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AUTONOMOUS UAS: A PARTIAL SOLUTION TO AMERICA'S FUTURE AIRPOWER NEEDS

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Abstract

This research paper examines the role autonomous unmanned aerial systems (UAS) will play in the US Air Force (USAF), along with the obstacles the USAF will face in their use and proliferation. To some, the idea of fully autonomous weapon systems making their own targeting and weapons employment decisions conjures up troubling images from movies like "Terminator" and "I, Robot." The US military already uses some semi- and fully autonomous technology (in both UAS and manned systems) and, as UAS technology matures, will look to increase these systems' autonomy. Despite improvements in UAS technology, the USAF will not be able to rely exclusively on autonomous systems because of their significant technological limitations, political resistance within the United States, international obstacles, doctrinal and operational problems, and service-related impediments. These obstacles will require the USAF to maintain a diverse force of autonomous UAS, manned aircraft, and man-in-the-loop (MITL) controlled UAS.

Future autonomous UAS will have several benefits. These are: the ability to eliminate risk to US personnel, the reduction in personnel requirements and the ability for new technology and capabilities to be quickly propagated across the entire fleet. To be able to capitalize on these benefits, autonomous UAS will need to accomplish certain technological milestones. The first is the ability to accomplish basic aircraft tasks (takeoff, land, in-flight refueling, etc). Additionally, autonomous UAS must be able to operate within future bandwidth constraints, as well as ensure the security of communications sent to/from UAS. Lastly, UAS will need to be able to correctly identify airborne and ground targets. This identification requirement will be most difficult during counterinsurgency missions where it is unrealistic for UAS to be able to correctly distinguish between civilians and insurgents.

Domestic resistance to autonomous UAS will come from politicians and their potential to alter the relationship between the military and society. Current conflicts show that political constraints and restraints will be placed on military forces, even if they may reduce US military superiority. Some believe autonomous UAS, because they do not endanger US personnel, could alter civil-military relations and lead to the over-use of military force and the alienation of the military from civil society.

International resistance to autonomous UAS attack systems is expected to be fierce and determined. One can expect there to be a call for international treaties to ban or restrict autonomous weapon systems. Groups have already begun lobbying governments to restrict or ban autonomous weapon systems. As an expeditionary air force, the USAF is normally dependent on allied and coalition nations. Thus, the USAF must ensure partner nations will allow basing and employment of autonomous UAS.

The USAF's doctrine and operations would be significantly affected by the integration of autonomous technology. Doctrinally, the USAF will need to make changes to various tenets of air and space power. The most important tenets affected are "centralized control" and "decentralized execution." Communication technology will enable military leaders to control operations at all levels of war, potentially leading to a military of "Tactical Generals." Operationally, the USAF will need to learn to properly integrate manned platforms with autonomous UAS. Additionally, autonomous UAS may not be able to integrate with coalition forces, especially those using the same equipment as potential enemies.

The last obstacles to autonomous UAS are service-related impediments. The USAF has always been a service that prides itself on its embrace of new technology. Though autonomous UAS seem like the logical evolution in aircraft technology, there will be stiff resistance to these

systems within the USAF. Such resistance will be overcome slowly and only at the direction of USAF and Department of Defense leaders.

Despite the many potential impediments to autonomous UAS, they will be a critical component of the USAF's future aircraft inventory. Though they will be able to accomplish many difficult and dangerous missions, they will not be able to conduct all missions without the aid of manned aircraft or human operators. Because of this, the USAF will need to ensure it maintains a complete inventory of manned aircraft, MITL UAS, and autonomous UAS.

Introduction

The US Air Force (USAF) expects autonomous unmanned aerial systems (UAS) to be a key component of its future fighting force. These systems will expand on the USAF's current UAS fleet's ability to conduct reconnaissance and strike missions. To some, the idea of fully autonomous weapon systems making their own targeting and weapons employment decisions conjures up troubling images from movies like "Terminator" and "I, Robot." The US military already uses some semi- and fully autonomous technology (in both UAS and manned systems) and, as UAS technology matures, will look to increase these systems' autonomy. Despite improvements in UAS technology, the USAF will not be able to rely exclusively on autonomous systems because of their significant technological limitations, domestic political resistance, international obstacles, doctrinal and operational problems, and service-related impediments. These obstacles will require the USAF to maintain a diverse force of autonomous UAS, manned aircraft, and man-in-the-loop (MITL) controlled UAS.

Current Policy & Doctrine

Current US policy and doctrine on autonomous UAS is limited. Current technology does not support autonomous UAS strike operations. Though UAS, like the RQ-4 Global Hawk, autonomously conduct surveillance missions, UAS airstrikes (by the Reaper and Predator UAS) require a MITL. Autonomous attack capability is in its infancy and will not be fielded for some time. The USAF expects its doctrine and policies to begin addressing "autonomous target engagement" between fiscal year (FY) 2010 and 2015, and "autonomous fight" between FY 2015 and 2025.[1] Also, the USAF plans on changing its organization, training, leadership, personnel, and facilities to allow for fully autonomous operations by FY 2025.[2] So, although the

USAF has a clear roadmap for its future autonomous UAS, current doctrine and policies do not address autonomous UAS operations.

Though current USAF policy and doctrine does not address autonomous UAS operations, it does address many of the potential capabilities for these assets (see Figure 1). Current UAS conduct intelligence, surveillance, and reconnaissance (ISR) missions, as well as some strike sorties.[3] The USAF believes its next generation of UAS will increase their capabilities to accomplish the following missions: electronic warfare, Suppression of Enemy Air Defenses (SEAD), ISR, Close Air Support (CAS), Communication Relay, Collection, Dissemination, and Specialized ISR.[4] As technology improves, autonomous UAS missions will further increase to include things like Strategic Attack, Counter-air, and Air Interdiction.[5] Autonomous UAS platforms will take advantage of modular payloads to quickly add new capabilities and sensors.[6] Also, plans call for future autonomous UAS to be fully networked with manned platforms like the F-22 and F-35, allowing manned and unmanned platforms to be fully integrated.[7] As technology improves, the USAF will continue to expand autonomous UAS mission sets.

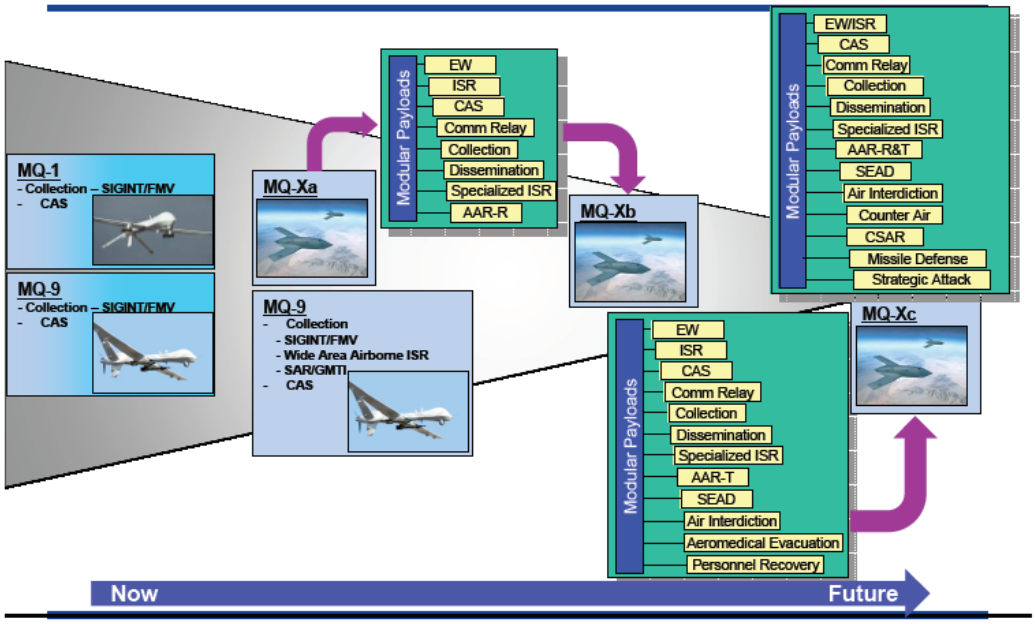

Figure 1: Air Force Unmanned Aerial System (UAS) Flight Plan 2009-2047

Benefits of Autonomous UAS

Autonomous UAS have several benefits over manned aircraft and current MITL UAS. The first benefit of autonomous UAS, like those of MITL UAS, is their ability to decrease risk to US personnel. The second major benefit of autonomous UAS is their ability to decrease personnel costs. Also, autonomous UAS could process information quicker than humans and allow the USAF to quickly propagate new capabilities throughout the fleet.

The first, and perhaps most important, benefit of autonomous UAS is their ability to reduce risk to US personnel. The USAF, arguably the most combat-capable air force in the world, has already conducted numerous operations with little to no casualties. For example, during Operation Allied Force (OAF), USAF and North Atlantic Treaty Organization (NATO) forces lost only two aircraft while flying over 30,000 sorties.[8] Miraculously, neither aircrafts' pilot was killed or captured.[9] Conversely, because UAS do not risk US service members (either pilots or combat rescue personnel), it went largely unnoticed by many that NATO had lost 25 of them.[10] NATO lost these aircraft because they flew dangerous reconnaissance missions, penetrating deadly surface-to-air missile (SAM) engagement zones that commanders would not allow manned aircraft to fly in. Unmanned aerial systems allowed NATO leaders to gain much-needed intelligence without risking friendly pilots. This was especially important during OAF since the frail alliance could have been broken by the capture and exploitation of NATO pilots by the Serbian government. Autonomous UAS would allow the USAF to continue to operate inside extremely lethal integrated air defense systems (IADS), as well as areas that have been contaminated by chemical, biological, or radiological substances.

The second major benefit of autonomous UAS is their ability to decrease personnel costs. Autonomous UAS would drastically reduce the number of USAF pilots and their associated

personnel costs. In 2006, the US military paid approximately $126,000 per service-member in salary, benefits, and healthcare.[11] As personnel costs have dramatically increased in recent years, it is reasonable to assume that these costs will continue to rise at a near exponential rate. In addition to pilot personnel costs, the USAF would be able to eliminate its costly pilot training infrastructure (bases, buildings, and support personnel). Eliminating pilots could also save the USAF much of the estimated $70-83 million in annual training range costs (since training could either be eliminated or accomplished in a simulator).[12] The USAF estimates in FY 2011 it will spend nearly $1.6 billion on air operations training and $1.01 billion on basic flight training.[13] Because most, if not all, flying training could be eliminated or accomplished in a simulator, autonomous UAS would reduce/eliminate maintenance costs associated with training flights, helping reduce the USAF's $2.4 billion depot maintenance budget.[14] In all, approximately 80 percent of an aircraft's life cycle costs are due to pilot training and proficiency flights.[15] Though autonomous UAS technology will be expensive, the Department of Defense (DOD) believes UAS costs should be kept comparable to current aircraft like the F-16 (the DOD set a goal of approximately $26.5 million in FY 1998 dollars).[16] Keeping autonomous UAS costs low would prevent them from becoming low-density, high-demand assets that are too expensive to risk against modern IADS. If costs are allowed to escalate dramatically, autonomous UAS would be too expensive to risk; thus negating their greatest tactical advantage. Although it is logical to believe (based on current weapons appropriation trends) autonomous UAS technology will cost more than current fourth-generation fighter aircraft, some costs would be offset by reductions in personnel, training, and maintenance. In addition to personnel costs, autonomous UAS would reduce recruitment problems. Currently, most youth in the US are unfit for military service.[17] Data released by the Pentagon says that 35 percent of youth do not meet physical standards, 18

percent are disqualified for illegal drug use, 9 percent are disqualified for mental problems, 6 percent are disqualified for having too many dependents, and 5 percent are disqualified for criminal records.[18] In all, as many as 75 percent of US youths (17-24 years of age) do not meet minimum entry standards, requiring the US military to grant waivers for approximately 20 percent of personnel.[19] Even if they do meet standards, only about 12 percent of America's youth are interested in joining the military.[20] The stringency of aviation medical standards further reduces the pool of potential pilot recruits. Autonomous UAS could drastically reduce/eliminate the number of recruits needed to meet the USAF's stringent aviation medical standards.

Another advantage of autonomous UAS is their flexibility in adding new capabilities and technology. Autonomous UAS would allow the USAF to add capabilities quickly to the entire fleet via modular software changes. This would be a tremendous advantage over current manned strike platforms that rely on human pilots who possess different levels of experience, aptitude, ability, and training. Furthermore, autonomous UAS have the ability to process information quickly, without the emotion and passion that can affect human decisions, ensuring consistent decision-making amongst all aircraft. To properly capitalize on these advantages, the USAF must overcome certain technological obstacles.

Technological Limitations

"There are no cease-fires in the war for technological supremacy."
- Defense Advanced Research Projects Agency

Autonomous UAS will require the USAF to achieve several technological milestones. Autonomous UAS must be able to autonomously conduct normal aviation functions (takeoff,

land, aerial refueling, etc), to operate within bandwidth constraints, ensure the security of communications sent to/from UAS, and correctly identify airborne and ground targets.

Prior to fielding, autonomous UAS must have certain basic capabilities. Currently, the USAF's RQ-4 Global Hawk aircraft performs autonomous reconnaissance missions. Thus, the technology already exists for autonomous UAS to perform basic flying tasks such as takeoffs, landings, and taxiing. In addition to basic tasks, UAS have already demonstrated the ability to perform in-flight refueling. In 2006, Boeing used a Learjet equipped with special flight controls to successfully demonstrate the feasibility of autonomous air refueling.[21] Therefore, there is no doubt future UAS will be able to autonomously perform basic aircraft functions. Recently, the USAF has drastically increased its number of UAS, making bandwidth management critical. In Operation Enduring Freedom (OEF), the US used only one-tenth the number of personnel deployed for Operation Desert Storm, yet used eight times the SATCOM bandwidth.[22] Global Hawk aircraft alone consumed five times more bandwidth than the entire US military in Operation Desert Storm.[23] The need for massive amounts of bandwidth is a critical vulnerability to UAS operations. Though making UAS more autonomous could decrease this vulnerability, the ability to retarget (or un-target) UAS in-flight means the USAF will still need large amounts of bandwidth. Much of this bandwidth is contingent on space assets. Recently, Chinese leaders have called a future space war "inevitable."[24] This view, along with China's successful anti-satellite missile test in 2007, shows how potential adversaries could deny the US use of its space assets.[25] Also, the US military has become increasingly reliant on commercial systems, with up to 80 percent of the bandwidth used during OEF being provided by commercial systems.[26] The possibility of enemy anti-space capabilities, along with the inability of the US military to

indigenously provide its needed bandwidth, means the US should be ready to fight future wars with less bandwidth, not more.

Future UAS operations must be capable of operating with reduced bandwidth requirements. This can be accomplished in a number of ways. Making UAS more autonomous will reduce bandwidth requirements. This could occur by programming UAS with applicable targeting criteria and rules of engagement, thereby eliminating the need for humans to maintain continuous contact and communication with the UAS. Bandwidth could also be reduced by utilizing "swarms" of UAS. Raytheon has developed the Advanced Multi-Unmanned Aerial System, allowing a single officer to control multiple UAS.[27] The officer communicates directly with one aircraft, which subsequently communicates and coordinates with the swarm's other UAS.[28] Not only does this reduce bandwidth requirements, it also reduces personnel requirements. The USAF estimates swarms would reduce personnel requirements by 64 percent (based on the current requirement for 50 combat air patrols) (see Figure 2).[29] The UAS swarms will be expected to work together to overwhelm targets by jamming enemy radars, bombing air defense systems, and destroying targets.[30] The UAS swarm will request/require human consent to attack a target then decide amongst themselves which UAS will attack and which will perform EA and/or SEAD.[31]

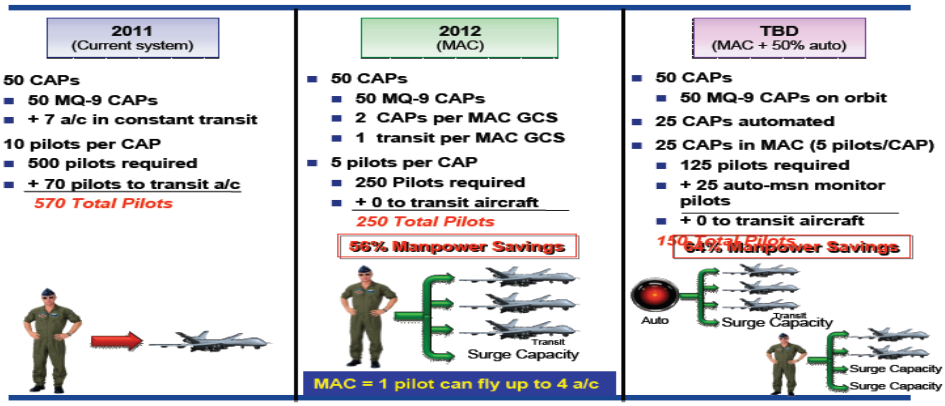

Figure 2: Air Force Unmanned Aerial System (UAS) Flight Plan 2009-2047

Security is a major concern for autonomous UAS operations. Nearly all autonomous UAS literature addresses the need for humans to retain the ability to "turn off" the UAS and prevent unintentional weapons release. This safety feature requires secure communication systems. As discussed previously, space is a contested environment. Unmanned systems require space assets for over-the-horizon communications/control and for navigating via the global positioning system (GPS). Current events have shown that space and cyberspace assets are not impervious to hacking or jamming. Iraqi insurgents were able to access real-time UAS video feeds with the help of $26 off-the-shelf software.[32] Though the insurgents were never able to take control of any drones, it did show the potential for cyber hackers to disrupt autonomous UAS operations. One way to make the autonomous UAS free from spoofing and hacking is to intentionally sever any links to ground controllers, making them truly autonomous. Though this would keep UAS from being hacked, the USAF would lose its ability to call off airstrikes or retarget the systems in-flight, reducing their flexibility and versatility (two of airpower's major advantages). Even if the USAF was willing to allow these systems to be truly autonomous, the USAF must ensure they can properly identify airborne and ground targets.

The development of consistent and reliable identification systems is the most daunting task for autonomous UAS. Currently, MITL UAS rely on operators to identify ground targets (today's UAS do not conduct air-to-air missions). Using technology already employed in manned aircraft, autonomous UAS could accurately identify aircraft beyond visual range (BVR). Though each operation's rules of engagement are unique, the USAF has allowed certain aircraft (like the F-15) to make BVR identifications for many years. This generally entails interrogating an aircraft's identification friend or foe (IFF) codes, as well as using systems like the non-cooperative targeting recognition (NCTR) system. In addition, autonomous UAS could reduce

fratricide risks by checking any potential hostile declarations against the location of friendly aircraft via a datalink system (such as the Link-16 system). Though reliable BVR identification systems have been around for many years, there are many systems that now put this capability in jeopardy. Adversary aircraft like the Su-27 Flanker have Digital Radio Frequency Memory (DRFM) jammers and towed decoys, diminishing the effectiveness of aircraft radars and the AIM-120 Advanced Medium Range Air to Air Missile.[33] Additionally, Russia produces anti-radiation missiles that potentially negate US aircraft targeting capabilities by homing in on an adversary's air-to-air radar.[34] As adversary technology continues to improve, the USAF can expect more, not less, air-air engagements to end up within visual range (WVR). This potential means autonomous UAS must develop technology to "visually" identify aircraft. New infrared missiles like the Aim-9X and Python V missiles use fifth-generation imaging seekers to track targets (see Figure 3).[35] Such missiles are a major improvement over previous missiles due to their ability to lock on targets before and after launch, and acquisition of small/low signature targets in lookdown, adverse backgrounds.[36] As long as the seeker can be properly cued autonomous UAS could use this imaging capability for WVR identification. In addition to air-to-air target identification, autonomous UAS will need to be able to identify ground targets.

Figure 3: Python 5 Seeker Image, Rafael Python 5 Brochure

Current UAS rely on human operators to conduct ground attack missions. Future UAS will be expected to autonomously conduct ground attack missions. For some missions, like strategic air strikes, the needed technology is already available. Current weapons, like Tomahawk cruise missiles and Joint Direct Attack Munitions (JDAM), are able to strike pre-programmed targets. These weapons are guided via GPS or inertial navigation systems to specific coordinates. Autonomous UAS could easily conduct similar missions. But as GPS jammers have become common (one can do a simple internet search and find products or directions on how to acquire/build GPS jammers), autonomous UAS may not be able to rely on just coordinates for attacking ground targets.[37] As such, the USAF must develop radar, thermal, or visual imaging systems that UAS could use to confirm target identification. In addition to striking fixed targets, autonomous UAS could conduct SEAD missions by using existing technology (like the HARM Targeting System) to electronically identify threat radars. Autonomous UAS could also use imaging technology similar to that of the Aim-9X (which has been tested against moving ground targets) to identify mobile targets like tanks and armored personnel carriers.[38] Like in air-to-air combat, autonomous UAS could use datalink systems (e.g., Blue Force Tracker) to deconflict potential hostile identifications with the location of friendly forces. Though autonomous UAS could be used against fixed targets or against military equipment, there are significant technical and practical challenges to them reliably distinguishing between civilians and soldiers. Though many robotics researchers believe it is possible to program this capability into autonomous systems, they tend to oversimplify the problem and underestimate the complexity of warfare. America's air operations in Iraq and Afghanistan have been vilified for causing civilian casualties. These civilian casualties are normally due to the difficulty of discerning between civilians and insurgents when no participants wear uniforms.

Thus, UAS will have limited capabilities to conduct close-air support and counterinsurgency missions. In these missions, the USAF will need to retain some capability to conduct MITL operations, or will need to retain MITL UAS or manned platforms.

Political Resistance

"It is good that we find war so horrible, or else we would become fond of it."
- Robert E. Lee

Domestic resistance to autonomous UAS will come from politicians and the potential for these systems to alter the relationship between the military and society. Domestic politics, especially in a democracy, plays an important role in the deployment/employment of military forces. Current conflicts show how political constraints and restraints will be placed on military forces, even if they may reduce US military superiority. Autonomous UAS could also alter civil-military relations and lead to the over-use of military force and the alienation of the military from civil society. Such considerations are important because they go beyond previously asked questions regarding technical feasibility, and address how autonomous UAS impact the country as a whole.

Politics should be paramount in any military operation. Carl von Clausewitz, arguably the most influential military philosopher since Sun Tzu, has described war as an extension of politics "by other means," where military operations are inextricably linked to the political objectives of the warring parties.[39] Though such political objectives and considerations have always been important, the military has seen a steady increase in the number of political constraints and restraints since the end of World War II. There were numerous limited conflicts in the Cold War that sought to achieve political objectives while avoiding nuclear war between US and Soviet forces. Fear of nuclear war led to the strict political control of military forces in

Korea and Vietnam. Though political control may irk military personnel, such political considerations will always be present. Strategic success in counterinsurgency operations, like the ones the US finds itself in today, normally requires the establishment of stringent political constraints and restraints on military forces. Current operations in Afghanistan give a good example of the political limitations that can be expected in future conflicts.

In Afghanistan, airpower is frequently condemned by the media and exploited by America's enemies for propaganda purposes. This condemnation is a result of collateral damage (both real and alleged) to the civilian population. General Stanley McChrystal, commander of US and International Security Assistance Force (ISAF) personnel, has been quoted as saying that the misapplication of airpower could "sow the seeds of our own demise" in Afghanistan.[40] The USAF has done an excellent job showcasing its precision attack capability; leading to the false perception that airpower can avoid all collateral damage. As General Stanley McChrystal says, Afghans believe American airpower is "omniscient and omnipotent, so if we bomb innocent civilians, they assume that was our intent."[41] This perception led General McChrystal to put tighter restrictions on airstrikes, effectively eliminating the ability to conduct airstrikes in urban or populated areas.[42] Though these airstrikes are performed at the request of ground commanders, moral outrage is normally directed at American airpower. Many times this criticism is because aircrews are perceived as detached from the destruction they cause on the ground.[43] Some believe this alleged detachment limits an aircrew's ability to make moral decisions, as opposed to ground forces that are much closer to the action. So, although current UAS strikes require a MITL and are thus similar to manned strike platforms, they are still harshly criticized. A recent Freedom of Information Act request by the American Civil Liberties Union labeled US UAS operations in Pakistan as "targeted killing program(s)" whose parameters

are "almost entirely obscure" from public scrutiny.[44] Making such UAS autonomous will only increase criticism from international and domestic groups. If autonomous UAS are strongly criticized by the US population and/or media, it is unlikely an American president would authorize their widespread use and risk his/her re-election campaign/presidential legacy. Thus, the USAF must ensure there is robust public and political debate prior to the widespread proliferation and use of autonomous UAS. Politicians may also be pressured to limit autonomous UAS operations because of their potential affect on US civil-military relations.

Autonomous UAS could further strain US civil-military relations. Since the end of conscription following the Vietnam War, most Americans do not worry about a family member being sent into combat.[45] In today's conflicts, it is the US military that is at war, not the nation as a whole. World War II demanded a shared sacrifice amongst all Americans that is not seen today.[46] So, although the US has been at war in Afghanistan for over eight years, most of the US does not actively think about the war, nor are they asked to sacrifice to aid the military's efforts. As of 2008, 1.4 million Americans were serving in the US Army, Navy, Marine Corps, and Air Force.[47] This equates to a mere 0.45 percent of the US population.[48] Though this number is extremely small, it is consistent with previous periods in US history (with exceptions like World War II where the percentage of Americans in the military jumped to 12 percent).[49] Thus, the percentage of Americans serving in the military is consistent with normal peacetime numbers, though small when compared to previous wars. With the lack of a draft, there is no threat of personal harm to the vast majority of Americans. Many thus believe the all volunteer force disproportionately places the burden to serve (and die) in combat on the poor and uneducated who cannot find better jobs. Though this is a common perception, data clearly refutes this. Current studies show that, despite a slightly disproportionate number of personnel hailing from

southern states, the US military accurately represents the overall population.[50] In fact, many of the military's recruits are better educated than their civilian counterparts and come from upper-income families.[51] Even so, some are troubled by the sheer lack of military service by the vast majority of America's population. Critics believe this lack of participation makes the US more prone to war because, if fewer American families are affected, there will be less public debate on the government's decisions to go to war.

A move towards autonomous weapon systems (air, surface, and naval assets) will lead to increased criticisms of America's willingness to go to war. Many fear autonomous weapon systems, by reducing the number of Americans put at risk, will lower America's threshold for war.[52] Politicians may see robotics as a way to authorize military action without the perceived commitment, while also limiting casualties (both friendly and enemy).[53] Like early airpower theory, some will argue autonomous weapon systems provide politicians a way to quickly achieve military victory without the usual horrors of war. Therefore, autonomous technology may give the public and its leaders the belief that it is possible to have a risk-free war.[54] Such ideas remind one of early airpower assertions that indefensible aircraft could bypass the battlefield and directly strike the enemy's homeland, resulting in quick wars that would ultimately minimize casualties. Unfortunately, to believe such ideas would be to ignore Clausewitz's often cited ideas of the "fog" and "friction" of war, as well as other sayings like "the enemy has a vote." Politicians and the American public must realize that no military operation is conducted without risk and that, regardless of technological advancements, war is not pain-free (for any of the parties involved). Failure to heed this advice could jeopardize the American democratic process by having a populace that lacked the commitment for widespread engagement and public debate prior to going to war.[55] The indifference these systems produce

could lead to American's viewing war as a "global spectator sport" where drone attack footage is casually watched by the public without an appreciation for the results.[56] Though some think this would lead to technologically advanced nations playing God with others' lives, this argument lacks credibility for two reasons. This is because of the improvements in global information technology and the limited number of personnel such technology will replace.

The American threshold for war will not be lowered to an unacceptable level by autonomous UAS. Though the US is currently using manned platforms and MITL UAS, they are still heavily scrutinized by American and international organizations. Information technology has allowed nations to push information (and agendas) nearly instantaneously around the globe. Thus, the inappropriate or immoral use of airpower is quickly critiqued and criticized throughout the world. Recently, US drone strikes in Afghanistan and Pakistan were criticized by numerous groups, including the United Nations (UN), saying they violated international laws and norms regarding extrajudicial executions.[57] Thus, the actions of American UAS assets in remote parts of the world will not be free from scrutiny, and removing direct human interaction would not reduce the likelihood of debate or examination.

Though autonomous UAS would reduce the number of Americans put in harm's way, the reduction would be negligible and should not affect America's threshold for war. The USAF (as of 31 March 2009) has 13,305 pilots (this includes all aircraft types, as well as pilots in non-flying assignments).[58] Thus, USAF pilots make up 0.95 percent of all US military members and approximately 0.00427 percent of the American population. Therefore, although autonomous UAS would reduce the number of personnel affected by war, it is a miniscule amount and should not have far-reaching effects on the US society's willingness to go war.

Autonomous UAS can expect to encounter political resistance within the US. Though some believe these systems could lower America's threshold for war and further the divide between the military and society, there is limited evidence this would happen. Thus, the USAF can overcome domestic resistance by facilitating the necessary public and political debates prior to operationally fielding these systems.

International Obstacles

"Too often, users believe that computers are some sort of a magic box that can solve any problem. In reality, computers merely do repetitive tasks very quickly. If those tasks are designed incorrectly, it merely enables someone to make many mistakes in an astonishingly small amount of time."

— Buck Woody, computer expert

International resistance to autonomous UAS attack systems is expected to be fierce and determined. This opposition is based on various parties' interpretation of the Law of Armed Conflict (LOAC). In addition to the LOAC, one can expect there to be a call for international treaties to ban or restrict autonomous weapon systems. As an expeditionary air force, the USAF is normally dependent on allied and coalition nations. Thus, the USAF must ensure partner nations will allow basing and employment of autonomous UAS.

The LOAC could have major implications on the use of autonomous UAS for strike missions. Every new technology requires nations to determine its conformity to the LOAC. Though many are eventually determined to follow the LOAC, certain weapons technologies (like chemical weapons, expanding bullets, and poison tipped spears) have been deemed illegal.[59] The US needs to ensure that it has fully determined the legality of autonomous UAS before making a serious investment in these platforms.

The LOAC is rooted in the Just War Theory (JWT). The JWT is based on the ideas of *jus ad bellum* and *jus in bello. Jus ad bellum* relates to the right to use force and go to war, while *jus in bello* governs ones conduct in war.[60] *Jus in bello's* main goals are to minimize unnecessary human suffering by combatants, as well as minimizing the impact of war on innocent civilians.[61] This is done by directing militaries to be discriminate and proportionate in their application of force.[62] Also, *jus in bello* demands weapons be banned if they do not support the tenets of distinction (ability to distinguish between civilians and combatants) and limitation (weapons do not cause unnecessary injury or suffering to combatants).[63] The Geneva Conventions, under Part III, Article 35, seeks to support these tenets by stating[64]:

> 1. In any armed conflict, the right of the Parties to the conflict to choose methods or means of warfare is not unlimited.
>
> 2. It is prohibited to employ weapons, projectiles and material and methods of warfare of a nature to cause superfluous injury or unnecessary suffering.
>
> 3. It is prohibited to employ methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment.

In addition to Article 35, Articles 51, 57, and 58 of the Geneva Conventions afford civilians protection against being indiscriminately targeted, and requiring militaries to "take all feasible precautions" against unnecessary loss of civilian life.[65] Also, Article 13 of the Geneva Conventions identifies legal combatants as those who are members of an armed force and commanded by a person responsible for his/her subordinates.[66] The US, and international community at large, must determine how autonomous UAS should be treated. If they are not themselves combatants, one must determine who is held responsible for any violations of the LOAC. Who could/should be prosecuted or punished if these systems malfunction? Does one hold military leadership responsible, or should the computer programmer who wrote the

malfunctioning software be held accountable? In missions where an autonomous UAS strikes a pre-planned, fixed target, malfunctions can be held to the same standard as cruise missiles. As long as military personnel launched the systems against legitimate military targets, the weapons should be considered legal. The issue gets complicated when weapons systems make real-time targeting decisions. Though these systems may eventually have software logic to help avoid the unintentional targeting of non-combatants, it is reasonable to assume that the software will not be perfect and the USAF must have a clear and strong legal argument to avoid condemnation or prosecution. Complicating things, the Geneva Conventions are ambiguously worded which leads to different interpretations. The US has already disregarded international opinion and used weapons deemed illegal by some nations and organizations.

The US currently employs multiple weapons that have been deemed illegal by other nations and groups. The two most famous examples of these are landmines and cluster bombs. Landmines are frequently cited as being indiscriminate weapons that cause a disproportionate number of civilian casualties. The 1997 Ottawa Treaty called for banning the use, stockpiling, production and transfer of anti-personnel mines.[67] There are currently 155 signatories to this treaty.[68] The US has refused to sign the treaty, putting it in the company of nations like Cuba, North Korea, Libya, Somalia, China, and Iran.[69] Like landmines, cluster bombs have come under increasing condemnation by the international community. In May 2008, 107 countries adopted the Convention on Cluster Munitions in Dublin, Ireland, prohibiting the use, production, stockpiling and transfer of cluster bombs.[70] Once again, the US did not sign the convention. Though only signatories of these treaties are bound to follow them, many US allies have signed these treaties, potentially straining future coalition operations. The US must be ready to deal

with future calls for bans on autonomous UAS. Though autonomous weapons technology makes many people nervous, several believe this technology will be able to comply with the LOAC.

Though many believe autonomous UAS (and other robotic weapon systems) are inherently illegal and immoral, some believe that these assets can be more moral than humans. Ronald Arkin, a leading philosopher on robotic technology, believes that autonomous weapons can use the "Three Rules of Robotics" to govern weapons employment.[71] These rules were written in 1942 by famous science fiction writer Isaac Asimov.[72] They state[73]:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2. A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Following these rules would essentially require human consent before any autonomous UAS could employ weapons (something many already propose). Some have also proposed that autonomous weapons should only be able to target other machines (aircraft, ships, buildings, etc), while requiring human consent to target/kill humans.[74] Such a requirement would help keep these weapon systems relevant in low-intensity conflicts (like counterinsurgencies) when humans are difficult to identify as combatants (especially in places like Afghanistan where it is common for the population to openly carry weapons). This would require autonomous systems to allow "dial-a-level" autonomy based on the mission.[75] Though this requirement would satisfy many critics, it would potentially make autonomous UAS vulnerable to hackers and require the USAF to maintain a larger than desired number of pilots and bandwidth capacity.

Current weapons technology already shows how autonomous UAS could be effectively, and legally, employed. Today, the US uses cruise missiles that autonomously fly to a pre-determined point and then attack. World-wide, pilots use electronic identification measures to fire missiles beyond-visual-range against other aircraft, relying on their aircraft's onboard sensors to properly identify enemy aircraft. Also, American aviators suppress enemy air defenses with the AGM-88 High-speed Anti-radiation Missile (HARM). The HARM uses signals emitted by ground threat radars to guide itself to its target.[76] It relies on "minimum aircrew input" to be cued and fired.[77] Once again, the aircrew is not required to visually identify the target, but simply consent to what the aircraft's sensors are telling them. Though human consent seems to be an effective safeguard against erroneous target identification by computers, human consent does not necessarily prevent fratricide or collateral damage. There have been numerous instances of fratricide, to include the US Navy shoot down of Iran Air Flight 655, where humans merely "rubber stamp" their computer's targeting decisions.[78] Thus, even when computers have made mistakes, humans do not necessarily prevent mishaps. Though this may lead some to lose all faith in autonomous targeting capabilities, the systems do not need to be perfect, just as good as humans. Some have termed this the "Military Turing Test," named after computer pioneer Alan Turing and his original "Turing Test."[79] The original "Turing Test" says that "if a human is unable to tell in a conversation with a robot and a real human, which is the man and which is the machine, then the robot conversing with the human has achieved intelligence."[80] Therefore, the capability does not need to be perfect, just comparable to a human's. Also, many believe autonomous UAS will make better decisions than humans because they do not get scared, enraged, vengeful, or worry about their own personal safety.[81] Overall, in a conventional war, autonomous UAS could make better choices than humans due to their ability

to quickly process vast amounts of information (such as identifying types of tanks, aircraft, surface-to-air missiles, etc). In an unconventional war (against insurgents or soldiers who illegally seek to blend in with the civilian population), it will be tougher to use autonomous UAS without some humans helping to make targeting and attack decisions. Even if autonomous UAS can demonstrate the ability to properly identify military targets, some will still seek to limit their use.

Regardless of how the USAF plans on employing autonomous UAS, there will be calls to ban autonomous weapon systems. Recently, four individuals (a physicist, a philosopher, a robotics expert, and a bioethicist) established the International Committee for Robot Arms Control (ICRAC), which campaigns for limits on robotic military hardware.[82] The ICRAC already plans on presenting a report to the European parliament on the dangers of robotics.[83] This is only the first group to lobby governments for restrictions on autonomous weapon systems. If groups like the ICRAC are eventually successful at getting nations to limit robotic weapon systems, the US must be ready to limit its reliance on such systems, or deal with the political fallout from their use. International bans on robotic weapon systems could result in calls for the prosecution of US military personnel in places like the International Criminal Court (ICC). Also, US policy could radically change between presidential administrations. Though former President George W. Bush opposed the US joining the ICC or signing the Ottawa Treaty, President Barack Obama (as a presidential candidate) stated the US should ratify both statutes/treaties.[84] Should the US become part of the ICC, it may lose flexibility in determining whether autonomous weapons technology complies with the LOAC. Though it is unlikely that President Obama will press for the US to become part of the ICC (due to the requirement for two-thirds of the senate to ratify any treaties), ICC rulings against robotic weapons systems

could make these systems politically counterproductive to US objectives. As a result, a president (based on his/her personal feelings or under pressure from allied or coalition nations) may decide to restrict or deny the military's use of autonomous weapon systems. Since presidential administrations change every four to eight years, the USAF needs to maintain a balanced force that can remain effective regardless of the political whims of America's leaders.

International politics could have a major impact on autonomous UAS. The US normally conducts coalition warfare which requires it to consider other nations' opinions. US relations with some allies have already been strained by treaties banning certain weapons. As groups and nations call for a ban on autonomous UAS, the US must ensure they gain the necessary legal backing for their use, or be ready to "go it alone" and tolerate any international condemnation.

Doctrinal and Operational Problems

The USAF's doctrine and operations would be significantly affected by the integration of autonomous technology. Doctrinally, the USAF will need to make changes to various tenets of air and space power. The most important tenets affected are "centralized control" and "decentralized execution."[85] Air Force doctrine says these tenets "are the fundamental organizing principles for air and space power, having been proven over decades of experience as the most effective and efficient means of employing air and space power."[86] Decentralized execution allows the USAF to "foster disciplined initiative, situational responsiveness, and tactical flexibility."[87] Unmanned aerial systems provide significant connectivity to USAF leaders. This connectivity gives leaders quick access to real-time information occurring at the tactical level of war. Technology is making it extremely easy for leaders at the highest levels of command to view, and even control, tactical operations.[88] There have even been examples of generals spending hours watching "Predator Porn," telling aircrew what munitions to drop or

where to place individual personnel.[89] The US military has recently espoused the virtue of the "Strategic Corporal," only to see its leaders become "Tactical Generals."[90] Such a situation could lead to centralized control and execution. What happens to the USAF if today's young officers are never given a chance to lead and make decisions? A general may be able to do the job of a captain, but a captain cannot do the job of a general.[91] A general uses his/her training, education, and experience gained as a young officer to make key strategic decisions and hone their leadership ability. The emergence of "Tactical Generals" threatens the long-term growth and grooming of military officers.

Integration of manned and unmanned systems would be a significant operational challenge. Fratricide fears would necessitate substantial and rigorous practice/war-gaming to integrate unmanned and manned systems. It is reasonable to assume military personnel would have significant misgivings about autonomous UAS and their ability to make accurate targeting decisions. A rigorous training regiment would help identify problems with autonomous UAS, as well as gain the trust of USAF aircrew. Failure to do this will cause problems similar to the early use of BVR missiles. During Vietnam, BVR missiles were not properly utilized because of a compelling human preference for visual identification of targets which led to restrictive rules of engagement, as well as American pilots being apprehensive to shoot BVR.[92] Thus, for autonomous UAS to be effective, they must gain the trust of military personnel and leaders. Integration of autonomous UAS would be especially difficult in coalition operations.

Autonomous UAS could severely complicate coalition operations. Many former Warsaw Pact nations have joined NATO or have participated in coalition operations with the US. This means some coalition nations use the same equipment as enemy forces, making proper target identification difficult. Autonomous UAS identification tools must be flexible enough to

identify targets in a variety of ways. As discussed before, American forces typically establish an aircraft as hostile by interrogating an aircraft's IFF code(s) to establish "absence of friendly," and then complete a hostile identification via systems like NCTR. American pilots also use systems like Link-16 datalink to ensure they are not targeting friendly aircraft. Generally, US IFF codes and datalink systems are not released to other nations (with few exceptions). Though other technology could be developed to accomplish combat identification, the USAF must ensure this technology could be transferred or released to coalition partners. Failure to do this could lead to autonomous UAS requiring MITL operations for weapons employment, negating many of their advantages and increasing their risk of being hacked. It could also mean coalition forces must be separated via time or geography if the USAF is unable to develop releasable identification technology. Thus, the US may need to limit autonomous UAS in coalition operations.

The last operational factor that must be considered is force management. Costs of autonomous UAS will be significantly higher than current UAS. Though the USAF plans on capping UAS costs, it is reasonable to assume these platforms will see cost increases. For example, the Joint Strike Fighter (JSF) program has seen its costs increase by 45 percent.[93] Also, due to recent fiscal problems, the 2010 Quadrennial Defense Review has called for the USAF to reduce its JSF purchase by 539 (from 1,763 to 1,224).[94] If the USAF experiences the same cost overruns and fiscal constraints during autonomous UAS development and production, it may be left with a limited number of platforms. This would have major ramifications on USAF doctrine and its concept for air operations. If autonomous UAS are allowed to become low-density high-demand platforms, it would limit the USAF's ability to conduct dangerous SEAD and strike missions (the optimum missions for autonomous UAS platforms). Thus, the USAF must ensure

autonomous UAS costs are minimized so it has enough aircraft to absorb combat losses, yet still continue operations.

Service-Related Impediments

The US Air Force has always been a service that prides itself on its embrace of new technology. Though autonomous UAS seem like a logical evolution in aircraft technology, there will be stiff resistance to these systems within the USAF. Such resistance will be overcome slowly and must be directed by USAF and Department of Defense leaders.

Each American military service has distinctive personalities that shape their views of themselves and the world. The USAF covets technology and its ability to make ever better aircraft.[95] Many USAF pilots associate with their aircraft more than their service institution.[96] For many, military service is simply the means by which they are able to fly magnificent machines.[97] Within the Air Force, there are distinctions amongst personnel based on their specialty. Since the USAF has always been obsessed with aircraft, pilots are at the top of its personnel caste system.[98] The USAF looks at its aviators as modern-day knights, chivalrous warriors who are able to meld man and machine together to become a lethal fighting machine. As such, the service makes a distinction between pilots and all other personnel.[99] This is why the USAF has always been led by pilots, and why pilots are even sometimes chosen to lead to non-flying organizations (such as mission support groups). Throughout its history, the USAF has elevated pilots above all others.

Current UAS policy is a good example of how the USAF attempts to keep pilots in control of its most effective/important assets. Currently, the USAF has 474 crews to fly its MQ-1s and MQ-9s.[100] Based on current/future combat air patrol requirements, the USAF believes it needs 1100 crews (see Figure 4).[101] Traditionally, the USAF has used experienced pilots (for

example F-15 and F-16 pilots) to fly UAS. This puts a strain on these communities as they must support UAS operations in addition to their normal assignment requirements (like operational fighter cockpits, pilot training instructors, air liaison officers, staff officers, etc). Though it had a major shortage in UAS pilots, the USAF was the only service that did not allow non-pilots to fly UAS.[102] The US Army and Marine Corps already use enlisted and warrant officers to pilot their UAS.[103] The USAF resisted this because it was not in-keeping with its service tradition, even though it could help solve its personnel problems. Recently, the USAF has decided to allow non-pilots fly UAS.[104] It was the harsh realities of today's conflicts that forced the USAF to change its policies (as well as the firing of the Air Force Chief of Staff and the Secretary of the Air Force).

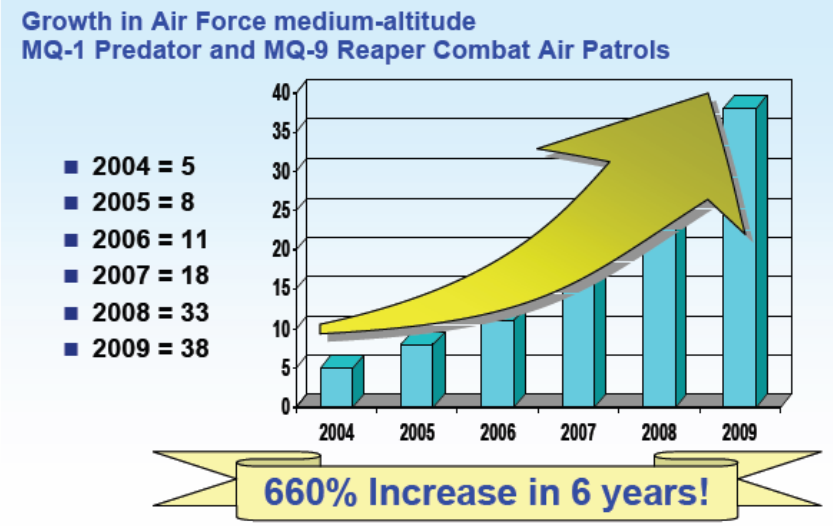

Figure 4: Air Force Unmanned Aerial System (UAS) Flight Plan 2009-2047

Although autonomous UAS could be much more effective and efficient than manned aircraft in carrying out certain missions, most USAF pilots will object to this technology. Since the USAF has always been led by pilots, it is easy to see how its leaders' biases and preferences could impede the development and application of this technology. Without changes being

mandated from higher leadership (like the Secretary of Defense), it will take time for the USAF to fully embrace the widespread use of autonomous UAS.

Conclusion

Autonomous UAS will be a critical component of the USAF's future aircraft inventory. Though they will be able to accomplish many difficult and dangerous missions, they will not be able to conduct all missions without the aid of manned aircraft or human operators. Because of this, the USAF must ensure it maintains a complete inventory of manned aircraft, MITL UAS, and autonomous UAS.

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[1] Deptula, "Air Force UAS Flight Plan 2009-2047," 20.
[2] Ibid.
[3] Ibid., 17.
[4] Ibid.
[5] Ibid.
[6] Ibid.
[7] Ibid., 19.
[8] Lambeth, "NATO's Air War for Kosovo," 246.
[9] Ibid.
[10] Ibid, 97.
[11] McMichael, "Gates: Draft not solution to personnel costs."
[12] Department of the Air Force, "Procurement Program," F-21.
[13] Department of the Air Force, "Fiscal Year 2011 Budget Estimate," 1.
[14] Ibid.
[15] Federation of American Scientists, "X-45 Unmanned Combat Air Vehicle."
[16] Department of Defense, "Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles," 14.
[17] McMichael, "Most US youths unfit to serve."
[18] Ibid.
[19] Ibid.
[20] Ibid.
[21] Kinneard, "Boeing Demonstrates UAV Automated Aerial Refueling Capability"
[22] Klausner, "Command and Control of Air and Space Forces Requires Significant Attention to Bandwidth"
[23] Ibid.
[24] Clark, "China Declares Space War Inevitable."
[25] Global Security, "Chinese Anti-Satellite [ASAT] Capabilities."
[26] Kueter, "The War in Space Has Already Begun," 1.
[27] Trsek, "The Last Manned Fighter: Replacing Manned Fighters with UCAV," 23.
[28] Ibid.
[29] Deptula, "UAS Flight Plan," 11.

[30] Chappell, "DARPA and the Future of Army Air and Missile Defense."
[31] Ibid.
[32] Gorman, "Insurgents Hack US Drones."
[33] Kopp, "Assessing Joint Strike Fighter Air Combat Capabilities."
[34] Kopp, "The Russian Philosophy of Beyond Visual Range Air Combat."
[35] Trsek, ""The Last Manned Fighter: Replacing Manned Fighters with UCAV," 9.
[36] Rafael, "Python 5-Full Sphere IR Air-to-Air or Surface-to-Air Missile," 2.
[37] Brewin, "Homemade GPS Jammers Raise Concerns."
[38] Trimble, "Aim-9X Goes Slumming with Air-to-Surface Mode."
[39] Clausewitz, *On War*, 605.
[40] Michaels, "Airstrikes in Afghanistan drop by almost half."
[41] Klein, "General Stanley McChrystal."
[42] MacAskill, "US commander in Afghanistan to order limits on air strikes."
[43] Singer, "Military Robots and the Laws of War."
[44] ACLU, "Request Under Freedom of Information Act."
[45] Singer, "Robots at War."
[46] Greene, "Where's the shared sacrifice of war?"
[47] US Census Bureau, "Department of Defense Personnel."
[48] US Census Bureau.
[49] Segal, "America's Military Population."
[50] Watkins, "Who Serves in the US Military?"
[51] Ibid.
[52] Singer, "Robots at War."
[53] Ibid.
[54] Ibid.
[55] Ibid.
[56] Ibid.
[57] Agence France Press, "US drone strikes may break international law: UN."
[58] US Air Force, "Service Demographics."
[59] ICRC, "The Law of Armed Conflict: Weapons."
[60] Roberts, "Counter-terrorism, Armed Force and the Laws of War," 117.
[61] Ibid, 116.
[62] Ibid.
[63] ICRC, "The Law of Armed Conflict: Weapons."
[64] ICRC, "International Humanitarian Law."
[65] Ibid.
[66] Ibid.
[67] ICRC, "Mine Ban Convention"
[68] Ibid.
[69] Ibid.
[70] ICRC, "Cluster munitions and international humanitarian law."
[71] Arkin, "Teaching Robots the Rules of War."
[72] Ibid.
[73] Ibid.
[74] Canning, "A Concept of Operations for Armed Autonomous Systems."
[75] Ibid.
[76] Global Security, "AGM-88 HARM."
[77] Ibid.

[78] Mick, "Can Robots Commit War Crimes."
[79] Ibid.
[80] Ibid.
[81] Arkin, "Teaching Robots the Rules of War."
[82] Fleming, "Campaign asks for international treaty to limit war robots."
[83] Ibid.
[84] Citizens for Global Solutions, "Candidates Questionnaire."
[85] AFDD-1, "Air Force Basic Doctrine," 28.
[86] Ibid.
[87] AFDD-1, "Air Force Basic Doctrine," 28.
[88] Singer, "The Rise of the Tactical General."
[89] Ibid.
[90] Ibid.
[91] Ibid.
[92] Watts, "Doctrine, Technology, and War," 25.
[93] Capaccio, "GAO Says Joint Strike Fighter Cost Is Rising."
[94] Rolfsen, "4-Year Plan Calls for Fewer JSFs, More Mobility."
[95] Builder, *The Masks of War*, 19.
[96] Ibid., 23.
[97] Ibid.
[98] Ibid., 26.
[99] Ibid.
[100] Hoffman, "Are Enlisted Airmen the Next to Pilot UAVs?"
[101] Ibid.
[102] Ibid.
[103] Ibid.
[104] Ibid.

Bibliography

Agence France Press. "US drone strikes may break international law: UN." http://www.google.com/hostednews/afp/article/ALeqM5iUaMrNjdCeSmf_4__CYrSIe26SBg

Air Force Doctrine Document 1 (AFDD-1), Air Force Basic Doctrine, 17 November 2003.

American Civil Liberties Union. "ACLU Requests Information on Predator Drone Program." http://www.aclu.org/national-security/aclu-requests-information-predator-drone-program

American Civil Liberties Union. "Request Under Freedom of Information Act." http://www.aclu.org/national-security/predator-drone-foia-request

Arkin, Ronald. "Teaching Robots the Rules of War." *H+Magazine*. http://hplusmagazine.com/articles/robotics/teaching-robots-rules-war

Brewin, Bob. "Homemade GPS Jammers Raise Concerns." *Computerworld Security*. http://www.computerworld.com/s/article/77702/Homemade_GPS_jammers_raise_concerns?taxonomyId=017

Builder, Carl H. *The Masks of War: American Military Styles in Strategy and Analysis*. Baltimore, MD: The Johns Hopkins University Press, 1989.

Canning, John S. "A Concept of Operations for Armed Autonomous Systems." Naval Surface Warfare Center: 2006.

Chappell, Paul K. "DARPA and the Future of Army Air and Missile Defense." *Air Defense Artillery*. October-December 2006.

Clark, Colin. "China Declares Space War Inevitable." *DoD Buzz*. http://www.dodbuzz.com/2009/11/04/china-declares-space-war-inevitable/

Capaccio, Tony. "GAO Says Joint Strike Fighter Cost Is Rising." *Washington Post*. http://www.washingtonpost.com/wp-dyn/content/article/2008/03/11/AR2008031102796.html .

Citizens for Global Solutions. "Candidate Questionnaire." http://globalsolutions.org/politics/elections_and_candidates/questionnaire/2004?id=20

Clausewitz, Carl von, *On War*, New Jersey: Princeton University Press, 1989.

Department of the Air Force. "PROCUREMENT PROGRAM: FISCAL YEAR (FY) 2011 BUDGET ESTIMATES, OTHER PROCUREMENT." http://www.saffm.hq.af.mil/shared/media/document/AFD-100128-066.pdf

Department of the Air Force. "Fiscal Year 2011 Budget Estimate." http://www.saffm.hq.af.mil/shared/media/document/AFD-100129-101.pdf

Department of Defense. "Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles." http://ftp.fas.org/irp/agency/dod/dsb/uav.pdf

Deptula, David, "Air Force Unmanned Aerial System (UAS) Flight Plan 2009-2047."

Federation of American Scientists. "X-45 Unmanned Combat Air Vehicle." http://www.fas.org/programs/ssp/man/uswpns/air/attack/x-45_ucav.html

Fleming, Nic. "Campaign asks for international treaty to limit war robots." http://www.newscientist.com/article/dn17887-campaign-asks-for-international-treaty-to-limit-war-robots.html

Global Security. "AGM-88 HARM." *GlobalSecurity.org*. http://www.globalsecurity.org/military/systems/munitions/agm-88.htm

Global Security. "Chinese Anti-Satellite (ASAT) Capabilities." *GlobalSecurity.org.* http://www.globalsecurity.org/space/world/china/asat.htm

Gorman, Siobhan, Yochi Dreazen, and August Cole. "Insurgents Hack U.S. Drones." *Wall Street Journal*. http://online.wsj.com/article/SB126102247889095011.html

Greene, Bob. "Where's the shared sacrifice of war?" *CNN.com*. http://www.cnn.com/2009/OPINION/12/20/greene.wartime.christmas.sacrifice/index.html

Hoffman, Michael. "Are enlisted airmen next to pilot UAVs?" *Air Force Times*. http://www.airforcetimes.com/news/2008/12/airforce_enlisted_uas3_122108/

International Committee of the Red Cross. "The Law of Armed Conflict: Weapons." www.icrc.org/Web/eng/siteeng0.nsf/htmlall/5P8EX4/$File/LAW5_final.pdf

International Committee of the Red Cross. "International Humanitarian Law." http://www.icrc.org/ihl.nsf/WebList?ReadForm&id=470&t=art

International Committee of the Red Cross. "Mine Ban Convention." http://www.icrc.org/web/eng/siteeng0.nsf/htmlall/mine-ban-convention-map-011009?opendocument

International Committee of the Red Cross. "Cluster munitions and international humanitarian law." http://www.icrc.org/web/eng/siteeng0.nsf/htmlall/section-ihl-cluster-munition?opendocument

Kinneard, Doug. "Boeing Demonstrates UAV Automated Aerial Refueling Capability," *GlobalSecurity.org*, http://www.globalsecurity.org/military/library/news/2006/11/mil-061127-boeing02.htm

Klausner, Kurt. "Command and Control of Air and Space Forces Requires Significant Attention to Bandwidth." http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/win02/klausner.html

Klein, Joe. "General Stanley McChrystal." *Time.com*. http://www.time.com/time/specials/packages/article/0,28804,1946375_1947252_1947255-2,00.html#ixzz0b8XtB3TK

Kopp, Carlo. "Assessing Joint Strike Fighter Air Combat Capabilities." *Air Power Australia Analysis*. http://www.ausairpower.net/APA-2008-08.html

Kopp, Carlo. "The Russian Philosophy of Beyond Visual Range Air Combat." *Air Power Australia Analysis*. http://www.ausairpower.net/APA-Rus-BVR-AAM.html

Kueter, Jeff. "The War in Space Has Already Begun." http://www.marshall.org/pdf/materials/459.pdf

Lambeth, Benjamin S. *NATO's Air War for Kosovo*. Santa Monica: RAND, 2001.

MacAskill, Ewen. "US commander in Afghanistan to order limits on air strikes." *Guardian.co.uk.* http://www.guardian.co.uk/world/2009/jun/22/mcchrystal-usa-afghanistan-air-attacks

McMichael, William. "Gates: Draft not solution to personnel costs." *Air Force Times*. http://www.militarytimes.com/news/2008/05/military_appropriations_052008w/

McMichael, William. "Most US youths unfit to serve, data show," *Air Force Times.* http://www.airforcetimes.com/news/2009/11/military_unfityouths_recruiting_110309w/

Michaels, Jim. "Airstrikes in Afghanistan drop by almost half." *USA Today*. http://forthegrandchildren.blogspot.com/2009/12/roe-real-outrage-of-obamas-afghanistan.html

Mick, Jason. "Can Robots Commit War Crimes?" *Daily Tech.* http://www.dailytech.com/Can+Robots+Commit+War+Crimes/article10917.htm

New Scientist. "Military Turing Test." *New Scientist Technology Blog*. http://www.newscientist.com/blog/technology/2008/02/military-turing-test-would-make-war.html

Rafael. "Python 5-Full Sphere IR Air-to-Air or Surface-to-Air Missile." http://www.rafael.co.il/marketing/SIP_STORAGE/FILES/1/921.pdf

Roberts, Adam. "Counter-terrorism, Armed Forces, and the Laws of War." In *Warfare Studies AY10 Coursebook*, edited by Sharon McBride, 116-133. Maxwell AFB, AL: Air University Press, October 2009, 117-121.

Rolfsen, Bruce. "4-year plan calls for fewer JSFs, more mobility." *Air Force Times*. http://www.airforcetimes.com/news/2010/02/airforce_qdr_022110w/

Segal, David & Mady Wechsler Segal, "America's Military Population." *Bnet*. http://findarticles.com/p/articles/mi_qa3761/is_2004412/ai_n9468428

Singer, P.W. "Robots at War: The New Battlefield." *The Wilson Quarterly*. http://www.wilsoncenter.org/index.cfm?fuseacion=wq.essay&essay_id=496613

Singer, Peter W. "Military Robots and the Laws of War." *Brookings*. http://www.brookings.edu/articles/2009/winter_robots_singer.aspx?emc=lm&m=222362&l=53&v=15260

Singer, Peter W. "The Rise of the Tactical General." *Brookings*. http://www.brookings.edu/opinions/2009/06_unmanned_systems_singer.aspx

Trimble, Stephen. "Aim-9X Goes Slumming with Air-to-Surface Mode." *The Dew Line*. http://www.flightglobal.com/blogs/the-dewline/2009/12/aim-9x-goes-slumming-with-air-.html

Trsek, Robert B. "The Last Manned Fighter: Replacing Manned Fighters with UCAVs." Maxwell AFB, AL: April 2007.

United States Air Force. "Service demographics offer snapshot of force." http://www.af.mil/news/story.asp?id=123143143

United States Census Bureau. "Department of Defense Personnel: 1960 to 2008." http://www.census.gov/compendia/statab/2010/tables/10s0498.pdf

United States Census Bureau. http://www.census.gov

Watkins, Shanea & James Sherk. "Who Serves in the US Military? The Demographics of Enlisted Troops and Officers." *The Heritage Foundation*. http://www.heritage.org/research/nationalsecurity/cda08-05.cfm

Watts, Barry D. "Doctrine, Technology, and War." In *Warfare Studies AY10 Coursebook*, edited by Sharon McBride, 15-35. Maxwell AFB, AL: Air University Press, October 2009.