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The Necessity of Precision, and its Implications for Ground Robotic Platform Lethality and Tactics

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ABSTRACT

On the modern battlefield, ground robotic vehicles have a need for a level of accuracy that approaches precision for rapid-fire cannon and anti-tank missiles, driven by the imperative to be able to neutralize opponents rapidly in an environment where resupply is seriously constrained and the first platform that shoots accurately most often wins. Moreover, employing precisely lethal unmanned platforms is strikingly different from traditional combat forces and the tactics to employ them must also adapt accordingly.

1. INTRODUCTION

U.S. combat formations equipped with Unmanned Ground Vehicles (UGV) must be able to leverage the capabilities of these robotic platforms to significantly expand the lethality, reach, survivability, awareness and flexibility of the employing formation. For those UGVs carrying lethality payloads, there are a number of capabilities the firepower solution should offer to maximize the robot's value and support to the maneuvering force.

The purpose of this paper is not to debate whether the employment of robots on the modern battlefield with the ability to provide lethal effects against humans is ethical, regardless if this is done autonomously, semi-autonomously or with a human in the loop. Armed robots have already been providing a significant combat multiplier to security forces around the world in the form of weaponized aerial and ground drones. There are open-source reports that robots have been or are being used to deadly effects in recent conflicts, particularly in Nagorno-Karabakh and Ukraine, and to lesser success on the ground in Syria.

This paper proposes that ground robotics are likely to advance in a manner similar to the leap that unmanned drones experienced with the movement from locally employed, hand-flown craft, focused on intelligence missions, to incredibly lethal platforms with world-wide reach. When that transition happens, it will have an effect like that of the Unmanned Aerial Systems (UAS), which is dramatically changing the way wars are fought and Armies are organized at both the tactical and operational levels of war.

While there are acknowledged limitations for the employment of UGVs on the modern battlefield to include "transportation, communication, firing, and issues with the operator's situational awareness" as experience by Russian forces in Syria,[1] this paper will suggest methods and techniques to shape these platforms and offer some thoughts about how to employ them. The long-term goal is to make these armed robots, particularly when employed on the ground, as efficient and effective as possible in support of maneuvering units. This can be done through the use of advanced weaponry mounted on advanced remote weapons stations with enhanced fire control systems, modern munitions, optional third effectors (ATGM/SAM/etc.) and innovative tactics.

2. THREAT OVERVIEW

Over the past fifteen years it has become increasingly likely that US, NATO and coalition forces will encounter substantial numbers of threat vehicles armed with enhanced lethality packages (including cannon of at least 30mm) in engagements with mechanized forces. The transition from an environment dominated by .50 caliber/12.7mm/14.5mm weapons to 30mm and larger weapons has occurred rapidly in many conventional armies around the world (especially those of near-peer adversaries) as well in those irregular forces that have the capacity to employ either armored vehicles or the ability to develop "technicals" (light pickup trucks with medium caliber cannon integrated into the vehicle bed).

Most US and allied medium and heavy wheeled vehicles and many light and medium armored vehicles rely on the venerable M2 .50 caliber machine gun. This system has been a mainstay of the weapons array for US and allied forces for almost 75 years, but the deployment of adversary 30mm weapons with rounds large enough to include specialized fuzes and range that is almost a third greater than that of the .50 caliber gun (2,000m vice 1,500m) presents a major challenge.

The proliferation of the 2A42 30x165mm cannon (and its simpler but nearly identical 2A72) in former Soviet republics and client states has been significant, with more than 10,000 armored vehicles in current service in Russia carrying one or the other of these weapons. The Russians have also been aggressive in offering the BMP-2 and the other platforms mounting these weapons on the international arms market, resulting in their widespread use around the world. Additionally, both China and India have been licensed to make variants of these cannons and have deployed them in significant numbers in their armed forces as well as exported additional thousands of 30mm-equipped vehicles that are almost identical to the Russian originals. In use since the 1970s, the net effect is that unclassified sources suggest there may be as many as 20,000 of these Soviet-designed armored vehicles with 30mm guns currently in use in a number of countries around the world.[2]

Figure 1: 2A72 Cannon on BMP-2

Additionally, both regular and irregular forces from our potential competitors have begun to employ UAS as a means to gain asymmetric advantage in combat situations. These systems have been used increasingly to achieve both tactical and strategic effects by employing both kinetic and non-kinetic payloads. Because they are light, highly maneuverable, difficult to detect and inexpensive, they can be extremely effective in a reconnaissance role.

Even very inexpensive commercial systems have the capacity to relay high-definition video and in some cases, grid coordinate data across multiple kilometers. Moreover, the kinetic capability of this type of platform should not be underestimated. The Saudis are being confronted with kinetic attacks on an almost daily basis that leverage Class I, II and III systems.[3] The impact of UAS in the war in Ukraine have been dramatic, shaping tactics as well as organizational structure of both armies. These types of UASs have been used to disrupt large maneuver units with targeted attacks on key nodes and capabilities.

3. BRING A CANNON

To counter these threats, tactical mobile forces employing robotic vehicles must have the capability to effectively engage 2km-plus targets while simultaneously providing support to dismounted Infantry formations. At the same time, the need for a level of accuracy that approaches precision for a rapid-fire cannon and anti-tank missiles is driven by the imperative to be able to neutralize opponents rapidly in an environment where the first platform that shoots accurately wins and resupply is seriously constrained. Concurrently, these forces must also have the capacity to detect and defeat small UAS and/or rotary-wing threats at ranges that can protect friendly forces from both observation and kinetic attacks.

To meet these challenges, the Army's future force of robotic combat vehicles must be equipped with a precise, reliable, modular medium caliber weapon system. The system must be able to engage light and medium armored vehicles, engage targets in defilade, destroy other light skinned vehicles and fortifications and provide suppressive fire on entrenched enemy formations. A truly successful solution will also greatly reduce the overall impact on the vehicle weight and cost.

As the weapon system on a robot will often be emplaced away from supporting friendly elements, a weapon that has the capacity to function even when a round misfires or when experiencing a feed failure is critical. In this situation, only those weapons which do not use a recoil- or gas-operated system should be considered as they are completely unaffected by a failure of the ammunition to properly function. The logical choice for the primary armament on a robot is therefore a chain gun.

Based on a report originating from the Naval Surface Weapons Center in Dahlgren, Virginia, dated September 23, 1983, when testing a chain gun, "29,721 rounds of endurance tests were fired with no parts breakage and without any gun stoppages ... It is significant that during firing of 101,343 rounds not one jam or stoppage occurred due to loss of round control in the gun or feeder mechanism ... [this] is in our experience very unusual in any weapon of any caliber or type."[4]

The Army currently has a weapon in its inventory that can accommodate these requirements. The M230LF and improved XM914 (Figure 2) chain guns provide 30mm x 113mm chemical munition firepower sufficient to defeat most light to medium armored vehicles currently fielded by anticipated near-peer adversaries. These cannons are based on the original link-less M230 cannon, which has served as the primary gun on the AH-64 Apache helicopter since 1982. Fitted with a longer barrel, linked feed system and delivering both greater muzzle velocity and absolute hangfire protection, the M230LF provides a significant advantage to unmanned ground systems in delivering reliable lethality at relatively low weight.[5]

Figure 2: XM914, 30mm x 113mm Cannon

3.1. Efficient Punch

They U.S. Army's Program Executive Office, Soldier, recognized the requirement for enhanced lethality above the current .50 cal baseline. They have, as a result, established a specific Product Director inside the Program Manager for Soldier Lethality who is responsible for the integration of medium caliber cannon.[6]

With the relatively low weight of the weapons (170 lbs.) and high rate of fire (200 rounds per minute), the M230LF / XM914 is one of the most lethal, capable and resilient direct fire weapons, pound-for-pound, available for employment as a payload on robotic platforms.

Granted, there is a direct trade-off when comparing the armor penetration power of 30mm x 113mm cannons versus other weapons in the medium-caliber category. The M230LF / XM914 can only provide about 25mm penetration of rolled homogenous armor, as compared to the 45mm penetration of a M242 25mm x 137mm cannon under the same conditions. However, the substantial reduction in length (2.1 meter vs. 2.6 meter), weight (160 lbs. vs 262 lbs.) and recoil forces (28kN vs 40kN) provide a significant advantage, particularly when attempting to maximize lethality on a small platform where size, weight and power are already at a premium.[7]

3.2. Better Bullets

As mentioned previously, the 30mm x 113mm round is a chemical energy munition. It has a fairly low muzzle velocity (838 meters per second, as compared to the 1,100 meters per second of the high explosive rounds for the M242) so must rely on the energy produced from the detonation of the round instead of energy produced from the speed of the round.

The current inventory of legacy ammunition provides for standard Target Practice (TP) rounds and the very capable High Explosive Dual Purpose (HEDP) round for the M230LF.[8]

Figure 3: M788 TP & M789 HEDP 30x113mm Rounds

Probably the main argument for transitioning from the .50 cal baseline to medium caliber firepower is that the 30mm round is the smallest projectile that can be fitted with an electronic fuse capable of delivering advanced lethal effects such as self-destruct and proximity detonation. This gives existing rounds great capability and offers significant potential for future growth.

The XM1198 High Explosive Dual Purpose – Self Destruct (HEDP-SD) was designed with a self-destruct feature so that if projectiles miss their intended targets (especially airborne platforms), they will detonate before hitting the ground, greatly reducing the risk of collateral damage. The self-destructing cartridge was developed, tested and approved under an urgent materiel release to support an initial 2021 fielding.[9]

To counter other emerging threats, such as small Unmanned Aerial Systems (UAS), the XM1211 High Explosive Proximity (HEP) cartridge is currently in development. The proximity fuse allows the round to detonate when it senses it is near a target, rather than requiring a direct hit, providing an increase in potential lethality and effective range and making a larger lethal footprint.[10] Repeated firings have demonstrated the effectiveness of the fuse in detecting even the smallest UAS.

The cannon is most effective in a C-UAS role when provided with a radar cued vector and mounted on a stabilized remote weapon station, Recent live-fire testing of this extremely capable round against maneuvering Class 1 and 2 UAS, demonstrated repeated kills against these small drones out to ranges approaching one kilometer.

Figure 4: Linked XM1211 HEP Rounds

A major challenge for infantry formations is effectively engaging targets that are in defilade positions at longer ranges, such as behind a wall or in a trench. Both these developmental munitions have the capability to provide very effective lethal or suppressive fires against these difficult threats.

With this system, infantry units accompanied by UGVs equipped with medium caliber cannons, perhaps loaded with a mix of HEDP and HEDP-SD or HEP, can counter most threats on the modern battlefield short of heavy armored elements. Even when faced with tanks, these advanced munitions provide the potential to destroy optics, sensor packages and other vital systems, and will provide a UGV with the potential to significantly degrade an armored element's combat effectiveness.

4. SMART MOUNT

The M230 was designed to be an area fire weapon as the primary anti-personnel, anti-material gun on the AH-64 Apache. While the M230LF and XM914 are improvements on the original model, the aforementioned low muzzle velocity has discouraged the use of the weapon for precision strikes.[11]

However, most of this inaccuracy can be attributed to the original gun mount. The gun and mount were designed to deliver area fire from an aviation platform.

When supporting ground infantry formations with a UGV, the ability to deliver precise fires is a significant advantage, reducing both the risk to the supported Soldiers as well as the logistic challenges associated with area fire medium-caliber weapons. An innovative Remote Weapon Station (RWS) can offer the best option to deliver this precision, as it combines a stable platform with sophisticated fire control solutions. When combined with on-board electro optical and thermal sensing cameras and an effective remote operating system, the resulting system allows a maneuvering or defending force the ability to precisely apply greatly increased levels of lethality while significantly reducing the overall risk to the team.

Figure 5: EOS R400 RWS on Pratt Miller EMAV

4.1 *Advanced Fire Control*

While the ability to remotely point and shoot a weapon is an important milestone in the development of lethal robotic platforms, the necessity to do so with accuracy is critical, not only to deliver the maximum negative effects on adversary forces but also to ensure the risk of friendly fire is minimized and the logistics challenges caused by the system are reduced.

To achieve precision, fire control systems must employ not only the basic ballistic firing tables of mounted weapons and ammunition, but also must account for a whole range of internal and external sources of errors. These systems must compensate for a wide range of meteorological factors, especially when employing low muzzle velocity rounds which are more susceptible to weather and temperature effects at longer ranges. They must also take into account the particular attributes of the weapon (recoil, cyclic rate of fire, cold and hot performance etc.), the ammunition (turn rate, velocity impacts from temperature/pressure, terminal stability, etc.) and also consider the characteristics of the mobility platform (stability, cant, deformation under shock, recoil recovery, vibrations, etc.). This tuning is particularly important when heavier weapons are employed on lighter robots to ensure consistent and effective target hits. Fire control software tuning is particularly critical to counter the shock and vibration of ground robotic vehicles, especially when the lethality system is employing high-volume burst or automatic firing.

The fire control system should also have an open software architecture, allowing for integration into an all-encompassing battle management system and be sufficiently adaptable to accept future enhancements such as assisted target identification and pixel change detection.

These characteristics will provide the basis to reduce the workload of the employing units in the future by allowing an RWS to provide UGV-based autonomous sector scans in silent watch and send alerts to soldiers if threshold requirements are met within an area of surveillance.

4.2 Seeing Far and Well

A significant advantage to enhancing UGVs with lethal RWS platforms is that it also provides operating units with the ability to see much further than with traditionally employed sensors. An advanced electro optical and cooled thermal sensor unit, paired with an eye-safe laser range finder will provide not only the ability to detect, recognize and identify targets in both daylight and reduced visibility but also generate the data to feed into the fire control system for precise fires. It is important to remember that, in the overwhelming number of operations and modes of employment, the RWS optics will be in use for a much greater period than will the weapon. If they are capable and able to deliver quality surveillance capabilities in multiple modes and environments the UGV can materially improve the security and lethality of the supported unit.

When employed on a unit's flank or in a hidden, protected emplacement forward of defending positions, a capable sensing unit provides friendly elements with advance notification of potential threats and the ability to respond. This is especially true when it is mounted on a robot – expanding the area to be surveilled without compromising the safety of any of the unit's Soldiers.

Most importantly, the sensing unit must be able to see and identify targets further than the longest-range weapon system within the employing unit's arsenal. Notwithstanding the debate on the use of killer robots on the modern battlefield, the risk of fratricide is arguably the greatest deterrent for the use of lethal unmanned systems. Fratricide is corrosive to morale and the effectiveness of military organizations. Being able to clearly see and identify what a robot is shooting at, in both daylight and reduced visibility, is a major factor in minimizing this risk.

4.3 Third Effectors

Recent combat operations have shown the effectiveness that small, light missiles can impart on heavy maneuver forces. The ability to carry one or more anti-tank guided missiles (ATGM), Surface to Air Missiles (SAM) or laser-guided 2.75-inch rockets can disproportionally increase the combat power of light maneuver forces, especially when these systems can be employed remotely from a UGV. The visual and electronic signatures of missile launch can compromise the location of a defending or attacking force. The robot's ability to be deployed forward or on the flanks of a unit while still supporting effective engagements of heavy targets.

A capable RWS should have the ability to mount and remotely fire these weapons through its own sensor unit and fire control systems, providing employing elements a fully integrated anti-armor or anti-air capability. This is critical for UGVs, as multiple, independent remote operator control stations greatly complicates the process of employing armed robots.

When employed at distance from the maneuvering unit, these third effectors have an even greater probability of a successful hit. The operators, not in close proximity to the launch, are no longer vulnerable to suppressive fire and can, if necessary, maintain control of the missile throughout an engagement.

Figure 6: RWS Firing Javelin ATGM

4.4 Next Generation RWS Slip Ring

As the conduit for direct fire and missile lethality as well as advanced sensing devices, the RWS slip ring must be able to pass power and data for the mission package while still maintaining the ability to rotate 360 degrees without interference. This was not a significant issue in the past, when weapons were largely unpowered and sights did not have the requirement to clearly see beyond 3km to 4km. Given the demand for powered chain guns and missiles on robots, the resulting increase in range of onboard effects and the dramatic increase in performance offered by modern digital sights, this has become a significant limitation.

Current slip ring designs are primarily mechanical, comprised of rotating disks with data and power leads that provide the RWS with the ability to rotate continuously without interruption. These solutions are limited by the physical capacity of the interface between the major rotating elements of the RWS pedestal. Except for very large slip rings, they are incapable of supporting sufficient data and power transmission to allow the employment of advanced cameras and power-hungry weapons. This restriction on power and data bandwidth has been a major limiting factor for the effective integration of late-generation thermal and daylight cameras, electrically driven cannons and advanced missile payloads which require both. This, in turn, impacts negatively on the firepower and optical capabilities that can be effectively employed on UGVs.

A future modification to consider for lethality on ground robotic vehicles would be to allow the integration of a supplementary data slip ring that is not restricted by the physical connections in the pedestal itself. A fiber-optic based auxiliary slip ring that provides options for multi-gig data transmissions will greatly reduce constraints on the capabilities of the system's sensor unit. With the significantly higher bandwidth of a fiber-optic link, the simultaneous flow of digital video from high performance daylight and infrared or thermal cameras can be accommodated as well as ensuring ample data feeds to missile electronic and sensor units. This will, in turn, enable much more capable image analysis and underpin the addition of AI to onboard lethality solutions.

A major additional advantage is available because system data can be managed by the fiber-optic device. The physical slip ring can now be dedicated to power, significantly increasing the wattage available to support cannons, missiles and other effectors so that power solutions requiring additional batteries or power solutions above the slip ring are not needed.

This type of power and data solution has been put to practical application on a prototype C-UAS RWS in cooperation with the U.S. Army's DEVCOM Armaments Center, under the Radar Assisted Medium Caliber program.

5. TACTICAL CONSIDERATIONS

There are several lethality considerations that can be used to shape the way we think about the employment of armed robots. While it is well beyond the scope of this paper to attempt to list all of them, there are aspects of precision that can significantly impact the tactics, techniques and procedures used to employ lethal unmanned systems.

When employing medium caliber firepower and advanced munitions on UGVs, precision is more a necessity than a virtue. Killing targets with a minimum outlay of both time and ammunition ensures both survival as well as the ability to continue to perform the mission without resupply. A very lethal robot with the onboard ready rounds necessary to kill only one or two targets will become rapidly ineffective. Achieving lethal effects quickly and having the capacity to continue the mission is essential.

The system must also be sufficiently precise and lethal to require the enemy to react to the robot. While the objective of employing a robot will likely be to have the robot find the enemy before they become aware of the platform, that will very often not be possible. The enemy has a choice at that point at which they detect the UGV – engage the robot or let it pass by. If the platform is not seen as a critical threat, an enemy can choose to allow the robot to bypass their protected position and wait to focus their fires on the operator. An opponent will know that the operator will very likely follow the same route across the battlespace as was used by the robot. Unless the robot is both effective and too lethal to allow into the rear area, the enemy can simply ignore the robot and wait for the operator to move through the engagement area.

This also argues that the robot must be seen as having a broad spectrum of lethality. While it may not need the ability to kill every target on the battlefield, it should be seen as being a threat to, in some way, impact the ability of almost every enemy platform it could encounter to continue their mission unimpeded. A medium caliber cannon is a good example of this kind of lethality.

Either the robot or the platform should have the capacity to autonomously identify threats. Communications links can never be counted on to be perfect under any circumstances, and moments matter when the survivability of a platform is at risk. Providing this capability greatly enhances the likelihood that the robot will see the enemy first and turn every engagement from a potential ambush into an even fight.

Wargames and exercises have often used robots as a substitute for a manned vehicle. While there is a greater tendency to put them at risk, it appears that the systems often simply replace the tasks that a manned platform could perform in combat. However, an unmanned platform with a very precise lethality solution represents a set of capabilities that argue for UGVs to be sometimes employed differently than a manned platform.

Examples of this type of tactic in the defense would include placing a single armed and very lethal robot on the opposite side of an engagement area in a "spider hole" (covered and concealed position), and having it join an engagement from behind the enemy after the battle has been initiated. The rapid and precise application of lethal fires to the rear of an opponent's formation while they are being engaged from the front can be devastating.

Another approach might be to have a strong group of unmanned systems occupy a main position in the defensive sector and initiate the fight with nothing but precision fires from unmanned platforms. This would force the opponent to deploy and initiate a hasty attack on the UGVs, while manned systems could maneuver from a flank or the rear and significantly disadvantage any remaining enemy vehicles.

On the offense, the presence of expendable lethal robots would enable a commander to maneuver very aggressively. This could take the form of sending an entire unmanned formation deep into the rear of a potential enemy defensive position and have the robots initiate an attack from the rear. The manned force could then close with the enemy from a different axis as they were maneuvering to counter that threat, giving the friendly force a significant advantage.

The Russian Military, while gaining valuable experience in the use of UGVs in combat during operations in Syria, and to some extent, Ukraine, believe that ground robotics are still 10-15 years away from being able to accomplish traditional military tasks as part of combined arms missions. They consider current UGVs to only be suitable for "one-off" assignments.[13]

A recent Congressional Research Office article updating the Army's Robotic Combat Vehicle (RCV) program re-stated that the intent for the lightest of the RCV platforms are considered an "expendable weapon system, meaning its destruction in combat is expected and acceptable."[12] Maneuver unit commanders can now decide the acceptable level of risk in employing the robots to maximize effectiveness, particularly when faced with a decision regarding equipment over manpower. Placing a UGV in a position where loss is a likely outcome is expected, especially if it will increase the survivability of friendly forces.

While the introduction of lethal robots into the mounted force is likely to have significant effects on these elements, it is probable that both the lower cost of fielding robots that support dismounted combat formations as well as the relative increase in combat power that will accrue to the light force from the incorporation of these platforms will argue for them to receive this type of asset first. The size and complexity (and therefore, cost) of a robot that can support ground operations is significantly less than the cost of robots that can effectively work with armored and mechanized units.

Moreover, robots that could augment today's mounted maneuver formations are unlikely to offer lethality options that are not already available to these units. Given the current limits of technology, the weapons options for these UGVs are most likely to mirror lethality packages that are organic to the lowest levels of these manned mechanized units. While the addition of UGVs is likely to be impactful, it is unlikely to represent as significant an increase in capability as will occur when robots are successfully incorporated into light formations.

The addition of robots into Light Infantry units provides the potential to add lethality options that are not currently available to these units. The introduction of maneuverable platforms carrying .50 caliber machine guns or light 30mm cannons as well as a significant supply of ammunition would offer a marked increase in the lethality and tactical options available to the Infantry company.

The U.S. Army now has a distinct opportunity to achieve an operational advantage in the employment of UGVs at the tactical level by effectively incorporating these systems into tactical units in both simulation and field exercises. Giving unit leaders, from brigade down to platoon level, effective and lethal robotic platforms will encourage them to develop techniques and procedures necessary to master the technical, tactical and operational employment of these important systems.

6. CONCLUSION

Effective lethality, let alone precise lethality, should be considered an essential requirement for the development and use of operational unmanned systems. It provides credibility, persistence, survivability effectiveness and the potential for innovative and unbound tactics and maneuver. It is too important a capability to ignore.

Care must be taken to ensure that not only the correct weapon is employed on the robot but that the mount it is placed on is capable enough to fully maximize the utility and lethality of the platform.

As the mount will be the conduit for the transmission of information between the lethality package and the unmanned ground vehicle operator, the remote weapon station must have superior fire control software, high-performance optics, and sufficient modularity to support missile systems. Importantly, it must also have the capability to pass significant amounts of both power and data through the slip ring to accommodate an uninterrupted steam of info to the employing unit.

Other technological advances, which could include artificial intelligence, target recognition and machine learning incorporated into the RWS sensor unit and fire control system will continue to expand the utility of unmanned ground systems, not only for lethality purposes but to provide a valuable ISR asset for the employing commanders.

Once the potential of these systems begins to be realized, the capabilities that an armed ground robot brings to the battlefield is very likely to produce a paradigm shift in a number of the critical areas that underpin the modern combat unit. Elements as fundamental as combat tactics, unit organization, leader development, logistics, doctrine and facilities are likely to have to evolve to accommodate lethal unmanned systems.

The inherent benefits that an advanced lethality package can provide to employing maneuver formations are now as important as the mobility system it is mounted on. Much like what we have seen with the effective introduction of UAVs into the fight in Ukraine, a competent killer robot, employed aggressively, can significantly alter the balance of power on the future battlefield.

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