Military Innovation through Lethal Logistical Capabilities

A Monograph

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What does the future of armed conflict look like for the US military and specifically the Army? This paper will argue an American Way of War and a need to modernize during an interwar period will shape the future of American armed conflict. These forces, combined with technological revolutions in the civilian sector will logically influence the direction of future military capabilities. The paper will present the idea of the third offset and how the US military will achieve it. Next this paper will show some of the efforts the military is making to automate logistics and illustrate the ways businesses are using autonomy to innovate. Finally, the monograph will make the argument that expresses what leading theorists believe the future of armed conflict will look like, and then make recommendations for how the US military can improve the future war-making concepts and capabilities.

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Abstract

Military Innovation through Lethal Logistical Capabilities, by MAJ E. Jerome Hilliard, US Army, 44 pages.

War is rapidly evolving, and the United States is at the forefront of innovation. The future of armed conflict is becoming ever more tied to technology and precision. What does the future of armed conflict look like for the US military and specifically the Army? This paper will argue an American Way of War and a need to modernize during an interwar period will shape the future of American armed conflict. The objective of defense capability modernization and innovation is to find a third offset. These forces, combined with technological revolutions in the civilian sector will logically influence the direction of future military capabilities.

This paper will introduce three characteristics of the American Way of War and then show examples of how militaries innovated during previous interwar periods, leading to the advantage for subsequent conflicts. The paper will then present the idea of the third offset and how the US military will achieve it. Next this paper will show some of the efforts the military is making to automate logistics and illustrate the ways businesses are using autonomy to innovate. Finally, the monograph will make the argument that expresses what leading theorists believe the future of armed conflict will look like, and then make recommendations for how the US military can improve the future war-making concepts and capabilities.

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Acronyms

A2/AD	Anti-access/Area Denial
ABC	Artificial Bee Colony
AI	Artificial Intelligence
AACUS	Autonomous Aerial Cargo Utility System
GPS	Global Positioning Systems
OODA	Observe, Orient, Decide, and Act
RAS	Robotic and Autonomous Systems
UAS	Unmanned Aircraft Systems

American Way of War

Theorists have created different categories of war since the beginning of human conflict. Limited and total wars are phrases used to describe campaigns. Cultures have even developed styles for how they conduct war, like the Western Way of War. Since 1941, the United States, comprised of a unique culture, has produced an American Way of War.[1] Some of the characteristics of this American Way of War are dependence on technology, a focus on firepower, and war that is sensitive to casualties.

The US military's dependence on technology is an asset that assists in enabling friendly forces to have an asymmetric advantage over the enemy. The military's reliance on technology was on display during Operation Desert Shield and Desert Storm. For example, during Operation Desert Storm, the US military had the technological advantage that gave them the ability to operate at night. Advances in night vision, thermal capabilities and the introduction of global positioning systems (GPS) provided US forces the ability to navigate in an open desert under cover of darkness to find, fix, and destroy the enemy. GPS allowed friendly units to develop more precise data for artillery, azimuths to objectives, and proper angles of approach for aircraft.[2] This advent of technology gave friendly forces a marked advantage over the enemy, which eventually led to victory over a near-peer threat.

The idea of a technology dependent military continues to ring true. Strategic problem solvers conclude that technological capabilities will help solve problems associated with mission command. General H.R. McMasters states that in "future armed conflict, increasingly capable and

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[1] Colin S. Gray, "The American Way of War," in *Rethinking the Principles of War*, ed. Anthony D. McIvor (Annapolis, MD: Naval Institute Press, 2005), 13-37.

[2] US Army Center of Military History, *War in the Persian Gulf: Operations Desert Shield and Desert Storm, August 1990 – March 1991* (Washington, DC: Center of Military History United States Army, 2010), 64, accessed October 31, 2017, http://www.history.army.mil/html/books/070/70-117-1/index.html.

elusive enemies will attempt to avoid our strengths, (and) disrupt our advantages."[3] He continues by stating, "Our Army's ability to conduct expeditionary maneuver and Joint Combined Arms Operations depends on a Mission Command Network."[4]

The Combined Arms Center and the Army Capabilities Integration Center published the Army's vision of the Mission Command Network on October 1, 2015. In this document, the authors revealed there will be a future need for a capability where all military services can gather, analyze, and share information across a common operating picture. The Mission Command Network will have the ability to link the soldier on the ground to strategic-level leaders from all services to provide a real-time forward line of troops for operations. In theory, this system will link all the military services to provide clarity and rapid situational understanding of the battlefield. General Brown, Commanding General of Combined Arms Center at the time stated, "The Mission Command Network is essential to our success, as a critical enabler for optimizing soldier and team performance."[5] These examples illustrate how today's military leaders who work on tomorrow's problems continue to find the means via technology.

The US dependence on technology also made it more prone to try to solve its problems and win wars through overwhelming firepower. The concept of overwhelming firepower is rooted in doctrine. Joint Publication 3-0, titled Joint Operations, defines the objective of the nature of warfare, "is to defeat an adversary's armed forces, destroy an adversary's war-making capacity, or seize or retain territory in order to force a change in an adversary's government or policies."[6]

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[3] LTG. H. R. McMasters, "Foreword: Director, Army Capabilities Integration Center," in *The Mission Command Network Vision and Narrative* (Fort Eustis, VA: Army Capabilities Integration Center, October 2015), 2, accessed October 31, 2017, http://usacac.army.mil/sites/default/files/documents/mccoe/MissionCommandNetworkNarrative1Oct15.pdf.

[4] Ibid.

[5] GEN. Robert E. Brown, "Foreword: Commander, Combined Arms Center," in *The Mission Command Network Vision and Narrative* (Fort Eustis, VA: Army Capabilities Integration Center, October 2015), 1, accessed October 31, 2017, http://usacac.army.mil/sites/default/files/documents/mccoe/MissionCommandNetworkNarrative1Oct15.pdf.

[6] US Department of Defense, Joint Publication (JP) 3-0, *Joint Operations* (Washington, DC: Government Printing Office, 2011), I-5.

Joint Publication 3-0 continues and lists mass as a Principle of Joint Operations and describes its purpose, "is to concentrate the effects of combat power at the most advantageous place and time to produce decisive results."[7]

General William DePuy, the first commanding officer for Training and Doctrine Command, reformed how the Army trained. Under General DePuy's tenure as commanding officer, the Army adopted the slogan, "An Army must train as it fights."[8] In 1976 Training and Doctrine Command published Field Manual 100-5, which emphasized the need to place, "liberal use of suppressive firepower to paralyze an enemy momentarily before maneuvering against him."[9]

The liberal use of firepower to suppress the enemy and enable maneuver was again on display during Operation Desert Storm. The Air Force disabled the Iraqi air defense, air force, and command and control structure through an elaborate air campaign.[10] The success of the air campaign degraded the Iraqi Armed Force's ability to obtain situational understanding, which allowed friendly forces the freedom to maneuver to defeat the Iraqi Army.

News channels televised some of the US air campaigns and it illustrated the accuracy of precision-guided munitions. The advances in technology that expanded the reach of mission command and slashed the time needed to gain a situational understanding of the battlefield also made it possible for the American public to view war from a very close angle. The instant access to the conflict as the conflict unfolded on television sometimes contained unpleasant views of reality, the reality that casualties are a product of war. American culture is sensitive when the

[7] US Joint Staff, JP 3-0 (2011), A-1.

[8] Robert H. Scales, "The Great Wheel," in *Certain Victory: The US Army in the Gulf War* (Fort Leavenworth, KS: US Army Command and General Staff College Press, 1993), 9.

[9] Ibid.

[10] Thomas A. Keaney and Eliot A. Cohen, "Was Desert Storm a Revolution in Warfare," in *Gulf War Air Power Survey Summary Report* (Washington, DC: US Government Printing Office, 1993), 248, accessed October 31, 2017, http://www.dtic.mil/dtic/tr/fulltext/u2/a273996.pdf.

topic discussed is friendly military casualties. America's public sensitivity influences political and military leaders and can affect the way it fights wars.

On January 29, 2017, an American counterterrorism unit conducted an operation on an enemy safe house in Yemen. The action resulted in gathering sensitive intelligence and left several wounded, one dead, and destroyed one American aircraft. The newly elected President of the United States, Donald Trump, and the President's administration approved this operation. Showing compassion to the family of the lost Navy seaman, the President invited the seaman's wife to a session of Congress and gave them a tribute during his address to Congress. This example reveals the level of importance one casualty can have on American society and politics.

Knowing this domestic sensitivity to casualties, enemies develop strategies on how to use casualty numbers against the United States to gain political leverage. In January 1991, during Operation Desert Storm, the Iraqi Army made one attempt to fight the US military. The intent of the battle from the Iraqi strategist's view was to force a bloody struggle, which they believed would weaken the US public's resolve to liberate Kuwait.[11]

The dependence on technology and focus on firepower where the United States is sensitive to casualties are only some of the characteristics of the American way of war. It is vital that the military be self-aware of the traits of an American way of war because such awareness allows the United States to better analyze how its strengths can be used against an enemy with an asymmetric disadvantage. These characteristics shape how the United States will fight battles in the future. The way it fights a war will not be the solution to every conflict, the same way a hammer is not the right tool for every home improvement project.

The United States has been fortunate to have technological advantages over its competitors since World War II. Much of this position came to fruition from hard work through innovation and luxury of having public and financial support. Carl Von Clausewitz said, "War is

[11] Keaney and Cohen, "Was Desert Storm a Revolution in Warfare," 248.

nothing but the continuation of policy with other means."[12] If a military is not preparing for the next conflict, then a government's ability to threaten military action is not credible and undermines a government's ability to keep the peace. Militaries that are ready for war are in a better position to prevent conflicts by presenting a credible deterrent. On the other hand, there are always those who oppose this assertion because they believe that war will never happen again. Therefore, for them there is no need to invest in military innovation and future capabilities. When the people in power concluded there was no viable threat to their country's sovereignty, they often lacked a sense of urgency to modernize their military and expand its warfighting capabilities. Quite often the lack of innovation during the interwar period had disastrous effects, and these types of countries were behind when the next war started. Change during interwar periods was and is very critical to the future of the military and the state's future existence.

Between World War I and World War II, the German government supported its military financially which prepared them for battle at the onset of World War II. The German army was held in high regard with the public during the interwar period. The German Army leader during World War I, Paul von Hindenburg, was elected president after the war and he gave the military the political support they needed to revolutionize.[13]

Britain, on the other hand, under Prime Minister Neville Chamberlain, accepted the idea of "limited liability," which stated that Britain's Army would only defend its homeland and not be committed to a continental conflict.[14] This idea negatively shaped the British Army and limited the number of resources it had to build, train, and prepare. As a result, the British Army did not have the resources it needed to develop capabilities for future conflicts. For example, the

[12] Carl Von Clausewitz, *On War*, ed. Michael Howard and Peter Paret (Princeton, NJ: Princeton University, 1984), 69.

[13] Williamson Murray, "Armored Warfare: The British, French, and German Experiences," in *Military Innovation in the Interwar Period*, ed. Williamson Murray and Allan R. Millett (Cambridge, UK: Cambridge University Press, 1996), 16.

[14] Ibid., 10.

British Army stopped developing the combat capabilities, such as the tank during this period, due to a lack of political funding.

The transformation mindset fosters internal debate and experimentation. The German military during the interwar period was an excellent example of an organizational culture that valued introspection and corporate review. After the invasion of Poland in 1939, the German Army examined its performance and determined it required reorganization and retraining prior to their invasion of France.[15] The military culture allowed debate over tactics and how to conduct war, which set a foundation of trust that enables honest feedback.

In free economic markets, organizations that do not continue to adapt, innovate, and provide customers with the products they desire go out of business because other businesses are willing to improve their products to gain customers. A characteristic of free economic markets is they are self-correcting. Blockbuster is an example from recent history that demonstrates how free capitalist markets correct themselves. Blockbuster rested on their laurels, failed to innovate as technology improved and ultimately filed for bankruptcy. Customers were able to stream movies over the Internet and streaming eliminating the requirement to go to a store to rent a movie. The idea of a self-correcting free market is similar to war, because in war the loser is eliminated.

Russell King, the executive vice president of Anglo American, a 35.5 billion dollar company with 195,000 employees, said in a 2006 *Business Strategy Review* that entrepreneurial ideas in large organizations must be focused.[16] Businesses need to have a set of rules that define the entrepreneurial activities within an industry to enable the entrepreneurial spirit. By

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[15] S. J. Lewis, "Reflections on German Military Reform," *Military Review* (August 1988): 63, accessed November 1, 2017, http://cgsc.cdmhost.com/cdm/ref/collection/p124201coll1/id/509.

[16] Russell King, "Entrepreneurial Hearts and Minds," *Business Strategy Review* 17, no. 4 (Winter 2006): 89-91, accessed November 1, 2017, http://onlinelibrary.wiley.com/doi/10.1111/busr.2006.17.issue-4/issuetoc.

establishing these guidelines, large organizations develop areas in which employees have the freedom to experiment and solve problems for the company independently.

A perfect example of focused entrepreneurialism was the US Navy's experimentation with naval aviation, which directly influenced today's design of the aircraft carrier. Through trial and error in simulation training, the US Navy realized the potential of the aircraft carrier. They understood that the navy that gained air superiority first would win the battle because they were able to spot enemy naval ships before identifying the friendly fleet. Air superiority gave the US Navy the element of surprise and the ability to directly attack or call in maritime gunfire on enemy ships. In the end, it gave the US Navy the advantage on the sea. Through wargaming, the US Navy was able to innovate and come to the conclusion that the more planes you had in the air, the more of an advantage you had at sea.[17] A ship's capacity to store aircraft influenced the size and design of aircraft carriers. The carrier became more substantial to hold more aircraft. Additionally, it stored planes inside and on top of the vessel to improve capacity. Engineers angled the recovery landing strip off the side of the ship to give the aircraft carrier the ability to launch and recover aircraft at the same time, which meant more aircraft were up in the air for more extended periods of time.

Financial support by the people of the United States tied to a continued sense of urgency during the current interwar period is critical to further innovation and expansion of military capabilities. In preparation for the next major conflict, the US military is focusing its entrepreneurial spirit on finding and exploiting a third offset by communicating the importance of modernization in published documents like the *US Army Robotic and Autonomous Systems Strategy*. This key document provides a framework and construction of the plan that underpins how the US military will modernize to develop and exploit an asymmetric advantage.

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[17] Murray, "Armored Warfare: The British, French, and German Experiences," 10.

David's battle against Goliath is an excellent biblical example that illustrates an asymmetric advantage or offset strategy. David who was a smaller opponent when compared to Goliath focused his efforts on Goliath's eye. By targeting Goliath's eye, David was able to defeat an enemy who was superior in size and strength. David's developed skill of precisely launching rocks provided him with standoff and the asymmetric advantage over opposing forces in battle. Dr. Andrew Ilachinski, a research analyst at the Center for Naval Analysis, defines an offset strategy, "As a general set of competitive peacetime policies designed to generate and sustain a strategic advantage over one's main adversaries."[18] The United States developed two offsets in the recent past with the invention of atomic bomb and stealth technology and the US military believes the solution to find a third offset lies with a bigger commitment to technology.

The first offset strategy was known as "New Look" and was an effort to gain an advantage against the Soviet Union in Eastern Europe. Geographically and physically outnumbered by the Soviets in Germany after World War II, the United States positioned and developed its nuclear weapon program to counteract Russia's geographic and numerical advantage in Europe. Russia had 175 active duty divisions and 125 reserve divisions compared to the United States which only had twenty-nine active and seven reserve divisions.[19] Two parts defined the New Look policy, expansion of nuclear devices and delivery capabilities through the development of the intercontinental ballistic missile. Eventually, the Soviet Union was able to match the US atomic threat capability, which set the conditions to develop a second offset strategy.

The development of stealth aircraft and precision strike capabilities was the second offset strategy. The US military's marriage to technology established the second offset becoming a

[18] Andrew Ilachinski, *AI, Robots, and Swarms: Issues, Questions, and Recommended Studies*, CNA Analysis and Solutions, January 2017, 27, accessed November 1, 2017, https://www.cna.org/CNA_files/PDF/DRM-2017-U-014796-Final.pdf.

[19] Larry Lewis, *Insights for the Third Offset: Addressing Challenges of Autonomy and Artificial Intelligence in Military Operations*, CNA Analysis and Solutions, September 2017, 17, accessed November 1, 2017, https://www.cna.org/CNA_files/PDF/DRM-2017-U-016281-Final.pdf.

pillar of the American Way of War.[20] The asymmetric capabilities the United States developed were on full display during Operation Desert Storm. The American public saw the video feed from precision bombs on the evening news as they were launched from their delivery platforms and hit their targets. The evolution of GPS, satellite communications, and night vision are other technologies associated with the second offset strategy.[21] Many of the world powers have developed capabilities comparable to the United States and have even developed countermeasures, like GPS jamming, which undermine the US military's technological strengths. These developments set the stage for the military to establish a third asymmetric capability.

Former Secretary of Defense Ash Carter described the current environment as an atmosphere where "nations like Russia and China are trying to close the technology gap with the United States, and as I noted, high-end military technology has diffused–sometimes becoming available to countries like North Korea and Iran, as well as non-state actors. At the same time, our reliance on technological systems like satellites and the Internet has grown, creating vulnerabilities that our adversaries are eager to exploit."[22] A shift from the military leading innovation, as seen during the first two offset strategies, to the commercial sector being at the forefront of the developing technological market describes the current innovation environment.[23] The understanding that the US military no longer has an unmatched advantage and smaller military structure is pushing the agenda to discover the third offset.

The third offset strategy is driving broad range experimentation and innovation in the military application of artificial intelligence (AI) and autonomous systems. Deputy Secretary of Defense, Robert Work outlined the five tenants that would shape the third offset strategy

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[20] Gray, "The American Way of War," 15.

[21] Ilachinski, *AI, Robots, and Swarms*, 28.

[22] Ash Carter, "The Path to an Innovative Future for Defense" (CSIS Third Offset Strategy Conference, as Delivered by Secretary of Defense, Washington, DC, October 28, 2016), accessed November 1, 2017, https://www.defense.gov/News/Speeches/Speech-View/Article/990315/remarks-on-the-path-to-an-innovative-future-for-defense-csis-third-offset-strat/.

[23] Lewis, *Insights for the Third Offset*, 6.

investments.[24] They were an investment in independent deep learning systems, human-machine collaborative decision making, assisted human operations, advanced manned-unmanned system operations, and network-enabled, semi-autonomous weapons hardened to operate in a future cyber/electronic warfare environment.

Robotic and Autonomous Systems Strategy

The Army Robotic and Autonomous Systems (RAS) Strategy published in March of 2017 says, "The Army must pursue RAS capabilities with urgency because adversaries are developing and employing a broad range of advanced RAS technologies as well as employing new tactics to disrupt US military strengths and exploit perceived weaknesses."[25] The former Vice Chief of Staff of the Army, General Daniel B. Allyn said the RAS Strategy is a document used to describe how the Army will integrate new capabilities into the future force to ensure asymmetric advantage.[26] The strategy ensures the military analyzes the new capabilities developed against current "doctrine, organization, training, material, leadership and education, personnel, facilities, and policy (DOTMLPF-P)," to ensure smooth integration into the Army force.

The RAS Strategy states that it will help the Army address three critical ways that are being pursued by adversaries to exploit US military perceived weaknesses: adversary investment in increased speed of detection and greater standoff, increased use of autonomous systems and amplified size and density of urban centers.

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[24] Robert Work, "CNAS Defense Forum" (Delivered by Deputy Secretary of Defense, Washington, DC, December 14, 2015), accessed November 1, 2017, http://www.defense.gov/News/Speeches/Speech- View/Article/634214/cnas-defense-forum.

[25] The Maneuver, Aviation, and Soldier Division Army Capabilities Integration Center (ARCIC), *The U.S. Army Robotic and Autonomous Systems (RAS) Strategy* (Fort Eustis, VA: U.S. Army Training and Doctrine Command, March 2017), 1, accessed November 2, 2017, http://www.tradoc.army.mil/FrontPageContent/Docs/RAS_Strategy.pdf.

[26] Ibid.

To address the issues listed above, the Army's RAS Strategy published five capability objectives to guide unmanned ground vehicles and unmanned aerial vehicles development. They are to increase situational awareness; lighten the soldiers' physical and cognitive workload; sustain the force with expanded distribution, throughput, and efficiency; facilitate movement and maneuver; and protect the force.[27] These objectives will mainly contribute to the Department of Defense in three ways: by reducing the number of soldiers in harm's way, increasing speed in time-critical operations, and providing platforms that can perform missions impossible for humans.[28] The RAS Strategy is broken down into three phases, near-term (2017 to 2020), mid-term (2021 to 2030) and long-term (2031 to 2040).

Technological improvements over the next twenty-five years to AI, autonomy, and command and control are critical to the RAS Strategy. Increases in these three crucial areas are projected to improve information flow and lower the overall operating cost of the Army. The RAS Strategy defines autonomy as, "the level of independence that humans grant a system to execute a given task in a stated environment." There are three levels of autonomy: humans in the loop, on the loop, and out of the loop.

The location where the human decision-makers fall on the "observe, orient, decide, and act (OODA)" loop for lethal autonomous weapons systems defines whether a human is in, on, or out of the loop. At one end of the spectrum, when operators control much of the functionality of a machine, the system describes a human in the loop. Conversely, when a system is entirely automated with no human control or oversight, it is a human out of the loop system. There are not many human out of the loop machines in existence today, but they are ever present in science fiction cinemas. Retired Colonel John Boyd developed the OODA loop as a way to command and control continually changing, complex environments, such as war. The idea behind the OODA loop is to progress through the stages faster than the enemy. By acting quicker than the enemy,

[27] ARCIC, *The U.S. Army Robotic and Autonomous Systems (RAS) Strategy*, 1.

[28] Ibid., 2.

the aggressor can destroy the enemy's ability to process and act on information.[29] Lethal autonomous weapons will enable operators to process information faster than currently capable.

Operators control many of the functions of a human in the loop system. Human operators can operate in any or all three facets of this system. They can serve as the essential operator, where the operator controls every action of the machine.[30] A child's remote control car is an example of a human in the loop system. The controller remotely controls the toy, determines its destination, and navigates the vehicle to the target. Predator drones are the military version of a human in the loop essential operator autonomous system.

The operator can also act as a moral agent and restrict the function of the system to issues like the use of force, but the machine controls the majority of the system's operations. The moral agent is valuable for targets near civilians, where striking the mark comes with the likelihood of causing collateral damage. The platform relies on the moral agent to decide whether the aim is worth the potential collateral damage sustained by destroying the target. For example, if the enemy ambushed an autonomous combat patrol inside an urban population center while civilians were in the streets, the system would require the command to return fire before the combat systems would engage.

Lastly, humans can act as fail-safes for human in the loop systems. When working as a fail-safe, the human operator maintains the ability to intervene in the operation of the system if the system malfunctions or fails.

The on the loop system delegates the "observe, orient, and act" portions of the loop to the autonomous system while the human operator maintains control of the deciding portion of the loop. In the loop systems are also thought of as supervised-autonomous systems, because the machine performs its operations under the observation of a human. In the on the loop system, the

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[29] Everett Dolman, *Pure Strategy: Power and Principle in the Space and Information Age* (New York: Frank Cass, 2005), 133.

[30] Ilachinski, *AI, Robots, and Swarms*, 147-152.

platform's operations are autonomous. Using autonomous vehicles as an example to illustrate a human on the loop system, the vehicle's AI software would be able to turn the car on, off, and operate the automobile completely autonomously. In this system, the operator would also have the ability to change the final destination and act as the moral agent or fail-safe in the event there is an emergency. The Tesla Motor Company's Autopilot feature or the Waymo rideshare services are examples of human on the loop systems. An autonomous system where the human merely designates the destination or objective and the platform is responsible for achieving the mission, describes a human out of the loop autonomous system. Russia's speculated "dead hand" program is currently the best example of a human out of the loop system.[31] This system will launch Russia's intercontinental ballistic missiles, "if its seismic, light, radioactivity, and pressure sensors detect a nuclear attack."[32]

For humans out of the loop, the system is fully autonomous, and the machine performs its task without human interaction. Humans do not supervise or have the ability to intervene in the event of an emergency. Department of Defense directive 3000.09 prohibits lethal fully autonomous robots. Currently, there are not many human out of the loop systems in existence. One example of a human out of the loop system is the Israeli Defense Force's Harpy. The Harpy uses loitering attack munitions and launches into a specific area where it flies a search pattern over its target area and hunts for programmed targets. Example targets can range from tanks to radar systems and once identified the attack munitions will fly into the target and destroy it.

Common control is, "The ability for one common software package to control an array of ground and air systems . . . . Common control will allow one soldier to control multiple robots with one controller." Combining humans in the loop autonomy with common control will give units the capability to mass effects on the battlefield with fewer soldiers.

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[31] *The Economist*, "Man and Machine: Autonomous Weapons Are a Game-Changer," accessed January 25, 2018, https://www.economist.com/news/special-report/21735472-ai-empowered-robots-pose-entirely-new-dangers-possibly-existential-kind-autonomous.

[32] Ibid.

In the near term, a goal of the RAS is to improve sustainment with automated ground supply. Automating ground resupply operations will improve the Army's ability to sustain high tempo operations by increasing throughput, efficiency, and extending the Army's operational reach.

In the mid-term, the RAS Strategy will expand convoy operations by fully automating logistical convoy operations and transition Leader-Follower program. The Leader-Follower concept will make the patrol leader no longer have to drive the lead vehicle. The Sustainment Center of Excellence is developing the Leader-Follower program, and it allows a manned vehicle to lead a convoy followed by several unmanned autonomous vehicles. Follower vehicles enabled by sensors and a digital wireless communication package installed on current trucks found in the Army fleet will have the ability to follow the lead vehicle. Initial capabilities fielded to Palletized Load System centric transportation units will operate in the consolidation area. Leader-Follower autonomous trucks will first conduct operations from sustainment brigade echelons to combat service support battalions and transport supplies to Brigade Support Battalions as far forward as Brigade Support Area.

The Army plans to expand the Leader-Follower program to additional sustainment vehicles currently in its fleet. The Army plans to expand this program from medium to heavy Tactical Wheeled Vehicles found inside everything from Composite Light Truck Companies to Composite Heavy Truck Companies. Trucks such as Line Haul Tractors (M915), Heavy Equipment Transport System, and Family Medium Tactical Vehicles included in the proposed Leader-Follower capability install. Currently, vehicles with the Leader-Follower system installed on them are restricted to improved roads. Rough payment is the limit of operation for these trucks, which means the Army expects these vehicles to move in semi-permissive, developed environments.

The Army deduces the Leader-Follower program will make sustainment more efficient by saving fuel, reducing maintenance costs, and extending operational reach. The instant electronic communication between vehicles with Leader-Follower capability will enable simultaneous braking and acceleration. Coordinated actions between the trucks result in no accordion effect when groups of cars speed up or slow down at unpredictable times. A reduction of distances between vehicles will improve fuel efficiency through drafting. The lead vehicle breaks the air for the rest of the trucks in the convoy while follower vehicles mimic the velocity of the lead vehicle. The Army assesses the reduction in personnel needed to conduct convoy operations as a result of the Leader-Follower capability will allow for 24-hour services, provide commanders flexibility, and improve sustainment responsiveness.

A paper prepared for the Army Capabilities Integration Center by fellows at The College of William and Mary found the Army could save as much as 25,000 dollars per soldier per year for each deployed service member no longer conducting convoy operations. If the military no longer requires the service member, the Army could stand to save as much as 300,000 dollars per year. The study was based on a soldier with the rank of E-4 and took into account the pay, allowances, and the cost to train, deploy and sustain the service member. Based on the Full Cost of Manpower model the average of a specialist with four years of service stationed stateside is 117,000 dollars per service member and if he or she gets deployed the cost is as much as 300,000 dollars. These values do not take into account the additional expenses incurred by the government if a soldier is wounded or killed in action while deployed.

The study used the percentage of accidents and casualty rates for Iraq and Afghanistan incurred yearly by soldiers with a military occupational specialty of a truck driver (88M) for the study. The study assumed a Leader-Follower convoy construct with a gun truck escort to develop its findings. The study "used ST 4-1, page 4-14 to determine the daily distance planning factor for a convoy, which was determined to be 144 kilometers. It calculated the total pallets of the classes of supply required for each day of operations and then divided that number be the capabilities per vehicle platform. After determining the number of trucks required, the study calculated the total number of soldiers required to operate the trucks. For example, one Day 0 with the supported headcount of 22,209, this required 562 pallets which take thirty-two M915 trucks for a total of sixty-four soldiers needed to man the trucks (eighteen pallets and two service members per M915)."[33] These variables set up the parameters for a vignette to sustain a notional unit for a year. The study calculated it would cost forty-three million dollars and result in seventy-seven soldiers killed or wounded in action. Using a Leader-Follower ratio of one manned truck to seven unmanned follower trucks would cost 7,200,000 dollars per year to sustain the unit and also reduce wounded or killed in action to a total of four.

Those were not the only savings the study found. The scenario also illustrated a potential 91 thousand dollar per soldier savings in medical treatment for every service member reduced in the MTOE and total military end strength. There was also financial savings in maintenance and fuel costs. Estimations assess there could be as high as a thirty percent reduction in maintenance costs and ten percent increase in fuel efficiency. The decrease in maintenance costs is directly related to the decline in accidents causing unscheduled maintenance. The majority of the fuel savings will come from the following vehicles drafting and conserving energy during convoy operations.[34] Automating convoy operations while still keeping soldiers in the loop illustrates the significant potential for future military innovation.

The Army is also working to develop programs for medium and large unmanned aircraft systems (UAS) to assist in logistical operations. The Army and Marine Corps logistics capability developers have partnered to create the Joint Autonomous Aerial Resupply System to provide flexible, responsive resupply options for brigades and below. Joint Autonomous Aerial Resupply System will have the ability to carry an 800-pound payload and designed to remotely resupply platoon-sized elements in challenging environments, like a mountain, hilly, or high threat urban

[33] Major General James Wright Fellows et al., "Force 2025 Application of Robotics and Autonomous Systems (RAS) to Operational and Tactical Logistics" (The College of William and Mary Mason School of Business, August 2017), 41.

[34] Ibid., 42.

terrain. The system is intended to supplement current methods of resupply when current methods are not feasible.[35]

This capability has the potential to make light infantry units more lethal. Infantry and Stryker Bridge Combat Teams at National Training Center struggle to quickly get anti-armor rounds to defensive battle positions. Each round is simulated using a twenty-six pound sandbag filled with dirt.[36] When Soldiers cache rounds in battle positions ahead of time, it is challenging to redistribute ammunition if the opposing force concentrates in a single position. Moving ammunition is especially challenging when friendly troops occupy defensive battle positions on the sides of the hills. When units have caches pre-positioned on flatbed trailers, the issue becomes getting the ammo from the flatbed trailer up the hill to the battle positions in time to resupply forces before the enemy penetrates defensive positions. The new UAS systems will solve problems like this one, providing the commander more flexibility.

The UAS can also assist in non-standard casualty evacuation of soldiers. Currently, Army aviation lacks the adequate capacity to provide routine aerial sustainment of maneuver forces and insufficient aerial resources to conduct casualty evacuation. The reliance on aerial resupply is projected to increase as the Army transitions to combined arms air-ground operations.[37] In the example listed above, UAS systems within the tactical units will assist in getting injured soldiers off the side of a steep hill. Evacuation of an injured service member is especially difficult if the wounded service member cannot walk and located in terrain similar to the mountainous terrain of Afghanistan. Often service members must resort to human resources to get a soldier to down to flat ground to get transferred to a vehicle and evacuated to a role one medical facility. The UAS

[35] LTC Jeremy Gottshall, “JTAARS - Building a Responsive, Organic Aerial Resupply Capability” (JTAARS Capability White Paper, May 2017), 2.

[36] Lockheed Martin, “Javelin: Fire and Forget Multi-Purpose Combat System,” 2006, 1, accessed November 2, 2017, https://www.lockheedmartin.com/content/dam/lockheed/data/mfc/pc/javelin/mfc-javelin-pc.pdf.

[37] Gottshall, “JTAARS - Building a Responsive, Organic Aerial Resupply Capability,” 5.

provides the capability to extract a soldier in this scenario straight from the point of injury to a higher-level medical facility.

The Marine Corps is developing an unmanned aerial vehicle system that turns current manned helicopters into autonomous aircraft to provide an alternate means to time-sensitive logistics. On December 15, 2017, the Aurora Flight Sciences displayed its Autonomous Aerial Cargo Utility System (AACUS). The AACUS is a Bell UH-1H helicopter fitted with a sensor, software package that allows the aircraft to fly autonomously. The system is designed entirely with off the shelf hardware and is a universal package product that can get installed on any helicopter platform. This modularity allows installation of the system on other aerial platforms giving them autonomous capability. AACUS consists of laser/light detection and radar sensors on the nose, bottom, and tail of the aircraft to detect objects in its surroundings. The system has also been installed and tested on a Boeing AH-6 Little Bird. The AACUS communicates with software on a tablet that runs much like the Uber ridesharing application. The operator and ground crew load the cargo, input a destination, and then give AACUS the approval to fly the designated route. Once on the ground at the landing zone and unloaded the AACUS sends a request to the operator of the tablet on the ground asking permission to fly to a destination. The Office of Naval Research is still developing the algorithms that will instruct the helicopter how to land in unprepared terrain, avoid dynamic moving obstacles, conduct aggressive no fly-over approach landings, and conduct autonomous in-flight mission re-routing to negotiate restricted airspace. These are hard programming problems and require operators to collect a lot of data through hours of flying. It will be years before the AACUS can do these things, but it is a step in the right direction.[38]

In the long term, the Army plans to have entire logistic efforts completely automated. Cargo trucks will deliver cargo entirely autonomously, and heavy UAS will assist in moving

[38] Amy Kluber, "Aurora Demos US Marine Unmanned Cargo-Delivery Huey in Final Test," Rotor and Wing International, December 15, 2017, accessed December 18, 2017, http://www.rotorandwing.com/2017/12/15/aurora-demos-us-marine-unmanned-cargo-delivery-huey-final-test/#.Wl6llCPMzOQ.

containers between sustainment nodes. These plans will extend logistical lines of communication in austere conditions.

The RAS strategy states, “Autonomy is a gateway technology that, once obtained, will be integrated into all ground vehicles, combat or otherwise. Ground vehicle autonomy increases force protection by having RAS conduct dirty and dangerous tasks. Immediate investment of semi-autonomous capability, such as automatic convoy resupply, will reduce the number of service members required to operate vehicles during convoy operations, thereby reducing the number exposed to risk.”[39] Currently, the Army is working to develop the convoy capability where separate driverless vehicles can follow a lead vehicle’s path in convoy operations. The Army’s planned integration and evolution of autonomous convoys are similar to how John Deere evolved their current self-operating tracker capability.

Autonomy in Civilian Industry

Autonomous vehicles started in the US farming industry. The John Deere Corporation saw an opportunity to help farmers become more efficient through the use of autonomy. “There are no federal rules specifically addressing self-driving tech for tractors, largely because farm equipment is designed for use in fields where it doesn’t pose the same level of risk to other vehicles or people as a self-driving vehicle on a public road. That lack of regulations is one reason that the future reached the farm first.”[40]

John Deere tractors can plant and cultivate crops almost entirely autonomously. Trackers with John Deer’s AutoTrac can sync with other farming equipment like combines to improve efficiency. Unmanned tractors pulling grain carts can pull alongside harvesting combines, parallel it, and allow the farming combine harvester to transfer the harvest from the combine to grain cart

[39] ARCIC, *The U.S. Army Robotic and Autonomous Systems (RAS) Strategy*, 12.

[40] Andrea Peterson, “Google Didn’t Lead the Self-Driving Vehicle Revolution. John Deere Did,” *The Washington Post*, June 2015, accessed December 18, 2017, https://www.washingtonpost.com/news/the-switch/wp/2015/06/22/google-didnt-lead-the-self-driving-vehicle-revolution-john-deere-did/?utm_term=.3b88bd0be5e3.

all while in motion.[41] Today, John Deere tractors are entirely self-driving and are accurate in navigation down to within an inch with the advent of today's GPS.[42]

A tractor operated by a human is a less accurate driver than an autonomously driven tractor. Environmental considerations like a dense fog, wind, or thick dust can reduce a farmer's ability to operate precise, straight lines. These ecological concerns can lead to overlap or gaps in the planting process. "Typically, when a tractor crisscrosses a field, the rows overlap by about 10 percent,"[43] Autonomously driven farm equipment eliminates overlap. Issues with overlap in such areas as seeding, fertilization, spraying pesticides, or driving over planted crops become eliminated. Today's farming equipment individually shuts off seed and pesticide spreaders in the event there is overlap due to irregularly shaped fields. Autonomously driven tractors drive so precisely they can follow the same pattern on terrain used to plant the corps and cultivate crops six to nine months later. The trackers even place the tires of the tracker and towed farm equipment in the very same rows used previously. This precision helps prevent the soil from getting compacted and becoming less productive. The increase in accuracy helps save money on fuel, reduces the amount wear and tear of the equipment, and leads to higher predictability of crop yield. These actions save farmers money through resource efficiency.

Alphabet, the owner of the search engine Google, is a leader in the autonomous vehicle revolution. In 2010, then called Google formally announced they were starting a self-driving car project. Google initially invested in autonomous driving by recruiting top talent engineers who won the Defense Advanced Research Project Agency's unmanned vehicle challenge races. Google's recruits included Chris Urmson from the Carnegie Melon University team that won the

[41] Big Ag, "Autonomous Tractors – The Future of Farming?," July 2017, accessed December 18, 2017, http://www.bigag.com/topics/equipment/autonomous-tractors-future-farming/.

[42] pmcmann, "Tractors and Technology: John Deere's Self-Driving Tractors," Harvard Business School, November 2016, accessed December 18, 2017, https://rctom.hbs.org/submission/tractors-technology-john-deeres-self-driving-tractors/.

[43] Gina Anderson, "How NASA and John Deere Helped Tractors Drive Themselves," Nasa.gov, November 2016, accessed December 18, 2017, https://www.nasa.gov/feature/directorates/spacetech/spinoff/john_deere.

2007 Urban Challenge, Mike Montemerlo from the Stanford University team that won the 2005 challenge, and Anthony Levandowski who built the world's first autonomous motorcycle.[44]

The Defense Advanced Research Project Agency developed the first Grand Challenge in 2004 to, "accelerate development of the technological foundations for autonomous vehicles that could ultimately substitute for men and women in hazardous military operations, such as supply convoys."[45] This challenge was the Defense Advanced Research Project Agency's first attempt at using the prize money to spur competition and advance technology. In the first year's race, no competitors were able to complete the 142-mile course. It was not until the second challenge in 2005 where five team's autonomous vehicles were able to complete the challenge, with the winning team claiming the two million dollar prize.

Alphabet's vehicle company that is developing autonomous vehicles for public use is called Waymo. Their expanded vehicle fleet drove more than three million miles autonomously on public roads across four states in the United States. Their vehicle fleet now consists of Chrysler Pacifica Hybrid minivans that have the fully-integrated hardware for complete autonomy. As of 2017, Waymo launched its driverless ride service under the "Earlier Rider Program" in the Phoenix, Arizona area. Members of the program get free unlimited shuttle service in Waymo's self-driving fleet.[46] Soon a family could own one car that can to take the kids to school, come back home pick up adults, drive them to work, and then park itself back in the garage, until the family needs it again. It will soon be feasible for more families only to own one car or choose not own a car at all and exclusively use driverless ride services like Waymo.

[44] Sebastian Thrun, "What We're Driving At," *Google: Official Blog*, October 2010, accessed December 18, 2017, https://googleblog.blogspot.com/2010/10/what-were-driving-at.html.

[45] Defense Advanced Research Projects Agency, "The DARPA Grand Challenge: Ten Years Later: Autonomous Vehicle Challenge Led to New Technologies and Invigorated the Prize Challenge Model of Promoting Innovation," March 2014, accessed December 19, 2017, https://www.darpa.mil/news-events/2014-03-13.

[46] Waymo, "Journey: We've Been Working on the Self-Driving Technology Since 2009," accessed December 19, 2017, https://waymo.com/journey/.

Three-dimensional mapping is critical to allowing autonomous vehicles like the ones Waymo operates to drive autonomously. Autonomous cars use a combination of sensors to create an understanding of their surrounding environment because currently, no single sensor can provide sufficient data under vastly different conditions.[47] Currently, there are two types of systems that vehicles use to map the surrounding area. Waymo's vehicles utilize a laser/light detection and radar as the primary sensor source and supplementary sound, navigation, and ranging, and sensors to gain an understanding of the vehicle's surrounding. Vehicles with this system are easy to recognize by the spinning laser/light detection and radar system mounted on top of the car. It looks like a spinning coffee can on top of the vehicle. Automotive manufacturers like Tesla and Mercedes Benz use a combination of cameras and shortwave radar to create a three-dimensional view of the vehicles' surroundings.

The systems work very similarly; they take a snapshot of their environment, assign positions to the all the objects detected in the picture, and assign coordinates to those objects. Distance, direction, and height define each objective. They then compare a new snapshot to the previous one to identify the location of the vehicle compared to the GPS data and track the proximity of the car to external objects. It requires vast stores of data for the computer to compare shapes of objects against an achieved record of items. This comparison is how the processor identifies things such as traffic signs, pedestrians, motorcyclist, horses, etc. The vehicle's software calculates and predicts the path of objects moving near and in the direction the car is going to determine and avert collisions.

For autonomous vehicles to plan routes, autonomous cars must acquire data about the trip by traveling along the course. The vehicle can collect this data by driving manually along the proposed route, or autonomously by allowing the computer to develop a solution to get to the

[47] Esa Jokioinen et al., "Remote and Autonomous Ships: The Next Steps" (The Advanced Autonomous Waterborne Applications Initiative, Whitepaper, June 2016), accessed December 20, 2017, http://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/aawa-whitepaper-210616.pdf.

destination. The ladder option is not ideal because, without prior data on the route, the vehicle will operate much like a Roomba vacuum and feel its way to the objective. Once the car has traveled the path and gathered the data required, autonomous vehicles could operate in conditions humans cannot. Environmental conditions such zero illumination, dense fog, and dust, are not obstacles like they are for human beings.

Near Future Combat Capabilities

Dr. Paul Scharre is a leading theorist on future warfare and Senior Fellow and Director of the Technology and National Security Program at the Center of a New American Security. Dr. Scharre's qualifications include establishing policy on unmanned and autonomous systems and future weapons technologies for the office of the Secretary of Defense from 2008 to 2013. His recent lectures include discussions about artificial intelligence and the future of war at the US Army War College in June of 2017.[48] Understanding the critical interwar period and influences of an American Way of War, Dr. Scharre believes the key to future warfare is human-machine teaming, also known as the centurion model of warfare. Future systems will combine manned and unmanned systems paired with cognitive automation to process large amounts of data to enable the human decision-making capacity. Robots will expand human capability, not replace humans, in accomplishing the mission and achieve the objective.

Technology will continue to change how humans fight wars. The difference is with the advancement of future technology standoff will continue to grow. Robots will continue to perform tasks overall directed by humans, but with a change in how they are commanded and controlled. An autonomous car example can help illustrate the point. Drivers give autonomous cars more control of car functions by allowing them to navigate themselves from one location to

[48] Paul Scharre, "The AI Revolution, Paul Scharre the Director, Future of Warfare Initiative" (CNAS Video File, June 2017), accessed December 22, 2017, https://www.cnas.org/publications/video/the-ai-revolution-paul-scharre-the-director-future-of-warfare-initiative.

another but operate under human direction to conduct the journey. Simple tasks continue to be automated, while human control remains in the reasoning behind the decision.

Regarding automation, there are a lot of instances where the human is the limiting factor for the system. Eliminating the human occupant will allow engineers to design machines that are smaller, more maneuverable, need less protection, and can operate for longer durations than a single human occupant. Therein lies the friction because by removing the human from the system, the system loses the most "advanced cognitive processing system on the planet: the human brain."[49]

The centurion model of warfare combines the computational power of computers with decision-making power of the brain. Current drone aircraft operated by the military are remotely operated airplanes and are one end of the autonomous spectrum. They run with little to no autonomy and are entirely dependent on maintaining connectivity to their operator. While something like an intercontinental missile is wholly independent and keeps no connection with a human operator after being fired, it is utterly dependent on preprogrammed automation. The centurion model always requires an operator to make decisions remotely, across multiple platforms, while the platform itself controls the tasks associated with the actual operation of the platform.[50]

Developing human-like cognition in AI is years down the road and is a problem that no one in the world has a solution to yet. The idea of allowing AI to make decisions in a military scenario makes many people uncomfortable because some decisions do not have a right answer. A typical situation that illustrates this concept is the trolley problem. There is an out of control trolley driving down the tracks, and you are standing at a railway junction box with the ability to move the trolley to another adjacent track. On the rails directly in front of the cart are five people

[49] Paul Scharre, "Yes, Unmanned Combat Aircraft is the Future," CNAS, August 2015, accessed December 22, 2017, https://www.cnas.org/publications/commentary/yes-unmanned-combat-aircraft-are-the-future.

[50] Ibid.

who are tied up and lying across the train tracks. On the adjoining set of train tracks is one tied up person who is also lying across the train tracks. You as the person standing at the railway junction box must make a decision, whether to pull the lever and divert the trolley and only harm one person or not pull the lever and harm five people. Choosing to not consciously make a decision and not participate or intervene, counts as making a decision. Decisions of this magnitude are a reality for military professionals. As it stands today, computers are good at gathering the data needed to assist in decision makers to make an informed decision, but do not have the intelligence required to make the decision alone.

If humans are in the loop and making decisions for autonomous systems, secure communications become vital. The large bandwidths of satellite dependent communications pipelines are unrealistic when operating in anti-access/area denial (A2/AD) environments of our near-peer competitors. Deliberately jamming satellites and targeting communications with large bandwidths is relatively simple. The military employs jam-resistant communication packages called low probability of intercept/low probability of detection in contested areas.[51] The communication platforms can transmit data as well as voice communication which enables them to communicate time, location, and navigation coordinates but are limited to line of sight. Line of sight communications will reduce communication time delays incurred when they use relays and satellites. The fact that the low probability of intercept/low probability of detection is a line of sight communication capability assists in making it hard to target.

Dr. Scharre argues that because of the reasons listed above the future of US military armed conflict will have humans managing swarms of unmanned autonomous vehicles. Autonomous combat platforms will collect and pass targeting information to manned combat vehicles an echelon behind the front line of troops. The future combat vehicles will be expendable, small, and hard to detect. These autonomous drones will find and recommend targets

[51] Scharre, "Yes, Unmanned Combat Aircraft is the Future."

for approval. Once approved, multiple platforms and drones will engage the target to overwhelm its defenses. These combat vehicles will not replace manned platforms, but they will enhance the commander's ability to maneuver.

Manned combat capabilities will be around for the near future. If the F-15 and F-16 are the example, they came into service in the 1970s.[52] New combat aircrafts like the F-35 and F-22 will probably be in service until at least 2040. A long time from now humans will be forward in the fight to command and control autonomous formations in real time.

Unmanned combat vehicles will play an essential role in the military's ability to project power through mass. As the number and size of megacities grow daily, the military will still need humans to provide the face-to-face solution to problems in urban environments. Constrained by caps to the military force structure, with a requirement to win in an A2/AD environment, unmanned autonomous vehicles provide an affordable solution to power projection and mass.

Autonomous combat vehicles will work in tandem with manned platforms to fight alongside or forward to conduct reconnaissance, target, and strike military targets. These capabilities will not be completely autonomous. They will have enough autonomy to operate independently, establish a line of sight network, to maintain an element of stealth, and resist jamming in an A2/AD environment. Human operators will make the lethal decisions and command and control the combat operations. Similar to how previous revolutions in military affairs changed how to fight battles, the current innovation in autonomy will change how conflicts soon get resolved. Just as the tank after World War I revolutionized ground combat during World War II, autonomous combat vehicles will do the same for fighting in the future.

When multiple decentralized platforms organize to conduct collaboration, it is swarming that is inspired by the behavior of animals in nature.[53] Organic swarms are inherently robust and resilient against predators, and adapt to changes quickly. Examples of animals that exhibit

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[52] Scharre, "Yes, Unmanned Combat Aircraft is the Future."

[53] Ilachinski, *AI, Robots, and Swarms*, 105.

swarming characteristics include ants, termites, bees, locusts, bird flocks, and schools of fish.[54] Natural swarms range in size from a couple of animals, like a family of killer whales hunting for food to millions of termites working together to build a termite mound. An essential characteristic of natural swarms is their ability to coordinate the actions of the group without direction or a central coordination center.[55]

Computer programs motivated by animal swarm characteristics are called swarm intelligence algorithms. There are multiple types of swarm intelligence algorithms such as ant-colony optimization and artificial bee colony algorithms.[56] Ant-colony optimization works very similarly to the way ants follow trails from their colonies to food. In nature, ants leave pheromone trails when searching for food. Once they identify a meal, other ants follow the path created by the ant that found the food. When the other ants follow the trail, they leave their pheromone scent on the trail creating a positive feedback loop and saturating the pathway, making it easier to identify.

Artificial bee colony (ABC) algorithms imitate honeybee swarms. Honeybees perform specific dances to communicate and collaborate on where to find nectar, create honey, and protect their hive. Each type of dance can communicate distance, abundance, and direction of nectar. For example, if the target flowers are within one hundred meters a bee performs a round dance or bees wiggle if the plants are further. If a bee's stomach is full of nectar, it will tremble to let the worker bees know they have nectar to transfer to the hive.[57]

The ABC algorithm mimics the honeybee’s foraging traits by placing drones or weapon systems in one of three categories: scout, onlooker, or employed. The algorithm clarifies bees as scouts when they are searching for a new food source and when they identify a potential flower

[54] Ilachinski, *AI, Robots, and Swarms*, 105.

[55] Ibid.

[56] Ibid., 111.

[57] Ibid., 113.

they transition to onlookers. If they recognize it as a source of nectar, the bee transitions to employed and will remain employed until the source of the nectar runs dry.[58] Combining a combat scenario with Boyd's OODA loop, the ABC algorithm would direct sensors to act as scouts to identify (observe) enemy positions, or platforms. Robotic swarms will establish a reconnaissance network, similar to the security rings that the carrier strike group forms around the aircraft carrier. Robotic swarms will provide an early warning by detecting potential threats. The weapon would then transition to an onlooker, orient on a potential target, and watch the mark until a human operator gives the authorization (human in the loop) to destroy the target (decide). When authorized, the algorithm would determine what capabilities they need to kill the target and terminate the threat (act).

Swarm intelligence algorithms can coordinate multiple different weapons platforms simultaneously. A swarm intelligence platform with various weapon systems will be able to use direct fire to suppress the enemy and launch drones to fix or destroy an enemy that takes cover behind structures.[59] Robotic swarms can also conduct parallel operations by performing multiple parts of the OODA loop simultaneously. While weapon systems are engaging targets, other sensors will act as scouts and onlookers ensuring 360-degree security. Much like a gunner and track commander team in an armored combat vehicle, the gunner can engage targets once approved, while the track commander simultaneously uses his optics to scan for additional threats. Robotic swarms provide reconnaissance capabilities too by creating a search grid in specified areas. Similar to the way carrier strike groups establish security rings around the aircraft carrier, swarms will provide early warning networks to identify threats.

Recommendations and Conclusion

The technological advances by US near peer threats, the responsibility to modernize during the interwar period, and the directives laid out in the RAS strategy make armed

[58] Ilachinski, *AI, Robots, and Swarms*, 113.

[59] Ibid.

autonomous logistical platforms the logical innovation medium to develop and integrate near-future capabilities. The United States is currently dealing with two types of threats that require the military instrument of national power. Insurgent threats originating from failing states and conventional threats from near-peer competitors. Competitors who are trying to establish themselves as regional powers to undermine the US ability to project power in their region.

Insurgent organizations capitalize on the ability to blend in with the local populace to use civilians as shields. Fighting from urban population centers provides insurgents an added level of protection from precision-guided munitions because of the collateral civilian damage the munitions can cause. Counterinsurgency warfare requires a human-to-human interaction, and if the recent battles against the Islamic State in Aleppo and Mosul have anything to teach us, it is urban warfare will remain close quarters, street-to-street battles for control. General Milley says, "After the shock and awe come the march and fight . . . to impose your political will on the enemy requires you . . . to destroy that enemy up close with ground forces."[60] This statement illustrates how critical a resource ground forces remain to conduct urban operations.

As communities around the world continue to migrate toward megacities, counterinsurgent warfare in urban environments will continue to present military forces problems. Currently, the world contains twenty-nine megacities with populations of at least ten million inhabitants. By 2040 two-thirds of the world's communities will live in urban areas.[61] Successful counterinsurgency operations require soldiers to regularly and continuously interact with the populace. Counterinsurgency campaigns need a lot of soldiers. General Abrams commanded 543,000 service members during the peak of the US commitment in Vietnam, in March 1969,

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[60] *The Economist*, "House to House: Preparing for More Urban Warfare," accessed January 25, 2018, https://www.economist.com/news/special-report/21735473-much-fighting-future-wars-likely-take-place-cities-preparing-more.

[61] *The Economist*, "The New Battlegrounds: The Future War," accessed January 25, 2018, https://www.economist.com/news/special-report/21735477-war-still-contest-wills-technology-and-geopolitical-competition-are-changing.

tasked to secure a Vietnamese population of 16.8 million South Vietnamese.[62] To put that number in perspective, the population of South Vietnam in 1969 is equivalent to the City of New York today with 8.5 million residents.[63] Securing of one megacity would put a significant strain on the military's human capital.

Urban warfare in a megacity would become the sole focus for defense forces and provide near peer threats free time and space to expand their military capabilities. The US Global War on Terror is an example of giving time for competitors to close the gap on military capabilities. An article about technology in warfare published by *The Economist* said, "While America and its allies have spent much of the past 15 years fighting wars against irregular forces in the Middle East and Afghanistan, its adversaries have been studying the vulnerabilities in the Western Way of Warfare and exploiting technologies that have become cheaper and more readily available."[64] The 2018 *National Defense Strategy* acknowledges the threat that China and Russia pose, replacing terrorism as the most significant threat to security. The *National Defense Strategy* also recognizes the atrophy of the US military advantage in inter-state conflict and declares to field a "joint force that possess decisive advantages for any likely conflict."[65] By automating logistics and reducing the number of Soldiers required to deliver supplies, the military will have more Soldiers available to conduct urban operations.

It is unlikely that Russia and China would seek an inter-state conflict with the United States, but are also unwilling to continue to accept the paradigm of American global dominance.

[62] US Army Center of Military History, *The U.S. Army in Vietnam*, *American Military History* (Washington, DC: Center of Military History United States Army), 676, accessed January 25, 2018, https://history.army.mil/books/AMH/AMH-28.htm; The Institute for Strategic Studies, *The Military Balance 1968-1969* (London: The Institute for Strategic Studies, 1969), 37.

[63] United States Census Bureau, "Quick Facts New York," accessed January 25, 2018, https://www.census.gov/quickfacts/NY.

[64] *The Economist*, "Stay Well Back: Using Clever Technology to Keep Enemies at Bay," accessed January 25, 2018, https://www.economist.com/news/special-report/21735476-counter-regional-challengers-america-needs-regain-its-technological-edge-using.

[65] Jim Mattis, *Summary of the 2018 National Defense Strategy of The United States of America: Sharpening the American Military's Competitive Edge*, 5, accessed January 25, 2018, https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

The unwillingness to accept the current global power distribution provides the friction that could lead to conflict. Both countries have demonstrated an inclination to utilize the military instrument of national power to expand their spheres of influence. For example, Russia continues to occupy South Ossetia and the Abkhazia region of Georgia and occupies the Donbass and Crimean territories in Ukraine. China is militarizing artificial islands in the South China Sea to extend their A2/AD bubble, which undermines the US ability to protect the vital commercial shipping lanes of the region.

Both countries are increasing their ability to project power beyond their borders. China is investing in their long-range anti-ship missiles, naval ships, and expanding their submarine force.[66] The thought of a conflict intervention near their borders is significantly riskier. *The Economist* Magazine assesses that, "If there were a new crisis over Taiwan, America would no longer send an aircraft-carrier battle group through the Taiwan Strait to show its resolve, as it did in 1996."[67] The high cost of intervention shapes a world where these powers have free reign to dominate neighboring countries. The types of threats that China and Russia represent warrant investment in human-machine teaming, swarm warfare, and autonomous systems. Swarm warfare capabilities provide the ability to defeat A2/AD threats and lower the risk to military forces if US armed forces need to intervene.

Arming autonomous logistical vehicles with anti-armor capabilities and operators acting in a human in the loop will provide commanders options in multi-domain battle. The ground force commanders will be able to bypass sections of enemy anti-armor platforms while still preventing them from targeting logistical lines of communication freely. This capability will also eliminate the requirement for logistical escort patrols. Ideally, a three-soldier team consisting of a driver, truck commander, and gunner could control a seven-vehicle logistical convoy. A logistical

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[66] *The Economist*, "Pride and Prejudice: The Odds on a Conflict Between the Great Powers," accessed January 25, 2018, https://www.economist.com/news/special-report/21735480-great-powers-seem-have-little-appetite-full-scale-war-there-room.

[67] Ibid.

vehicle convoy utilizing a human on the loop algorithm in the Leader-Follower has the potential to move supplies more efficiently for less cost of current capabilities.

Arming the autonomous supply convoys with anti-armor common control weapons platforms and cheap expendable drones will benefit maneuver, audacity, and tempo. An ABC algorithm that controls all the mounted direct fire weapon platforms and drones employed in a human in the loop system can maintain 360-degree security, identify potential targets, and engage targets. Commanders will have more latitude to bypass armored formations knowing their logistical convoys have an anti-armor capability.

The gunner will primarily monitor the integrated weapon system. An ABC algorithm will orient weapon systems to scan the area around and ahead of the convoy, identifying and nominating potential threats. The gunner will verify selected targets, allowing the autonomous algorithm to determine which vehicles from the convoy should engage the threat. AI can coordinate the engagement of direct weapons systems better than multiple independently operated weapons systems and allow fighting formations to apply the principles of direct fire control more effectively. Additionally, the weapons platforms not engaging the enemy will conduct parallel operations and continue to scan for additional threats to maintain security. The AI may also decide to launch expendable drones in swarms to overwhelm targets that utilize cover for survival. Swarms of expendable unmanned aerial vehicles launched from the logistics vehicles could assist in destroying threats while suppressing them with the direct fire weapon systems of the convoy. When gunners are unsure if a nominated target is a threat, the service member can direct closer investigation of the potential target and launch drones to investigate the danger while they are still on the move.

Engineers can incorporate the data archived from these autonomous vehicles and integrate it in future autonomous combat vehicle platforms. These concepts will facilitate expansion into unmanned anti-armor platforms teamed with manned armored combat platforms. The AI algorithms used to allow vehicles to operate autonomously can also facilitate target acquisition. The algorithm that identifies obstacles, other vehicles, and routes can also determine enemy combat platforms. Human-machine teaming will facilitate economy of force while not relinquishing the ability to overwhelm the enemy by maintaining the ability to maneuver and overpower him with mass at the objective.

In much the same way John Deere identified a potential for autonomy in an unregulated space, the military has an equal opportunity. The military must court leading civilian businesses by offering the industry an unmonitored area to develop autonomous capabilities and assist the government in developing the Third Offset. Implementing these capabilities on logistic vehicles provides a semi-permissive environment to work through unexpected problems and a launching pad to expand into more focused combat capabilities. In the future unoccupied autonomous platforms will conduct high risks tasks such as combined arms breach and clearing minefields under direct fire.

Uninhabited autonomously operating vehicles with a human in or on the loop offer vast possibilities over current capabilities. Autonomous systems are more persistent than their human counterparts. Autonomous systems will be cheaper and easier to manufacture because engineers will not have to design with protection of human occupants in mind. Machines also do not get tired and can operate for much longer and more frequently than their human counterparts.

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