highest altitude of any military asset, have the widest field of view. They are not vulnerable to air defenses.

Unmanned satellites, like unmanned aerial vehicles, do not put U.S. military personnel at risk.

Inherent disadvantages of spacecraft. Spacecraft are exceedingly vulnerable, both to natural phenomena and to planned attack. Once damaged or broken, spacecraft are difficult and expensive to fix. Spacecraft are much less flexible than systems flying through the atmosphere because of the cost and difficulty of "re-tasking." In general, spacecraft must be placed in orbit to perform their originally intended mission until they break or the mission is no longer required.

Standoff weapons

Standoff weapons are an additional alternative to force delivery. The logical step after precision guided munitions, standoff weapons have internal guidance systems that allow the weapon to be fired from a distance out of harms way, and, in some cases, without even being seen. Standoff weapons may be may be powered (missiles) or unpowered (glide).

The U.S. military has successfully used cruise missiles in several conflicts. Cruise missiles may be launched from ships or from bomber aircraft. Two standoff weapons currently being acquired are the Joint Standoff Weapon (JSOW) and the Joint Air-To-Surface Standoff Missile (JASSM). The Joint Standoff Weapon is an air-to-surface, glide weapon with a range of 24 to 64 kilometers.[x] The Joint Air-To-Surface Standoff Missile is a powered weapon with a range of much greater than 200 kilometers.[xi]

While there is no technical reason that standoff weapons could not be launched from UAVs, there is little to gain from such an arrangement, since both systems seek to avoid putting military personnel within the reach of enemy fire.

Inherent advantages of standoff weapons. Like UAVs and spacecraft, standoff weapons keep military service members safe by keeping them out of the range of enemy fire. Standoff weapons increase the element of surprise because they are smaller than manned aircraft delivering more conventional missiles and bombs.

Inherent disadvantages of standoff weapons. Because decision-making occurs from a distance there is less complete information available than if pilots can actually see what they are attacking. Standoff weapons are more susceptible to jamming and other decoy tactics.

Options Assessment

Mission Basket #1: Intelligence Gathering

	Cost	Capability	Reliability
Best	Unmanned aerial vehicles	Unmanned aerial vehicles	Spacecraft
<---->	Spacecraft	Manned aircraft	Manned aircraft
Worst	Manned aircraft	Spacecraft	Unmanned aerial vehicles

Manned aircraft

While some manned aircraft, such as the U-2 and SR-71, have been designed specifically for intelligence gathering missions, most manned intelligence aircraft are modified fighter or cargo aircraft. Aircraft such as the E-3 AWACS (Airborne Warning and Control System) and E-8 Joint Surveillance Targeting and Attack System combine intelligence gathering with command and control capabilities into a single platform.

Cost. Modern manned aircraft cost tens of millions of dollars to procure and are relatively expensive to maintain because of their high performance in terms of speed, maneuverability and stealth. The training of pilots adds to this cost. Fully trained pilots must still regularly fly actual aircraft to maintain their proficiency, adding regular aircraft maintenance costs to operations.

Capability. Manned aircraft are generally capable in multiple ways. Fighter aircraft equipped with sensors can perform tactical reconnaissance and battle-damage assessment. Strategic reconnaissance is generally performed by larger aircraft flying at higher altitudes. They can be equipped with multiple sensors. A pilot on board gives flexibility to missions to search for different things and allows mission changes if a pilot finds something that should be checked out further. Manned aircraft are limited in capability by two factors. First, they can remain in one area for a limited amount of time, reducing the surveillance they can provide. Second, they are always at risk of being shot down, limiting the places they can fly.

Reliability. Tactical fighter aircraft modified for intelligence gathering have survivability advantages because they can defend themselves without assistance from other assets. However, their high performance characteristics give them lower mission-capable rates than other aircraft.

Spacecraft

Spacecraft used for intelligence gathering are closely guarded secrets, though the fact that the U.S. has and uses them has been well known for decades. The precise missions they fulfil and their exact capabilities are not publicly known.[xii]

Cost. Satellite systems cost hundreds of millions of dollars to develop and launch into orbit. In order to provide regular coverage of all areas of the earth's surface, a constellation of satellites is necessary.

Capability. Spacecraft use radar, optical sensors and electronic intercept capability to collect information.[xiii] While they offer reconnaissance capability, they have little surveillance capability because the low orbits necessary for high resolution prevent satellites from remaining over one geographical location. Orbiting at altitudes of several hundred kilometers, intelligence satellites can collect imagery with a resolution of better than 10 centimeters, which is enough to characterize vehicles and military installations. Optical imagery is not effective through cloud cover.[xiv]

Reliability. In general, satellites are the most reliable system for intelligence gathering, providing constant information even before a crisis develops. The regular schedule of satellite orbits makes it possible, in some circumstances, for adversaries to hide themselves or their equipment while the satellite flies overhead. Obviously a large event such as moving thousands of troops cannot be hidden, but smaller events can be hidden from satellites. Damaged satellites are difficult and time-consuming to fix and launching a replacement cannot be done quickly in a crisis.

Unmanned aerial vehicles

Cost. UAVs have the potential to provide very low cost intelligence gathering capability. The UAVs currently being developed will cost less than $10 million per aircraft. At this cost, some amount of attrition should be acceptable to commanders. Intelligence gathering UAVs are not projected to carry any weapons to defend themselves. Adding weapons or stealth technology to increase survivability will significantly add to UAV cost. Pilots "flying" UAVs in a simulator will receive identical training to those flying actual aircraft, so actual UAVs will have to fly much less than manned aircraft currently do, reducing maintenance and operating costs.[xv]

Capability. The greatest asset of UAVs in the intelligence gathering mission basket is their ability to spend an extended period of time watching one location. UAVs can be equipped with multiple different types of sensors including radar, optical, and infrared. The UAVs currently in development have a variety of operating ranges, from 100 kilometers for the Shadow 200 to thousands of kilometers for the Global Hawk.

Reliability. UAVs have experienced more difficulties with icing than larger, manned vehicles in testing to date.[xvi] UAVs may be more vulnerable to being shot down or crashing. Survivability may be a critical factor. Although Predator UAVs were in limited use in NATO's Kosovo bombing campaign, four were shot down, compared with only two manned aircraft.[xvii] Further development is necessary to make UAVs more resistant to enemy jamming.

Conclusion

Unmanned vehicles appear ideally suited to assume the bulk of the intelligence gathering missions. Their long loiter times at low cost make surveillance relatively easy compared to manned aircraft. Manned aircraft will continue to perform intelligence gathering that can occur outside the range of enemy attack and those missions that combine intelligence gathering with information processing and communications, such as AWACS. Satellites with superior reliability will continue to provide a supplemental intelligence role.

Missions Basket #2: Communications

	Cost	Capability	Reliability
Best	Spacecraft	Spacecraft	Manned aircraft
↕	Unmanned aerial vehicles	Unmanned aerial vehicles	Spacecraft
Worst	Manned aircraft	Manned aircraft	Unmanned aerial vehicles

Manned aircraft

Large, high-altitude aircraft like the E-3, E-8 and RC-135 perform many of the current communications missions. They link headquarters with tactical aircraft, and collect and process electronic emissions from enemy communications. The Navy's EA-6B performs most of the jamming missions required, blocking out enemy warning and tracking radars to protect other U.S. air assets.

Cost. No new purchases are planned for these types of manned aircraft, but upgrades to their electronic systems will cost millions over the next decades.

Capability. The manned communications aircraft perform multiple missions simultaneously, often collecting intelligence as well as coordinating communications between friendly aircraft. The jamming capability is the weakest of the manned aircraft missions. The EA-6 is an old aircraft, but with the retirement of the Air Force EF-111 and F-4G it is left to perform the jamming mission alone.[xviii]

Reliability. As long as the U.S. has air superiority, the high-altitude communications aircraft function extremely effectively. They could be vulnerable in a situation without air superiority.

Spacecraft

The U.S. has several communications satellite systems, operating in different parts of the electromagnetic spectrum.[xix]

Cost. The U.S. military continues to upgrade its communications ability with additional satellite constellations that are more durable, have greater capacity and are more resistant to jamming.[xx] Acquisition and launch costs are very high, but once in space satellites are the cheapest option to operate.

Capability. Spacecraft perform the bulk of the friendly communications missions, and are also capable of intercepting enemy electronic emissions. The several different constellations of communications relay satellites operate at different frequencies, offer coverage over the entire earth and are jam-resistant.[xxi]

Reliability. Communication satellite constellations have redundancy built in by having individual satellites with overlapping coverage of the earth's surface. As with intelligence gathering satellites, these spacecraft are less vulnerable to deliberate attack or accident than aircraft, but are more difficult to fix or replace if damage does occur. Spacecraft are less flexible than aircraft. When Iraq invaded Kuwait in August 1990, for example, the U.S. was very concerned that Saudi Arabia would be the next target. The U.S. had virtually no intelligence assets on the ground, however, and had to wait hours in order to divert communications satellites to help with intelligence gathering. This left senior officials without the means to communicate.[xxii]

Unmanned aerial vehicles

Cost. UAVs flexibility reduces their cost for the communications missions. UAVs currently in development for intelligence gathering could be modified to carry communications payloads at nominal expense. Existing sensors for signals intelligence and jamming capability could be added as well.

Capability. UAVs will be less flexible in their application to communications missions than manned aircraft. While the EA-6, for example, can jam surface-to-air missile radars and also fire missiles at the batteries, UAVs will offer only the jamming capability. However, because of the lack of pilot vulnerability, UAVs would be able to perform for dangerous and risky missions, depending on the probability of loss the commander is willing to risk. UAVs could be used as communications relays similar to satellites. This may be particularly useful in some special situations, such as urban environments.[xxiii]

Reliability. Reliability has been one of the major reasons a most U.S. UAV programs in the past two decades have been cancelled. Recent testing with the Predator UAV, which could be modified for communications missions, have had poor reliability results with no system lasting more than 13.2 hours before some critical failure.[xxiv] Future developments hopefully will improve this performance.

Conclusion

While spacecraft are the most suitable system for communications relay, UAVs will be able to provide backup and redundancy in case of satellite damage or malfunction. For the more intrusive communications missions, UAVs appear suited to taking over from manned aircraft and spacecraft, because of their flexibility relative to satellites and the

dangerous situations that these missions demand. Planners will have to be prepared for a relatively high attrition rate, because of the lack of mission flexibility relative to manned aircraft, such as EA-6 aircraft.

Missions Basket #3: Force Application

	Cost	Capability	Reliability
Best	Standoff weapons	Manned aircraft	Standoff weapons
<---->	Unmanned aerial vehicles	Standoff weapons	Manned aircraft
Worst	Manned aircraft	Unmanned aerial vehicles	Unmanned aerial vehicles

Manned aircraft

The U.S. currently performs much of the force application mission with manned fighter and bomber aircraft. There are no current plans to upgrade the bomber fleet, but the Joint Strike Fighter will take over most of the fighter ground strike role when it becomes operational, some time after 2010. It is designed to serve as the primary air-to-ground strike capability for several decades.

Cost. Tactical fighter aircraft continue to become more expensive, although some analysts believe that the increased capability has caused the real cost to decline over time. Whether this is true or not, using manned aircraft to perform the force application mission is the most expensive air option, upwards of $50 million per aircraft.

Capability. The Joint Strike Fighter will in all likelihood be very capable, but is still a decade or more away from operational use. Currently the U.S. military uses F-16, F-15E and F/A-18 aircraft as its primary ground attack fighters, with the B-1, B-2, B-52 and F-117 performing bombing roles. The sharp increase in the use of precision guided munitions has increased the capability of manned aircraft. Only 9% of bombs dropped during the Gulf War were precision weapons, but 35% of the bombs dropped in Kosovo in 1999 were precision guided. In Kosovo, those bombs accounted for 74% of the damage. However, NATO pilots generally flew at high altitudes to avoid casualties, increasing the amount of collateral damage.[xxv]

Reliability. Manned fighter aircraft are a mature technology, although each generation of fighter has had development difficulties. Because of their high performance, fighter aircraft are prone to break down at relatively high rates. Additionally, the growing surface-to-air missile threat may cause significant problems for U.S. air-to-ground attack. The number of nations with the most advanced surface-to-air missile technology will grow extensively in the next decade, because of the relative inexpensive of buying these systems.[xxvi]

Standoff weapons

Cost. Standoff weapons have been very expensive relative to other munitions, upwards of $1 million for each cruise missile, but costs appear to be falling. The new Joint Air-to-Surface Standoff Missile (JASSM) has a cost estimate of $400,000 each. The shorter range Joint Standoff Weapon will cost about $180,000 each. [xxvii] Compared to the expensive of manned aircraft, these costs are very low.

Capability. Standoff weapon technology is advancing quickly. Today's air- and sea-launched cruise missiles can be fired from more than 1000 kilometers from their target. The JASSM will have a range slightly under 1000 kilometers. They are extremely accurate, guided by various combinations of global positioning and inertial guidance systems. Originally designed to carry nuclear warheads, they have been modified to carry 2000- and 3000-pound conventional munitions. Standoff weapons will soon have the capability to penetrate hardened targets.[xxviii]

Reliability. The small radar cross section of standoff weapons and their low-altitude flight pattern increase their survivability. Standoff weapons, like UAVs, are susceptible to enemy jamming and decoys.

Unmanned aerial vehicles

Cost. According to the military's own estimate, a combat unmanned aerial vehicle is projected to cost around $11 million and be ready by 2010.[xxix] An outside estimate is that a combat UAV capable of surviving 15 missions will cost $25-35 million.[xxx]

Capability. To date, research on using UAVs for force application has focused on the suppression of enemy air defenses mission. Although UAVs would likely be slower than manned aircraft, they could perform more violent maneuver techniques to avoid being shot down. UAVs could also be used for target acquisition and designation to aid standoff weapons. The hazardous close air support mission has not been explored in research and development, but UAVs may be able to meet this requirement because they could be controlled by the ground forces they are supporting.[xxxi]

Reliability. Commanders should expect a high attrition rate of UAVs used in strike roles. Some defensive measures or stealth capability may need to be added to UAVs to make them more survivable, but if the cost of each vehicle is low enough, high attrition may be acceptable.

Conclusion

Standoff weapons should have the lead role in force application. Manned aircraft will continue to perform the air superiority mission, but standoff weapons, with the guidance and targeting assistance of spacecraft and UAVs are the best option for ground attack. As the U.S. purchases standoff weapons in greater numbers the costs should continue to decline. Overall, standoff weapons will help prevent U.S. casualties, particularly the major political cost of having a downed pilot fall into enemy hands.

Conclusions and Recommendations

Unmanned aerial vehicles, together with standoff weapons, show great potential to assist U.S. military airpower in the 21st century. UAVs appear unlikely to completely replace manned aircraft or spacecraft in the foreseeable future. Instead, UAVs will serve as a supplement to other systems, increasing redundancy, and take a leading role in some specific intelligence gathering missions.

Manned aircraft appear to have come up lacking in this analysis. They do not appear best suited for any of the three mission baskets presented, leading to the question of whether manned aircraft are an obsolete technology. To some extent, manned aircraft were set up to fail, because the greatest single asset of a pilot is the flexibility that he or she brings to the battlespace, the ability to perform multiple missions with one aircraft and respond to changing a situation in real time. Multiply capable manned aircraft, combining command and control with surveillance, or battle-damage assessment with close air support, will continue to have a military airpower role. Despite decades of development, remote guidance systems for UAVs have not matched the situational awareness of pilots, such as the ability to avoid decoy targets and continuing to fly safely in the presence of electronic jamming.

Space remains a useful operational environment and the role of military spacecraft may continue to grow in coming decades. Two factors, however, appear to prevent space from becoming more important to the military than operations within the atmosphere. First, space is still a harsh natural environment. Spacecraft must be built to particularly high durability standards. Despite predictions, space travel is still extremely expensive, limiting the options to fix damaged spacecraft, or replace a malfunctioning satellite with a new one. The second limiting factor is political. Since the 1967 Outer Space Treaty banning space-based nuclear weapons, international political pressure has been against any weapons deployment in space. There is little reason to think that these pressures will soon disappear. Instead, spacecraft will likely remain as a support to other military operations.

Best Uses for Unmanned Aerial Vehicles

Unmanned aerial vehicles appear ready to take the lead role in intelligence gathering missions. They are significantly less expensive than manned alternatives, making attrition more acceptable to military planners. This will allow them to be more risky in their employment of UAVs in order to gather more complete intelligence. In addition, UAVs are suited to the dangerous jamming mission against enemy communications and radar equipment while manned aircraft deliver standoff weapons against ground targets.

Possible Uses for Unmanned Aerial Vehicles

Unmanned aerial vehicles show promise to supplement other systems in carrying out communications and force application missions. UAVs could serve as a redundant backup to spacecraft in relaying allied communications, particularly in some special environments such as urban centers. While standoff weapons show the most potential for force application, UAVs may be able to assist in targeting designation and other supporting missions.

Force Structure Recommendations

Increased focus on unmanned aerial vehicles will require tradeoffs in other areas. There is uncertainty about what the military will be willing to give up in order to pursue further UAV development. Three major military procurement programs are affected by the increased potential for UAVs and standoff weapons.

F-22 air superiority fighter. The F-22 is enormously expensive, up to $200 million per aircraft depending on how the cost is calculated. However, the fighter will be vastly superior to any current U.S. aircraft or any other fighter being developed around the world in speed, stealth, and avionics. In order to use UAVs and standoff weapons effectively, air superiority will be more important than ever to U.S. air forces, so the military should proceed with F-22 procurement. Scaling back from a planned buy of 339 aircraft to 125, and supplementing the F-22 with additional F-15 fighters, which are still very capable, will free up an estimated $10 billion dollars over the next two decades.[xxxii]

Joint Strike Fighter. The U.S. military plans to purchase more than 2,800 of the new Joint Strike Fighter, which is projected to begin operations in 2010. Under this plan the Joint Strike Fighter will replace the F-16, A-10 and AV-8B as the sole ground attack fighter. The Joint Strike Fighter will cost approximately $40 million more per aircraft than F-16s.[xxxiii] With increased reliance on UAVs and standoff weapons, the U.S. would be better served by canceling the Joint Strike Fighter program or scaling it back dramatically. Canceling the program could free up $100 billion over 25 years. Firing standoff weapons at a safe distance from their targets does not require the best available technology, so the U.S. military could continue to rely on current aircraft designs, and simply replacing planes as they wear out. In addition, standoff weapons do not need to be launched from fighters, so a combination of U.S. military bombers, ships, and existing fighter designs will be adequate.

Evolved expendable launch vehicle. The U.S. military is currently developing a space launch vehicle to replace its Delta, Atlas, and Titan space launch vehicles. The primary goals of the new EELV are to improve "assured access to space," and to make U.S. industry more competitive commercially.[xxxiv] While the new launch vehicle may provide cost savings over time, the expanding UAV role as a backup to space systems will make it less important to have quick launch capability. If further development shows the EELV will save money, it should continue to be funded. However, if it will only improve launch capability, it can be canceled for further savings.

Ethical Considerations

On its face, the major advantage of UAVs is their ability to protect U.S. airmen by keeping them out of the skies where they are vulnerable to enemy fire. Full-dimension protection should continue to be an objective of military planners. But there are two concerns worth noting that may make invulnerability less desirable. The more protected U.S. forces are, relative to its adversaries, the less stable the situation. This is the asymmetry concern. Secondly, protection may take away the desire to avoid conflict. This could be called "self-deterrence."

Asymmetry

Militaries will always try and exploit any advantage available, including technological advances in order to inflict more damage to enemies while sustaining less damage themselves. As the difference in capabilities between the two sides in a conflict increases, the more likely it is that the disadvantaged side will turn to other means.

The U.S. already enjoys a tremendous advantage in nearly all areas of military capability. U.S. personnel are better trained and better equipped than any military in history. Air superiority is almost a given in any U.S. military operation, opening the way for other airpower operations including intrusive intelligence gathering and attacks. This airpower dominance of the U.S. will encourage U.S. adversaries to seek other ways to defeat U.S. forces, possibly including chemical or biological weapons.

Deterrence

A second ethical concern that UAVs raise might be called "self-deterence." The risk of casualties when entering a conflict has the appropriate effect of dampening enthusiasm for war. As the U.S. pursues technologies that reduce the risk of casualties, there may be fewer reasons to avoid conflict. The U.S. could potentially become more involved in conflicts around the world that it would otherwise avoid. One retired marine general commented after the 1999 NATO campaign in Yugoslavia that one "troubling...aspect of the so-called 'immaculate' air campaign is the ability to drive an enemy to his knees without shedding a drop of the bomber's blood. Normally, the litmus test of going to war was the willingness to suffer casualties in pursuit of its objective."[xxxv]

A Vision of the Future

While this report has referred at times to some specific air and space systems, both in operational use and in development, it is not clear which developing technologies will be operationally capable in coming decades. The criteria laid out in this report: cost, capability and reliability can be used, however, to evaluate specific systems as they become mature technologies ready for full procurement.

Future U.S. military conflicts are also difficult to describe. Whether the U.S. continues to focus its military equipment and training on fighting Major Theater Wars, shifts

resources towards the increasing number of Small Scale Contingencies, or develops an entirely new operational concept will drive future defense acquisitions.

UAVs appear to have a role in any of these military operations, however. If the U.S. military continues to operate in low-intensity conflict in several places around the world at once, intelligence gathering UAVs with their ground control stations will be necessary to monitor peacekeeping operations or other situations likely to become more serious. In perpetually dangerous theaters such as North Korea, UAVs could be used around-the-clock to provide surveillance of the demilitarized zone. Those types of repetitive missions could be preprogrammed eliminating the possibility of enemy jamming of the control system. Because of their small size, UAVs and their ground stations can be placed on cargo aircraft and moved rapidly to anywhere on the globe.

UAVs have had development difficulties in the past, and they will not be the perfect military system in the future. However, they offer great potential to U.S. air forces and should be given a high priority in future acquisition efforts.

Notes

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