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Copeland, Jason, C. Major, USMC

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A combination of emerging and existing technologies will shape the future As the number of platforms and data streams grow and become cost effective, from UAS, facial recognition, AI, a machine must replace the human to increase the capacity and processing speed. Swarms of limited AI enabled small-unmanned aerial systems (SUAS) will change the character of a future war and provide the necessary biometric targeting information to separate and target the adversary amongst the friendly or neutral population from whence they seek refuge from bullets and bombs.

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United States Marine Corps
School of Advanced Warfighting
Marine Corps University
3070 Moreell Avenue
Marine Corps Combat Development Command
Quantico, Virginia 22134

FUTURE WAR PAPER

Swarms of Flying iPhones: Using Limited Artificial Intelligence to Root Out an Adversary.

SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF OPERATIONAL STUDIES

AUTHOR: Major Jason C. Copeland, USMC

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Mentor: Dr Benjamin Jensen, Ph.D

Approved: _____

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The Commandant of the Marine Corps put forth the Marine Corps Operating Concept (MOC) in September of 2016 to spark an educated discussion on the future of warfare as well as the challenges that Marines will face.[1] The future challenge facing the Marine Corps stems from the need to divorce the civilian population from the adversary who hides, harbours, or simply lives unassumingly amongst them. The expectation is to use precision and smart weapons to limit the collateral damage of the local civilian populations as much as possible as most history suggests post the total war period in World War II. There is no reason to assume future wars will be any different. As history has demonstrated since phalanxes wielded pikes; evolving technology will make future wars more lethal. The 2018 National Defense Strategy prophesizes that "success no longer goes to the country that develops a new technology first, but rather to the one that better integrates it and adapts its ways of fighting."[2] This declaration seems obvious at first read, but what if the real problem is not a singular technology, but a combination of emerging and existing technologies? Unmanned aerial systems, still photograph and video fidelity, facial recognition algorithms, and artificial intelligence (AI) have increased in capability while reducing in cost and access in a few years providing real time targeting and information to forward units while the data sorting, collating, and cataloging of the data still moves at the speed of a human. As the number of platforms and data streams grow, a machine must replace the human to increase the capacity and processing speed. Swarms of limited AI enabled small-unmanned aerial systems (SUAS) will change the character of a future war and provide the necessary biometric targeting information to separate and target the adversary amongst the friendly or neutral population from whence they seek refuge from bullets and bombs.

Defining the Problem:

Marine Corps Doctrinal Publication-1 *Warfighting* (MCDP-1) reminds us of the Clausewitzian dictum the nature of warfare remains a truly human endeavour, the character

constantly evolves.[3] Therefore the discussion of future warfare will not be separated from technology integration. Even the most battle-hardened warriors in future conflicts will require a technological or cognitive advantage. The cognitive advantage for an infantry unit looking to root out an adversary is in the collection, aggregation, and identification of the adversary amongst the population. Overlapping technology, to include low-cost commercial platforms, can help create the advantage. The fights of the future, like those of the past 15 years of stability operations in the Middle East, will be intertwined with the local population. Like these population-centric conflicts, the onus is on the uniformed fighting force to distinguish the plain-clothes-clad adversary from non-combatant.

The populations around the world are also migrating closer to the sprawling coastal urban areas possibly leading to a more complex fight.[4] According to a United Nations study the estimated 47 per cent of the population of the world lives in urban designated areas, an increase from 30 per cent in the 1950s.[5] This urbanization trend is not likely to decrease in the future. The urbanization and centralization of a local population will continue to provide opportunities for an adversary to conceal itself within a large body of people. Despite the challenges associated with operations in urban or other complex terrain, the MOC reminds us that we cannot simply bypass this obstacle since "mission demands in complex terrain will place a greater requirement to conduct sustained, foot-mobile operations in and among populations."[6] Hence, there is arguably much more of a requirement to identify, separate, and target an adversary in future conflicts.

The current character of war across the range of military operations increases the need for speed and tempo and the synthesis of information. Processing, exploiting, and disseminating the petabytes of data will be impossible for humans to quickly process. The collection of information to sort is overwhelming and maybe even impossible to complete. To be relevant, the

information must be processed and intelligence returned at a much greater pace. Joint Publication 3-60 *Joint Targeting* describes a dynamic targeting environment as "the current operations 24-hour cycle that requires more immediate responsiveness than is achieve in deliberate targeting, or human targeting."[7] The average staff officer, even if that person works twenty four hours straight, most likely cannot produce actionable intelligence from the mounds of information to sort through.

Additionally, this Information, Surveillance, and Reconnaissance (ISR) support has a large manpower requirement to observe and dissect the downlinked feed. Extremely raw data comprised of ISR produced by the layers of UAS support flying over a theater of operations also compounds to problems of making sense of all the information feeds. According to Jon Harper in a January 2018 *National Defense Magazine* article he states the DOD has an "ISR Data Glut." The over 11,000 drones streaming and recording video at a non-stop pace around the world cannot effectively or possibly be analyzed only with a network of humans at video terminals.[8] Adding more UASs to the already overloaded system in search of the unblinking eye of surveillance compounds the problems of separating usable information from the white noise.

However, the military is rapidly investing SUAS systems for enhanced situational awareness at the small unit level. These SUAS are mostly for observation and tactical actions, but if the video feed could be analyzed, sorted, and stored then technology could create a cognitive advantage. This processing of information will overload a human system as the proliferation of SUAS enters the battlefield. In a technological age, the military must turn to the processing power of computers to sort through the video to identify the population. The computer is built to sift, catalog, and identify patterns unseen by shift work operators staring at a screen on a constant basis without the limits of human endurance. In short, machines that are

programmed effectively are much more effective at a seemingly mundane task with marginal human error or interaction on the streams of UAS data clogging a human constrained system.

Current UAS Platforms:

To effectively unclutter the data streams of information into usable intelligence, one needs to examine and refine the Unmanned Aerial System technology, UAS for short. The current size and classification of these systems ranges from smaller, limited range, quad copters to large armed National Level Assets, both armed and remote piloted. Group 5 is large UAS platforms with extended-range, on-station time, and the most enhanced optics. Group 1 is shorter in range, duration, and camera abilities. The Department of Defense has dramatically increased the UAS use around the globe increasing the intelligence, surveillance, and reconnaissance ISR capabilities and situational awareness over the past decade. However, once the full motion video passes over an area no data is recorded or exploited. Humans hover around screens trying to positively identify a hostile action or intent. There are petabytes of unexamined data lingering or lost when left solely to human eyes. The value of the ISR feed in the future will be centered on the data collection of the individuals in the videos.

Correctly identifying friend from foe in the population from thousands of feet above the surface of the Earths creates a challenge. The camera resolution on Group 5 UAS still at large distances struggles to produce a clear enough image to accurately recognize and identify a non-combatant from an adversary. Janes Information Group data on the RQ-4B Global Hawk Integrated Systems Suite is built around a dual infrared and radar camera with the "visible wavelength imagery as required."[9] To correctly identify people and targets on the ground, the military turns to the Group 5 UAS, the largest and most capable of the UAS family. The Marine Corps currently does not field a Group 5 UAS with the most capable camera and relies on the joint force for the information or must accept a reduced camera quality.[10] By noting the visible

spectrum last on the capabilities, Janes leads us to believe this is the least capable or at least the least thought of portion of the entire system. These UAS systems carry a very heavy price tag as well with Japan purchasing three in November of 2018 from Northrup Grumman for $489.9 Million US Dollars. At this price, a conventional ground unit most likely will never benefit from capabilities of this UAS and must rely on a smaller, less capable support. This ultimately creates an information gap in Marine areas of operations or lack of information to feed into intelligence gathering. The intelligence support needs to be as closely located to forward units with the population they patrol amongst now and in future fights.

The Marine Corps does not need to acquire a Group 5 UAS when existing technology can provide better resolution. The camera resolution in an iPhone has grown steadily over the past decade. An iPhone X can accurately depict a certain human face or fingerprint to unlock the cell phone. The 2010 iPhone 4 contained a five-megapixel camera, similar to the one on the current RQ-11 Raven used by the military. To put this in perspective, seven generations later the iPhone X sports a 12-megapixel capacity, and will only improve as time passes. However, attaining fingerprints and facial recognition from a large vertical distance will challenge most of the existing technology. Making an iPhone fly is altogether another challenge; however, the small size is about right for future small UASs.

Smaller and less capable UAS versions usually fall in to the Group 1 range similar to the RQ-11 Raven. Janes describes the Raven as a close range reconnaissance, surveillance, and target acquisition (RSTA) micro-UAV with a barely functional five-megapixel camera.[11] The Marine Corps transitioned to the Raven to standardize procurement across the US military as reported by Janes in November 2006.[12] While integrating parts and maintenance with the rest of the DOD is an important step, the UAS platform does not provide enough fidelity in the full

motion video for non-human, or computer-derived, targeting. Experimentation with future platforms will be critical to developing and acquiring the correct technology in future conflicts.

The Marine Corps continues to search and compare smaller UAS capabilities. Yasmin Tadjdeh in an August 2018 article in *National Defense* highlights the Marine Corps experimentation with eleven different platforms in the SUAS category.[13] These SUAS systems are cheaper to procure and operate as opposed to the Group 5 Global Hawk category. Also, with multiple SUAS working in conjunction with one another, a family of systems emerges to give the ground user a better situational understanding of the population in the operating environment. While the platforms themselves are most likely to evolve over the course of time, the characteristics for the SUAS should remain constant. The improvements need to focus on quality and more importantly quantity. The large quantity of information required is not generated from multiple SUAS operating in the same area. A swarm of SUAS working together with linked video data streams however can provide the information to separate adversary from population.

Swarms of SUAS:

Swarms, as defined in the 2017 CAN study, is inspired by nature, insects, birds, and other independent societies that "can perform tasks that are beyond the capabilities of any individual member."[14] While a swarm does require a set of rules or Queen to govern, the overall outcome is the complex adaptive system of systems working together for a desired outcome. The desired outcome is part of the interactive programing required for the Swarm of SUASs to be effective. A mass of SUAS operations will provide multiple camera angles, depth, and fidelity to an operating environment. In every operating environment, there will be dead space, avenues of approach, large distances between units, or even human terrain that needs to be mapped and

patrolled. Swarms of SUASs can aide the commander to cover gaps in observation, real time imagery in security patrolling efforts, and provide locally sourced information.

Additionally, swarms are not new in military history or even future conflict studies. Overwhelming an enemy with a concentration of volume of forces and firepower from multiple directions is an ingredient in most military battles and campaigns. Authors John Arquilla and David Ronfeldt of RAND Corporation published a study in 2005 entitled "Swarming and the Future of Conflict" studying animal, insect, and human "swarms" to develop a BattleSwarm doctrine based off historical case studies.[15] These case studies go back hundreds of years and multiple domains however usually limited in scope to a single domain at a time. The authors posit that the BattleSwarm doctrine will be an evolution of the AirLand Battle to win future conflicts. However, the authors also agree the BattleSwarm is going to need to be further developed outside of a national defense research institute publication.

The military will need to produce the swarms of SUAS. However, the military will also require civilian engineering and expertiese. Civilian industry leaders are rapidly producing the swarm technology not only for military purposes also. Adam Stone notes in " Gremlins and Swarms" that the US Air Force is producing "dozens or hundreds of highly autonomous drones acting in coordinated fashion" to maneuver and attack aircraft.[16] This approach by the Air Force minimizes the risk to mission and the force to counter a threat. The same concept and technology can be adapted to separate an adversary from the population.

The Swarm concept is currently being examined by Dr. Timothy Chung in the Defense Advanced Research Projects Agency (DARPA) led Offensive Swarm-Enabled Tactics (OFFSET) for small unit infantry forces.[17] In OFFSET, the Swarms will operate in diverse missions in complex, compartmentalized terrain. In compartmentalized terrain, swarms of drones could navigate more easily than humans. The swarms can map the terrain for following the lead

UAS, learning for the group that follows. The following iterations can then navigate the same corridor at increased speeds and with greater accuracy with each pass. The internal dynamics of the swarm tactics within a predetermined program or self-generated path are for the engineers to solve. The required outputs or information requirements are for the military, specifically the infantry formations, to define.

Artificial Intelligence

Artificial Intelligence (AI) is the technology that has the potential to create a breakthrough in autonomous processing information. Autonomous processing information, as defined by DOD Directive 3000.09 *Autonomy in Weapon Systems,* establishes policy for the development and use "to minimize the probability and consequences of failures in autonomous and semi-autonomous weapon systems that could lead to unintended engagements."[18] The policy, written more for the application of kinetic fires, broadly outlines three categories for autonomous: *Semi-autonomous*: human "in the loop," *Human-supervised:* human "on the loop," and *Autonomous:* human "out of the loop." For targeting and removing an adversary from the local population, a fully autonomous human "out of the loop" would be the preferred route. However, there are challenges in the UAS platform to acquire and layer the data in a population-centric campaign.

Project Maven, a Department of Defense (DOD) initiative founded on April 26, 2017 created the first initiative to "augment or automate Processing, Exploitation, and Distribution (PED) for tactical UAS and Mid-Altitude Full Motion Video (FMV) in support of the Defeat-ISIS campaign."[19] With the heavy assistance from Google AI teams, the DOD increased the effectiveness and efficiency of analyzing the video to distinguishing inanimate objects from people using limited AI. With a human in the loop as in Project Maven, the computer program quickly identified weapon systems and objects in hours of ISR feeds, freeing the analyst to focus

on the applications where human intuition was required. The byproduct of the artificial intelligence of Project Maven is the increase in accuracy and speed of discerning the objects of interest.

This is the value of artificial intelligence in a computing program that learns and evolves at it solves problems. Thomas Davenport and Rajeev Ronanki describe the learning from AI as "cognitive insights" in a 2018 *Harvard Business Review* article. They also state that machine learning can detect patterns in vast volumes of data and interpret their meaning.[20] This research into the "cognitive insights" is also described as "analytics on steroids" detecting patterns either unknown to humans, or at such a rapid rate that a human could not keep up. The analytics speed is what makes the AI a valuable asset in adversary identification. The military cannot develop the AI on its own and must be assisted by civilian industry.

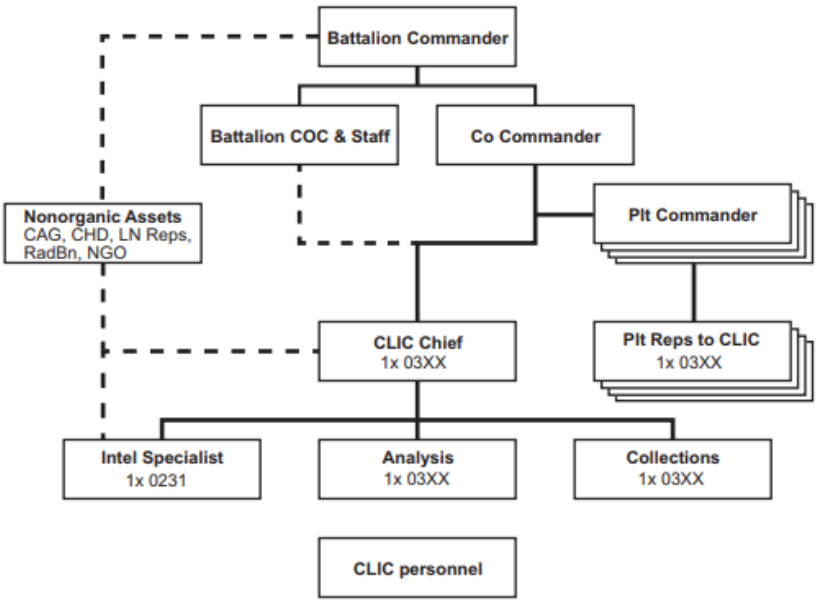
For example, the use of smart phones is becoming more ubiquitous around the globe. Not only are younger generations inundated with screen time at early ages, elder generations that are not "digital natives" are users as well. One of the most well known brands of smart phones is an iPhone, which as early as 2011 in the iPhone 4s introduced us to the "Siri" function.[21] This voice recognition narrow AI function demonstrated the ability for a remote hardware system to "learn" the owners voice and respond accordingly on command. Additionally, by 2013 the iPhone 5s compounded the Siri function to include a "touch ID" also learning to recognize any fingerprint entered into the phone. By 2017, the iPhone X could learn and recognize a face to unlock the phone devised "Facial Recognition" AI feature. In a military sense, the data collection from many of these Siri, Touch ID, and Facial Recognition functions could be documented and stored to map the human terrain with already programed "unique" voices, fingerprints, and faces. This is an example of the civilian industry developing a capability for commercial use that also has military applications.

Civilian industry is also developing AI applications that would overlap with military needs. On April 10th, 2018, Facebook Chief Executive Officer Mark Zuckerberg testified to the US Congress about privacy surrounding the facial recognition software it employs on users of the social media site.[22] When a user uploads a picture, the Facebook AI system uses a computer analytic model to identify faces, infer behavior, and link other users together that may be "friends" on the site. Facial recognition and machine learning is used by airports and other security agencies to quickly screen passengers and also log potential travelers with stolen or counterfeit passports.[23] Two such travelers were even caught using the system in Washington, DC's Dulles Airport.[24] Recognition and sorting of friend and foe amongst a neutral population for law enforcement but also a military formation in a combat situation would provide a cognitive edge. However, sorting through all the data inputs from Facebook to Facial recognition would overwhelm even the most intelligent and driven human and even a Marine.

U.S. Marine Corps Specific:

Specifically, a Marine Corps squad already has more than enough to be concerned without manually sorting through digital data. The Marine Corps Squad has recently re-organized to include an assistant squad leader and systems operator to fly the squad's UAS and other technology centric advances.[25] Arguably there could be a cognitive overload for a leader executing commanders' intent, fighting three fire teams, and trying to integrate and make sense of a UAS feed while winning a firefight. The individual squad leader should not have to focus on the direct employment or application of supporting SUAS swarms. However, they could effectively receive redirecting intelligence for a patrol based on subsequent intelligence updates produced by the swarms of SUAS supporting, compiling, and sorting real time information into intelligence.

Redirecting this information must be integrated into Company Level Intelligence Cell (CLIC) formation. Inside the CLIC resides the capacity and capability required to effectively integrate the SUAS Swarms with the Company Operations Section and Fire Support Teams. Also integrated at the company headquarters level is the power capacity and ability to link the home base station to larger data centers at higher headquarters locations. The CLIC formation identified in the Marine Corps Information Publication 2-1.01 Company Level Intelligence Cell is already resident without a change to the table of organization. Either a representative from another "Nonorganic Asset" can add the information from the swarms of SUASs or simply a link to the database can plug straight into the CLIC Intel Specialist.



Legend:

CAG - civil affairs group
Co - company
Intel - intelligence
LN - local nationals
NGO - nongovernmental organization
Plt - platoon
RadBn - radio battalion
Reps - representatives

Figure 1-1. Notional Infantry Battalion Company Level Intelligence Cell Organization.

Either way, as seen in the diagram, the structure already exists. The intelligence gathered will assist the platoon and company commanders without adding another screen to the squads making split second decisions. The focus will not be on filling out a census data sheet during a patrol, which dominates the experiences of many Marines in Iraq and Afghanistan. Historian James Russell outlines in his 2011 book *Innovation, Transformation, and War* the profound impact of the squad size "census patrols" conducted by 1st Battalion, 6th Marines during the Anbar Awakening in 2006-2007 in Ar Ramadi, Iraq.[26] The identification of key tribal and religious leaders became a cornerstone of helping to secure an area, even though by 2007 a Marine battalion had already rotated through Ar Ramadi six times. If five other Marine Battalions did not populate a digital database to turn over information and intelligence on an area, a squad patrol of thirteen Marines through the city of almost 500,000 people speaking a foreign language with multiple dialects is all but impossible as a strictly human endeavour.

Putting it all Together:

The census operations, or patrols to identify the population, used to be strictly a human endeavour, but with the proliferation and advancement in technology in small-unmanned aerial systems additional capabilities are available for tomorrow's fight amongst the population. History in recent conflicts in the Middle East remind us to assume that there will be other sympathizers, enablers, conscriptions, and anti-US foreign fighters that will join the conflict, only increasing the size of the adversaries. The data required will not be harvested by a single SUAS. Swarms of SUASs will scour the area of operations with smart phone-like facial and voice recognition capabilities providing real-time information back to a machine learning enabled database. This information will be then processed and overlapped with existing data using limited AI. In this way a face, name, location, and a host of other information can identify

each individual amongst the crowds of people, helping to separate adversary from his sanctuary amongst the people.

In the future, advances in camera fidelity, AI technology, and battery power will make that Marine simply a synthesizer of information provided by an autonomous swarm and AI-backed satellite patrol. The swarms of SUAS required will need enough battery life for a short period of flight with the ability to recharge at the base station, or hive, which also is the data terminal for the images gathered. The data terminal and charging base would transmit back the images to a central computing database to merge with existing biometric data on local population, terrain, patrol routes, and any other anomalies. The limited "on the loop" artificial intelligence at the data center will allow for faster analysis of the data to transmit back to the forward edge of the battlefield increasing lethality of the ground formation. The lethality, scale, scope, and effectiveness of any ground unit, squad included, would dramatically go up, and alleviate the burden of watching a single screen the entire time.

In addition to increasing lethality, the cost savings of operating the SUAS are significant. Unlike Group 5 Global Hawk valued at millions of dollars, the SUAS swarm should be developed with disposable technology that can be upgraded or replaced quickly. By keeping the platform small like the PD-100 Black Hornet or the Sky Ranger, the Marine Corps will be able to quickly adapt upgrades as they become available, similar to the iPhone and the increasing camera fidelity.

However, cost savings are not the only thing that drives innovation. Killing the adversary also drives innovation. Hidden within the data and civilian population are combatants and targets. To destroy the targets, the military writ large operates under a "hostile act or hostile intent" authenticated by a human. Weapons release will most likely never defer to an automated system to kill a human combatant, even in the most horrific and bloody combat scenarios.

However, the data collected before the decision to target another human can be exploited by machines to shorten the decision to strike. By removing the autonomous from weapons release authority in the set "rules" provided to the AI, the ethical and possible legal concerns cease to exist.

Barriers to Progress:

There are numerous challenges implementing the swarms of AI SUASs on the battlefield. The challenges are not rooted in organization or training or any other aspect of DOTMLPF but the new "P" which is privacy. Privacy concerns and debates will no doubt erupt within the United States and abroad for storing non-combatants biometric data information. Ensuring the facial recognition and biometric data collected of US citizens and other non-combatants are not stored post conflict termination could mitigate this potential hazard. This does not account for adversary and non-combatant data, which could be separated and destroyed for the case of non-combatants, or retained for future transnational and trans-regional conflicts.

Additionally, the technology for an effective SUAS is simply not available yet. The flying iPhone would need a mult-megapixel camera, long loiter times in the air, extended range from the base station which recharges the SUAS, and a high bandwidth data downlink. The power requirements of a swarm box and charging station alone will be cumbersome and challenging with current battery technology and power generation requirements at the company level. Industry and military minds are looking for ways to solve these problems quickly. That said, the technology must also develop at a much lower price point for the military to fully invest in the capabilities.

Lastly, industry partners similar to Google and Project Maven need to continue to develop the AI capabilities to for exploitation. This will be a challenge in the future for the military as many of the employees working on the project signed a petition to no longer be

associated with the project citing deep ethical grievances.[27] These concerns have not stopped the DOD from further investing in AI research at $2 Billion Dollars over five years in September of 2018.[28]

Conclusions:

The 2018 National Defense Strategy predicts "new commercial technology will change society and, ultimately, the character of war."[29] This commercial technology to change the character of war is not singular. A combination of technologies specifically swarms of integrated small UASs leveraging AI, and sophisticated cameras for facial recognition will change the character of future war. These swarms of SUASs will assist the ground commander in finding the adversary hiding in plain site amongst a neutral population. The technology application is currently limited both by computing power as well as the clarity of the video feed from large, high flying, expensive, and remotely piloted UAS platforms. To be fully effective, the UAS must close the distance on the population to compile a database of higher resolution photos for exploitation by machine learning computers.

As the MOC reminds all leaders "no level of automation or use of robotics will replace the fact that war will always center on violence directed by humans against other humans."[30] That said, the violence in future wars will undoubtedly need a technological edge to offset the advantages of an adversary hiding in plain sight. The advancements in technology would not occur if the overlapping problem sets are developed independently. The Marine Corps, and military has identified a problem, and the solution is in the integration and overlapping of AI, Swarms of UASs and the advancement of camera resolution to save innocent human lives, not indiscriminately target them. To win the future conflicts the Marine Corps must find ways to "exploit man-machine and artificial intelligence interface to enhance performance" as the MOC directs.[31]

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