Unmanned Systems Acquisition and Technology Development: Is a More Integrated Approach Required?

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Abstract

UNMANNED SYSTEMS ACQUISITION AND TECHNOLOGY DEVELOPMENT: IS A MORE INTEGRATED APPROACH REQUIRED? by MAJ Gilge, Eric J., U.S. Army, 61 pages.

Over the course of the last 100 years, historic trends show there has been a clear and steady move towards the use of unmanned systems limited only by the technologies available to make the systems effective compared to manned systems. There is the potential that unmanned systems constitute a disruptive technology that may change the way wars are fought. An analysis of the current acquisition and technology development process and of the potential impact of unmanned systems on warfare shows that the U.S. should develop a more integrated approach for unmanned system development.

The military's acquisition and technology development process consists of a top down approach, a bottom up approach, and the development of high risk, high pay off technologies. These are the Joint Capabilities Integration and Development System (JCIDS), the Joint Urgent Operational Needs (JUON) process, and through initiatives by the Defense Advanced Research Projects Agency (DARPA). Though each of these fills a much needed role, there is little that is done to integrate these different processes.

Unmanned systems are potentially a disruptive technology and may change how wars are fought. They may have an increasing impact on operational art and friction. Operational reach, tempo, sequencing, and matching ends and means may be profoundly affected. The qualitative nature of friction could also change. Additionally, many of the ways unmanned systems are different are due to value judgments that U.S. policy makers must make. There are other strategic considerations in how their use is interpreted by a global audience, what type of characteristics we will need in our future soldiers, airmen, and sailors, and how they will affect the overall likelihood of war or peace.

There is the need to take four steps in order to mitigate risk and take full advantage of the potential of unmanned systems. First is the need to establish a strategic vision for unmanned systems. Next, we must continue to pursue and fund distributed development initiatives like those currently undertaken by organizations like DARPA. Then we need to ensure we continue to fund research into long duration unmanned systems technologies that general industry does not have the market incentives to develop on their own in order to ensure these niche technologies have the ability to be developed. Last, we need to establish programs that foster a continuous constructive dialogue between academia, general industry, defense industry, defense scientists, and defense planners so that a synthesis of ideas can develop.

Table of Contents

Introduction

In 1941 the French and British armies had a substantially larger number of technologically superior tanks than the German army, yet this seemed to matter little when the Germans attacked in June, 1941. Though the Germans had not mechanized as much of their force as the French or British, the way they went about it was vastly different. While the French and British armies divided up their tanks evenly among their infantry regiments, the Germans brought them together into large Division and Corps-level formations to use as a deep strike and shock element. They also maximized the effectiveness of this concept by building their armored vehicles to execute this concept. Armor, infantry, artillery, and air defense systems were designed to complement the strengths and weaknesses inherent in each system to gain the most in executing their specific operational concept. Using these highly mobile formations they were able to outmaneuver the French and British formations at the operational level of war. The effects were devastating as France was defeated in 6 weeks.[1]

Flash forward, it is now 2025, and tensions in the North China Sea have reached a boiling point. Japan began a military build-up in 2015 to balance out China's military expansion. Two Japanese merchant vessels, including an oil tanker, have been torpedoed and sunk, causing massive ecological and economic damage. Japanese Naval Defense Forces have dispatched destroyers to escort their vessels and the United States has sent a Carrier Strike Group to the region. Evidence points to China, although they deny it. Two days after the Carrier Strike Group arrives in the North China Sea, a Chinese cruiser is sunk when it appears to threaten the Carrier Strike Group in disputed waters. China uses this event as reason to launch a massive attack on the Carrier Strike Force and U.S. bases in Japan and Guam using large swarms of unmanned combat aerial vehicles (UCAVs). The UCAVs are small and technologically simple compared to the

[1] Williamson Murray and Alan R. Millet, *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1998), 6-49.

carrier- and land-based manned and unmanned fighters of the U.S. and Japan, but they outnumber the U.S. and Japanese aircraft nearly thirty to one and attack in swarms. The number of Chinese UCAVs destroyed is in the thousands, but they eventually overwhelm the capabilities of the Carrier Strike Group's air defenses. At the end of the day, an entire Carrier Strike Group has been sunk and our bases in Japan and Guam are destroyed. Casualties are in the tens of thousands for us, but almost zero for the Chinese.

The expansion of unmanned systems on the battlefield has accelerated dramatically over the past ten years. Over 500,000 flight hours were logged by unmanned aircraft systems (UASs) between 2001 and 2008 in Iraq and Afghanistan while unmanned ground vehicles (UGVs) have executed 30,000 missions to detect or neutralize 15,000 improvised explosive devices over the same time period.[2] There has also been numerous official government documents over the past few years meant to coordinate and synchronize the acquisition of unmanned systems. These include the *Department of Defense Unmanned Systems Integrated Roadmap* in both 2007 and 2009, the *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, and the *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047*. Each of these Department of Defense or service component documents focuses exclusively on development of technologies and strategies for acquisition of this newly developing technology.

The Office of the Secretary of Defense offers the following definition of an unmanned vehicle. "Unmanned Vehicle. A powered vehicle that does not carry a human operator, can be operated autonomously or remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload. Ballistic or semi-ballistic vehicles, cruise missiles, artillery projectiles, torpedoes, mines, satellites, and unattended sensors (with no form of propulsion) are not considered unmanned vehicles. Unmanned vehicles are the primary component of unmanned

[2] Department of Defense (DOD), *Unmanned Systems Integrated Roadmap 2009-2034* (Washington, D.C.: Dept. of Defense, 2009), xiii.

systems."[3] The unmanned system would include the vehicle and other equipment such as a remote operating station required for the vehicle to function. Though one could make the argument that many cruise missiles, satellites, mines, and other unattended sensors have attributes very similar to the first sentence in the definition, the Department of Defense specifically excludes these from being included as unmanned systems. No explanation is given for not including these systems in any government policy.

But do unmanned systems constitute a change in the nature of warfare? Unmanned systems give a military an advantage on the battlefield in numerous ways. In his work "A Theoretical, Legal and Ethical Impact of Robots on Warfare," Colonel Thomas Cowan lists ten distinct advantages a military would gain by using unmanned systems. These include: reducing or eliminating risk of harm to a nation's soldiers, reduction in personnel costs, resilience to hazardous environments, elimination of the need to protect a human crew and thus save space and energy, smaller size leading to greater survivability, high risk suicide missions are an option, capabilities not degraded by emotional responses such as fear, possibilities for reduced logistics, and operators of remotely operated unmanned systems do not require the physical attributes of a soldier.[4] Though one could question the validity of some these claims, collectively they illustrate the significant differences of unmanned systems, along with the potential for great advantages on the battlefield that a military could exploit. Cowan goes on to conclude in his paper that unmanned systems, though he uses the term robots, will fundamentally change the very nature of warfare because of the impact of the ten advantages he lists.[5]

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[3] Department of Defense (DOD), *Unmanned Systems Integrated Roadmap 2007-2032* (Washington, D.C.: Dept. of Defense, 2007), 1.

[4] Thomas H. Cowan, "A Theoretical, Legal, and Ethical Impact of Robots on Warfare," (Master's research project, U.S. Army War College, 2007), 3.

[5] Ibid., 14.

It is not just Cowan who sees the significance of the influx of unmanned systems on the battlefield. There are senior military leaders that advocate for a greater emphasis on unmanned systems because of the profound impact they may have, but there are also senior leaders who warn that the impact of unmanned systems may be overstated. U.S. Army Lieutenant General Rick Lynch has strongly advocated for increased use of unmanned systems. He claims that the U.S. military is not leveraging unmanned systems nearly enough and are missing out on opportunities to provide capabilities to soldiers that could protect soldier's lives. As someone who has a master's degree in robotics and a former Division commander in Iraq, he holds some authority on this issue.[6]

U.S. Air Force General Roger Brady has publicly advocated against an overemphasis on unmanned systems. He feels that remotely operated unmanned systems do not even meet the definition of a weapon system. He contends that current unmanned systems have little value due to their overreliance on commercial data links, the overly complex systems of control, and the vulnerability of these data links and control systems to enemy disruption and manipulation. Brady argues that in any truly competitive battlefield, unmanned systems would have little utility compared to manned systems.[7] Also, there are those outside the military who are skeptical of the impact unmanned systems will have on warfare. Fred Kaplan, a Pulitzer Prize winning journalist on national security and U.S. foreign policy, argues that unmanned systems are just an

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[6] Stew Magnuson, "Efforts to Field New Kinds of Ground Robots Have Had Little Success," (National Defense Magazine. June, 2010), http://www.nationaldefensemagazine.org/archive/2010/June/Pages/EffortstoFieldNewKindsofGroundRobots.aspx (accessed August 20, 2010).

[7] Eric Beidel, "Uncertainty, Challenges Mark Future For Military's Unpiloted Aircraft," (National Defense Magazine. October 2010), http://www.nationaldefensemagazine.org/archive/2010/October/Pages/Uncertainty,ChallengesMarkFutureForMilitary'sUnpilotedAircraft.aspx (accessed October 6 2010).

incremental improvement over our current weapon systems, and though they offer additional tools for our soldiers, sailors, and airmen, they are not revolutionary.[8]

A number of authors have forwarded the concern that there is no overarching concept that is driving unmanned system development and acquisition. One such author is P.W. Singer. He advances the argument that though we are acquiring a vast number of unmanned systems to give new capabilities to the individual soldier, we lack a plan for how we will fight wars in the future using these systems collectively. He lays out two possible operational concepts. One he bases on remotely piloted vehicles operating from "mother ships" in manned airplanes or ships with remote control stations. The other relies on simple autonomous unmanned systems that work in "swarms" to overwhelm their targets. The mother ship concept gives greater command and control but has inherent weaknesses in that the unmanned systems are useless if the enemy destroys the "mother ships." The swarm concept is more resilient but a commander must give up some of his control as there is no human controlling the individual actions of the autonomous unmanned systems.[9] These are two very different operational concepts of use for unmanned systems, each feasible, each with strengths and weaknesses, each with issues regarding political acceptability, and each depending on very different requirements for technology advancement. There may be yet other operational concepts that Singer does not envisage. If we pick an inappropriate operational concept, we may be unprepared for future conflict.

This paper examines the claim that military applications of unmanned systems technology are sufficiently different from previous technologies to generate a discontinuity, not just in how wars are fought, but in how capabilities are developed. There is the potential that unmanned systems constitute a disruptive technology that may change the way wars are fought.

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[8] Fred Kaplan, "Wonder Weapons Don't Win Wars," (Slate Magazine. May 19, 2010), http://www.slate.com/id/2254374 (accessed October 6, 2010).

[9] P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century* (New York: Penguin Press, 2009), 205-236.

An analysis of the current acquisition and technology development process and of the potential impact of unmanned systems on warfare shows that the U.S. should develop a more integrated approach for unmanned system development. To set the context the first section reviews the historical development and current guidance on unmanned systems. Then the second section will look at one theory and one frame work for technology innovation and the current process in theory used by the U.S. military to acquire unmanned systems and to develop the technology. The third section lays out the current processes the U.S. military uses for technology innovation in practice. The forth section analyzes both the nature of the technology and what potential impacts this new technology could have on war. This analysis assists in determining whether the current acquisition processes and technology development processes are adequate for the nature of the technology and the impact it could have on war. The final sections summarize the argument and makes four recommendations for a more integrated process for unmanned systems acquisition, and lay out areas for further research.

This paper does not address such things as the appropriate operational concept for incorporating unmanned systems into the U.S. military. Nor will it provide specific recommendations for policy changes on specific types of unmanned system technology it should pursue. These areas require research and analysis well beyond the scope of this paper. Hopefully this analysis of the nature of the technology and potential impacts on warfare can contribute to the larger debate by considering the previously neglected question of whether unmanned systems technologies demand new ways of thinking about capability development.

Trends in Unmanned Systems

Historical Development

One of the key things that must be outlined to set the ground work is the development of unmanned systems technology over time, the current state of the technology, and how the Department of Defense (DOD) and the services envision it to progress over the coming years. As will be shown, as the technology development progresses from remote controlled to semi-autonomous to fully autonomous systems, the impacts on warfare could become more radical. There are forces inherent to the competitive nature of weapons development that will drive this progression. Once we have shown the progression of the technology development has taken and the visions set forth for future development by the DOD and the services, the analysis in the following section of the acquisition and technology development process can be made in context.

The development of unmanned systems goes back to the early part of this century with the development of unmanned ground vehicles used to break through obstacles. The casualties on the western front of World War I were tremendous. In reaction to this, in 1915 Feliz Sabah designed a tracked vehicle that could be remotely guided through the no man's land to the enemy's defenses with up to 1000 pounds of explosives. However, Sabah's design was never used to any real effect.[10] Shortly thereafter in 1918 another engineer at the Caterpillar Tractor Company, E. E. Wichersham designed and developed a demolitions carrier called the Land Torpedo. It also was never used. In World War II the Germans made significant attempts to develop unmanned systems. In 1939 the Borgward Company developed an 8,000 pound vehicle for remotely destroying enemy mines with an explosive charge in a container on its front. Named the B1V Demolition Vehicle, 500 of the vehicles were built. It was intended to be operated manually until it was no longer safe to drive. The operator would then dismount and control the vehicle with a radio remote control. After approaching the mine and releasing its explosive charge, it would then back off and a time delay would detonate the charge. Often, however, something would go wrong and the charge would detonate prior to the BV1 backing off.[11]

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[10] Robert Finkelstein and Steven Shaker, *Unmanned Vehicle Systems: Military and Civil Robots For the 21st Century and Beyond* (Arlington: Pasha Publications Inc., 1994), 9.

[11] Steven M. Shaker and Alan R. Wise, *War Without Men: Robots on the Future Battlefield* (McLean: Pergamon-Brassey's International Defense Publishers, 1988), 15-17.

The Germans also developed the Goliath Demolition Vehicle during World War II. It was smaller than the BV1 and was solely an unmanned system operated through a remote control box attached to the vehicle with a cable. The Goliath looked like a small Mk 1 British tank from World War I and was only 3 feet tall and about 5 feet in length. It could deliver a 132 pound charge and was originally meant for attacking enemy bunkers and pill boxes with a secondary mission of mine clearing. Over 7,000 of all variants of the Goliath were manufactured.[12] The early unmanned ground systems were primarily developed to conduct military missions that were considered too hazardous for a human to attempt, such as attacking an enemy pill box or clearing enemy mines and obstacles. They were meant to reduce friendly casualties and extend standoff distance. However, the technology of the time severely limited the effectiveness of these early systems.

In the 1980s numerous systems were developed that could act with some level of autonomy, although within very specific parameters. The Tomahawk cruise missile systems, Patriot Air Defense Weapon System, Aegis Automatic Special Weapon System, and the Assault Breaker systems were all developed to identify and track targets and, within the restraints placed on them, engage a target automatically. The Tomahawk cruise missile is given a target location and then upon arriving near this location it scans the area with its radar to acquire the target. This allows for more precise engagement of a target. It has the ability to acquire a target through its radar and destroy the target based on its discrimination criteria. The Tomahawk primarily continued the trend for greater stand off from threats to reduce casualties.

The U.S. Army designed the Patriot to provide air defense against enemy aircraft and theater ballistic missiles. It was capable of engaging targets out to 50 miles, far beyond the abilities of a human operator to sense or see the aircraft or missile themselves. The human operators were completely reliant on the Patriot to determine whether the acquired target was

[12] Shaker and Wise, 15-17.

enemy or friendly. The U.S. Navy designed the Aegis to defend ships from multiple aerial, surface and sub-surface threats. It too, like the Patriot, acquired hostile targets well beyond a human's ability to see or sense, much less identify them. As with the Patriot system, the speed of the hostile threats demanded that once a threat was acquired by the Aegis system, minimal time was available before a decision had to be made to engage it.[13]

Also during the mid-1980s, a program by the name of Assault Breaker was developed with the intent of breaking up Soviet deep penetration columns, key to affecting the execution of Soviet offensive doctrine. This program was made up of target acquisition platforms such as the aerial Joint Surveillance Target Acquisition System (JSTARS) and the Army Tactical Missile (ATACM). These systems would be linked to automatically engage columns of Soviet armor once they were identified. While this system was canceled in 1983, the JSTARS and ATACM were each acquired individually. The automatic linkage for target engagement was never fully developed though.[14] Minimal human decision making would be involved, presumably so as to ensure the ATACMs could engage the Soviet armor columns the JSTARS had identified prior to them moving out of position. Though none of these systems are typically thought of as unmanned systems, they do act with a certain level of autonomy. They do show a new trend, in that they require a certain level of automation because of the time and space considerations. Human abilities to make a decision based on the information available are not fast enough. The U.S. military compensated for this by moving a certain amount of the decision making into the computer system by linking the target acquisition elements of the system directly to the

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[13] Erin McDaniel, "Robot Wars: Legal and Ethical Dilemmas of Using Unmanned Robotics Systems in 21st Century Warfare and Beyond," (Ft. Belvoir: Defense Technical Information Center, 2008), 39-44.

[14] Armin Krishnan, *Killer Robots: Legality and Ethicality of Autonomous Weapons* (Farnham, England: Ashgate, 2009), 24.

engagement capability. Humans may play a role in confirming that the limited data on their screen conforms to what they would expect from the signature of a hostile entity.

Unmanned ground vehicles have been developing rapidly during and since the 1980s. Such systems as the ROBART I and ROBART II were developed to conduct physical security-type missions on an installation perimeter. These systems began to create a greater linkage between sensors and the computing capability to actually form a picture of their environment and calculate ways to move through that environment. In 1983 the Defense Advanced Research Project Agency (DARPA) and Robot Defense Systems developed a system capable of following a non-linear fence line around the outside of a military base.[15] These systems are important as they show the Army's move into the use of unmanned ground vehicles for situations that would free up soldiers from boring, simplistic, and redundant tasks such as patrolling the perimeter of a military base. Autonomy was necessary to actually free up soldiers, as a remotely operated vehicle would just displace one repetitive task for another.

DARPA continued this research through the 1980s and worked on developing technology for both remotely operated and autonomous vehicles. The Tank and Automotive Command (TACOM) also worked to develop systems that could be used to reduce the risk to a crew in a hostile environment. They developed the Robotic Obstacle Breaching and Assault Tank (ROBAT) that was intended to clear a breach lane through a minefield using multiple explosive line charges. It was to be remotely guided to the minefield with a television camera sensor and connected to the operator in another vehicle with a fiber optic cable.[16] The ROBAT was never fielded, but the Army continued to develop systems to attempt to create greater standoff for the soldier.

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[15] Gregory Nardi, "Autonomy, Unmanned Ground Vehicles, and the US Army: Preparing for the Future by Examining the Past," (Ft. Belvoir: Defense Technical Information Center, 2009), 39.

[16] Shaker and Wise, 63.

There has been enormous growth in the development and use of remotely operated unmanned ground vehicles, primarily due to the wars in Iraq and Afghanistan. UGVs include the 97 pound Talon, 66 pound Matilda, and 42 pound PackBot, used by Explosive Ordinance Disposal (EOD) teams to defeat Improvised Explosive Devices (IEDs) and by units to conduct reconnaissance or surveillance of high risk objectives. These UGVs are all remotely operated by a secure radio signal and have a camera and manipulating arm. An EOD soldier uses the UGV to interrogate suspicious looking items with its arm to confirm or deny they are IEDs and if necessary dismantle or destroy identified IEDs. The UGV provides the EOD soldier standoff from what would otherwise be a very hostile situation. There have been efforts to arm these same UGVs with weapons packages, such as automatic weapons or shotguns. The Special Weapons Observation Reconnaissance Detection System (SWORDS) is based on the Talon and has an automatic rifle capable of hitting a target at 2,000 meters. The same company that makes the Talon and SWORD is working on a successor called MAARS that would be more heavily armed than the SWORD.[17] Even though none of these UGVs have any sort of autonomy, they have seen limited use in combat. They have not yet fired a shot at an enemy, although they have deployed to Iraq and Afghanistan with units. This is not due to the availability of systems such as SWORDS, but primarily due to concerns of commanders with a new technology. There were also instances in testing of "involuntary movements" that certainly added to these concerns. Brigadier General Miller, the officer responsible for urgent equipment requirements for the Marine Corps, remarked while addressing questions as to why there have not been more armed UGVs fielded to deployed forces that "there has not been a request for an armed robot coming from the field."[18]

In 2001 Congress continued this trend of embracing unmanned technology by setting a goal that by 2010 one third of all deep strike aircraft be unmanned and by 2015 one third of all

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[17] Krishnan, 28-29.

[18] Magnuson.

ground support vehicles be unmanned.[19] This goal is certainly not going to be met, but not for lack of trying. Again in 2007, Congress legislated that the Department of Defense revise its policy on unmanned systems. In the John Warner National Defense Authorization Act for Fiscal Year 2007, they called on the Department of Defense to establish policy for the U.S. military on unmanned systems that would address their

> preference for unmanned systems in their acquisitions of new systems, addressing joint development and procurement of unmanned systems and components, transitioning Service unique unmanned systems to joint systems as appropriate, the organizational structure for effective management, coordination and budgeting for the development and procurement of unmanned systems, and developing and implementation plan that assesses progress toward meeting goals established in Section 220 of the Floyd D. Spence National Defense Authorization Act for FY 2001.[20]

The U.S. military has laid out its current acquisition strategy for unmanned systems in a collection of both joint and service-specific roadmaps. The *Unmanned Systems Integrated Roadmap for 2009-2034* is the Department of Defense's overarching document that establishes how they will develop unmanned systems technology and acquire the unmanned systems themselves. It was "the culmination of a deliberate and methodical exercise to address the elements" [21] of the National Defense Authorization Act of 2007. Based on the Department of Defense's Unmanned Systems Integrated Roadmap each service has developed its own roadmap or a similar document. The U.S. Air Force has the *Unmanned Aircraft Systems Flight Plan 2009-2047* addressing UASs while the U.S. Army has the *Eyes of the Army: Unmanned Aircraft Systems Roadmap 2010-2035* that does the same for UASs in the Army. Currently most of the published unmanned systems plans and roadmaps speak mainly to UASs, likely due their more advanced capabilities, but the U.S. Army plans to publish a UGV plan later this year, closely modeled on its UAS roadmap.

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[19] United States, *National Defense Authorization, Fiscal Year 2001* (Washington, D.C.: U.S. G.P.O., 2000), 38.

[20] Department of Defense (DOD), *Unmanned Systems Integrated Roadmap 2009-2034*, 4-5.

[21] Ibid., 5.

The *Unmanned Systems Integrated Roadmap 2009-2034* was published by the Department of Defense in April of 2009 to provide "a feasible vision for capitalizing on unmanned systems technologies."[22] It acknowledges that there has been tremendous advancement in unmanned systems but finds that "these successes, however, likely represent only a fraction of what is possible and desirable."[23] As a result of the National Defense Authorization Act of 2007, the roadmap identifies the missions that are feasible for unmanned systems and lays out what an associated industrial base would need to look like to produce the needed enabling technologies for unmanned systems. Overall, it provides a menu of the possible missions unmanned systems could conduct, the required performance characteristics for unmanned systems to perform these missions, and the enabling technologies required to achieve the performance characteristics. It explicitly states that it is not meant to identify operating concepts, requirements, or specific programs for adoption. These areas would need further research and analysis.[24] This document then seems to inform the development of individual service plans for unmanned systems acquisition.

The Air Force's vision for UASs from the present out to 2047 is a family of unmanned aircraft systems in the ranges of small man portable, medium "fighter size," large "tanker size," and special vehicles with unique capabilities. Each of these unmanned systems would have the capability to operate autonomously at some level. They would have common airframes with a set of interchangeable, common payloads and standard interfaces that could be specifically task organized to fulfill a U.S. Air Force Core Function required by the Joint Force.[25]

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[22] Department of Defense (DOD), *Unmanned Systems Integrated Roadmap 2009-2034*, 1.

[23] Ibid.

[24] Ibid.

[25] United States Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047* (Washington, D.C.: Dept. of Defense, Headquarters, United States Air Force, 2009), 3.

The U.S. Air Force envisions the eventual development of autonomous UASs.[26] At first autonomy would be used to reduce manpower requirements and reduce workload. Such things as auto takeoff and landing would then develop into the ability to autonomously transit. Over time, they would take advantage of swarming technology so that multiple UASs would act autonomously within an area of interest while connected to each other and a "swarm commander" through a wireless network. They would share information about the threat and deconflict collisions through the network. There is also the goal of achieving the ability for a "loyal wingman," where manned-unmanned teaming would allow an UAS and a manned aircraft to work directly together on such missions as air interdiction, attack on integrated air defense systems, and offensive counter air.[27] Full autonomy is certainly not ruled out in the vision the U.S. Air Force lays out. The U.S. Air Force claims in their *Unmanned Aircraft Systems Flight Plan 2009-2047* that as automation decreases the time available in the decision cycle will be reduced to mere microseconds. Then the requirement for unmanned systems to make lethal decisions may become a necessity with humans "on the loop" instead of "in the loop" fulfilling a role that monitors that decisions are being properly executed, but not actually making the decisions. They go on to acknowledge issues such as ethical and moral concerns and feel that the ethical debates and policy decisions must be made immediately to guide the development of this technology, rather than it developing over time unsupervised. The U.S. Air Force then proposes that ideally the increased use of autonomous unmanned systems should be incremental, allow incorporation of human intent into the autonomous decision cycle, and by synchronized over time and by doctrine, organization, training, materiel, infrastructure, leadership, personnel, facilities, and policy (DOTMILPF-P).[28]

[26] United States Air Force, 33-34.

[27] Ibid.

[28] Ibid., 41.

The U.S. Army has also laid out its vision for UASs, which is very different in both format and substance to the U.S. Air Force's plan. Their vision is laid out in near term, mid-term, and far-term time frames with a DOTMILPF-P analysis for each time period. The U.S Army does put forth specific concepts and visions in its UASs Roadmap. However, these are not meant to be directive or set priorities, but rather provide a starting point for UASs in the U.S. Army. The near-term period stretches from the present until 2015.[29] This period is characterized as being a transition period, with numerous non-integrated systems used to cover capability gaps identified in current operations. Such concepts as manned/unmanned teaming are developed to gain the strengths of both manned and unmanned systems and to mitigate the weaknesses of each.[30] Some major issues raised in the U.S. Army UAS Roadmap that must be addressed include use of unmanned systems for casualty evacuation, joint policy for interoperability and commonality, and standardization of rules of engagement to facilitate clearance of fires when unmanned systems are involved.[31]

In the Mid-Term period stretching from 2016 to 2025, UASs will become fully integrated. Many of these UASs will actually be optionally piloted vehicles. These will be aircraft that could have a pilot onboard or at the flip of a switch, operate as part of an unmanned system. During this timeframe the majority of surveillance and communications extension will be done by unmanned systems and they begin to do missions such as armed reconnaissance, attack, sustainment, and resupply.[32] Some key issues that will need to be resolved during this period are whether unmanned systems can be used to transport soldiers and casualties.[33]

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[29] Department of the Army, *Eyes of the Army: U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* (Washington, D.C.: Dept. of Defense, U.S. Army Unmanned Aircraft Systems Center of Excellence 2010), 32.

[30] Ibid., 33.

[31] Ibid., 42.

[32] Ibid., 49.

[33] Ibid., 55.

In the Far-Term from 2026 to 2035, the U.S. Army sees UASs becoming more semi-autonomous, survivable, interoperable, and requiring less sustainment.[34] As systems evolve from remotely operated to semi-autonomous, more functions will migrate from the human operator to the unmanned vehicle, with the fire decision always in the control of the operator.[35] The most contentious issue is how to allow enough data exchange between the unmanned vehicle and the human operator, as "it is widely accepted that weapons release will always have a human decision maker responsible for the judgment of the engagement."[36] The U.S. Army is currently developing a vision for UGVs meant to complement their UAS plan and is to be heavily based on their UAS plan.[37]

Looking at the overall Department of Defense's unmanned systems plan and then those for UASs for the U.S. Air Force and U.S. Army we see that they have very ambitious goals. There is a clear conflict between the U.S. Air Forces plan that concedes full autonomy is a near certainty and the U.S. Army's plan to always have a human in the decision cycle. A possible reason for this may be the different subcultures of the Army and the Air Force. A potential explanation is that because airmen have placed their lives in the hands of technology since before the inception of their service, their culture is more open to automation technology. In contrast, the oldest and most prestigious branches of the Army have emphasized the importance of men and morale over equipment.

There also seems to be a gross duplicity in the development of UASs technology by both the U.S. Army and U.S. Air Force. The Department of Defense's *Unmanned Systems Integrated*

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[34] Department of the Army, *Eyes of the Army: U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 59.

[35] Ibid., 60.

[36] Ibid., 63.

[37] Department of the Army, *Army Unmanned Ground Vehicle Strategy Memorandum* (Washington, D.C.: Dept. of Defense, Headquarters United States Army Maneuver Center of Excellence, 2010), 1-2.

Roadmap 2009-2034 fails to perform some of the most important functions required to synchronize the efforts of the individual services. It does not establish clear priorities for what capabilities each service should develop or establish a process to set policy regarding contentious issues, such as the development of autonomous decision making. The U.S. military clearly intends to move away from remotely operated unmanned systems toward more autonomous systems. The systems and processes used to adopt this new technology should reflect the level of impact the new technology is likely to have on warfare.

Over the course of the last 100 years there has been a clear and steady move towards the use of unmanned systems that has only been limited by the technologies available to make the systems effective compared to a manned system.[38] But as technology continues to advance and we are able to integrate sensors with faster computer processors approaching low levels of artificial intelligence, it is reasonable to assume that eventually unmanned systems will reach a level where they can be as effective as a manned system, at least at the select tasks that matter in an engagement. Even if they are not effective in an engagement at a 1:1 ratio, we can expect them soon to reach a point where a number of individually less effective unmanned systems are more effective than an individual manned platform and still more cost effective. Both the U.S. Army and the U.S. Air Force acknowledge this in their UAS plans.

Once the technology reaches this level, will it have a profound impact on warfare or will it just change its execution on the margins? The answer to this question is imperative in determining whether we need to treat unmanned system technology development as we would any other technology or if we need to give it special considerations such as a more integrated process. To determine this, next we will look at a theory of technology-driven innovation and a

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[38] Armin Krishnan, *Killer Robots: Legality and Ethicality of Autonomous Weapons* (Farnham, England: Ashgate, 2009), 30.

framework for technology development. Then we will examine the military's technology development and acquisition process in theory and in practice.

Technological Innovation Process

Theories of Incorporating New Technologies

There is one theory and one framework that seem to have relevance to the determination as to whether the unmanned systems acquisition and technology development process is adequate considering the impact unmanned systems may have on warfare. Clayton Christensen's theory lays out a theory that not all technologies are the same. Some are disruptive and have much greater and unpredictable impacts on existing markets. He postulates that innovators must treat these disruptive technologies differently. Then Neville Curtis and Peter Dortmans' framework establishes a way for scientific discovery to influence concepts of employment and then these concepts to refine the efforts of the scientific community. This theory and framework help in the next sections analysis of DOD's processes and practices of acquisition and technology development and then the potential impacts of unmanned systems on warfare.

Clayton Christensen's theory of technology-driven innovation has had significant impact on how the business world assesses new technologies and innovates. Christensen distinguishes between sustaining technologies and disruptive technologies. Sustaining technologies are those that improve a product's performance in a way that the majority of consumers in the major markets have previously valued. Advancements in sustaining technologies are usually incremental and linear in nature, but they can be radical. Disruptive technologies are those that initially bring poorer performance but substantially change how costs and benefits are associated within the market. Initially this is with only a select few customers. The characteristics of disruptive technologies that include being cheaper, simpler, more convenient, and smaller allow their creators to establish and then service a niche market. At first they expand slowly but as the characteristics of the new technology become more widely known, they can displace the more accepted and initially more effective sustaining technologies.[39]

An example of a sustaining technology would be the compact disk within the music industry. Like the advancement from the vinyl record to the cassette tape, the incremental advance to the compact disk was a vast improvement over the traditional cassette tape with its improved sound quality and durability. It was a somewhat radical leap in that people had to purchase new compact disk players to replace their cassette tape players. But it was not a disruptive technology in that mainstream consumers still bought music albums on compact disks from record stores at roughly the same price as cassette tapes.

Digital file technology in the form of MP3s was a disruptive technology. Initially used by only a small group college and high school students, it allowed people to convert music from a compact disk to a digital file. This file could then be played on a personal computer with an MP3 player and transferred to other computers and devices. Initially inferior sound quality, small digital file storage capacity, large file size, and limited transfer speeds on the Internet made digital audio files a poor replacement for compact disks. But digital audio files were more convenient and much cheaper, initially available for free through file-swap sites like Napster. They were also much smaller in that one could store and access their entire music collection on one computer instead of boxes of compact disks. Improvements were made that increased storage capacity in computers and portable MP3 devices like the iPod, and bandwidth on the Internet increased. The initial niche market of college students grew and in a few years, the music industry was forced to completely change its business models as mainstream consumers stopped buying compact disks. Retail record stores that did not adapt (and most did not) went out of business. Those that did adapt no longer had the need for store clerks or even stores in the traditional sense,

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[39] Clayton M. Christensen, *The Innovator's Dilemma: The Revolutionary National Bestseller That Changed the Way We Do Business* (New York: Harper Business, 2000), xviii, xxiii-xxviii.

as consumers could buy digital files over the Internet and then download them onto their computer or device.

The Christensen model of disruptive technology can also be adapted for military use. Sustaining technologies are those that advance and improve performance along a path that the military has traditionally valued. These improvements are generally linear in character and show stable and steady performance improvements. These improvements then result in improvements to warfighting but not in completely new ways of fighting. Disruptive technologies provide the military with improvements along a path that was not previously valued. These improvements allow "novel linkages among the components and occur in an unstable architecture."[40] These novel linkages can potentially lead to new forms of warfighting. The results of these novel linkages are very difficult to predict, as they do not provide value to the current tactics and operational concepts.[41]

Some unmanned systems potentially are disruptive technology, with those that incorporate autonomy holding the greatest potential as being disruptive. Currently in many areas of performance, they are a poor substitute for manned systems. Remotely operated unmanned systems do not offer the situational awareness that an operator has in a manned system and the digital data links to the system also limit responsiveness. Autonomous and semi-autonomous unmanned systems currently have very limited capabilities. They do not even come close to being able to outperform the capabilities of a manned system. But they show the characteristics of a disruptive technology. In certain niche capabilities such as in bomb disposal and intelligence, surveillance, and reconnaissance (ISR), they are showing that they provide advantages that sustaining technologies do not. This calls into question the ability of the current military

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[40] Terry C. Pierce, *Warfighting and Disruptive Technologies: Disguising Innovation* (Cass series--strategy and history. London: Frank Cass, 2004), 25.

[41] Ibid., 26.

technology development and acquisition process to recognize and exploit the potential of unmanned system technology, if the technology radically alters the existing “market” structure.

The impact of unmanned systems being potentially disruptive is that leaders must take a different management approach to disruptive technologies. The nature of disruptive technologies also makes them a very difficult sell to leadership, as few leaders initially will value the new capabilities provided by a disruptive technology. This could lead to an underestimation of the potential usefulness and impact of disruptive technologies on warfare.[42] Essentially, if unmanned systems are disruptive, then using the same methods to develop this technology as we do other technologies will likely generate suboptimal results.

Another theory has been developed by Peter Dortman and Neville Curtis. Their theory is specifically meant to link technological innovation to warfighting concepts. They lay out a framework that specifies in a much more specific manner the relationship between technology development and future warfighting concepts. They establish a three way relationship between these technological concepts, cultural contexts, and warfighting concepts. These three areas constantly relate to and influence each other. [43] This three way relationship sets the environment in which their framework then attempts to link new technological innovations to new methods of warfare. In their framework scientific disciplines create scientific concepts that develop into enabling technologies. Enabling technologies aggregate to form technological concepts that then suggest military applications. These military applications indicate battlespace effects that inform future combat paradigms, which provide context for future warfighting concepts. Influence also flows the other way as future warfighting concepts invoke future combat paradigms that identify battlespace effects. These battlespace effects then suggest military applications that identify

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[42] Pierce., 26-27.

[43] Peter J. Dortmans and Neville J. Curtis, *Towards an Analytical Framework for Evaluating the Impact of Technology on Future Contexts* (Edinburgh, S. Aust: DSTO Systems Sciences Laboratory, 2004), 3.

technological concepts. These technological concepts indicate enabling technologies that drive scientific concepts and then expand scientific disciplines. They also assign specific domains of responsibility between academia, defense scientists, general industry, defense industry, and defense planners in the linking of these elements.[44]

What seems to be novel in this rational linkage of the science to the warfighting concept is its emphasis on relationships and the need for a deliberate interdependence on each other. This, along with the association of the elements of the framework to specific actors, gives this model utility for a disruptive technology such as unmanned systems. If the actors are given the ability to interact, share ideas, and have the influence on each other in an iterative process as the framework advocates, then there is a great potential to achieve synergy. The ideas generated by this constant dialogue would draw from the unconstrained, abstract thinking provided by the academia all the way to the more practical, real world constrained thinking of the defense planners. As this synthesis of ideas occurs, unmanned systems technology would benefit from a co-evolution as the science behind the various unmanned systems technologies influences warfighting concept development for unmanned systems in a meaningful way and feedback from these changes to warfighting concepts drives development of certain capabilities that were not seen as useful by the scientific community.

U.S. Military New Technologies Acquisition and Technology Development

To assess if our current process for unmanned systems acquisition and development is adequate for the impact unmanned systems potentially has on war, a detailed analysis of our current acquisition and technology development must be done. In theory, the basis for all technology development by the U.S. military is the Joint Capabilities Integration and Development System (JCIDS). In practice, technology is also developed as part of the Joint

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[44] Dortmans, 15-16.

Urgent Operational Needs (JUON) process and through DARPA. These will be discussed in detail in the following section. Joint Capabilities Integration and Development System

The U.S. military acquires its weapons systems through an acquisition system made up of three interrelated but distinct systems. The first is the system that generates the requirements, the JCIDS. This process is governed by the Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01G.[45] The Planning, Programming, Budgeting, and Execution (PPBE) system allocates resources through a budgeting process and is governed by Department of Defense Directive 7045.14 (The Planning, Programming, and Budgeting System).[46] Lastly, the Defense Acquisition System (DAS) actually procures the weapon platforms, material, services, or other systems needed to meet requirements. Department of Defense Directive 5000.1 (The Defense Acquisition System) governs this process.[47] There is no formal process that coordinates the efforts of these systems, but it is described as a "system of systems."[48] The JCIDS and DAS will be analyzed in greater detail, as these are the most relevant to identifying how the U.S. military makes decisions on technology development.

The current JCIDS process was established in 2003 and reflects a change from the previous Requirement Generated System. The Requirement Generated System was a bottom up threat-based system, whereas JCIDS is a top down capabilities based system. Under the Requirement Generated System, each individual service would develop weapons to support capabilities it decided it needed to counter threats identified during threat based assessments and related individual service visions and requirements. The intent of the JCIDS process is that it uses the national security policy documents, such as the National Security Strategy, National Defense

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[45] Moshe Schwartz, *Defense Acquisitions How DOD Acquires Weapon Systems and Recent Efforts to Reform the Process* (Washington, D.C.: Congressional Research Service, 2009), 3.

[46] Ibid.

[47] Ibid.

[48] Ibid.

Strategy, and National Military Strategy to provide the broad strategic guidance to identify the requirements of the nation.[49] The specific military documents that drive the requirements are the combatant commanders' contingency plans, joint doctrine, and the Joint Operational Concepts developed by the Joint Forces Command.[50]

These requirements are the major inputs to Capabilities Based Assessments, which determines the specific capabilities required to achieve the military requirements of the nation. A Capabilities Based Assessment is meant to also identify gaps in our capabilities and the risk incurred to the nation because of these gaps. It then assesses whether there is a non-material solution to fill these capability gaps. Solutions to fill capability gaps are looked at as either being a change to doctrine, organization, training, materiel, infrasture, leadership and education, personnel, or facilities (DOTMILPF).[51] If a materiel solution is identified and assessed as being required, then an Initial Capabilities Document is produced justifying this need to bridge the identified capability gap. This Initial Capabilities Document is approved by the Joint Requirements Oversight Council who is responsible for identifying and prioritizing warfighter requirements. In their approval, they confirm the capabilities necessary for the requirement, that a gap in capability exists, and that there is a need to fix the capability gap.

The Joint Requirements Oversight Council could recommend a non-materiel solution in the form of changes to doctrine, modification to the organizational structure of a unit or units, or other changes within DOTMILPF. If the Joint Oversight Council approves the Initial Capabilities

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[49] Stephen Howard Chadwick, *Defense Acquisition Overview*, *Issues, and Options for Congress* (Washington, D.C.: Congressional Research Service, Library of Congress, 2007), 4.

[50] Department of Defense (DOD), *Capabilities-Based Assessment (CBA) User's Guide Version 3* (Washington, D.C.: Dept. of Defense, Joint Chiefs of Staff, March, 2009), 13.

[51] Department of Defense (DOD), "CJCSI 3170.01G, JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM" (Washington, D.C.: Department of Defense, Joint Chiefs of Staff, March 1, 2009), A-2.

Document, then system development, which may include weapons platforms, materials, services, or other systems to achieve the capability, begins its initial phases in the DAS.[52]

In the DAS, the identified system requirement undergoes a Materiel Solution Analysis to determine what the options are for solutions. Solutions may be found to be in modification to a current system, acquisition of a currently available system, or development of technology to support a new system. If it is determined that a feasible option exists in the form of developing technology to support a new system then the new system enters into the Technology Development stage. During this stage the necessary technologies are brought to maturation through research and development efforts and prototypes are developed by multiple competitive defense contractors. To encourage innovation the decision authority leaves the operational characteristics of the required weapons system as broad as possible to still achieve the same capability. A Capabilities Development Document then specifies in detail the key performance parameters of the system. At the conclusion of the Technology Development stage the competitive prototypes are tested in a relevant environment to prove technology maturation. The weapon system then enters into the Engineering and Manufacturing Development stage. It is here that the sub-systems are all integrated together and then a production representative system proves its ability to achieve all of the key performance parameters laid out in the Capabilities Development Document and that it can be manufactured using current processes. At this point it enters the Production and Deployment stage and begins low rate initial production. Finally upon confirmation that there is sufficient quality control over the manufacturing process, full rate production is achieved until all required systems are procured for use.[53]

In summary, the U.S. military's current formal process uses a system of systems, each governed by a directive or instruction. This process relies on the identification of requirements

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[52] Schwartz, 4.

[53] Ibid., 7-11.

through the analysis of national level security documents, joint operational concepts developed by Joint Forces Command, and contingency plans developed by Combatant Commanders. These requirements then drive associated capabilities necessary to meet the requirements. If a gap in capability exists that cannot be met by something other than a new weapon system, then development of new technologies is begun with the intent of producing a new weapon system to fill the capability gap. The intent of the process is driven by the logic of eliminating the pursuit of unnecessary technologies and allocation of resources toward unneeded weapon systems. All resource allocation is focused towards achieving the goals, objectives, and overall strategy of the nation.

However, as a top down approach it is heavily reliant on the national strategy, operational concepts, and contingency plans anticipating and identifying the future requirements of the joint force. An inherent weakness of top down planning for capability development is that any disruptive innovations that are not foreseen by military strategy, operating concepts, and contingency planning documents cannot be exploited until these high level documents change.

The risk of this approach is that the operating concepts that provide the requirements for capabilities must be the right ones. If not the wrong capabilities may be identified as being necessary and because of the long lead time required to get through the entire process, quick adjustments are difficult. There is also the likelihood that if the technology seems too farfetched or inferior to existing (manned) systems when the Material Solutions Analysis is completed, it will never enter the Technology Development phase and industry and academia will never have the incentives or resources to develop the technology. This is what then leads to other bottom up solutions and long range technology development.

Technological Innovation in Practice

Although there is a process meant to coordinate, integrate, and drive the acquisition of new technology from the top down, there has also emerged alternative, bottom up processes for the acquisition of new technologies into the force. One of these processes is for commanders in the deployed force, or preparing to deploy to combat, requesting technological solutions to capability shortfalls through the Joint Urgent Operational Need (JUON) process.[54] Also, there are initiatives to drive bottom up technology development through organizations such as the Defense Advanced Research Projects Agency (DARPA), which sponsors events such as the Grand Challenge and Autonomous Robotic Manipulation (ARM) program.

The JUON process is a way for an operational commander to address urgent needs. Each service has its own system with the U.S. Army being the first to establish a system in 1987.[55] For the Army, the Office of the Deputy Chief of Staff, G3/5/7 is the overseer of the process. In 2004, the Department of Defense defined an urgent need as "urgent, combat commander-prioritized operational needs that, if left unfilled, could result in loss of life and/or prevent the successful completion of a near-term military mission."[56] The Army established in Army Regulation 71-9 that a commander should use an operational needs statement (ONS) to identify these shortfalls that could jeopardize mission accomplishment.[57] In order to gauge the scope of these urgent operational needs, the Army has processed or is processing nearly 7,000 urgent operational needs between 2006 and 2010. This process is completely outside the formal defense acquisition process. There is no mention of the JUON process in any part of the three acquisition systems previously laid out.[58] This has resulted in the Department of Defense having to establish "more

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[54] Department of Defense (DOD), *Report of the Defense Science Board Task Force on the Fulfillment of Urgent Operational Needs* (Washington, D.C.: Dept. of Defense, Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, 2009), 12.

[55] United States Government Accountability Office and William Solis, Warfighter Support Improvements to DOD's Urgent Needs Processes Would Enhance Oversight and Expedite Efforts to Meet Critical Warfighter Needs : Report to the Committee on Armed Services, U.S. Senate (Washington, D.C.: U.S. Govt. Accountability Office, 2010), 10.

[56] Ibid., 10-11.

[57] Department of Defense (DOD), *Report of the Defense Science Board Task Force on the Fulfillment of Urgent Operational Needs*, 12.

[58] United States Government Accountability Office and William Solis, 23.

than 20 ad hoc offices, agencies, task forces, and other organizations to respond and fulfill these diverse needs."[59]

The need for the JUON process shows that there is a significant shortfall in the logic of a purely concept-driven acquisition strategy. It has resulted in a formal acquisition process deficient in the ability to quickly generate new capabilities for our soldiers, pilots, and sailors systematically or effectively.[60] It is too "inward-looking," its planning fails to foresee new realities that emerge, and it fails to harness the innovation within the commercial sector or other government organizations.[61] This has led to a reality where top down acquisition is not achieving the needs of those on the ground.

At the same time, there are definite weaknesses of a bottom up approach to unmanned system development and acquisition. The U.S. Army has used the JUON process to acquire additional unmanned aerial systems such as the MQ-1C Sky Warrior, a variant of the U.S. Air Force's MQ-1 Predator, to be used in Iraq and Afghanistan.[62] This initial JUON acquisition has cost $152 million between 2008 and 2009.[63] Due to the accelerated acquisition of a limited number of systems, there were some limitations in capability, resulting in delivery of an incomplete system. Additional costs will be incurred as fixes are integrated into these systems to complete them. Between 2008 and 2013 $1.3 billion will be spent developing or acquiring the Sky Warrior.[64] Additionally, the U.S. Air Force's MQ-9 Reaper UAS has also been designated an

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[59] Department of Defense (DOD), *Report of the Defense Science Board Task Force on the Fulfillment of Urgent Operational Needs*, vii.

[60] Ibid., 1.

[61] Ibid., 4.

[62] Department of the Army, *Eyes of the Army: U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 46.

[63] United States Government Accountability Office and William Solis, 32.

[64] United States Government Accountability Office and Michael J. Sullivan, Defense Acquisitions Opportunities Exist to Achieve Greater Commonality and Efficiencies Among Unmanned Aircraft Systems : Report to the Subcommittee on Air and Land Forces, Committee on Armed Services, House of Representatives (Washington, D.C.: U.S. Govt. Accountability Office, 2009), 43-44.

urgent operational need since it began operational use in 2002, in the aftermath of the September 11th attacks. The Reaper is similar to the Predator and Sky Warrior but slightly larger with greater capability in terms of payload and flight time. By 2013, more than $1.6 billion will have been spent or allocated towards Reaper development and acquisition.[65] One of the emerging trends is that although some collaboration between the services is happening, much of the time each service pursues service-specific airframes, ground stations, payloads, and subsystems. The fact that each service is pursuing its own independent acquisition strategy is resulting in a massive duplication of effort, possibly resulting in the waste of resources. Additionally, the constantly changing requirements result in programs with massive cost increases as additional capabilities must be integrated into the system post-development or there are increases in the number of systems being procured.[66]

As of 2010, there have only been a limited number of requests through the JOUN process for unmanned systems, especially UGVs and unmanned systems with the ability to act autonomously. This is most likely due to commanders' lack of knowledge that the technology even exists or a lack of trust in the technology. There was a similar lack of trust with the early UAVs. As a limited number of systems gained trust with commanders, their utility was seen, trust was gained, and over time other applications emerged, such as moving from an ISR role to a lethal strike role.[67] This illustrates a key point though. There had to be a primary generator that got the initial unmanned systems into theater and facilitated their use by commanders, so that the process of utility observation, gaining trust, and the emergence of new applications could begin. Introduction of a disruptive technology needs to start somewhere, and DARPA is the current agency responsible for pushing the limits of knowledge and trust.

[65] United States Government Accountability Office and Sullivan, 36-38.

[66] Ibid., 2-4.

[67] Magnuson.

DARPA develops long term technology innovation strategies for the Department of Defense. DARPA was founded in 1958 in response to the Soviet Union's launch of Sputnik. Their purpose is to provide an ability to develop disruptive technologies outside of but along-side the individual service's acquisition goals.[68] Their mission is "to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research bridging the gap between fundamental discoveries and their military use."[69] They attempt to achieve this by sponsorship of projects so as to bring basic scientific discoveries to maturation to be used effectively for military purposes.

The DARPA Urban Challenge was held in 2007, and built on previous DARPA Grand Challenges held in 2004 and 2005. The Grand Challenge events were held in response to the mandates in the 2001 National Defense Authorization Act and showed that an autonomous vehicle was capable of navigating a 244 kilometer route through the desert. The intent of the Urban Challenge was to get teams to build a vehicle capable of autonomously navigating a 97 kilometer course in an urban environment that included interactions with other autonomous vehicles as well as with manned vehicles.[70] DARPA defined autonomy as being able to complete the designated course without a human driver and no remote control. The vehicle would only be able to use its sensors to assess its environment and follow the route it was given. This route would require the unmanned vehicle to merge, pass, and negotiate intersections with other manned and unmanned vehicles acting independently around it. Monetary prizes were offered to the team that not only finished the course in the fastest time but in the safest manner by following the rules in the California Driver Handbook. Initially, 89 teams from both industry and academia,

[68] Department of Defense (DOD), *Report of the Defense Science Board Task Force on the Fulfillment of Urgent Operational Needs*, 26.

[69] Department of Defense (DOD), "DARPA Mission," (Washington, D.C.: Dept. of Defense, Defense Advanced Research Projects Agency), http://www.darpa.mil/mission.html (accessed October 6, 2010).

[70] Martin Buhler, *The DARPA Urban Challenge Autonomous Vehicles in City Traffic* (Berlin: Springer, 2009), 2.

and many teams made up of both, submitted applications. Of these, 39 made it to the qualification phase and 11 teams competed in the final competition. Of the finalists, six team vehicles successfully completed the entire course and showed that it was possible for an autonomous vehicle to navigate safely in an urban environment.[71]

The Autonomous Robotic Manipulation (ARM) program is intended to help facilitate hardware and software development that results in a robot with the ability to perform highly complicated tasks similar to a human hand and arm with limited supervision. They are using a number of industry and academic research teams to develop hardware and software, but what is unique is another track of outreach in that an identical robotic hand will be available for any person in the public to develop software for and upload over the internet and then get immediate feedback through live video over the internet of the results.[72]

DARPA's initiatives identify a need to stimulate greater innovation by providing the incentives for organizations and businesses from multiple fields to work together in an attempt to extend the realm of the possible. Under normal market conditions, it would be highly unlikely for industry and academia to work together on a project that had such a low likelihood of resulting in a marketable product. This is natural for most disruptive technologies. There is little incentive to make the effort to develop the technology because the initial technology, even if feasible, does no better than the status quo and thus an established market with guaranteed profits does not exist. DARPA is an organization that provides incentives to industry and academia to invest in these disruptive technologies.

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[71] Department of Defense (DOD), "DARPA Urban Challenge," (Washington, D.C.: Dept. of Defense, Defense Advanced Research Projects Agency), http://www.darpa.mil/grandchallenge/index.asp (accessed October 6, 2010).

[72] United States Department of Defense, "News Release: DARPA unveils new robotics program," (Washington, D.C.: Dept. of Defense, Defense Advanced Research Projects Agency, August 19, 2010), http://www.darpa.mil/news/2010/ARMAug2010.pdf (accessed October 6, 2010).

Interestingly, the way in which DARPA uses incentives to stimulate disruptive technologies is very different from both the top down and bottom up models described above. DARPA sets the rules of the challenge, clearly defines the goal, and offers a substantial reward for the best solution measured under real world conditions. They do not specify *how* the unmanned system should operate; only what it needs to accomplish. The competitive setting in some ways mirrors biological evolution, by encouraging variation and parallel development, then selecting and positively reinforcing the winning system.

There are numerous technologies that the JUON process and DARPA are acquiring and developing. They range from advanced sensors to stealth technology to advanced lightweight body armor. If we are to show a need to treat unmanned system technology differently then we must show that it is unique in some profound way that necessitates the U.S. military to take a different approach to this technology.

Why Are Unmanned Systems Different?

In order to determine if the acquisition and technology development processes reviewed in the previous section are optimal for unmanned systems, we must look at the specifics of the nature of unmanned systems technology and potetial impacts unmanned systems could have on warfare. The difference between unmanned system technology and other technology can be divided into two distinct categories. First, the nature of unmanned systems technology is qualitatively different than other technologies. Second, the potential impact of unmanned systems technology on warfighting is far greater than other current technological innovations. These differences in the nature and impact of the technology could lead one to conclude that certain unmanned systems are disruptive in nature and could lead to new and novel ways of warfighting.

Nature of Unmanned System Technology

Unmanned systems, unlike many other technologies, require the convergence of numerous disciplines. These disciplines include sensors, mechanics, computing hardware and software, artificial intelligence, power, communication, and even biology. In the Unmanned Systems Integrated Roadmap, there are data sheets outlining 68 enabling technologies identified as necessary for the development of unmanned systems. Some seem to have broad implications and some are very narrow.[73] Many of these enabling technologies are common to all domains while some are only relevant to their specific domains. Some of the enabling technologies common to all are “power grazing, alternative energy sources enabling long mission endurance, dynamic obstacle detection, dynamic detection and avoidance, collaborative tactical teaming, etc.”[74] Other important ones are a world model that evolves from simple to artificial and then highly representative. Also there is human robot interaction that evolves from voice control to warfighter association and finally hierarchical collaborative behaviors.[75] The air domain includes specific technologies ,to enable UASs such as “lightweight, long endurance battery and/or alternative power technology, effective bandwidth management/data compression tools, stealth capability, and collaborative or teaming technologies that will allow UASs to operate in concert with each other and with manned aircraft” as well as a “robust on-board sense and avoid technology.”[76] The ground domain includes enabling technologies such as “complex world modeling, ground based hazard detection, lane detection/road following, anti-tamper/ self-protection, highly dexterous manipulation, collaborative teaming in urban environments, etc.”[77] Other critical enabling technologies in the ground domain include mechanical systems such as electro-mechanical/hydraulic systems, artificial muscle systems, and hybrid bio-mechanical systems.[78]

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[73] Department of Defense (DOD), *Unmanned Systems Integrated Roadmap 2009-2034*, 150-174.

[74] Ibid., 48.

[75] Ibid.

[76] Ibid., 48-49.

[77] Ibid., 49.

[78] Ibid., 49.

The requirement for unmanned system development to be multidisciplinary could potentially have a number of impacts on the development of this technology. Due to the considerable number of disciplines and fields that must come together to develop a suitable system, technology readiness and maturity develops nonlinearly, due to interdependencies. Much like friction in war, these interdependencies will lend themselves to produce nonlinear results.[79] For example, if there is a major advancement in one field, such as power systems, this could have a dramatic ripple effect, as this advance may allow for capabilities in another area, such as mechanics, which were previously impossible. These advances in mechanics could have impacts then on other areas as well. One must add to this the difficulty in bringing together these multiple disciplines to coordinate their work. This makes the progression of unmanned systems technology very difficult to predict over time. There may be vast lengths of stagnation as a certain discipline holds up the development of key enabling technologies, followed by breakthroughs with extremely rapid and cascading effects. As with other nonlinear systems, the interrelationship between disciplines and fields leads to unpredictable results and outcomes.[80]

The impact of nonlinearity is that it is very difficult to forecast how fast the field of unmanned system technology will progress based on its previous progression. Although the *Department of Defense's Unmanned Systems Integrated Roadmap 2009-2034* and the individual services attempt to lay out a timeline of the progressions of technology development, it is far from certain that this is the timeline the technology will follow. Add to this the previously discussed disruptive nature of this technology and there is a possibility that impacts could come faster or much slower than anticipated.

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[79] Alan Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," *International Security* 17, no. 3 (Winter 1992/93):72-77.

[80] Ibid.

Potential Impact of Unmanned Systems on Warfare

Unmanned systems have the potential to have disruptive impacts on warfare that may require a more integrated approach to their acquisition and technology development. As novel ways of combining unmanned systems technologies develop, they offer potential increases in capabilities in areas that the military may have not valued previously, due to the novel uses not supporting current tactics and operational concepts. There are many examples of potential novel ways of combining these new technologies that may lead to capabilities that may change warfare. This section explores six key areas where it can be argued that unmanned systems will have the potential to have the greatest impact on warfare. Unmanned systems could change the fundamental dynamics of the operational level of war and operational art, including tempo, depth, operational reach, and end state. The friction of war, often exacerbated by the complexities of morale and fear experienced by human protagonists, could be qualitatively changed as many decisions are transferred to non-human entities, especially at the tactical level. There are profound ethical and legal implications of having life and death decisions made by a non-human entity. The further one side can extend its stand-off from the lethality of the battlefield, the lower the potential for casualties to that side becomes. There will be impacts on the acceptability of war as a policy option as perceived by society, government, and the military. This will affect the use of military power in a dispute with other nations, particularly for a nation state with a perceived "unmanned systems edge." The message that the use of force communicates will be very different if soldiers are free from danger and if humans are out of the decision loop for lethal uses of force. Finally, stand-off from the battlefield may threaten the "warrior psyche" that is a core component of the soldier's identity and a desired characteristic of our soldiers, airmen, and sailors. In a war that is prosecuted with little contact with the enemy where force is inflicted with little threat to one's self, the very identity of the soldier may be fundamentally altered.

Potential Impact of Unmanned Systems on Operational Art

Unmanned systems have the potential to profoundly impact the dynamics of the operational level of war and its associated operational art. If we assume that the aspirations of those developing unmanned systems technology are even partly achievable, then these tactical capabilities will have a ripple effect on operational level considerations.

There are multiple definitions of the operational level and operational art. The operational level of war is where tactics and strategy overlap, where a unified commander translates strategic goals into tactical objectives and phases operations into coherent campaigns.[81] The definition most widely embraced by the U.S. military identifies the operational level as where tactical engagements are aligned with strategic military goals and objectives.[82] According to U.S. Army doctrine, the operational level "links employing tactical forces to achieving the strategic end state."[83] There is an associated art when planning and executing at the operational level called operational art. Operational art is "the application of creative imagination by commanders and staffs – supported by their skill, knowledge, and experience – to design strategies, campaigns, and major operations and organize and employ military forces."[84] Operational art also includes the integration of ends, ways, and means across levels of war.[85] However, there is much more to operational art than these definitions suggest. Because war is a human endeavor, it is this highly unpredictable and complex human dimension that links these conditions. Also, operational art is meant to transform into a holistic system what would otherwise be disconnected individual

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[81] Steven Metz, *Armed Conflict in the 21st Century: The Information Revolution and Post-Modern Warfare* (Carlisle, PA: Strategic Studies Institute, U.S. Army War College, 2000), 51.

[82] Department of Defense (DOD), Joint Publication (JP) 3-0, *Joint Operations*, (Washington, D.C.: Government Printing Office, 13 February 2008), II-2.

[83] Department of the Army, FM 3-0, *Operations*, (Washington, D.C.: Government Printing Office, 27 February 2008), 6-3.

[84] Department of Defense (DOD), Joint Publication (JP) 3-0, *Joint Operations*, IV-3.

[85] Ibid.

tactical engagements, battles, and tasks, in order to focus this system in the most advantageous way against the enemy's system of opposition. Otherwise war would be incoherent "with relative attrition the only measure of success."[86] In the application of operational art, commanders consider factors such as the end state, operational reach, tempo, simultaneity and depth, phasing and transitions, and risk, among others. They use these elements in the design of operations when they frame the problem, formulate the design, and continually refine their design.[87] The greatest probability for the impact of unmanned systems on operational art lies within fundamental changes to the dynamics of and relationships between operational reach, tempo, sequencing operations, and aligning strategic end state and objectives.

One area where unmanned systems could change the dynamics of operational art is the extension of the operational reach of the commander. The U.S. military defines operational reach as the "distance and duration across over which a joint force can successfully employ military capabilities."[88] One can analyze this as both a temporal and a spatial issue. From the factor of space it allows the commander to extend his reach into what would otherwise be sanctuaries for the enemy.[89] Unmanned systems give a commander the ability to extend his reach into environments too dangerous for a soldier or pilot, such as a deep ground maneuver or flying into airspace covered by an integrated air defense system. They also allow a commander to extend his operational reach into an area too politically sensitive for a presence of U.S. military personnel on the ground or in the air. The ability of unmanned systems to operate independent of human endurance gives a commander the ability to extend his reach over a much greater time-frame than previously possible. Points, areas, and even individuals on a battlefield can be monitored over a

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[86] Department of the Army, FM 3-0, *Operations*, 6-4.

[87] Ibid., 6-6 thru 6-7.

[88] Department of Defense (DOD), Joint Publication (JP) 3-0, *Joint Operations*, IV-14.

[89] Rand D. LeBouvier, "Extending Operational Reach With Unmanned Systems," (Ft. Belvoir: Defense Technical Information Center, 2003), 8.

much longer time frame and thus extend a commander's reach over a particular target for a longer period of time.[90]

There have been arguments made that the operational level of war may disappear entirely as the increased tempo makes phasing and sequencing of tactical tasks irrelevant. The U.S. military defines tempo as the "rate of military action" and "controlling or altering that rate is necessary to retain the initiative."[91] The tempo of some operations could speed up to the point that the decisive victory is achieved in a matter of days, hours, or potentially minutes. This could lead to phasing of operations losing relevance.[92] At the same time, simultaneity and depth could take on much greater relevance. This increase in tempo could be gained by linking manned and unmanned sensors to advanced data processing systems, and then using artificial intelligence technology to filter and prioritize the most relevant data. The unmanned systems would provide recommendations for the commander to act on. These recommendations could even be changed directly to actions by the unmanned system to speed up the tempo even further.[93] A commander who delegates decisions for the use of lethal force to an unmanned system would have a distinct advantage in the tempo of their decision cycle over a commander who retains the human as the limiting factor in the decision cycle. In some situations, certainly in tactical engagements, this advantage could be decisive. This advantage could also lead to a disadvantage if the unmanned system makes the wrong decision to use lethal force in a tactical engagement because of a failure to take the context of the situation into account. This is known as the frame problem to those that conduct artificial intelligence research, and has been investigated by philosophers as a larger issue within epistemology. The frame problem can be stated as: how does one represent the effects of

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[90] Ibid., 9.

[91] Department of Defense (DOD), Joint Publication (JP) 3-0, *Joint Operations,* IV-16.

[92] Metz, 51.

[93] Thomas K. Adams, "The Future of Warfare and the Decline in Human Decision Making," *Parameters 31, no. 4* (Winter 2001-02): 64-65.

one's actions when there are certain unspoken effects that are too numerous to specifically list out?[94] If the frame problem remains unsolvable for artificial intelligence, then it may not be possible ever completely remove the human from the loop.

Since some decisions will almost certainly be made by humans, the enemy will do everything possible to attack the nodes and the communications links between human decision makers and unmanned systems. Therefore, it is important to keep these linkages as short and streamlined as possible so they remain defensible. This may mean having decision makers in the same theater of war. The same consideration may have to be made for the operators of remotely piloted and semi-autonomous unmanned systems. For instance, we currently have the freedom to remotely operate aircraft from the continental U.S. flying over Central Asia. We can only do this because the enemy does not have the capability to threaten the communications linkages between the operator and the unmanned aerial system. Against enemies that are more capable, we may have to move the operators closer to the UAS. This could possibly mean putting these operators just outside the high threat environment, or even in a manned vehicle just on the boundary of the high threat environment. Decisions such as these will become a part of the operational art.

Some have also argued that with the advent of unmanned systems, the end state and conditions of the operation may be unachievable merely by the use of unmanned systems. This could be most strongly argued in regards to counterinsurgency operations, where the perceptions and support of the host nation populations are of supreme importance and legitimacy can be decisive.[95] The use of unmanned systems to achieve tactical objectives could in and of itself jeopardize the achievement of the operational objectives because of the population's potentially negative perceptions of unmanned systems. Though their use may provide lower tactical risk to

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[94] Stanford University, "The Frame Problem," Stanford Encyclopedia of Philosophy, http://plato.stanford.edu/entries/frame-problem/ (accessed October 6, 2010).

[95] Department of the Army, FM 3-24, *Counterinsurgency Operations,* (Washington, D.C.: Government Printing Office, December 2006), 1-20 thru 1-21.

the operational commander's forces, lower casualties, and greater efficiency and flexibility, their use or presence in the host nation could lead to failure at the operational level if they damage the force's legitimacy or erode the trust of the population. A commander would need to make a conscious decision during his campaign design process, based on how the population may interpret the use of unmanned systems, prior to using them to foster the conditions leading to the desired military end state.[96]

In summary, from an operational art perspective, future commanders can be expected to need to incorporate into their planning process decisions on what operations to use unmanned systems over manned systems, given their ability to extend his operational reach over both time and space. At the same time commanders will have to decide what decisions are best made by unmanned systems, or an automated artificial intelligence, as opposed to himself or a human subordinate. This will put the commander at a distinct advantage or disadvantage, depending on the enemy's own use of unmanned systems. Additionally, the commander needs to consider where to locate the human decision makers in relation to the battlefield and in relation to the unmanned systems, balancing risk and effectiveness. Considerations for synchronization and depth as well as relative tempo for the operation would need to be taken into account in making those decisions. Lastly, the commander will need to decide if the mere use of unmanned systems helps or hinders the setting of conditions necessary to achieve the end state.

Friction

Friction in war has typically been associated with war's human element. The U.S. Army considers friction, along with uncertainty and chance, to have always characterized warfare and is certain to continue to be a part of our operating environment.[97] Friction in war is a concept

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[96] Samuel N. Deputy, "Counterinsurgency and Robots: Will the Means Undermine the Ends?," (Ft. Belvoir: Defense Technical Information Center, 2009), 11-18.

[97] Department of the Army, FM 3-0, *Operations*, 1-17 thru 1-18.

originally advanced by Carl von Clausewitz. “Everything in war is very simple, but the simplest thing is very difficult. The difficulties accumulate and end by producing a kind of friction.”[98] Additionally he adds that friction “cannot, as in mechanics, be reduced to a few points, is everywhere in contact with chance, and brings about effects that cannot be measured.”[99] Watts analyzed all references to friction by Clausewitz to identify eight factors that make up Clausewitzian friction: danger, physical exertion, inadequate information, human interactions within friendly forces, unforeseen events, political and physical limitations of force, a thinking and competitive enemy, and the nonalignment of means to the ends.[100] This concept has been given additional precision as it applies to modern warfare and has been shown to have roots in mathematical theories such as chaos and nonlinearity.[101] These modern theories show that although Clausewitz did not have the scientific terminology to articulate what he observed, he nevertheless clearly identified nonlinearity in a complex system. This nonlinearity, stemming from the interplay of the eight factors of friction, results in what seem like relatively insignificant changes having substantial impact on outcomes, and conversely, large changes having relatively insignificant impact on outcomes.[102]

There have been arguments that friction can be eliminated in modern conventional war through the implementation of initiatives to bring clarity to the battlefield by streamlining communication and command and control processes with better application of information technology.[103] Another initiative to link units and individuals on the battlefield to share

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[98] Carl von Clausewitz, *On War* (Princeton, N.J.: Princeton University Press, 1989), 119.

[99] Ibid., 120.

[100] Barry D. Watts, *Clausewitzian Friction and Future War* (Washington, D.C.: Institute for National Strategic Studies, National Defense University, 1996), 32.

[101] The linkage of these theories is outlined in Watts, 105-107 and Alan Beyerchen, “Clausewitz, Nonlinearity, and the Unpredictability of War,” *International Security* 17, no. 3 (Winter 1992/93): 87-88.

[102] Watts, 120-121.

[103] This is the general argument throughout William A. Owens and Edward Offley, *Lifting the Fog of War* (Baltimore, MD: Johns Hopkins University Press, 2001).

information is meant to significantly reduce friction[104] and to significantly improve military forces' abilities to synchronize their efforts through reducing the likelihood of surprise and gained efficiencies.[105] The U.S. military's stance on friction on a networked battlefield is much more conservative and seeks to "exploit information advantage in the context of fog and friction of war"[106] versus eliminating fog and friction. Some have argued that unmanned systems could also drastically reduce friction in warfare by taking the human being out of the equation. Unmanned systems would no longer be affected by human tendencies that lead to friction such as laziness, fear, forgetfulness, stress, tiredness, and misunderstanding. Commanders would no longer have to put effort towards motivating their soldiers; they could concentrate solely on getting the other factors of the military operation right.[107]

This only accounts for the human factors of friction and does not appreciate the factors of friction that includes the unforeseen, political and physical limitations of force, the thinking, competitive enemy, or aligning means with ends. It seems that these remaining elements of friction would be more than enough. However, taking out the human and replacing it with a non-human entity making decisions really just moves the friction from the human into the machine. This does not eliminate it, but it does lead to qualitative changes to friction. Instead of laziness and fear, an unmanned system is limited by its current programming, unable to adapt to an unanticipated situation; instead of forgetfulness and misunderstanding an unmanned system can only follow orders to the letter with no ability to use initiative within the commander's intent.

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[104] David S. Alberts, John J. Garstka, and Frederick P. Stein, *Network Centric Warfare: Developing and Leveraging Information Superiority* (Ft. Belvoir: Defense Technical Information Center, 2000), 72.

[105] David S. Alberts, John J. Garstka, Richard E. Hayes, and David A. Signori, *Understanding Information Age Warfare* (Ft. Belvoir: Defense Technical Information Center, 2001), 37-39.

[106] Department of Defense (DOD), *The Implementation of Network-Centric Warfare* (Washington, D.C.: Dept. of Defense, Office of Force Transformation, 2005), 16.

[107] Cowan, 7.

As unmanned systems become more advanced, there is also the problem that they must incorporate increasingly complex systems of communications, sensors, computer hardware, and software code. How complex computer code will react all the time in all environments is impossible to predict. The variables of these interactions are numerous and interdependent, and so it takes on a nonlinear, non-predictable nature, very much like Clausewitzian friction.[108] This environment is made even more complex when the enemy actively works to make it as complex as possible by employing electronic warfare attack to interfere with communications and infect unmanned systems software with viruses; imitate visual cues to confuse sensors; and use kinetic attack to damage hardware. The only possible prediction is that the impact of unmanned systems on friction will be unpredictable.

Legal and Ethical

The legal and ethical implications of soldiers remotely using lethal force or unmanned systems autonomously making lethal decisions have the potential to put great limitations on or provide opportunities for the development and use of unmanned systems. These legal and ethical implications may even be too complex to be fully understood until after the first war crime is committed by an autonomous unmanned system.

There are three levels of concern with the ethical dimensions of unmanned systems. The first is when a soldier or pilot remotely operates an unmanned system from a location off the battlefield and out of harm's way. There have been concerns raised that these soldiers and pilots would be more prone to use lethal force. The argument runs along the following lines. There is their distance emotionally from the enemy making them less able to empathize with the enemy. Additionally they would have less situational awareness of the battlefield so would not see the

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[108] Jesse Hilliker, "Should We Turn the Robots Loose?," (Research project, Naval War College, 2010), 10.

impact of their actions. These new battlefield realities increase the death and destruction on the battlefield especially for civilians caught in between.[109]

However, the reality emerging regarding unmanned aerial systems does not support this line of reasoning. Free from threat of violence upon themselves, pilots are more likely to use caution and limit their use of violence.[110] The sophistication of sensors and loitering ability of remotely operated unmanned systems allows for the impacts of their actions to be very clear to operators. The fact that the operator's actions are recorded permanently also injects a level of caution and concern for always doing the right thing. There is a real possibility that this trend may not continue. As more advanced unmanned systems are developed, humans may play less of a direct role in their operation. Semi-autonomous and autonomous unmanned systems may only have targets selected by a human operator. This adds significantly more emotional distance between the human and their lethal actions. Also it allows the human to diffuse their responsibility, and mentally reconcile their actions by making the unmanned system responsible for the lethal action.[111]

There is another concern in that not only do we have a duty as a military profession and as a society to limit violence on the enemy and civilians, we also have the duty to limit the violence our own soldiers and pilots and sailors confront waging war on our behalf. Because of unmanned systems ability to limit casualties, it would be unethical not to pursue their use as much as possible. This is very similar to the fast tracking of programs such as mine resistant

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[109] Edward Barrett, "Rise of the Drones: Unmanned Systems and the Future of War," (written testimony, U.S. House of Representatives Committee on Oversight and Government Reform, Washington, D.C., March 23, 2010), 2, http://oversight.house.gov/images/stories/subcommittees/NS_Subcommittee/3.23.10_Drones/Barrett.pdf (accessed October 6, 2010).

[110] Ibid.

[111] Krishnan, 129-130.

armored program to protect our soldiers from improvised explosive devices in Iraq and Afghanistan.[112]

Third, there is also the potential for the escalation of violence onto the civilian population. There is the possibility of two countries going to war each with unmanned systems operated from command and control centers deep in their own territory with communications links that cannot be disrupted. If one side calculated it could not win through attrition or could not win fast enough by only targeting the other side's unmanned systems, they may resort to attacks on the other side's civilian population in a play to raise costs to the enemy to such an extreme. This could then result in what was conceived as a bloodless war escalating into direct targeting of civilians by unmanned systems. The carnage could be unprecedented and hardly preferable to the status quo. Although this debate on the ethical status of remotely operated unmanned systems is not over, there is another more contentious debate regarding accountability for the use of lethal force by autonomous unmanned systems.

The ethical implications of the use of force by autonomous unmanned systems have been debated by many with various conclusions. Under the law of war someone would have to be held accountable if a war crime were to be committed. Three possible entities could be held accountable if an autonomous unmanned system committed a war crime: the manufacturer who built the system, the commanding officer who ordered its employment, or possibly with the machine itself.[113] There are issues with holding each of these responsible. The manufacturer could not possibly be held responsible against a claim that its system would never act in error. The very nature of the system being autonomous would mean the engineers had to build it in such a way that there was some flexibility in its programming. When looking at the commander, he can order its employment, but the unmanned system itself makes the decision for the use of lethal

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[112] Barrett, 1.

[113] Robert Sparrow, "Killer Robots," *Journal of Applied Philosophy* 24, no. 1(2007): 69-71.

force. Again, because the system has the autonomy to make this decision itself, the commander could not be held responsible for the independent actions of his robotic subordinate (unless the order itself was illegal). Then it comes down to the unmanned system itself. Is it possible to punish something unable to feel pain or care about its own existence? Robots clearly cannot. This is one of the characteristics that make autonomous unmanned systems advantageous – they do not feel pain or fear for their own existence – so thus they are ideally suited for war. If no one can be held accountable for the war crime, then its use would be unethical.[114] The legal implications are less clear though.

There are countervailing arguments that attempt to show that it is not only possible for the use of unmanned systems to be legal, but more legal than humans making these decisions. Some have noted that for an autonomous unmanned system to legally employ lethal force it does not have to be perfect in its decisions to follow the law of war, it only has to be better than a human would be at making the equivalent decision. Advancements in the technology for sensors and artificial intelligence could lead to the fidelity in decision making for an unmanned system to be able to analyze a battlefield situation and make the right choice according to the law of war. If an unmanned system has the ability to refuse an unlawful order, the ability to record unlawful behavior and then report it up the chain of command, and the ability to follow the protocols of the Laws of War such as the Geneva Convention, Rules of Engagement, and Codes of Conduct then an unmanned system could do a better job than a human at executing its tasks in a lawful manner.[115] Each of these capabilities is a technical problem that we likely will be able to achieve in the near term future as sensor technology gains fidelity and software algorithms are developed to be sophisticated enough to simulate value judgments through devices such as an ethical

[114] Ibid., 69-75.

[115] McDaniel, 78.

governor.[116] However, there is also the aforementioned frame problem, where an artificial intelligence would need to be able to put a situation in context in order for it to make an effective assessment of its decisions, so there is an assumption this can also be overcome. Since an unmanned system makes decisions free of fear, anger, and vengeance, the unmanned system could drastically reduce war crime activity on the battlefield, which "could result in a fighting force more humane than an all human one."[117] Even if an unmanned system advances to a point that it can do a better job than a human soldier at making legal choices, it may not necessarily make it a better option in the eyes of our military leaders or society though. Unmanned systems that obey the letter of the law but lack compassion could dehumanize the face of the U.S. military, which may undermine the political objectives of military intervention.

Regardless of how advanced the unmanned system has become, the fact that it is able to act autonomously injects a level of uncertainty into its behavior. Just like a human, if given the ability to make a decision on its own, it will sometimes make an unpredictable decision. We attempt to deter through coercion, egregious decisions outside the norm such as war crimes and criminal behavior; or we discount the action as an accident alleviating anyone of responsibility. Because of the ability to coerce and punish, we are able to accept the risk of this behavioral uncertainty with a human soldier or pilot.[118] Neither coercion nor punishment is possible with an unmanned system, although it would likely be possible to disseminate software patches quickly once problems were identified. Again, it is the very things that make unmanned systems appealing that also make them problematic. It is unknown if military commanders or society will be able to overcome this paradox and accept the risk of this uncertainty with an unmanned system. Also, calling a catastrophic action of an unmanned system under any circumstances an

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[116] Ronald C. Arkin, *Governing Lethal Behavior in Autonomous Robots* (Boca Raton: CRC Press, 2009), 125.

[117] Ibid., 44.

[118] Krishnan, 144.

"accident" may not be acceptable to military leaders or society like it would with a person. Like other ethical considerations regarding warfare, our societal perceptions may shift over time, but this also implies we could become less accepting of lethal decisions made by autonomous unmanned systems. In the future we may determine that even though an unmanned system is better at making the right choice of when to use lethal force on the battlefield, the occasional mistake is still a risk that is unacceptable if we are unable to hold a human being accountable for this mistake.

Strategic Communication

The use of unmanned systems could speak to the world in unintended ways. This could have huge impacts from a strategic communications side of perceptions of our national will and even our nation's value of non-American human life. It may be perceived that we are willing to "down grade" the decision to take the life of a non-American life, whether it be a soldier, criminal, or civilian, to a non-human entity in an effort to protect our own soldiers. The blow back from such a perception could generate second and third order effects that could make the use of unmanned systems counterproductive. This is an area that has had little if any thought or research put into it and is a concern of some of our senior military commanders.[119] In some regions there is already a backlash against the use of unmanned systems. In Pakistan, U.S. use of unmanned aerial systems has led to popular pop songs denigrating American honor as a country in the way we fight.[120] There are conceivable scenarios in which the enemy uses unmanned systems, specifically the autonomous variant, against us by staging an engagement that confuses

[119] During remarks made at the Warring Futures Conference held by the New American Foundation in Washington D.C. on 24 May, 2010 Major General Robert E. Schmidle Jr., USMC raised the concern that we need to understand how other cultures will interpret our use of unmanned systems and the message it will send to them. He also emphasized the human element and the impact of unmanned systems use on the enemy's will to fight. http://www.newamerica.net/events/2010/warring_futures (accessed November 1, 2010).

[120] Singer, 311.

or forces the unmanned system to make an inappropriate decision to use lethal force. The enemy could use civilians as human shields or force civilians into the line of fire.[121] A video of an autonomous unmanned system killing a civilian would have effects on host nation, international, and U.S. perceptions that we need to understand if we are to effectively prepare for and counter them. It is possible we could cause drastically more harm to the achievement of our strategic objectives from the use of unmanned systems intended to achieve tactical advantage by limiting our own casualties. An all too likely perception could become that the U.S. is the “Evil Empire” and anyone taking on our “robot armies” are the “Rebel Alliance,” regardless of the nobleness of our cause or intentions.[122] As we use unmanned systems more to fight a “bloodless war” we may incite even greater terrorism against us as the enemy attacks a perceived weakness, our fear of death. This could very likely then lead to increased terror tactics in the U.S. on civilians.[123] Just as during the Cold War, nuclear weapons forced wars between the two super powers to be waged by proxy in the third world, the proliferation of unmanned systems will likely have unforeseen consequences. We also need to think of the perceptions among those who would go to war with the U.S. as allies in a coalition.

The National Security Strategy lists collective action as a key element of combating violent extremism, nuclear proliferation, and armed conflict. This collective action will find its cornerstone in allies that share common interests and values.[124] What are we communicating to Allies by not risking the lives of our own soldiers and pilots? They may not be willing to risk their soldier’s lives and take disproportionate casualties by deploying them to a combat zone

[121] David P. Bigelow, "Fast forward to the robot dilemma," *Armed Forces Journal* 145, no. 4 (November 2007): 18-19.

[122] Singer, 309-310.

[123] Ibid., 312-313.

[124] United States, *National Security Strategy* (Washington: White House, 2010), 3.

alongside our unmanned systems.[125] Some allies see our use of unmanned systems as being casualty averse. We are only willing to live up to our commitments to our allies if there is a technical solution that allows us to limit boots on the ground.[126] If our allies perceive us to be unwilling to commit or share in the sacrifice, it does not leave a very strong foundation to build upon for collective action. Allies and coalitions are built on shared sacrifice, both in blood and treasure. If we do not show a willingness to sacrifice blood our alliance may be seen as unreliable or unbalanced. No one wants to be the cannon fodder for someone else's national interests.

Warrior Psyche

There is a potential for impact on the warriors themselves. We are entering a time when our warriors no longer need to go to war but can remotely pilot their craft from a continent away. Many have seen that an essential element of a morally acceptable war is that the soldiers on each side share an equal risk of harm, or in other words endure a shared sacrifice. With no sacrifice, then it becomes akin to an immoral massacre. Autonomous unmanned systems making independent decisions would render the idea of warrior sacrifice obsolete.[127]

Others have postulated that if the tactical engagements are executed by unmanned systems, then we no longer need the same attributes among our soldiers or military leaders. Currently, young physically fit men fill the role of our soldiers. As we move more and more of these roles to unmanned systems we may want to change the attributes of this new breed of soldier. An attribute such as technical knowledge may displace physical fitness. Youth may become less important as a selection criteria.[128]

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[125] Metz, 50.

[126] Singer, 311.

[127] Christopher Coker, *The Future of War: The Re-Enchantment of War in the Twenty-First Century* (Blackwell manifestos. Malden, MA: Blackwell Pub, 2004), 130-133.

[128] Steven M. Shaker and Alan R. Wise, *War Without Men: Robots on the Future Battlefield* (McLean: Pergamon-Brassey's International Defense Publishers, 1988), 1-3.

Both of these arguments are based on assumptions that may not turn out to be true. The slow fading of the concept of sacrifice may not hold up. We have seen that unmanned systems will always be limited and commanders will likely need to decide what decisions are important enough to keep in the human realm and which are not. As long as humans are making the key decisions, this is a critical node that the enemy will target and attempt to destroy, since it would more directly threaten the will to fight. The humans making these decisions will thus shoulder a substantial level of sacrifice during warfare. The attributes for the ideal soldier in a future war employing autonomous unmanned systems may not be as cut and dry either. The farther operators and key decision makers are from the battlefield and the unmanned systems, the more complicated the communications linkages become, and the easier it becomes for the enemy to disrupt, corrupt or sever them. Fighting our wars with technicians at computer terminals in fixed continental U.S. bases could put us at a distinct disadvantage. Operationally, it may be more effective to keep our soldiers out of direct contact with the enemy, but not so far removed from the battlefield that we give the enemy a vulnerable communications link to target. This will likely mean a technically competent force is required, but one also with the physical rigor to operate in austere environments. Assuming that invulnerable communications links cannot be guaranteed in future conflicts, unmanned systems operators will still require the bravery and fortitude to make decisions while under threat to their own safety.

Clausewitz's Trinity

As society becomes comfortable with non-human entities making life and death decisions, there is the potential for the public, the government, and even the military itself to become more detached from the use of lethal force to obtain policy goals. Clausewitz's trinity describes this complex interplay. The three forces that either constrain war or empower it are the passion; chance, probability, and the creative spirit; and rationality. These three areas of passion, chance, and rationality are typically associated with the passion of the people, the uncertainty and genius of the military mind, and the rationality of the political aims of government or a society's leaders. Passion, chance, and rationality are the aspects that are always present, regardless of the presence of a coherent people, well-defined military, or legitimate government.[129] Each of these three forces holds war "in balance" like an "object suspended between three magnets."[130] As a pendulum suspended between magnets, "once set swinging among three centers of attraction, behaves in a nonlinear manner – it never establishes a repeating pattern" and as such "is never determined by one force alone but by the interaction among them, which is forever and unavoidably shifting."[131] Each of these three areas could be altered by unmanned systems either to increase or decrease the likelihood of war, as well as the dynamics in war. The reduction in the potential for casualties may reduce the people's passion for war. A reduction, increase, or change, in friction, could make the military a more or less likely advocate for war. If friction is reduced in a force dominant in unmanned systems, then uncertainty is reduced and it becomes easier to predict a winner. The side with unmanned systems would favor war. If it is increased then the opposite is true. Most alarmingly, if the friction changes and the military do not understand this change, they would be basing their level of advocacy on miscalculations of the certainty of outcomes. The government may also be more inclined to go to war if the costs in blood and treasure are reduced for their relative political gain.[132] A change in any aspect of this trinity would throw the balance off, if not countered by an equal change in one of the other aspects of the trinity. A change in all of the aspects of the trinity would have very unstable and unpredictable results.

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[129] Edward J. Villacres and Christopher Bassford, "Reclaiming the Clausewitzian Trinity," *Parameters* 25, no. 3 (Autumn 1995): 13.

[130] Clausewitz, 89.

[131] Villacres, 14.

[132] Cowan, 6-8.

The likelihood of the trinity being thrown out of balance is certainly debatable. Previously, we have discussed the fact that friction will not be eliminated with the introduction of unmanned systems, and likely will not decline, but merely change in a qualitative nature. The elimination of human casualties is also a shortsighted view, as has been discussed in the risk associated with the placement of the human decision makers on the battlefield. Any thinking and competitive enemy will work to attack the human decision makers in our system, as this will be a critical node. Additionally, our use of unmanned systems may incite increased terror attacks within the continental U.S., off-setting any reduction of military casualties. This use of terrorism as an asymmetric response to the use of unmanned systems would likely enflame the passions of the people, but could also coerce the people into capitulation as a causal link is established in people's minds between the terrorist acts and the use of unmanned systems.

There is also uncertainty with the government as to whether the use of unmanned systems will reduce or increase the costs of waging war to achieve political objectives. Some have advocated that unmanned systems could lower the costs associated with war. This could result in countries engaging in more wars, as changes in pre-war cost/benefit analysis reduce the incentives for countries to pursue non-violent alternatives.[133] There is also the possibility that unmanned systems could raise the costs of war, in the sense of treasure. Though it is hard to put a price tag on a human life, a cynic would say it is rather cheap, whereas there is a specific and direct monetary cost to the state with the loss of an unmanned system. The more capable the unmanned system, the more expensive it will theoretically be. Also, as has been previously discussed, a greater tempo is likely to be seen in a war with unmanned systems. This leads to the potential that entire armies, air forces, and navies of unmanned systems could be lost in a matter of days. There is also the possibility a non-state actor such as a security-contractor could use "these less visible weapons" in a way "that could facilitate the circumvention of legitimate

[133] Barrett, 2.

authority and pursuit of unjust causes."[134] It is possible that a non-state actor with adequate resources in money, technical know-how, and a handful of competent operators could effectively use unmanned systems against a country to obtain political objectives, especially a country with limited technical capabilities.[135] One of the primary restraints on non-state actors has always been their lack of ability to mobilize manpower. As unmanned systems become more automated and less manpower intensive these new weapons could change the balance of power between non-state actors and the nation state, having a profound impact on the Clausewitzian trinity.

How unmanned systems will affect Clausewitz's trinity overall is very difficult to predict. There are many variables involved that relate to each other in various degrees, resulting in unpredictable outcomes. For every change in one aspect of the trinity there could be a corresponding offsetting change in another aspect. We would be foolish though to dismiss the potential for unmanned systems to have revolutionary changes in the balance of the Clausewitzian trinity.

Summary

There are numerous trends with unmanned systems that have emerged during this study. There is a need for top down acquisition to provide capabilities that support national security requirements, goals and objectives achieved militarily though broad concepts. Military concepts then drive capabilities filled through DOTMILPF, with some materiel solutions being best achieved through unmanned systems. Sometimes our concepts may not keep up with the reality of the security environment so there is also the need for bottom up requests to fill unforeseen capability gaps. An organization must be looking at its development outside the normal acquisition system because unmanned system technology is multidisciplinary and some unmanned systems are potentially a disruptive technology. Unmanned systems could be

[134] Ibid.

[135] Cowan, 8.

disruptive because they provide lower performance in the short-term, by potentially being cheaper, simpler, and more convenient than manned options. As novel ways of combining the new technologies develop, they offer potential increases in capabilities in areas that the military may have not valued previously, due to the novel uses not supporting current tactics and operational concepts. As some in the military begin to see the value of these new capabilities they also change the existing concepts as they displace sustaining technologies and as the technology develops and exceeds the capabilities of the former technology. There are many examples of potential novel ways of combining these new technologies that may lead to capabilities that may change warfare. They may have an increasing impact on operational art and friction. Operational reach, tempo, sequencing, and matching ends and means may be profoundly affected. The qualitative nature of friction could also change as more decisions move to non-human entities in order to support the high tempo decisions that will have to be made in future engagements. Additionally, many of the ways unmanned systems are different are due to value judgments. There are other strategic considerations in how their use is interpreted by a global audience, what type of characteristics we will need in our future soldiers, airmen, and sailors, and how they will affect the overall likelihood of war or peace. Any changes in how we are developing unmanned system technology should improve our current systems of JCIDS, JUON, and DARPA in order to better integrate and coordinate their efforts, mitigate the risks of wasting resources, missing opportunities of new unmanned system enabled concepts and capabilities, and help civilian and military leadership to make the value judgments associated with the application of force using unmanned systems.

Recommendations

There is the need to take four steps in order to mitigate risk and take full advantage of the potential of unmanned systems. First is the need to establish a strategic vision for unmanned systems. Next, we must continue to pursue and fund distributed development initiatives like those currently undertaken by organizations like DARPA. Then we need to ensure we continue to fund research into long duration unmanned systems technologies that general industry does not have the market incentives to develop on their own in order to ensure these niche technologies have the ability to be developed. Last, we need to establish programs that foster a continuous constructive dialogue between academia, general industry, defense industry, defense scientists, and defense planners so that a synthesis of ideas can develop.

There is a need for a strategic vision for unmanned systems at the Department of Defense level that would coordinate the efforts of the three distinct processes and integrating the outputs of each of these processes into a coherent whole. A strategy for unmanned systems technology development and acquisition must be spelled out in the National Defense Strategy and the National Military Strategy. These documents would help set priorities for resources, set parameters for concept development, and provide a platform for a public discourse on topics involving value judgments. Additionally, the national level strategy documents must address legal issues surrounding unmanned systems both internal to the U.S. and in international law. These national level documents would then direct, integrate, and focus the development of a long range Unmanned Systems Strategy to merge concept development, technology development, and acquisition of unmanned systems across the defense industry, all services, as well as DARPA. This would be much more authoritative than the current Unmanned Systems Roadmaps created by the Department of Defense. This would then be the document that directs and focuses the development of a strategy and concept for each domain by their respective services. Additionally, further analysis may identify the need for a service or combatant command to draft a strategy and concept for unmanned system decision making and artificial intelligence.

Second, we need to continue initiatives that provide the incentives for organizations such as academia, general industry, and the defense industry to work together on distributed development of unmanned systems technology. Initiatives such as DARPA’s successful Urban Challenge should be used as a model to continue to drive unmanned systems technology. These initiatives that set a goal, provide a competitive atmosphere for a monetary and prestigious incentive, in a real world environment seem to enable the greatest amount of creativity and innovation. By forming groups that without incentive do not have the motivation to work together, we gain a greater synthesis of ideas to allow for unmanned systems technology to develop a niche and show its potential, or lack thereof possibly in some areas. These initiatives offer the greatest return for the relatively low cost of organizing the competition and providing a monetary prize.

Third, we need to continue to fund the long-term development of technologies in unmanned systems so that these technologies can potentially gain a foothold or niche in the market and show their potential value. This includes both the development and the testing of the technologies by soldiers in realistic environments during exercises and combat deployments so that they can identify novel, unforeseen uses of the new technology. A robust development and experimentation regimen that gets the new unmanned systems into the hands of soldiers, airmen, and sailors would allow them to make potential novel linkages and identify new tactical and operational methods.

Last, we must establish the environment that allows for the building of relationships between academia and scientists, general industry, defense industry, defense scientists, and defense planners. Some of this could be cultivated through initiatives such as Urban Challenge and conventions, seminars, workshops, and government/industry/academia working groups. Other ideas could be to increase the number of mid-level officers who go to engineering programs in robotics, artificial intelligence, and other unmanned systems related disciplines or shorter-term programs that allow former defense planners to temporarily work in academic, general industry, or defense industry and then go back to their defense planner job. This would help the officers gain an appreciation for the state of unmanned systems technology development and influence development in useful ways.

Areas for Further Research

There are numerous areas that require further research based on the elements laid out. Some areas that could use more rigorous study and analysis include the impact of unmanned systems on operational art, or possibly the limited impact it may have. Very little has been written on this subject. Another area is changes in the qualitative nature of friction associated with unmanned systems. Gaining a greater appreciation for how friction may change qualitatively as more decisions begin to be made by autonomous unmanned systems may have a great utility. It may not be so much what is gained, but what is lost, as commanders no longer can rely on traditional leadership skills to motivate and inspire in times of adversity. Then there is the potential impact on the world with public perceptions of our use of lethal force. International and domestic public perceptions may make the adoption of unmanned systems, especially those with autonomous capabilities, infeasible. We need to gain a greater understanding of how our use of lethal force by autonomous unmanned systems will be received by different cultures we will come into conflict with in the future as well as the effects on our own culture. This greater understanding would be of great utility in development of the Department of Defense's strategic vision for unmanned systems. This short list of areas for further research is certainly not exhaustive, but only the areas that show the greatest need for analysis and gaining a greater understanding.

BIBLIOGRAPHY

Adams, Thomas K. "The Future of Warfare and the Decline in Human Decision Making." *Parameters* 31, no. 4 (Winter 2001-02): 57-71.

Alberts, David S, John J Garstka, and Frederick P Stein. *Network Centric Warfare: Developing and Leveraging Information Superiority*. Ft. Belvoir: Defense Technical Information Center, 2000.

Alberts, David S, John J Garstka, Richard E Hayes, and David A Signori. *Understanding Information Age Warfare*. Ft. Belvoir: Defense Technical Information Center, 2001.

Arkin, Ronald C. *Governing Lethal Behavior in Autonomous Robots.* Boca Raton: CRC Press, 2009.

Barrett, Edward. “Rise of the Drones: Unmanned Systems and the Future of War.” written testimony, U.S. House of Representatives Committee on Oversight and Government Reform, Washington, D.C., March 23, 2010. http://oversight.house.gov/images/stories/subcommittees/NS_Subcommittee/3.23.10_Drones/Barrett.pdf (accessed October 6, 2010)

Beidel, Eric. “Uncertainty, Challenges Mark Future For Military’s Unpiloted Aircraft.” National Defense Magazine. October 2010. http://www.nationaldefensemagazine.org/archive/2010/October/Pages/Uncertainty,ChallengesMarkFutureForMilitary’sUnpilotedAircraft.aspx (accessed October 6 2010).

Beyerchen, Alan. “Clausewitz, Nonlinearity, and the Unpredictability of War.” *International Security* 17, no. 3 (Winter 1992/93): 59-90.

Bigelow, David P. “Fast forward to the robot dilemma.” *Armed Forces Journal* 145, no. 4 (November 2007): 18-22.

Buhler, Martin. *The DARPA Urban Challenge Autonomous Vehicles in City Traffic.* Berlin: Springer, 2009.

Chadwick, Stephen Howard. *Defense Acquisition Overview, Issues, and Options for Congress*. Washington, D.C.: Congressional Research Service, Library of Congress, 2007.

Christensen, Clayton M. *The Innovator's Dilemma: The Revolutionary National Bestseller That Changed the Way We Do Business.* New York: HarperBusiness, 2000.

Clausewitz, Carl von. *On War.* Princeton, N.J.: Princeton University Press, 1989.

Coker, Christopher. *The Future of War: The Re-Enchantment of War in the Twenty-First Century.* Blackwell manifestos. Malden, MA: Blackwell Pub, 2004.

Cowan, Thomas H. “A Theoretical, Legal, and Ethical Impact of Robots on Warfare.” Master’s research project, U.S. Army War College, 2007.

Department of the Army. *Army Unmanned Ground Vehicle Strategy Memorandum.* Washington, D.C.: Dept. of Defense, Headquarters United States Army Maneuver Center of Excellence, 2010.

Department of the Army. *Eyes of the Army: U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035.* Washington, D.C.: Dept. of Defense, U.S. Army Unmanned Aircraft Systems Center of Excellence, 2010.

Department of the Army. FM 3-0, *Operations.* Washington, D.C.: Government Printing Office, 27 February 2008.

Department of the Army. FM 3-24, *Counterinsurgency Operations.* Washington, D.C.: Government Printing Office, December 2006.

Department of Defense (DOD). *Capabilities-Based Assessment (CBA) User’s Guide Version 3.* Washington, D.C.: Dept. of Defense, Joint Chiefs of Staff, March, 2009.

Department of Defense (DOD). “CJCSI 3170.01G, JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM.” Washington, D.C.: Dept. of Defense, Joint Chiefs of Staff, March 1, 2009.

Department of Defense (DOD). "DARPA Mission." Washington, D.C.: Dept. of Defense, Defense Advanced Research Projects Agency. http://www.darpa.mil/mission.html (accessed October 6, 2010).

Department of Defense (DOD). "DARPA Urban Challenge." Washington, D.C.: Dept. of Defense, Defense Advanced Research Projects Agency. http://www.darpa.mil/grandchallenge/index.asp (accessed October 6, 2010).

Department of Defense (DOD). Joint Publication (JP) 3-0, *Joint Operations.* Washington, D.C.: Government Printing Office, 13 February 2008.

Department of Defense (DOD). "News Release: DARPA unveils new robotics program." Washington, D.C.: Dept. of Defense, Defense Advanced Research Projects Agency, August 19, 2010. http://www.darpa.mil/news/2010/ARMAug2010.pdf (accessed October 6, 2010).

Department of Defense (DOD). "Report of the Defense Science Board Task Force on the Fulfillment of Urgent Operational Needs." Washington, D.C.: Dept. of Defense, Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, 2009.

Department of Defense (DOD). *The Implementation of Network-Centric Warfare*. Washington, D.C.: Dept. of Defense, Office of Force Transformation, 2005.

Department of Defense (DOD). *Unmanned Systems Integrated Roadmap 2009-2034.* Washington, D.C.: Dept. of Defense, 2009.

Department of Defense (DOD). *Unmanned Systems Integrated Roadmap 2007-2032*. Washington, D.C.: Dept. of Defense, 2007.

Deputy, Samuel N. "Counterinsurgency and Robots: Will the Means Undermine the Ends?." Ft. Belvoir: Defense Technical Information Center, 2009.

Dortmans, Peter J., and Neville J. Curtis. *Towards an Analytical Framework for Evaluating the Impact of Technology on Future Contexts.* Edinburgh, S. Aust: DSTO Systems Sciences Laboratory, 2004.

Finkelstein, Robert, and Steven Shaker. *Unmanned Vehicle Systems: Military and Civil Robots For the 21st Century and Beyond.* Arlington: Pasha Publications Inc., 1994.

Hilliker, Jesse. "Should We Turn the Robots Loose?" Research project, Naval War College, 2010.

Kaplan, Fred. "Wonder Weapons Don't Win Wars." Slate Magazine. May 19, 2010. http://www.slate.com/id/2254374 (accessed October 6, 2010).

Krishnan, Armin. *Killer Robots: Legality and Ethicality of Autonomous Weapons.* Farnham, England: Ashgate, 2009.

LeBouvier, Rand D. "Extending Operational Reach With Unmanned Systems." Ft. Belvoir: Defense Technical Information Center, 2003. http://handle.dtic.mil/100.2/ADA417223 (accessed October 6, 2010).

Magnuson, Stew. "Efforts to Field New Kinds of Ground Robots Have Had Little Success." National Defense Magazine. June, 2010. http://www.nationaldefensemagazine.org/archive/2010/June/Pages/EffortstoFieldNewKindsofGroundRobots.aspx (accessed August 20, 2010).

McDaniel, Erin A. "Robot Wars: Legal and Ethical Dilemmas of Using Unmanned Robotics Systems in 21st Century Warfare and Beyond." Ft. Belvoir: Defense Technical

Information Center”, 2008. http://handle.dtic.mil/100.2/ADA502401 (accessed August 20 2010).

Metz, Steven. *Armed Conflict in the 21st Century: The Information Revolution and Post-Modern Warfare.* Carlisle, PA: Strategic Studies Institute, U.S. Army War College, 2000.

Murray, Williamson, and Alan R. Millet. *Military Innovation in the Interwar Period*. Cambridge: Cambridge University Press, 1998.

Nardi, Gregory J. “Autonomy, Unmanned Ground Vehicles, and the US Army: Preparing for the Future by Examining the Past”. Ft. Belvoir: Defense Technical Information Center, 2009. http://handle.dtic.mil/100.2/ADA506181 (accessed August 20, 2010).

Owens, William A., and Edward Offley. *Lifting the Fog of War.* Baltimore, MD: Johns Hopkins University Press, 2001.

Pierce, Terry C. *Warfighting and Disruptive Technologies: Disguising Innovation. Cass series--strategy and history.* London: Frank Cass, 2004.

Schwartz, Moshe. *Defense Acquisitions How DOD Acquires Weapon Systems and Recent Efforts to Reform the Process*. Washington, D.C.: Congressional Research Service, 2009.

Shaker, Steven M., and Alan R. Wise. *War Without Men: Robots on the Future Battlefield.* McLean: Pergamon-Brassey’s International Defense Publishers, 1988.

Singer, P. W. *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century.* New York: Penguin Press, 2009.

Sparrow, Robert. “Killer Robots.” *Journal of Applied Philosophy* 24, no. 1(2007): 62-77.

Stanford University. “The Frame Problem.” Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/entries/frame-problem/ (accessed October 6, 2010).

United States. *National Defense Authorization, Fiscal Year 2001*. Washington, D.C.: U.S. G.P.O., 2000.

United States Air Force. *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047.* Washington, D.C.: Dept. of Defense, Headquarters, United States Air Force, 2009.

United States. *National Security Strategy.* Washington: White House, 2010.

United States Government Accountability Office, and William Solis. “Warfighter Support Improvements to DOD's Urgent Needs Processes Would Enhance Oversight and Expedite Efforts to Meet Critical Warfighter Needs: Report to the Committee on Armed Services, U.S. Senate.” Washington, D.C.: U.S. Govt. Accountability Office, 2010.

United States Government Accountability Office, and Michael J. Sullivan. “Defense Acquisitions Opportunities Exist to Achieve Greater Commonality and Efficiencies Among Unmanned Aircraft Systems: Report to the Subcommittee on Air and Land Forces, Committee on Armed Services, House of Representatives.” Washington, D.C.: U.S. Govt. Accountability Office, 2009.

Villacres, Edward J, and Christopher Bassford. “Reclaiming the Clausewitzian Trinity.” *Parameters* 25, no. 3 (Autumn 1995): 9-19.

Watts, Barry D. *Clausewitzian Friction and Future War.* Washington, D.C.: Institute for National Strategic Studies, National Defense University, 1996.