Potential for Army Integration of Autonomous Systems by Warfighting Function

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Strategists analyze military history to understand the evolution of war. However, they often turn to science fiction to predict the future of war. *Star Wars: Episode 1–The Phantom Menace* captures a standard vision of the future of ground combat—autonomous robots marching into war with the guidance of their human overlords. This view follows fairly simple logic: Combat is dangerous, so why not use technology to reduce the risk to humans? Meanwhile, other movies are equally adept at capturing the opposing view of the use of autonomous systems in combat. Take *The Matrix* and *Terminator* movies as examples. These movies preach a cautionary tale that autonomous systems can create an unparalleled capacity to destroy an adversary; however, left unchecked, the overuse of autonomy can destroy humanity.

These beliefs are captured in the Army's official stance toward the use of autonomous systems, which clarifies that autonomous systems are intended to support the warfighter, not replace them.[1] As such, the vision of dropping a large number of robotic combatants onto a battlefield, as seen in the *Star Wars* movies, is science fiction. However, the use of autonomous systems moving soldiers into combat is readily becoming science reality.

It is widely known that the Army has steadily been investing in the development of autonomous systems. As shown conceptually in figure 1 (on page 124), which plots the combat power of the Army against the total end strength, the use of autonomous systems provides a strategic advantage. Autonomous systems provide a combat multiplication factor that allows the Army to increase its combat power while potentially reducing troop numbers. Currently, the investments in autonomy are limited by financial constraints as well as the state of technology. Though these limited investments still result in a significant increase in the combat multiplication factor, these increases are small compared to what is possible if autonomous systems are integrated to their maximum capacity.

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Marines with 3rd Battalion, 5th Marine Regiment test new equipment such as the unmanned Multi-Utility Tactical Transport (MUTT) vehicle 8 July 2016 in a simulated combat environment at Marine Corps Base at Camp Pendleton, California. The MUTT is designed as a force multiplier to enhance expeditionary power, enabling marines to cover larger areas and providing superior firepower with the smallest tactical footprint possible. (Photo by Lance Cpl. Julien Rodarte, U.S. Marines)

This article sets out to explain the maximum extent that the Army can integrate autonomous systems into its operations given the inherent limitations of the technology. These limitations determine the appropriateness of using autonomous systems to perform each of the broad range of Army tasks that are captured through the warfighter functions. While certain tasks will remain human driven, other tasks can be fully automated, although most tasks will fall somewhere between. In turn, this analysis provides insights and guidance into the resource allocation and implementation of autonomous systems.

Warfighting Functions

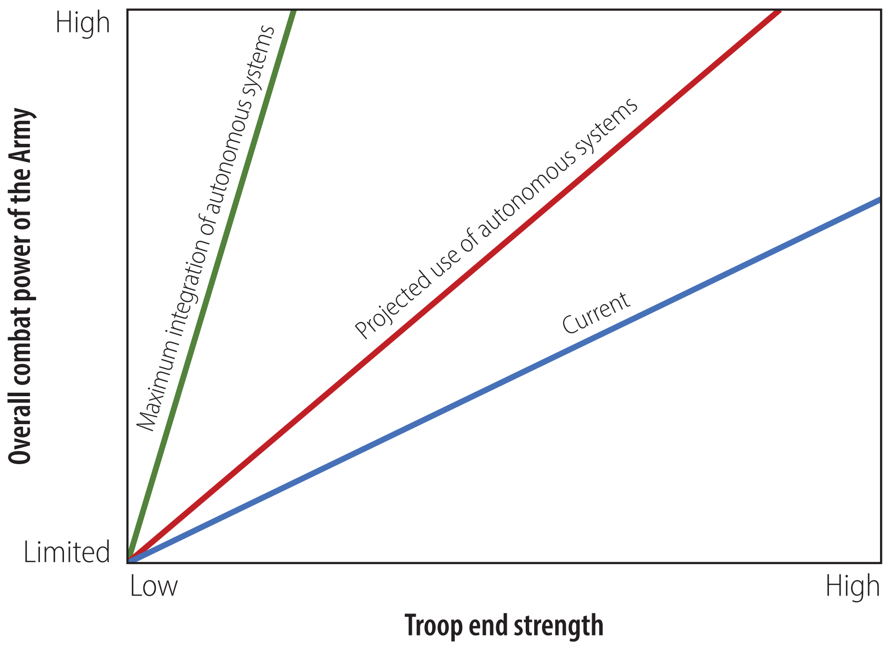
To remain competitive in a multi-domain operational environment, the question is not "should we" but "where do we" become more autonomous? The Army is made up of over a million different soldiers comprising over 450 different military occupational specialties, ranging from infantrymen to plumbers to veterinarians. Some of these jobs could greatly benefit from the addition of autonomy while others would not. The broad range of tasks associated with these different duty positions are typically captured in the six warfighting functions.

A warfighting function is a group of tasks and systems (people, organizations, information, and processes) united by a common purpose that commanders use to accomplish missions.[2] The six warfighting functions of the U.S. Army are

- mission command: the integration of the other five warfighting functions to enable a commander to balance the art of command and the science of control;
- movement and maneuver: the achieving of a position of relative advantage over the enemy and other threats to the employment of force;
- intelligence: the gathering and processing of information to develop an understanding of the enemy, terrain, and civil considerations;
- fires: the use of Army indirect fires, air and missile defense, and joint fires through the targeting process;
- sustainment: the providing of support and services to ensure freedom of action, extend operational reach, and prolong endurance; and
- protection: the preserving of the force so that a commander may apply maximum combat power to accomplish a mission.[3]

Each warfighting function is comprised of several top-level subfunctions. For example, the sustainment warfighting function includes providing logistics, personnel, and health-service support. In turn, each of these top-level subfunctions include several lower-level subfunctions. Providing logistics support, for example, comprises providing maintenance, transportation, supply, field services, operational contract, distribution, and general engineer support.

Altogether, 205 different lower-level subfunctions constitute the full scope of Army missions.[4] These lower-level functions are fairly specific and provide enough granularity for analysis of the appropriateness of autonomy for that function. For example, little autonomy can be applied toward providing religious support. However, a high level of autonomy can be applied toward employing communications security. The results are then aggregated up for each top-level subfunction and warfighting function.



(Figure by authors)

Figure 1. Trade-Off between the Overall Combat Power and Troop End Strength at Varying Levels of Integration of Autonomous Systems

Rules for Autonomy

A review of different federal policies and strategies provided a set of rules related to the implementation of autonomous systems in ground combat. The appropriateness of applying autonomy to each lower-level subfunction is subject to the following six rules:

1. Autonomous systems should be used over humans in potentially dangerous situations, subject to the other rules.
2. Autonomous systems will be preferred over humans for computationally intensive tasks, thus allowing an overall reduction in the likelihood of human mental errors. Similarly, autonomous systems should be used for severely mundane tasks that require mental endurance.
3. Military command positions, whether they be American, allied, or adversary, will remain human.
4. Humans will be preferred over autonomous systems for certain tasks that require a human-to-human connection, such as key leader engagements and chaplain support.
5. The usage of autonomous systems cannot result in a decrease in the Army's ability to perform its missions.
6. Human judgment, or "human-in-the-loop," will be required for any activities that involve killing a human.

The United States has already laid the groundwork for the sixth rule with Department of Defense Directive 3000.09, *Autonomy in Weapon Systems*, which limits the development of autonomous weapons that do not include humans in the kill chain.[5] On a global level, similar initiatives are underway, since autonomous killing systems would set off a technical arms race where countries would rapidly develop more advanced artificial intelligence with faster kill chains.[6]

Levels of Autonomy

While autonomous systems are often envisioned as Terminator-style robots, in reality, autonomous systems can range from automated payroll software to remote-controlled drones to cruise control on vehicles.

With a broad range of levels of autonomy, it is useful to categorize autonomy into fixed ranges. The table displays four different levels of autonomy that will be used for this analysis.

A value of 0 indicates that no automation is currently being used; an example of an autonomy level of 0 would be driving a traditional car. A value of 1 indicates that a human uses an automated system to increase their ability to complete the task, such as a cruise control system in the car. A value of 2 indicates that the human and automated system are working together to complete the task, though the human is primarily providing the system with inputs, such as a "self-driving" car with a backup human or remote operator. A value of 3 indicates that the human is taken out of the loop, and the system is performing the task on its own, such as a fully autonomous car that can navigate itself through traffic from one waypoint to another.

Each lower-level subfunction of the warfighting function was analyzed to determine the maximum level of autonomy subject to the rules identified in the previous section.

Table. Different Levels of Autonomy

Autonomy Level	Description
0	No autonomy, humans only
1	Automated system aids humans
2	Human manages automated system
3	Automated system only

(Table by authors)

(Figure by authors; subfunctions in blue italics indicate areas currently using autonomy)

Figure 2. Autonomy Levels for the Intelligence Warfighting Function

Intelligence Warfighting Function

The intelligence warfighting function is the most pervasive and encompassing task in the military because its results drive all operations.[7] As shown in figure 2, the intelligence warfighting function is made up of four subfunctions with the potential to use a significant amount of autonomy.

Currently, autonomous systems are supporting human analysts in virtually all of the subfunctions, since they allow the analysts to more readily collect and process data. Unmanned aerial vehicles have been used for intelligence gathering for decades. Additionally, autonomous software codes are used for cyberspace monitoring to gather intelligence. There are also systems under development, such as the U.S. Special Operations Command's hyper-enabled operator, that will use a higher level of autonomy to automate the full intelligence process from collection to analysis.

The use of autonomous systems for these warfighting functions are driven by rules 1 and 2. Intelligence gathering is a dangerous activity, often requiring humans to travel behind enemy lines to collect data about the enemy and terrain. Much of this data can be collected by autonomous systems as they have the capacity to collect and process a large amount of raw data.

Despite these benefits, certain subfunctions are limited in the amount of possible autonomy. Intelligence support to ground operations will still require a human-in-the-loop to understand the human dimension associated with ground operations. Additionally, targeting requires a human-in-the-loop to allow for human judgment in the data analysis. However, intelligence support to situational understanding, and intelligence, surveillance, and reconnaissance can both achieve a fairly high degree of autonomy.

Movement and Maneuver Warfighting Function

The movement and maneuver warfighting function encompasses those functions involved in moving and employing direct force against enemy forces.[8] The subtasks include maneuver operations, tactical movements, direct fires, occupying areas, performing reconnaissance, and other related tasks. Figure 3 (on page 127) displays the possible levels of autonomy for the movement and maneuver warfighting function.

Currently, there is a large push to integrate autonomy into this warfighting function, especially for the tactical movement and reconnaissance subfunctions. For example, the Squad Multipurpose Equipment Transport is a robotic vehicle that follows a dismounted squad, enhancing their movement by carrying much of their equipment. Another important effort is the Future Vertical Lift Aircraft, which will include autonomous flight capabilities, allowing units not to be constrained to the human-limits of flight crews.[9] Several other programs, such as the Defense Advanced Research Projects Agency's Squad X Experimentation Program, are looking at further enhancing the use of autonomous systems, especially for reconnaissance.

Several projects also involve integrating autonomy into tactical maneuver and direct fire operations.

A QinetiQ Talon 5 robot moves a drone 7 May 2019 during a Raven's Challenge exercise at Winter Park, Colorado. Raven's Challenge is an annual event that provides interoperability training in a realistic, domestic, tactical environment to explosive ordnance disposal personnel and public safety bomb squads of both military and government agencies. (Photo by Sgt. Zakia Gray, U.S. Army)

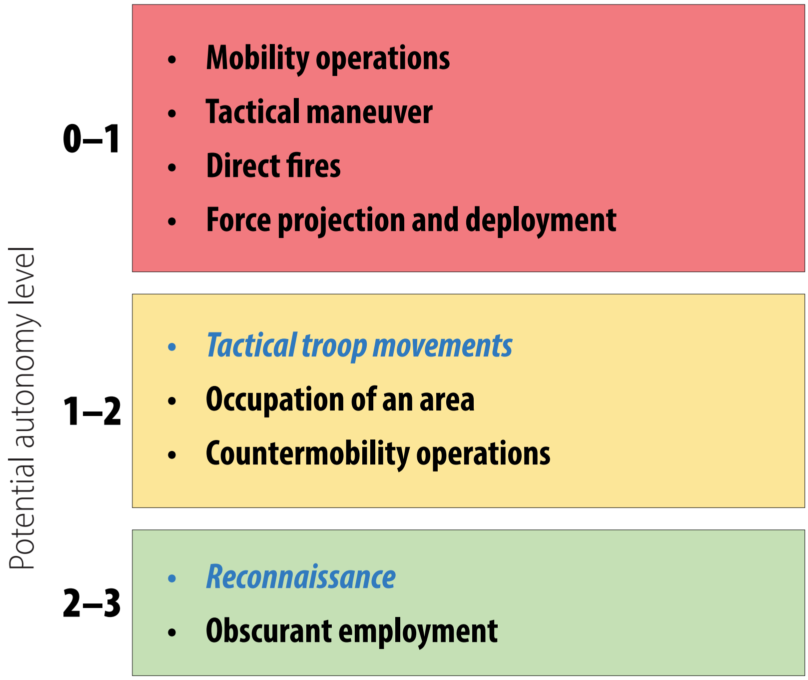


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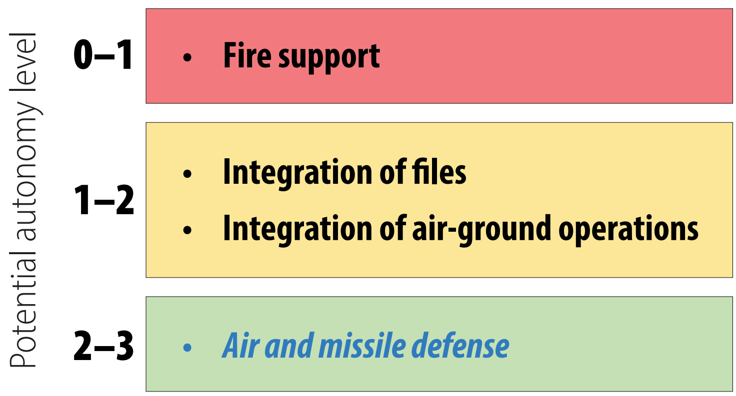
Figure 3. Autonomy Levels for the Movement and Maneuver Warfighting Function



(Figure by authors; subfunctions in blue italics indicate areas currently using autonomy)

Figure 4. Autonomy Levels for the Fires Warfighting Function

However, these projects are fairly constrained, such as the Advanced Targeting and Lethality Automated System Program, which is simply a remote-operated gun on a mobile platform that provides additional standoff from a target; however, it still requires a designated operator.

The level of autonomy is set for the movement and maneuver warfighting function based on rule 6, and a high level of autonomy is possible for two of the subfunctions—performing reconnaissance and employing obscurants—because they do not require the use of lethal force. A lower level of autonomy can be integrated into three of the other subfunctions—tactical troop movements, occupying an area, and countermobility operations. These subfunctions can involve the use of force, so human involvement is required though it can be primarily oversight. The other four subfunctions—mobility operations, tactical maneuver, direct fires, and force projection—involve the direct use of force, as such, autonomy can be used in only a very limited capacity.

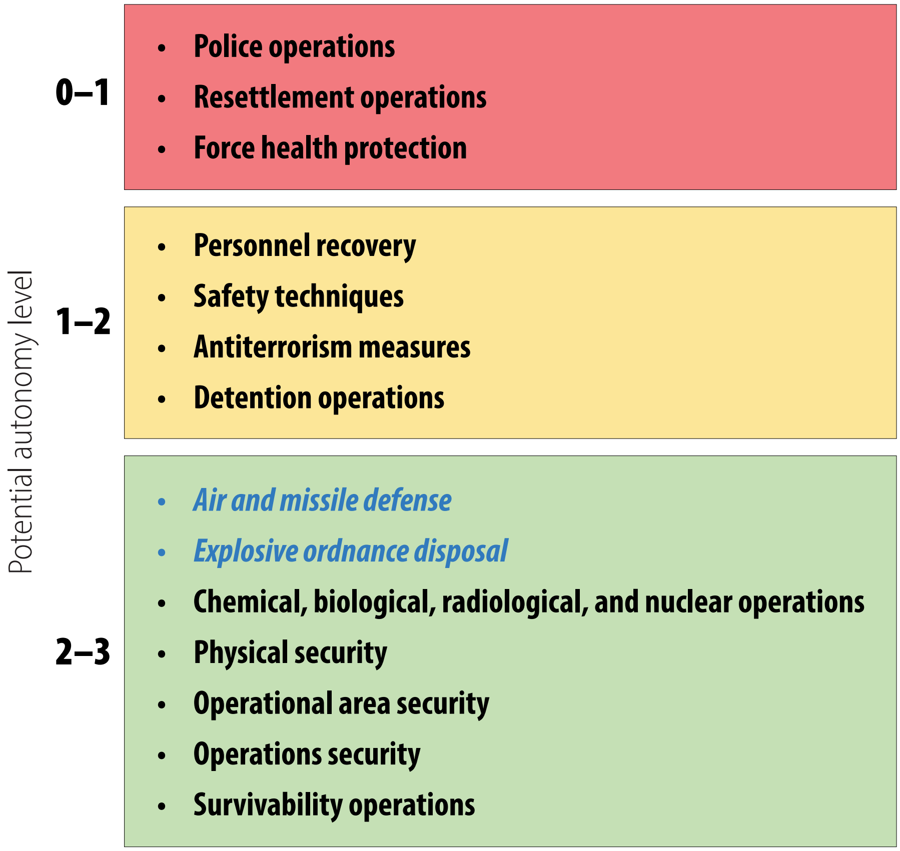
The integration of autonomous systems is fairly limited by the requirement of having a human in the kill chain. As such, autonomous systems are more useful for defensive operations than offensive operations. Offensive operations involve closing in on and killing the enemy, which inherently requires a human in the loop. However, security and defensive operations tend to involve deterring the enemy, which can be done without lethal force, hence allowing autonomy.

Fires Warfighting Function

Army Doctrine Reference Publication 1-03, *The Army Universal Task List*, gives the four top-level subfunctions for the fires warfighting functions: integrate fires, provide fire support, integrate air-ground operations, and employ air and missile defense.[10] Each subtask and the associated autonomy levels are displayed in figure 4.

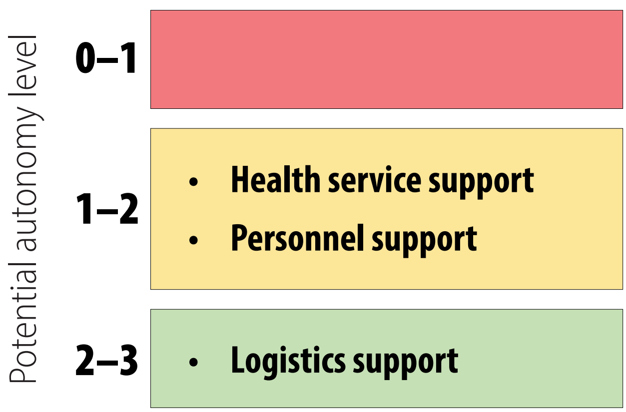
The current usage of autonomy in the fires warfighting function is limited to detecting threats and supporting the computations required for providing direct fire support. However, humans are still required to aim and fire weapons. Most artillery systems, such as the M109 Paladin, include computer software to help automate the targeting process. Additionally, these systems are being upgraded with advanced automated technology to allow for better threat detection, faster targeting, and automated aiming.

Similar to the movement and maneuver warfighting function, rule 6 sets which subfunctions in the fires warfighting function can use autonomy. Fire support involves the direct employment of force against an enemy, so although autonomy can support the soldier, its usage is limited. The integration of fires and air-ground operations are both supporting subtasks. Therefore, a certain amount of autonomy is applicable, although humans are still required for prioritization of fires. Air-missile defense is a defensive operation and does not require killing humans. Additionally, it is a computationally intensive process that requires very fast action. As such, this subfunction is ripe for the use of autonomous systems.



(Figure by authors; subfunctions in blue italics indicate areas currently using autonomy)

Figure 5. Autonomy Levels for the Protection Warfighting Function



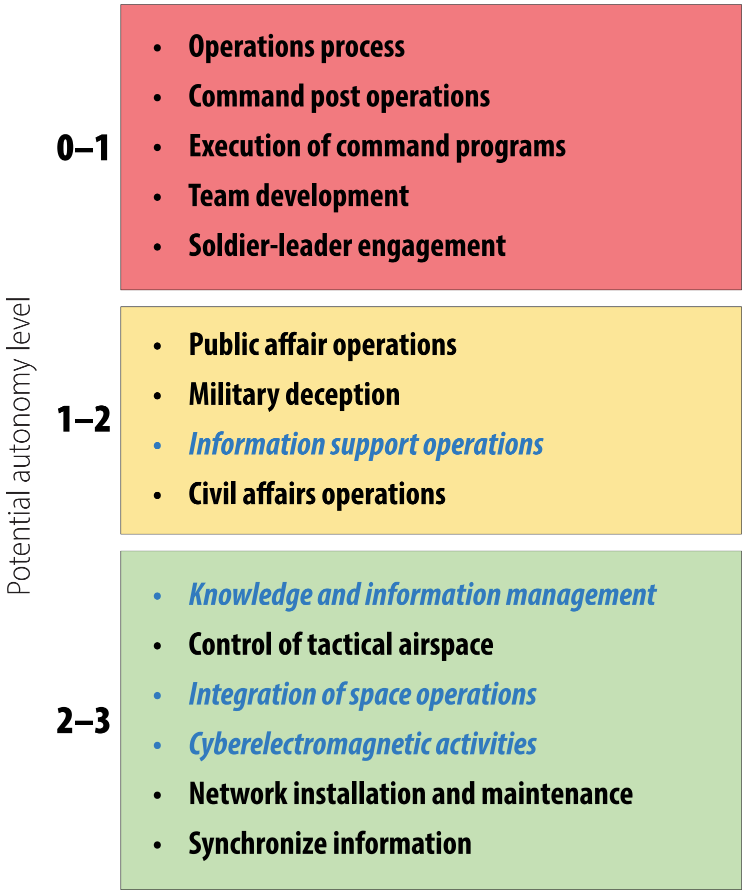
(Figure by authors)

Figure 6. Autonomy Levels for the Sustainment Warfighting Function

Protection Warfighting Function

The protection warfighting function is comprised of fifteen top-level subfunctions ranging from law-and-order operations to explosive ordnance disposal to air-missile defense.[11] These subfunctions are categorized by their possible levels of autonomy in figure 5.

The protection warfighting function is primarily defensive in nature. As previously discussed, autonomy can be better applied to defensive operations rather than offensive. However, the use of autonomy for this warfighting function is set by rule 4, since some of its functions require substantial human-to-human interaction, including police operations, resettlement operations, and health protection. Other subfunctions still require some human-to-human interaction, such that a human must be kept in the loop. These subfunctions include personnel operations, safety, antiterrorism measures,



(Figure by authors; subfunctions in blue italics indicate areas currently using autonomy)

Figure 7. Autonomy Levels for the Mission Command Warfighting Function

and detention operations. However, the bulk of the tasks associated with the protection of warfighting functions can incorporate a large amount of autonomy.

Despite the high potential, the current usage of autonomous systems in the protection warfighting function is somewhat limited. Air-missile defense systems use autonomous systems to track and destroy incoming fires. Additionally, explosive ordnance disposal personnel use remote-controlled autonomous systems such as TALON and PackBot robots to provide standoff from explosives.

The protection warfighting function has numerous opportunities for the use of advanced autonomy in future operations. These opportunities are for a number of reasons. First, protection is inherently responsive in nature, such that an action is performed following a specific input. These actions normally require a fast response time, and autonomous systems have the potential to have faster response times than humans. Second, many of the tasks follow doctrinal steps, which require minimal human judgment and are ripe for autonomy. Third, many of these tasks involve placing humans in compromising positions.

Take survivability operations for example. The construction of a fortified battle position requires digging fighting positions and placing and filling Hesco baskets (used to construct large barriers). A remote-operated front loader, often used for commercial applications, would allow a soldier to perform these tasks from a protected location. With further integration efforts, one could imagine drawing a battle position on a map, and a team of autonomous systems surveying the area, performing the threat assessment, designing an optimal battle position, and constructing it prior to humans arriving on-site. Upon completion of the fortified position, autonomous systems could help detect and deter encroachment into the area.

Sustainment Warfighting Function

The sustainment warfighting function is broken down into three high-level tasks: logistics, personnel, and health service support.[12] Figure 6 (on page 128) displays how much autonomy can be applied to each of these subfunctions.

Currently, autonomous systems are used sparingly for the sustainment warfighting function. Automating the tasks that fall under logistics would require significant updates to the bulk of military vehicles and equipment. This process is expensive, resources are limited, and current sustainment capabilities are sufficient. However, with the increased threat of improvised explosive devices and the dangers associated with convoy operations, autonomous convoys, which leverage self-driving technology, would reduce troop numbers while also saving lives.

Similar to the protection warfighting function, rule 4 sets the limits on the maximum autonomy levels for each subfunction. Both health service support and personnel require a certain amount of human-to-human interaction; however, certain portions of these subfunctions can be automated.

For example, financial management support, which falls under personnel support, can benefit from autonomous software that handle payroll. However, chaplain support, which also falls under personnel support, will still require a chaplain.

Logistics can achieve a significantly higher degree of autonomy. Many of the tasks included under logistics support follow set procedures; for example, performing preventive maintenance checks and services on a vehicle requires going down a checklist and making sure that the vehicle functions properly. When processes follow very set procedures, they are ripe for autonomy.

Additionally, there are numerous strategic benefits from incorporating autonomy into the sustainment warfighting function. The displacement of humans by autonomous systems would expand operational reach. Enemies have traditionally targeted supply lines as easy targets, which then require additional security, drawing away soldiers from more critical missions. Autonomous systems would require less security and can assume more risk, allowing them to move faster and through areas that are not safe for humans.

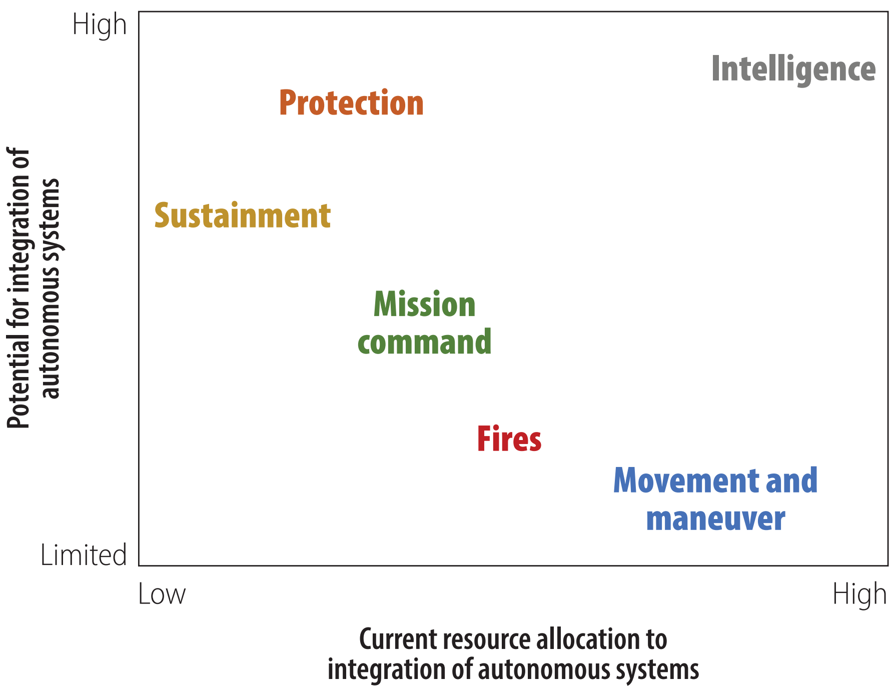
A marine with 3rd Battalion, 5th Marine Regiment looks down at an autonomous "dragon fire" system 13 July 2016 at Marine Corps Base Camp Pendleton, California. The system, meant to enhance observation of an enemy before marines engage them, was built by the Marine Corps Warfighting Laboratory. It is durable, invertible with front and rear cameras, and both day and night capable. (Photo by Lance Cpl. Julien Rodarte, U.S. Marines)

Mission Command Warfighting Function

As the name implies, the mission command warfighting function involves providing command guidance and leadership to integrate the other five warfighter functions to perform unified land operations. The mission command warfighting function can be broken down into fifteen subtasks, which are categorized by possible autonomy levels in figure 7 (on page 129).

Rules 3 and 4 set the maximum limits for the use of autonomy in this warfighting function. Leadership and command guidance must be provided by humans, so autonomy is limited for the operations process, command-post operations, and execution of command programs. Additionally, human-to-human interactions are required for team development and soldier-leader engagements. A slightly higher degree of autonomy can be applied to tasks that are not directly tied to leadership positions. These tasks include public affair operations, military deception, information support operations, and civil affairs operations. However, the usage of autonomy will only play a supporting role due to the necessary human-to-human interactions associated with these tasks.

Several of the subfunctions are tied to the virtual domain, and the application of automation would greatly enhance these subfunctions. These include knowledge management, control of tactical airspace, integration of space operations, cyberelectromagnetic activities, and network and synchronizing information.



(Figure by authors)

Figure 8. Current Resource Allocation toward the Integration of Autonomous Systems Plotted against the Overall Potential for Integration

Due to the requirement of humans being in leadership positions, little effort has been put into developing autonomous systems to support this warfighting function. However, there is a significant opportunity for certain subfunctions that are not related to being in leadership positions.

Current Resource Allocation toward Autonomy

Figure 8 plots the current resource allocation toward autonomous systems against the overall potential for integration. The plot shows that a significant amount of resources are allocated for the intelligence, movement and maneuver, and fires warfighting functions. However, both the movement and maneuver and the fires warfighting functions are limited into how much total autonomy can be applied to it. Meanwhile, much fewer resources have been allocated for the protection and sustainment warfighting functions, which have a significant potential for the overall integration of autonomous systems.

The current alignment of resources to potential for automation is not optimized. This is due to equipment and technology development for the movement and maneuver, fires, and intelligence warfighting functions receiving priority over the other three warfighting functions. For example, though the *Army Equipment Modernization Strategy* includes investments for all warfighting functions, priority is given to these three warfighting functions, with more risk being assumed for the other three warfighting functions. Likewise, most of the Army science and technology near-term, mid-term, and long-term investments are related to these warfighting functions.[13]

While the investments in the fires and movement and maneuver warfighting functions offer new capabilities to the soldier, a much larger benefit can be made from applying autonomy to the sustainment and protection warfighting functions. Since these warfighting functions can achieve a much higher amount of integration of autonomous systems, the combat multiplication factor is higher. More simply stated, entire companies of protection and sustainment personnel can be replaced with autonomous systems supported by a few personnel for leadership and quality assurance. These new autonomous systems will potentially be faster, more efficient, and safer.

Note that though man-unmanned pairings and integrating robots into the squad is in the distant future, commercial technology is currently available to support the sustainment and protection warfighting function. Self-driving vehicles that can convoy, robotic maintenance systems, package delivery systems by drones, autonomous network monitoring, and GPS-guided farm equipment are all technology that could have military applications.

Reduction in Numbers and Benefits

The integration of autonomy into the warfighting functions creates opportunities for a reduction in troop count, assuming that the Army wishes to maintain a given level of combat power. Typically, an autonomy level of 1 will result in a new capability that will allow the Army to complete the task more expediently. An autonomy level of 2 will not only result in a new capability but also the ability to reduce the number of soldiers. This reduction is typically at an individual level, such that individuals in a squad could be replaced with an autonomous system. Meanwhile, an autonomy level of 3 will result in replacing an entire unit with an autonomous system, only leaving a few humans for quality assurance.

The sustainment and protection warfighting functions both have a significant number of tasks that can be automated. Additionally, in the Global War on Terrorism, approximately 70 percent of deployed soldiers were tied to these two warfighting functions. As such, the application of autonomy toward these warfighting functions would allow for a significant reduction in boots on the ground.

The largest benefit of replacing humans with autonomous systems is safety. Using autonomous systems in dirty, dangerous, and dull situations reduces the risk to soldiers. However, there are substantial cost savings as well. For monetary reasons, the U.S. government has strived to reduce troop numbers in the past while maintaining the overall strength of the force. The most cost-effective, long-term method is through incorporating autonomous systems. Though these systems carry an initial high development cost,

An autonomously activated device emits vapor to obscure the rear of a utility task vehicle 26 April 2019 during the Robotic Complex Breach Concept, a military event focused on autonomous technologies at Yakima Training Center, Washington. (Photo by Lance Cpl. Nathaniel Hamilton, U.S. Marines) the reduction in troop numbers across the Army would offset these costs. Soldiers carry a large life cycle cost since they must be trained, paid, billeted, and equipped while they are in the service; additionally, the U.S. Department of Veterans Affairs provides health care after they leave the military.

Alternatively, the Army may decide to keep its end state. In that case, the use of autonomous systems could afford a redistribution of personnel by military occupational specialty. The current heuristic is that for every individual combat soldier, there are approximately two to three support soldiers. Increased investment in autonomy for the sustainment warfighting function has the ability to significantly reduce this ratio. With a constant end state, this could result in an increase in combat soldiers.

Conclusion

Some may perceive the future of autonomous systems in the Army as formations of armed robots marching into combat; however, this situation is unlikely due to the constraints placed on autonomous systems in combat. Moreover, it is shortsighted because it only addresses a small portion of the tasks that the Army is required to perform.

This study set out to determine what the maximum integration of autonomous systems into the Army would look like. In particular, it looked at each of the warfighting functions and supporting subfunctions to determine the applicability of using autonomy to support that function. In some instances, an autonomous system could perform the function with little human oversight, while in other instances, only humans can perform the function.

The results found that while autonomy could benefit all the warfighting functions, the intelligence, protection, and sustainment warfighting functions could benefit the most. This finding does not align with the current Army investments into autonomous systems, which are more focused on the movement and maneuver, intelligence, and fires warfighting functions. Significant benefits can be realized through the application of autonomous systems to the protection and sustainment warfighting functions, resulting in an increase in combat power while reducing troop numbers. ■

Notes

1. *The U.S. Army Robotic and Autonomous Systems Strategy* (Fort Eustis, VA: U.S. Army Training and Doctrine Command, March 2017).
2. Army Doctrine Publication (ADP) 3-0, *Unified Land Operations* (Washington, DC: U.S. Government Printing Office, October 2011).
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