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Bringing Discrimination to Conflict: Modernizing Area Denial Through Area Access Control

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BRINGING DISCRIMINATION TO CONFLICT: MODERNIZING AREA DENIAL THROUGH AREA ACCESS CONTROL

By Major M.R. Littlechild

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DEDICATION

To the thousands of innocent victims who have lost life or limb due to the explosive threat lurking just beneath the surface. A solution is being developed so that the future will be safer for your children.

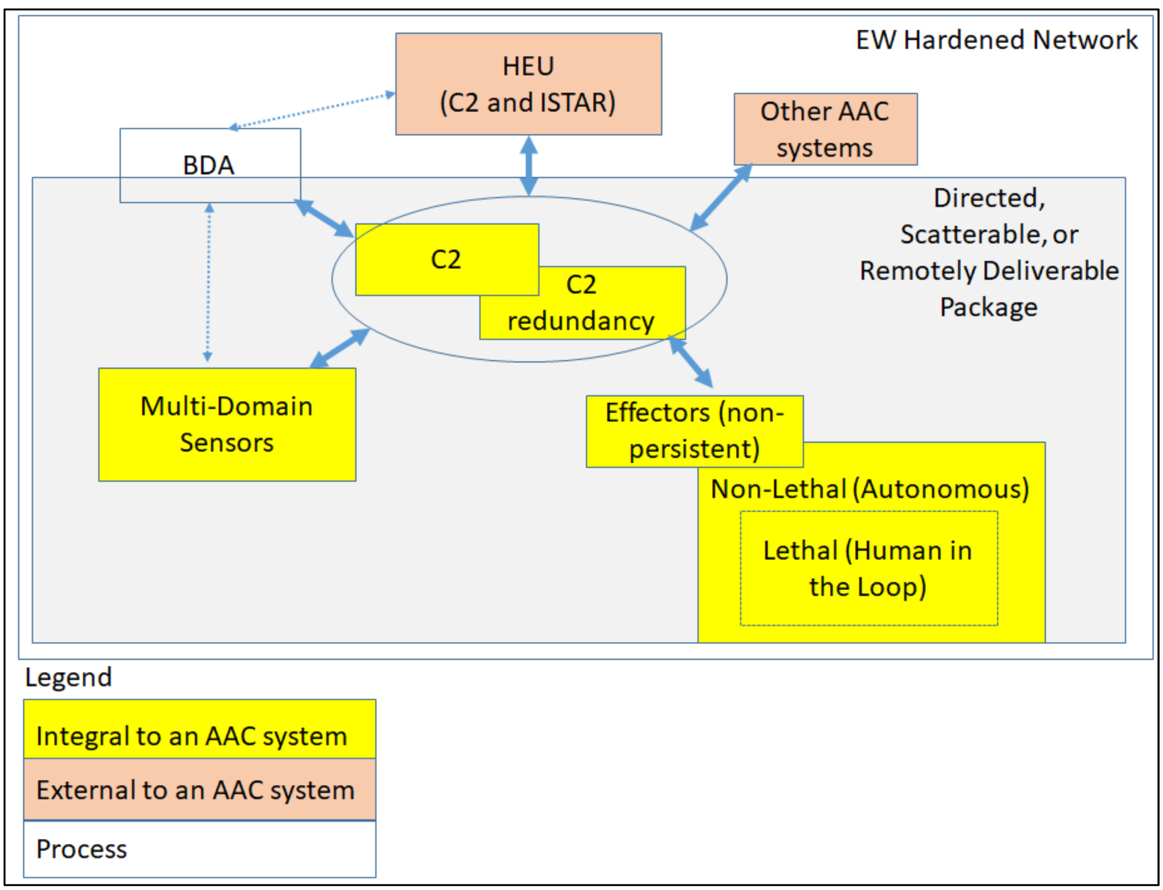
ABSTRACT

Mobility is crucial in assuring battlefield success, and counter-mobility is one tools available to a commander to enable them to overcome an adversary's advantages in mobility. Unfortunately, traditional counter-mobility technologies such as landmines are indiscriminate and persistent, requiring significant time, labour, and resources to emplace, and they create an enduring risk to civilians once the conflict has ended. A non-persistent and discriminate area access control (AAC) system must be developed to allow battlefield commanders to shape contemporary land forces. Such a system will increase lethality on the battlefield while simultaneously decreasing the risk of creating a humanitarian crisis once nations lay down their weapons.

This exploratory study takes a practitioner's perspective to the problem, drawing upon the work of the North Atlantic Treaty Organization (NATO), who has been studying this issue over the last decade. NATO has produced an AAC model that includes sense, command, and effector blocks, and this model is analyzed in this study against doctrine and academic literature to determine its efficacy. Updates to the model are recommended, including layering non-lethal and lethal effectors, ensuring that a human is in the loop for lethal effectors, using multi-domain targeting sensors, and clearly highlighting the relationship between the multi-domain sensors of the AAC system and those of formation ISTAR. When qualitatively tested in an unclassified-level case study, the proposed AAC model is effective against a Russian adversary with the caveat that further study and testing is required such that the system includes a network that is resistant to contemporary electronic warfare threats. For interoperability purposes, NATO must take the lead to develop this hardened network spine, allowing nations to

choose sense and effector capabilities that meet their need – the system is plug and play. Further, it is presented that this AAC system will only be successful in shaping and deterring an adversary once prototypes are developed, refined, and demonstrated, as lethality is what will deter and shape.

NATO nations need to overcome their complacency and stop relying on antiquated area denial technologies so that they pose a credible deterrent force. AAC is the discriminate and non-persistent area denial capability that NATO nations need to strengthen their strategic A2AD network, especially in vulnerable locations such as the Baltics.



INTRODUCTION

Throughout the ages, societies and militaries have sought to deny access of their territory to adversaries by using physical obstacles or weapons. As the nature of conflict continues to evolve through technological advances, evolving geopolitical relationships, and the fluctuating physical environment, so does societal perceptions. The post-Cold War operating environment is evolving from a military hegemony under the United States (US) to one that is arguably multi-polar but clearly highly contested.[1] Russia, China, Iran, North Korea, as well as other state and non-state actors are challenging the established western liberal democracies by conducting nefarious actions below the threshold of conflict,[2] while concurrently shoring up their own defences with modern anti-access and area denial (A2AD) capabilities to both deter and reduce the ability of their adversaries to gain access with their land forces to their shores.[3] A2AD are those

> coordinated operations by an adversary's air force and integrated air defenses to achieve a degree of air parity or local air superiority over its territory. Land based operations might include short to medium range artillery, rockets or missiles at either littoral penetration points, or forward staging bases. Enemy forces can be used against maritime forces to include anti-ship cruise missiles, ballistic missiles and submarines[4]

A2AD is a strategic capability used by states as a deterrent mechanism to protect their borders and interests. It is in no way a new concept, and its recent rise in significance has

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[1] Department of National Defence, *Strong Secure Engaged: Canada's Defence Policy* (Ottawa: DND Canada, 2017), 50.

[2] Department of National Defence, *Pan-Domain Force Employment Concept: Prevailing in an Uncertain World* (Ottawa: DND Canada, 2020), 36.

[3] Richard Witwer, "The Future of Armour in an Anti-Access Area Denial Environment" (master's thesis, U.S. Army Command and General Staff College, 2014), 10.

[4] Andrew F. Krepinevich, *Why AirSea Battle?* (Washington DC: Center for Strategic and Budgetary Assessments, 2010), 10.
Area denial has been more specifically defined as "those actions and capabilities, usually of shorter range, designed not to keep an opposing force out, but to limit its freedom of action within the operational area." Sam J. Tangredi, *Anti-Access Warfare: Countering Anti-Access and Area-Denial Strategies* (Annapolis: Naval Institute Press, 2013), 7.

been enabled in part due to the "dramatic improvement and proliferation of weapons and other technologies capable of denying access to freedom of action within an operational area."[5] Contemporary weapon systems are more powerful and can influence larger areas and more resistant targets, resulting in fewer munitions being required to have the same effects of earlier technologies.[6] Even when nations break into the strategic A2AD bubble and mass land forces for operations, they still need to move. Without mobility, land forces cannot operate, and A2AD is accordingly a strategic deterrent, or at least a factor that makes senior leaders think twice before making strategic military decisions.

U.S. Army After Next developers note that speed and manoeuvre are important to battlefield success, and this will remain constant in the future fight.[7] The operational concept of denying an adversary's ability to move within the strategic A2AD bubble is counter-mobility. Counter-mobility disrupts the land operation system of systems that hinges on mobility:

> Ground is held when infantry occupies it. Infantry cannot advance to take ground in the face of artillery and so must have protected mobility. Protected mobility platforms will not survive contact with tanks and must therefore be chaperoned by friendly tanks. Tanks are destroyed if they lack situational awareness and protection from air attack, and so the force must have reconnaissance assets and air defences. The whole force needs engineering support or it will be unable to cross gaps or breach obstacles.[8]

Counter-mobility is not simply actions that stop a land force from moving. More accurately, it is about separating the aforementioned combat systems such that the

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[5] US Department of Defence, *Joint Operational Access Concept* (Washington DC: Department of Defence, 2012), ii.

[6] David A. Koplow, *Death by Moderation: The U.S. Military's Quest for Useable Weapons* (New York: Cambridge University Press, 2010), 11.

[7] Daniel W. Krueger, "Countermobility for the Army After Next: An Obstacle to Maneuver Ascendancy?" (strategy research project, US Army War College, 1998), iii.

[8] Jack Watling, "Land Forces: A Diverging Trinity," *Whitehall Papers* 96, no. 1 (2019): 24.

combined adversarial capability is degraded. Counter-mobility operations, consisting of synchronized tactical effects across all domains, can grind a land force to a halt. When effectively conducted, counter-mobility operations greatly improve the chances of battlefield success.

Commanders can employ obstacles[9] within their counter-mobility plan to apply effects upon the enemy. Whether explosive or non-explosive, obstacles, reinforced with fires and localized manoeuvres, shape the enemy in accordance with a commander's intent. Landmines have been employed in obstacles throughout the ages and have many advantages over other technologies, most notably because they are cheap and easy to produce.[10] Unfortunately, they are also remarkably persistent and do not discriminate[11], killing and maiming innocent victims well after the cessation of hostilities. The horrors of landmine casualties around the world led to an international call for action for nations to remove the landmines from their inventory. The *Ottawa Treaty*[12] calls for a complete ban on the use of anti-personnel (AP) mines, but they continue to be in the armouries of non-signatory nations. Further, the use of "smart mines" and anti-vehicle mines (AVM) persists, as does a threat to innocent bystanders of war.

Despite the ethical concerns, counter-mobility, obstacles, and most specifically, landmines, do provide a specific and arguably required capability. The North Atlantic Treaty Organization (NATO) has identified a capability gap in controlling movement in

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[9] The term barrier is also used.

[10] Koplow, 133; Norman E. Youngblood, "The Development of Landmine Warfare" (doctoral dissertation, Texas Tech University, 2002), 191, 261.

[11] "A weapon may be considered inherently indiscriminate if it cannot be directed at a specific target…Second, a weapon may be considered inherently indiscriminate if the effects of its use are uncontrollable over time." Kjolv Egeland, "Lethal Autonomous Weapon Systems under International Humanitarian Law," *Nordic Journal of International Law* 85, no. 2 (2016): 96.

[12] Formally known as the *Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction*.

non-line of sight areas due to the banning of AP mines.[13] To fill this gap, NATO is pursuing the concept of area access control (AAC), which it has defined as "a command and control (C2) system for various sensors and effectors in order to control access to or create an obstacle in a specific land-based operational area."[14] AAC is a new concept for degrading an adversary's capacity to manoeuvre that theoretically overcomes the shortfalls that landmines have with target discrimination and persistence. The concept is in its infancy and only one of NATO's many priorities. As such, the capability gap persists.

As long as this gap persists, it will be necessary to explore contemporary solutions to traditional problems. The Commander of the Canadian Army, Lieutenant-General (LGen) Eyre, stated "the Army we need for the future is not necessarily the Army we have today….."[15] In *Advancing with Purpose: The Canadian Army Modernization Strategy, 4th Edition,* LGen Eyre has identified a number of applicable principles for modernization, notably a requirement for interoperability with the USA, NATO, and the American, British, Canadian, Australian and New Zealand (ABCANZ) Armies Program; and simplicity, in that technology must be leveraged but not at the expense of ease of use.[16] Further, countries seek overmatch of their adversaries while modernizing.

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[13] NATO Industrial Advisory Group, *Final Report of NIAG SG.174 on Area Access Control Capabilities (*2014), 3.
Canada has removed AP mines as a capability. It retains only DM21 blast AVMs Land used on their own. Landmine and Cluster Munition Monitor. "Canada," (n.d.). http://archives.the-monitor.org/index.php/publications/display?url=lm/1999/canada.html
Authors note: Without protection mechanisms such as AP mines or AHDs, and without specialized fuzes, DM21s create minefields of minimal stopping power and are likely little deterrence to enemy force commanders.

[14] NATO, Allied Procedural Publication 34, *Testing and Interoperability of Area Access Control Obstacle Systems* (NATO Standardization Office, 2019), 1-1.

[15] Department of National Defence, *Advancing With Purpose: The Canadian Army Modernization Strategy* (Ottawa: DND Canada, 2020), 22.

[16] *Ibid*., 26-27.

Capabilities cannot be developed to level the playing field - they need to overwhelm.[17] Historically, this has meant overwhelming with mass. A trend of weapon systems being less powerful, less deadly, and less destructive means that traditional technologies such as minefields are decreasing in relevance.[18] NATO nations must recognize this trend and the necessity to change how they fight. The need for counter-mobility in particular persists.

Recent conflicts, most notably the war in Nagorno-Karabakh, have reinforced the need for militaries to evolve. Elements traditionally found on the battlefield, such as tanks, artillery, and infantry, competed with technologies such as loitering munitions and drones, and these new technologies had devastating effects on the traditional systems.[19] Social media was flooded with footage of armoured vehicles burning on the battlefield as a result of precision drone strikes, leading some critics to argue that the age of the tank is over.[20] Others refute this, contending that poor training and tactics instead enabled the success of the drones.[21] It is likely that this and other factors were at play to some extent in this conflict, and its far too early to cast aside tanks. Russian and China show no signs

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[17] National Research Council, *Making the Soldier Decisive on Future Battlefields* (Washington, DC: The National Academies Press, 2013), 16.

[18] Koplow, 18.

[19] Shaan Shaikh and Wes Rumbaugh, "The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense," *Centre for Strategic & International Studies*, last modified 8 December 2020, https://www.csis.org/analysis/air-and-missile-war-nagorno-karabakh-lessons-future-strike-and-defense; Stijn Mitzer and Joost Oliemans, "Aftermath: Lessons Of The Nagorno-Karabakh War Are Paraded Through The Streets Of Baku," *Oryx*, last modified 26 January 2021, https://www.oryxspioenkop.com/2021/01/aftermath-lessons-of-nagorno-karabakh.html

[20] Jatinder P. Joshi, "The Nagorno-Karabakh War: Advantage Hindsight: A View," *Air Power Asia*, (January 3, 2021): 12; Franz-Stefan Gady and Alexander Stronell, "What the Nagorno-Karabakh Conflict Revealed About Future Warfighting," *World Politics Review,* last modified 19 November 2020. https://www.worldpoliticsreview.com/articles/29229/what-the-nagorno-karabakh-conflict-revealed-about-future-warfighting.

[21] Joshi; Robert Bateman, "No, Drones Haven't Made Tanks Obsolete," *Foreign Policy,* last modified 15 October 2020. https://foreignpolicy.com/2020/10/15/drones-tanks-obsolete-nagorno-karabakh-azerbaijan-armenia/

of disappearing continue to develop new ground armoured combat vehicles.[22] As such, even though traditional persistent and non-discriminatory explosive obstacles have been largely regulated out of use, the Nagorno-Karabakh conflict has given military leaders around the world a glimpse into what the future conflict could look like, and counter-mobility continues to be needed.

A non-persistent and discriminate AAC system must be developed to allow battlefield commanders to shape contemporary land forces. The removal of AP mines has left a capability gap for *Ottawa* signatory nations, and this gap can be filled with AAC, giving NATO nations a credible AD component to their own A2AD capability. The traditional counter-mobility mind set and doctrine may need to shift, but whatever challenges are associated with this cultural and technical change will be small when compared to the effect of Canada getting steamrolled on the battlefield due to its archaic counter-mobility technologies.

Academic studies in this field have largely focused on the use of AP mines and their effects upon the population. NATO is exploring how to fill the capability gap from a practitioner's perspective and has established the framework for the concept of AAC. This study will continue the practitioner's discussion, drawing upon academic resources to amplify where applicable, to answer a number of research questions. Specifically, what capability do landmines provide, and how can they be replaced? What are the capability requirements of an AAC system? What technologies could be employed within an AAC system? What effects does an AAC system need to produce? How would AAC be

[22] Joseph Trevithick, "The Army Wants New Networked Mines That Leap Up To Attack The Vulnerable Tops Of Tanks," *The Drive,* last modified 6 April 2021. https://www.thedrive.com/the-war-zone/40080/the-army-wants-networked-mines-that-leap-up-to-attack-the-tops-of-tanks

employed in an operational theatre? Finally, how well would an AAC system work against a threat actor?

This study will analyze counter-mobility literature and doctrine to determine what capabilities and shortfalls exist. These considerations will be applied to a start state AAC system that has been outlined in NATO studies. A draft design will be tested qualitatively using a case study analysis of the Canadian-led Enhanced Forward Presence battle group defending Latvia from the Russian 4th Tank Guards Division reinforced with Spetsnaz elements. A series of exploratory questions will draw out the shortfalls of the draft AAC system such that a final AAC system can be proposed. The intent of this paper is not to provide one AAC system that can be fielded by NATO nations, but it will contribute to the ongoing discussion on the topic to inform capability development.

Minefields are a technology of the past. Countries need to take action to remove mines from their inventories and take steps to bring AAC into doctrine and policy, thereby developing a component of a credible NATO A2AD capability. Further, soldiers deserve a weapon system that will give them the edge on the battlefield. The transition away from minefields will represent a culture shift for NATO nations and will require senior leader engagement, but militaries need a discriminate system they can rely on to do what mines have historically done. Leaders and soldiers alike are demanding change, the opportunity is upon us to actually lead that change.

LITERATURE REVIEW

Landmine Warfare

To understand the requirement for an AAC system, it is first necessary to explore the doctrinal environment within which it will nest as well as the shortfalls of existing counter-mobility technologies. There are multiple layers and concepts applicable to the discussion. At the strategic level, the concept of relevance is A2AD.[23] A2 is the bubble that keeps an adversary outside your borders while AD restricts your movement when inside the bubble. A2AD draws upon the breadth of multi-domain capabilities from the land, air, maritime, space, and cyberspace domains, as well as the electromagnetic spectrum to create a significant strategic deterrent to invading a nation's territory or interests.[24] Russia and China, for example, have established formidable A2AD networks to respectively deter a NATO invasion and US incursion into the South China Sea.[25] Although formidable, nations must assume that their A2 bubble will be breached and AD components will be needed to limit an adversary's freedom of action on the ground.

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[23] Anti-access is defined as "those actions and capabilities, usually long-range, designed to prevent an opposing force from entering an operational area." Area denial, on the other hand, is "those actions and capabilities, usually of shorter range, designed not to keep an opposing force out, but to limit its freedom of action within the operational area. Tangredi, 21.

[24] Vincent Alcazar, "Crisis Management and the Anti-Access/Area Denial Problem" *Strategic Studies Quarterly* 6, no. 4 (Winter 2012): 51.

[25] Visarion Neagoe and Silviu-Stelian Borsa, "Anti-Access/Area Denial Strategy – Conventional War, Hybrid War or Asymmetric War?" *Strategic Impact* 3, no. 4 (2019): 16-17; Alcazar, 42.

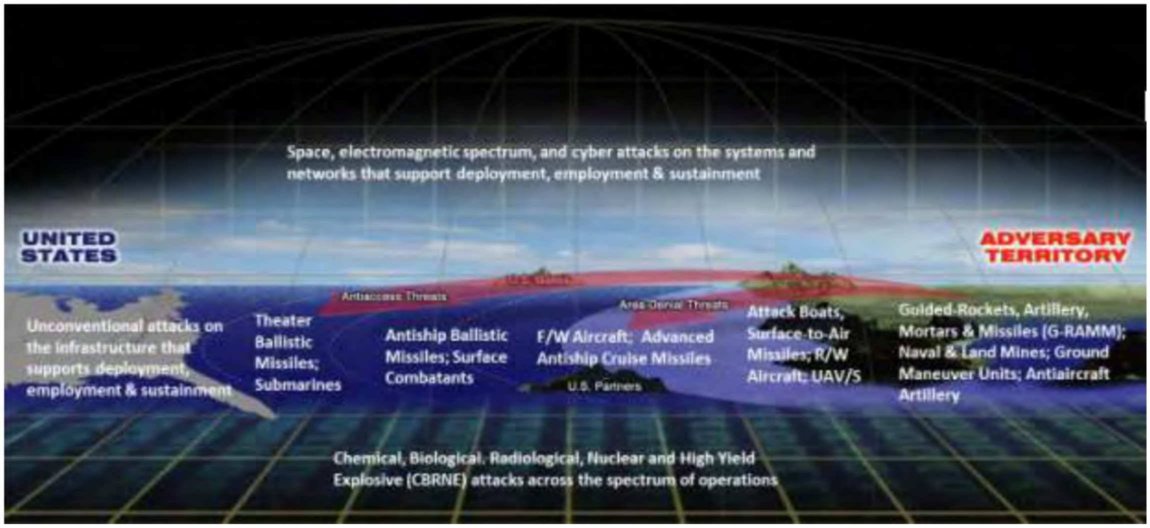

Figure 1 -- A2AD Capabilities as part of a Layered, Integrated Defence
Source: US Department of Defence. *Joint Operational Access Concept*, 11.

AD is multi-faceted, but one element of significance is counter-mobility.[26] Terrain itself can be a natural physical obstacle to movement, but it will likely require reinforcement so that the enemy manoeuvre within the terrain is in accordance with the friendly force commander's intent. Counter-mobility layers direct and indirect fires with obstacles to reinforce the existing terrain to block, disrupt, fix, or turn an adversary's land forces.[27] The psychological effect comes from the nature of the obstacles themselves, including how they are designed and employed. The enemy cannot be confident in their actions. When these capabilities are successfully integrated, they shape the enemy's movement in accordance with the friendly force commander's plan.

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[26] Counter-mobility is "either physically or psychologically affecting the enemy force so that its ability to maneuver is impeded even more than the difficulties posed by the existing media of the battlespace." Krueger, 6.

[27] Although these specific probabilities of encounter are for scatterable mines, the percentages give an idea of relative density and level of effort for each tactical effect – "Disrupt (low density, 40-50% chance of encounter), Fix (med density, 5-60), Turn (high, 75-85) Block (high, 85+)." Department of the Army, FM 20-32, *Mine/Countermine Operations* (Washington DC: HQ Department of the Army, 1998), 3-7.

Obstacles are tactical effectors which are emplaced in accordance with the manoeuvre commander's counter-mobility plan. Coordinated within the larger counter-mobility plan through the process of barrier planning, obstacles "attack the mobility of adversaries, enhance the effectiveness of friendly fires, deny adversaries the use of terrain, disrupt sustainment operations, and inflict damage to enemy forces."[28] While some are meant to neutralize an enemy, they can also be emplaced to warn and therefore deter.[29] They can degrade an enemy's ability to mass fires, while enabling friendly forces to do exactly that by increasing target acquisition time and focusing the enemy into a smaller area, making it much easier to engage.[30] Although the emplacement of obstacles is a tactical task, they can have effects up to the strategic level. Obstacles emplaced prior to hostilities can provide a deterrent and thus strategic effect. At the tactical level, obstacles support tactical offensive or defensive activities.[31] Obstacles can be an impressive force multiplier for a commander and will remain relevant well into the future. That said, landmines provide another complexity to this discussion and their relevance is contentious.

[28] US Department of Defence, JP 3-15, *Barriers, Obstacles, and Mine Warfare for Joint Operations* (Washington DC: Department of Defence, 2018), vii.
[29] *Ibid*., 1-2.
[30] *Ibid*., II-3.
[31] *Ibid*., ix.

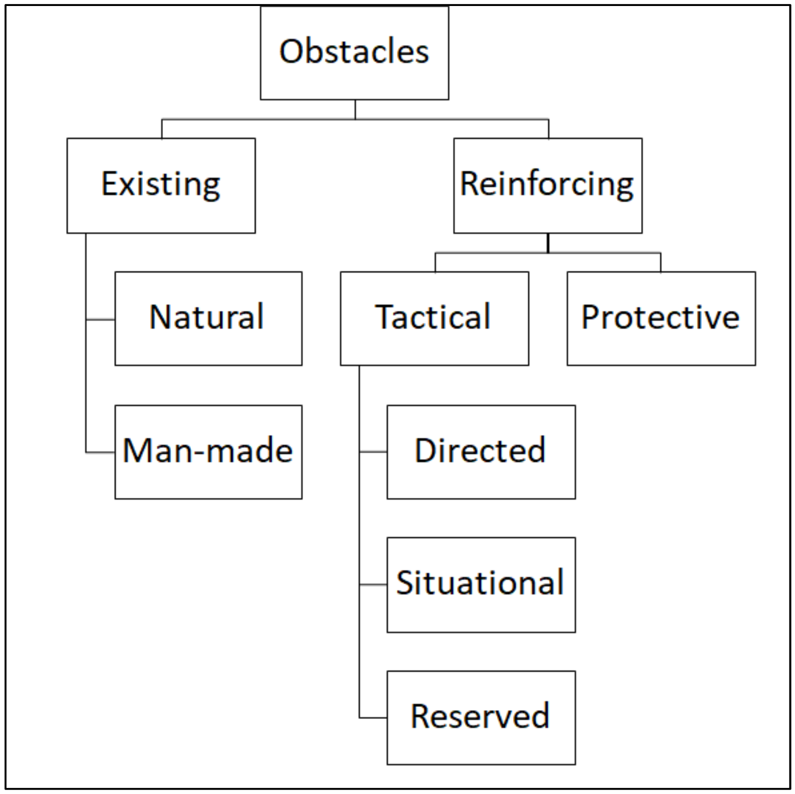

Figure 2 -- Obstacle Hierarchy
Source: Department of National Defence, B-GL-361-201-FP-001, 1-1-2.

Landmines are munitions designed to be placed under, on, or near the ground or other surface area and to be exploded by the presence, proximity, or contact of a person or vehicle.[32] There have been examples of mines used throughout history, and their use increased in prevalence late in World War I (WW1) when the German Army used them to counter-measure tanks, the new threat on the battlefield.[33] Like other obstacles which create effects on the physical plane, minefields shape the enemy's advance.[34] Although some sources present mines in much the same way as other obstacles types by saying

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[32] United Nations, *Protocol on Prohibitions or Restrictions on the Use of Mines, Booby-Traps, and Other Devices as Amended on 2 May 1996 (Protocol II as Amended on 3 May 1996) Annexed to the Convention on the Prohibitions or Restrictions on the Use of Certain Conventional Weapons which may be Deemed to be Excessively Injurious or to Have Indiscriminate Effects* (1996), 2.

[33] C.E.E. Sloan, *Mine Warfare on Land* (Exeter: A. Wheaton & Co, 1986), 1.

[34] Walter Natynczyk, "Technology in Battle: Smart Mines" (Exercise Leonardo da Vinci, Canadian Forces Staff College, 1992), 2.

"mines are essentially a means of providing terrain enhancement for defensive purposes,"[35] others clarify that mine obstacles differ from other obstacles and create a new dimension to the land war. As stated by the former Chief of the General Staff in the United Kingdom, General Sir Nigel Bagnall, mines augment the physical effect of obstacles with a new psychological effect, as when it comes to the mind set of vehicle crews: "….dash [is] replaced with caution, determination by prudence, and contempt by a healthy respect. The psychological effect of mines is then a factor of considerable importance in itself."[36] Field Marshall Sir William Slim made a similar comment: "Everything that is shot or thrown at you or dropped on you in war is most unpleasant, but of all horrible devices, the most terrifying…is the landmine."[37] Mines are a unique obstacle thanks to this additional psychological uncertainty they create.

Landmines come in many forms. From a traditional perspective, anti-vehicle (AVM),[38] anti-personnel (AP), and off-route mines (ORM) are employed on their own or are used to reinforce other obstacles. They assist in shaping the battlefield by "autonomously delaying or killing the enemy at a safe distance from friendly forces,"[39] enabling the enemy to be shaped and friendly firepower to be concentrated more efficiently.[40] AVM are employed when there is a vehicular (not necessarily but generally armoured) threat. Like other obstacle types, AVM are vulnerable to adversary countermeasures, and as such, AP mines were introduced to discourage soldiers from

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[35] Sloan, 113.

[36] *Ibid*., v.

[37] US DoD, JP 3-15, *Barriers, Obstacles, and Mine Warfare for Joint Operations*, (Washington DC: Department of Defence, 2018), I-1.

[38] AVM is used interchangeably with the term anti-tank mine. The term AVM has been used so that relation can be maintained with the *DAVM*.

[39] National Research Council, *Alternative Technologies to Replace Antipersonnel Landmines* (Washington, DC: The National Academies Press, 2001), 1.

[40] *Ibid*., 26; Koplow, 136. US DoD, JP 3-15, I-2.

breaching the AVM minefield.[41] AP mines are much more sensitive than AVMs as they require less force to actuate the mine's fuse. ORMs, also known as off-site or horizontally acting mines, on the other hand, have a more limited range and effect, and their utility is contested.[42] Often, minefields employ a mixture of each of these mines, targeting different elements of an attacking force.

Mines have become increasingly sophisticated for a number of reasons. The first is to protect the mines themselves from evolving mine counter measures.[43] Second, mines have become more sophisticated such that they can attack their target in a variety of ways. The first mines exploded when driven upon. These mines are classified as track cutting or single impulse mines. Mine designers refined designs, creating what are called belly attack mines to direct the effects of the mine at the vulnerable underside of a vehicle. Full width attack were then developed.[44] Specialized fuses, whether they be tilt rods, seismic sensors, acoustic sensors, magnetic influence fuses, among a host of others, have been developed in an effort to defeat counter measures and more effectively attack vehicular targets.[45] The threats posed by these specialized fuses have been mitigated to some level with increased armour and counter measures, but they still remain a threat. It should be noted that these fuses make AVM much more sensitive and an increased threat to personnel. The posture, load, and foot fall of a person can make them an inadvertent

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[41] Sloan, 35; National Research Council, *Alternative Technologies*…, .36.

[42] Sloan, 28.

[43] These include manual, mechanical, and explosive breaching methods. Department of National Defence, B-GL-361-001-FP-001, *Engineers in Operations* (Ottawa: DND Canada, 2018), 11-8.

[44] Sloan, 22-24. FWA mines attack have fuses to attack either the track or the belly of the vehicle, and are estimated to increase the probability of engaging a target successfully by two or three times. *Ibid*., 24.

[45] Landmine Action, *Alternative Anti-Personnel Mines: the Next Generations* (London: Landmine Action, 2001), 6.

target of the mine.[46] Efforts have been made to make landmines more discriminate, but they continue to be a largely indiscriminate weapon on the battlefield.

A technological advance of particular interest is the anti-handling device (AHD). AHDs detonate the mine if the mine is tampered with.[47] AHDs make mines much more sensitive and make AVM antipersonnel in nature.[48] AHDs slow minefield breaching efforts and add to the psychological nature of mine warfare. Just like AP mines though, they have the shortcoming that they are indiscriminate. It is estimated that between 50 and 75 percent of AVM mines are equipped with an AHD capability,[49] making them a sizeable indiscriminate threat.

Scatterable (SM)[50] and remotely delivered mines (RDM)[51] are specifically designed to be delivered in a specialized manner. They can be either AVM, AP, or a mix of each type of mine, with many fuse types applicable. SM and RDM form situational obstacles, emplaced in accordance with the commander's requirements to augment the effects of existing minefield. RDM are differentiated from SM by treaty with RDM defined as munitions delivered beyond 500m from its launcher.[52] SM and RDM obstacles can be force multipliers, rapidly delivering counter-mobility effects to areas of concern, but they have numerous drawbacks. They are generally not marked or fenced due to the

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[46] *Ibid*.

[47] US DoD, JP 3-15, B-10; Landmine Action, 19.

[48] Landmine Action, 19.

[49] *Ibid*.

[50] Examples of SM tasks include: "rapid mine laying when time is short; the imposition of quick response obstacles ahead of an unexpected enemy thrust; thickening of other obstacles such as weak minefields and woods; scattering of mines in areas unsuitable for mechanical mine laying; and closing lanes or gaps in minefields." Sloan, 27.

[51] Examples of RDM tasks include: "disruption of enemy movement by mining in front of or amidst their manoeuvre formation; separating lead elements from follow-up off logistic forces; harassing enemy breaching or bridging operations; denial of helicopter landing sites or paratroop drop zones; and attacking HQ locations, artillery positions, or supply dumps." *Ibid*.

[52] *Ibid*., 25; United Nations, *Protocol 2…*, 2.

distance between the obstacle and the emplacing force; they are scattered within a general area and the location of each mine is not known. RDM emplacement needs to be prioritized amongst other artillery missions. Mines may land in inconsequential locations, among others.[53] Only one single RDM mission is known to have occurred in conflict in history and it unfortunately resulted in many duds that posed a subsequent threat for the emplacing force.[54] Regardless, the concept has merit. Commanders must balance these deficiencies against the clear advantages of rapid and offset obstacle emplacement, and such practices could still be of use when delivering AAC systems to distant locations on the battlefield.

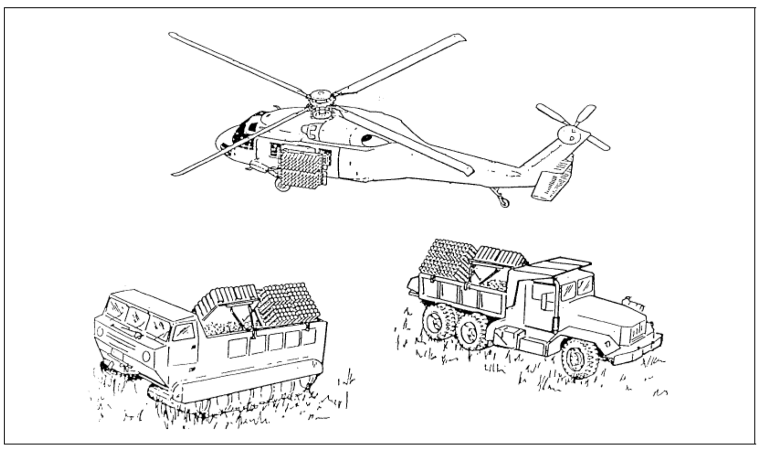

Figure 3 -- Examples of Delivery Mechanisms for Scatterable Mines.
Source: Department of the Army, FM 20-32, 3-16.

[53] Koplow, 135.

[54] On Jan. 30, 1991, three howitzer units from Fifth Battalion, 11th Marine Regiment, fired the first and possibly only artillery-delivered scatterable mine mission in history, spreading more than 850 mines between a series of observation posts located along the Saudi-Kuwaiti border. Although those mines were supposed to self-destruct, contract deminers found hundred of their duds in Kuwait after the war. John Ismay, "The U.S. Army Is Trying to Develop New Land Mines — Ones That Don't Harm Civilians." *The New York Times*, last modified 13 November 2018. https://www.nytimes.com/2018/11/13/magazine/army-landmines.html

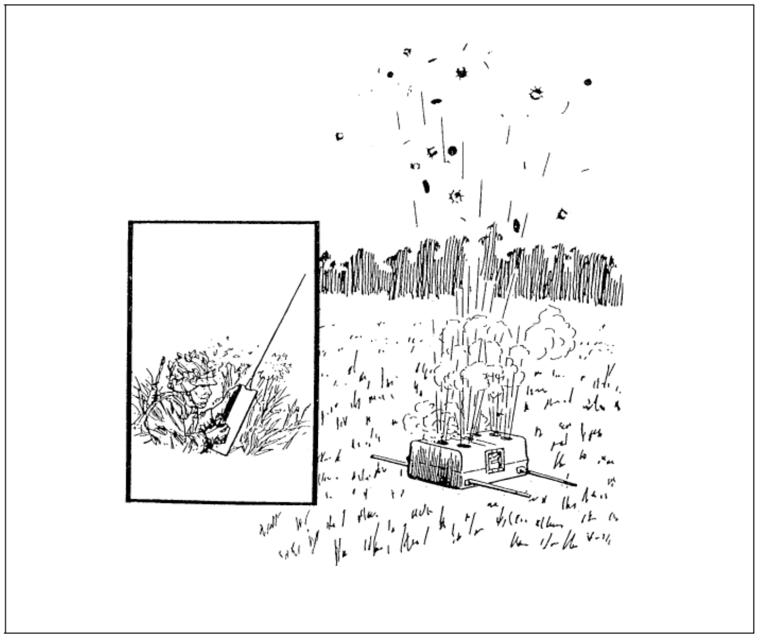

Figure 4 -- Modular Pack Mine System (MOPMS). MOPMS is essentially a minefield in a suitcase that is hand-emplaced on the battlefield and generally employed as a situational obstacle. Each MOPMS contains 17 AT and 4 AP mines, covering an area of 70m by 35m.[55] A single radio-control unit can run up to 15 MOPMS on the battlefield. They can also be hardwired to a controller. The MOPMS is recoverable and reusable.[56] Source: Department of the Army, FM 20-32, 3-22.

Arms manufacturers have developed new technologies in an effort to make mines less persistent and therefore less of a risk after their intended window of use. Many modern mines can have either self-destructing, self-neutralizing, and/or self-deactivating features.[57] Some mines combine many of these features in an effort to achieve 100 percent safety assurance.[58] That said, during the First Gulf War in 1991, deployed smart mines failed at a rate of 150 times higher than that reported by the Department of Defense

[55] Department of the Army, FM 20-32, 3-21.

[56] Todd South, "Army researchers building 'smart' land mines for future combat," *Army Times*, last modified 12 July 2019. https://www.armytimes.com/news/your-army/2019/07/12/army-researchers-building-smart-landmines-for-future-combat/

[57] Self-destructing mines blow themselves up after a predetermined period of time. Self-neutralizing mines are designed such that they render themselves inoperable after a predetermined period of time. The electronic circuitry of a self-deactivating mine on the other hand will wear out after a period of time (commonly as a result of a battery running out of power). UN, *Protocol 2*, 3.

[58] Koplow, 144.

(DoD).[59] A former American Principal Deputy Assistant Secretary of Defense for Special Operations/Low Intensity Conflict professed that many American officers would never use scatterables in conflict due to the lack of trust in these mines.[60] It must be noted that even if this issue of persistence is eliminated, it does not address the more menacing issue with mines – their indiscriminate nature of attack.

From an operational perspective, mines have a number of other drawbacks that could be overcome with a new concept for counter-mobility. First and foremost is the scale of resources, manpower, and time required for traditional tactical minefields to have the required effect upon the adversary.[61] Although it is estimated that 20 percent of tank losses in World War II can be attributed to mines,[62] the Soviets needed to employ over 200 million mines in their war with the Nazis.[63] In more modern conflicts, there have been examples of mines not being deployed into a theatre due to the logistical burden.[64] Another challenge with modern smart mines is the introduction of circuitry and power sources that has created a shelf life for the mine and therefore a requirement for life cycle

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[59] Friends Committee on National Legislation, "Understanding Landmines," last modified14 February 2020. https://www.fcnl.org/updates/2020-02/understanding-landmines; US General Accounting Office, *GAO-02-1003: Information on U.S. Use of Land Mines in the Persian Gulf War* (Washington DC: US General Accounting Office, September 2002), 27-31.
1,314 "Gator" cluster bombs littered the Kuwaiti and Iraqi sands with almost 90,000 AVM mines and 27,500 AP mines. Deminers working in Kuwait reported finding 205 dud AVM and 841 dud AP mines. Further, artillery delivered smart mines failed as well, with 746 AVM and 185 dud AP mines reported Note that these stats do not include the number of dud mines found in Iraq. Ismay; GAO, 27.

[60] Human Rights Watch, "In Its Own Words: The U.S. Army and Antipersonnel Mines in the Korean and Vietnam Wars, V. Epilogue: 'Smart' Mines are a Dumb Solution," last modified 2017. https://www.hrw.org/legacy/reports/1997/gen1/General-04.htm

[61] Natynczyk, 3; National Research Council, *Reducing the Logistics Burden for the Army After Next: Doing More with Less* (Washington, DC: The National Academies Press, 1999), 6-9.

[62] Sloan, 2.

[63] *Ibid*., 3.

[64] Natynczyk, 3; Liam Collins and Harrison Morgan, "Affordable, Abundant, and Autonomous: The Future of Ground Warfare," *War on the Rocks*, last modified 21 April 2020. https://warontherocks.com/2020/04/affordable-abundant-and-autonomous-the-future-of-ground-warfare/

management.[65] Mines may be cheap and relatively easy to produce, but they are not easy to manage.

Most tellingly, there is much debate amongst commanders with regards to their utility overall. Mines hinder the movement of friend and foe alike. This reduces the overall advantage that some countries, such as the US, have over their adversaries.[66] One former Marine Commandant is quoted as saying

> What the hell is the use of sowing all [these scatterable smart mines] if you're going to move through [them] next week or month?...We have many examples of our own young warriors trapped by their own minefields or by the [old] French minefields [in Southeast Asia]. We had examples even in Desert Storm.[67]

It was noted earlier by Field Marshal Slim just how effective the psychological effect of mines is on soldiers, but this clearly needs to be weighed against the manoeuvre requirements of a land force. Other technologies, such as anti-tank guided missiles (ATGM), have achieved significant success with far less logistical burden, threat to one's own mobility, and persistent and indiscriminate threat.[68] These are just some drivers for the need to modernize the concept of employing mines in counter-mobility obstacles.

A larger issue is the impact that mines continue to have in the post-conflict environment. They are indiscriminate and persistent. It is estimated that there are between 60 and 100 million mines left in the fields of up to 80 countries worldwide.[69] Most of

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[65] Edward Chin, Christopher E. Kramer, and Ken R. Schulters, "Area Denial," *US Army*, last modified 8 June 2016. https://www.army.mil/article/169261/area_denial

[66] National Research Council, *Alternative Technologies*…, 2; Koplow, 147.

[67] Human Rights Watch, *V. Epilogue*.
Another General is quoted: "Our Army's battle doctrine is predicated on maneuver, on the very ability of units to shift rapidly on a fluid battlefield. And even mines sown by friendly forces get in the way of that freedom to maneuver-not to mention the debilitating effect of taking casualties from your own weapons." Human Rights Watch, *V. Epilogue*.

[68] Watling, 26; Sandra I. Erwin, "U.S. Antitank Weapons Could Replace Landmines, Study Says," *National Defense* 84, no. 559 (Sep 1999): 17.

[69] Koplow, 137.

these mines are basic in design and as such continue to be a real threat to the populations of those countries.[70] Deemed as "weapons of mass destruction in slow motion" by former UN Secretary General Boutros Boutros Ghali,[71] legacy mines cause between 10,000 and 20,000 casualties annually.[72] 2015 research demonstrated that 78 percent of all landmine victims were civilian.[73] Physical casualties are not the only concern. Legacy mines also hinder the development of the nations they lie in,[74] can undermine the popular support of the government,[75] as well as render agricultural land unusable.[76] From an escalation of force perspective, mines do not warn of their presence unless they are well marked, and they escalate immediately to lethal effects. Their legacy of persistent and indiscriminate effects is not commensurate with the operational effect they have during the conflict itself.

The international community has reacted to the devastation wreaked by mines around the world. Action was taken on 3 December, 1997, when 122 countries signed the *Ottawa Treaty*.[77] As of January 2018, 164 states are party to the treaty, with key non-signatories including the US, Russia, and China.[78] This treaty has also been called the

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[70] Office of International Security and Peacekeeping Operations, *Hidden Killers 1994: The Global Landmine Crisis* (Washington DC: Department of State, December 1994), executive summary.

[71] United Nations Meetings Coverage and Press Releases, "We Must Eliminate Land-Mines Once and For All, Says Secretary-General to Resumed Session of Review Conference on Certain Conventional Weapons," 22 April 1996. https://www.un.org/press/en/1996/19960422.sgsm5968.html

[72] Koplow, 133.

[73] The Monitor, *Landmine Monitor 2016* (November 2016), 2. http://www.the-monitor.org/media/2386748/Landmine-Monitor-2016-web.pdf

[74] Geneva International Centre for Humanitarian Demining, *The Humanitarian and Developmental Impact of Anti-Vehicle Mines* (Geneva, September 2014), 14.

[75] US Department of Defence. JP 3-15…, I-3.

[76] Ann Peters, "Landmines in the 21st Century," *International Relations* 13, no. 2 (August 1996): 37; Mine Action Information Center, *The Landmine Action Smart Book* (Harrisonburg: James Madison University, 2004), 4.

[77] Sara Schmitt, "The Ottawa Convention at a Glance," *Arms Control Association*, last modified January 2018. https://www.armscontrol.org/factsheets/ottawa.

[78] *Ibid*.

"*Mine Ban Treaty*," but this has led to significant confusion. The *Ottawa Treaty* is specifically related to AP mines, and does not regulate the use of AVMs.[79] This is a concern, as a 2010 study presented that civilians are vulnerable to AVM as well as AP mines – civilians constitute three quarters of AVM casualties.[80] A legacy AVM will detonate when a family vehicle drives over it. Also, the sensitive nature of some fuses as well as the presence of AHDs make many AVMs as sensitive as AP mines.[81] Attempts have been made to ban AVM but they have failed; however, some regulation has been achieved through the 2006 *Declaration on Anti-Vehicle Mines* (*DAVM*). The *DAVM* does not focus on eliminating the use of AVM, it instead focuses on minefield marking and minefield transfer between parties.[82] Many countries such as China, Russia, the US, among others, have presented their reservations with the *DAVM* as AVM mines have significant operational importance to them. These countries take a realist geopolitical approach to arms control and the operational necessity to maintain a credible deterrence overrides the potential humanitarian impact.[83] China asserts that there would be an economic impact in having to upgrade or replace mines, while Russia asserts that the non-detectability of their AVM is a crucial aspect in conflict.[84] These reservations

[79] United Nations, *Convention on the Prohibition on the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction,* (1997).

[80] Dan T Clarke, "Anti-Vehicle Landmine Restrictions: Failure in Arms Control" (exercise Solo Flight, Canadian Forces College, 2017), 14.

[81] "Recently, the Department of National Defence (DND) reports that tilt rod fuses were separated from all M21 anti-vehicle mines in stock and destroyed in compliance with the treaty. The 20,000 stripped M21s are scheduled for destruction in the coming year." Landmine and Cluster Munition Monitor.
In addition, "Canada has FFV 028 self-neutralising anti-vehicle mines…. the Dutch Ministry of Defence believed the magnetic influence mine would not be in accordance with the Ottawa Treaty because of the highly sensitive nature of its sensor…both the CF 1996 and 1998 mine databases warn that the mine may be set off by the metal components in a mine detector. DND confirms that the mines are controversial and reports that its tests remain inconclusive." *Ibid*.

[82] United Nations, *Declaration on Anti-Vehicle Mines*, 16 November 2006.

[83] Clarke, 7.

[84] United Nations Office for Disarmament Affairs, "Statement from the Russian Federation at April 2014 Meeting of Experts on MOTAPM," 2014. https://unoda-web.s3-accelerate.amazonaws.com/wp-

confirm that countries acknowledge that mines, or a mine-like capability, still have a place on the battlefield.

Mines have historically been an effective component of obstacles, but it is clear that "future operations will require more advanced munitions that are policy-compliant and much more capable than the "dumb" conventional mines they will replace."[85] Although some nations continue to rely heavily on mines, [86] other nations are drawing down their use. The US has used mines only once since the First Gulf War.[87] Acknowledging the problematic nature of indiscriminate munitions, in 2014 the US administration under then President Obama restricted the use of AP mines to the Korean peninsula – a decision reversed six years later by the Trump administration, which nonetheless specified the requirement for said mines to have self-destruction and self-neutralization features.[88] The reservations of many nations to sign the *DAVM* reinforces the desire to maintain stocks of AVMs, although this is interesting in that the banning of AP mines makes minefields largely ineffective in the face of modern breaching capabilities.[89] A controllable mine-free barrier system that has similar effects to a

content/uploads/assets/media/AF01BBFA7095933EC12579D50028D4B1/file/CCW_MOTAPMStatement_am_Russian_Federation.pdf

[85] Edward Chin, Christopher E. Kramer, and Ken R. Schulters.

[86] There are more than one million mines along the demilitarized zone on the Korean peninsula, and another two to three million more held in reserve. Koplow, 136.

[87] Ismay. Allegedly a single munition was used in Afghanistan in 2002.

[88] Patrick Tucker, "US Expected to Loosen Restrictions on Land Mines — Smart Ones, Anyway," *Defense One*, last modified 30 January 2020. https://www.defenseone.com/technology/2020/01/us-expected-loosen-restrictions-land-mines-smart-ones-anyway/162773/.
The Biden administration does not plan to change the policy of the Trump administration: "Landmines, including anti-personnel mines, remain a vital tool in conventional warfare that the United States military cannot responsibly forgo, particularly when faced with overwhelming enemy forces in the early stages of combat," Mike Howard, a Pentagon spokesperson told The Daily Beast on Apr. 6, 2021. "Withholding a capability that would give our ground forces the ability to deny terrain temporary and therefore shape an enemy's movement o our benefit irresponsibly risks American lives." Trevithick.

[89] National Research Council, *Alternative Technologies*…, 15.

minefield does not exist,[90] but one is desired such that battlefield commanders can achieve the effects they need without incurring years of post-conflict hazard due to the weaknesses inherent in current mine systems. AAC could be the answer that nations are searching for.

Area Access Control

The banning of AP mines has led to a significant capability gap for those nations who abide by the terms of the *Ottawa Treaty*. The NATO Industrial Advisory Group (NIAG) conducted a study in 2014 and recognized that "NATO's ability to control movement in non-line of sight areas has diminished considerably."[91] The NIAG presented that "an AAC system delivers lethal and non-lethal effects to personnel and vehicle targets (including armoured vehicles) through the use of state of the art sensors, effectors, and command and control systems."[92] AAC and the AD component of A2AD are commonly confused; AAC is one tactical element within the larger AD strategy. The concepts within the NIAG report could fill the requirement for a discriminate and non-persistent system to replace minefields and to reinforce a nation's A2AD capability.

The NIAG envisions an AAC architecture consisting of three primary building blocks: a sense function; a command function; and an effector[93] function.[94] A similar systems architecture was presented in other literature, identifying the requirement for "precise real time surveillance systems to automatically detect, classify and track vehicles and/or people; precise firepower to immediately suppress movement of enemy forces;

[90] NIAG, 5.
[91] *Ibid*., 3.
[92] *Ibid*.
[93] The word effector is deliberately chosen here, as the elements within this system provide an effect, lethal or non-lethal, on a target. They are not necessarily weapons.
[94] NIAG, 3-5.

command and control systems (a 'man-in-the-loop') to cue the precise firepower."[95] These elements are deliberately left vague as AAC is a system and is not tied to specific technologies. That said, AAC is clearly not a traditional directed reinforcing obstacle, which consist of only active or passive effectors. It does, however, resemble traditional situational reinforcing obstacles, in which a commander must decide when to put the obstacle into a targeted area of interest (TAI) based on the identification of an enemy within a named area of interest (NAI). The sense and command function of this system brings to the barrier something that traditional mine obstacles did not have in the past: discrimination. Persistence on the other hand will depend on the effector technology chosen.

NATO continued the work of the NIAG in its publication of *APP-34*. In addition to the recommendation for AAC systems to detect, locate, and identify targets (sense), as well as the command and act functions identified by the NIAG, additional considerations are outlined. AAC systems should also be able "to give an overview and the status of the available lethal and non-lethal effectors to disrupt or deny those threats, and a remote-controlled way to activate and de-activate specific effectors as required."[96] This implies a central command node that has immediate access to the entire network, and that this command node, or nodes, needs to be hardened in such a way that it is reliable under the conditions of modern conflict. Electronic warfare (EW) is of particular concern and mitigation must be implemented so that the AAC system is effective. This recommendation also implies that an AAC system should be plug and play so that the actual effector can be chosen based on the task at hand. An additional consideration

[95] Landmine Action, 41.
[96] NATO, Allied Procedural Publication 34, 1-1.

clearly outlined in *APP-34* is the need "to de-activate any effectors in order to provide safe passage and allow maintenance and/or recovery/reuse of the system components."[97] This has the same implications as the previous statement, but there is also an element of trust that needs to be innate within the system. Those soldiers directed to cross the obstacle, whether it be on foot or in a vehicle, need to trust that the system is deactivated. As discussed earlier, there is a psychological element to mine warfare, and the AAC system cannot be such that the soldiers do not trust their own obstacles enough to cross them when required. These are particularly important considerations when designing an AAC system for the advance and withdrawal movements inherent to high intensity conflict.

It is implied that for an AAC system to be effective, networking between the sensor, command, and effector functions must be robust as well as scalable both vertically and horizontally. Large quantities of information need to travel between the array of dispersed sensors which are likely over the horizon, the command nodes, and the effector, which could and likely would be an array of many weapons systems potentially over the horizon from the friendly force.[98] It is likely that there would be numerous potential targets, so the system should apply discrimination to determine which targets should be tracked or attacked.[99] The discriminatory nature of this system makes it more complex than traditional obstacles, and as such it is vulnerable to a number of potential counter-measures. Understanding the complexity of such a system does enable threat

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[97] *Ibid.*
[98] Watling, 32; Landmine and Cluster Munition Monitor.
[99] Tangredi, 33.

mitigation to ensure its effectiveness over time. With mitigation from counter-measures, this system in general has great potential.

Sensor

Sense provides a commander with knowledge.[100] Sensors distributed throughout the operating environment are what provide the data to develop this knowledge. Sensors are focused in to NAIs to find and identify targets, giving the commander time to make a decision on what to do with the observed targets. Sense is related to time. The broader and more diverse a sense network is, the more time that is made available for decision making. Sensors can include ground reconnaissance elements, radar, electronic warfare assets, unmanned aerial systems (UAS), amongst a host of other tools, all coordinated within the commander's Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR) plan. From an AAC perspective, *APP-34* notes that "the main function of sensors is to observe activity in the field and convert the activity into a standardized information format that can be evaluated by the C2 component."[101] An AAC system will be another element within the formation ISTAR network. The challenge rests with the sheer amount of data available to the commander, who, when provided too much information, risks failing to act.

There are two layers of sense that need to be differentiated. The first layer is formation ISTAR – a broadly dispersed sensor screen that will identify the adversary's axis of advance and potential intent so that massed precision and area-effect munitions, attack aviation, or other capabilities available to the commander, can inflict attrition or

[100] Department of National Defence, B-GL-300-001/FP-001, *Land Operations* (Ottawa: DND Canada, 2008), 4-19.
[101] NATO, Allied Procedural Publication 34…, 1-1.

shaping actions upon the enemy formations.[102] ISTAR cues effects, to include AAC assets, such that they are in the right place at the right time to effect the enemy. The next layer of sense, integral to the AAC system itself and consisting of shorter-range sensors, is required to identify specific targets. These two layers of sense do not necessarily need to be independent of each other, but they do need to be networked in a secure manner so that there is a handover between the long and short-range sensors once the AAC system is deployed. Once this occurs, the short-range integral sensors can further discriminate targets and enable the launch of effectors.

Although it will be argued later that full autonomy should not be considered at this time, it would be irresponsible to not consider the benefits of human robot interaction (HRI) and to incorporate some level of autonomy into the sense function of an AAC system. The operating environment is complex, so rapidly developing understanding is critical, especially when discriminating between combatants and non-combatants.[103] A human brain uses object detection, recognition, tracking, multi-sensor fusion, and motor control to develop scene understanding.[104] In a related manner, the field of autonomous target recognition (ATR) outlines a target recognition process in which processor algorithms follow a sequence from detection to attack.[105] From a machine perspective, a concept of how target recognition is developed is as follows: detection; discrimination; preclassification; classification; and identification. This enables the successive isolation of a target signature from the environmental noise in order to discern its identity for

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[102] NATO, Allied Joint Publication 3.2, *Allied Joint Doctrine for Land Operations* (NATO Standardization Office, 2016), 2-19.

[103] Nathan Leys, "Autonomous Weapon Systems and International Crises," *Strategic Studies Quarterly* (Spring 2018): 53.

[104] Bruce T. Schacter, *Automatic Target Recognition – Second Edition* (Washington: SPIE Press, 2017), 171.

[105] Natynczyk, 6.

subsequent targeting.[106] Figure 5 demonstrates in more simple terms how this sequence works. A human is not included in this loop, however, this technology could assist a human during the target engagement process by cuing them on to potential targets and enabling target prioritization and engagement.

APP-34 identifies a number of sensor functions that should be resident in an AAC system, many of which resemble ATR. These include detection, tracking, classification, identification, positive identification, target reporting, and advanced engagement techniques.[107] A comparison against the ATR process reveals that the process is quite

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[106] Marvin N. Cohen, "Target Recognition for Autonomous Smart Weapons," *Journal of Electronic Defence* 13, no. 7, (July 1990): 39.
Definitions of each phase:
Detection. In the first phase, vehicles are detected by the IR sensor which takes and compares sequential pictures. Concurrently, the radar cuts through the noise in an effort to confirm the vehicle's presence.
Discrimination. An important step, the discrimination process is particularly difficult with slow vehicle movement. This requires the sensor to be high enough for the radar to scan a large enough area to distinguish hot spots (such as engines or exhaust) from the surroundings. The IR sensor can be programmed with target recognition features to assist in the discrimination.
Preclassification. This function requires programming to direct sensors to pass over certain targets while engaging others. It screens targets by their general characteristics, such as size and general shape, rather than the specifics. In this way, objects of no military value, such as civilian traffic, can be discarded.
Classification. At this point, targets still being considered are grouped by class definition. Useful class definitions could be wheels versus tracks.
Identification. Considered the most sophisticated stage of the process, identification is achieved by a refinement of the classification algorithm. While precise vehicle type could be the determinant, others are possible. Identification friend-or-foe (IFF), mine clearance equipment or other distinguishing features could be programmed to initiate an attack sequence.

[107] NATO, Allied Procedural Publication 34…, 1-10.
Definitions by function:
Detection. AAC sensors should be able to detect the presence of both personnel and / or vehicle movement.
Tracking. The AAC sensors should be able to track personnel and / or vehicle movement and provide estimates of direction and speed.
Classification. The AAC sensors should be able to classify and quantify personnel and / or vehicles (e.g. total number of people and / or tracked or wheeled vehicles, etc.).
Identification. The AAC sensors should be able to identify the types of targets (e.g. T-72, BMP, etc.) in a multi-target environment.
Positive Identification. The AAC sensors should be able to discriminate between enemy combatants, non-combatants, and friendly force.
Target Reporting. The AAC sensors should be able to report the presence and total number of targets, report the engagement of targets, and report potential battle damage assessment (e.g. burning vehicles no longer moving, etc.).
Advanced Engagement Techniques. The AAC sensors could be able to count target passes and therefore seek specific high value targets to engage (e.g. a breacher vehicle, main battle tank, etc.) or to increase disruption by attacking mid-formation.

similar. Where the two processes differ is a certain level of additional sophistication is required for an AAC system. ATR seems directed at conventional conflict, with the sensors directed towards vehicular traffic. AAC notes that personnel are also present in the operating environment and as such the sensors would need to be sophisticated enough for them to distinguish personnel from the background environmental noise, not to mention the additional challenge of differentiating between friend (combatant and non-combatant), foe, and civilian. Further, an ATR system is autonomous, whereas *APP-34* leaves space for non-fully autonomous AAC. *APP-34* notes that "the AAC sensors should be able to report the presence and total number of targets, report the engagement of targets, and report potential battle damage assessment [BDA] (e.g. burning vehicles no longer moving, etc.)."[108] BDA cues the command function to a decision to re-engage if necessary. Both ATR and *APP-34* provide a good start state for designing a sense function, but there needs to be further discussion as to the level of human interaction prior to target engagement.

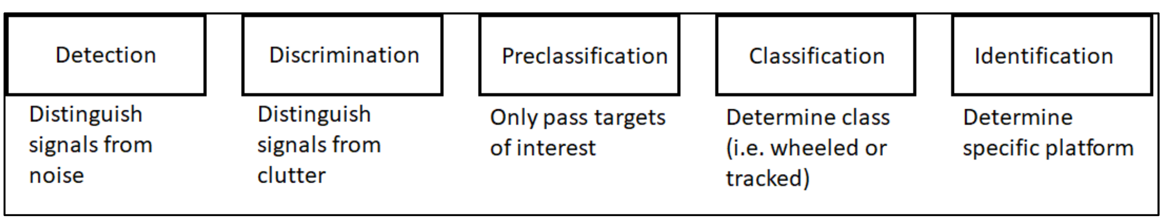

Figure 5 -- Cohen's Stages of Recognition
Source: Cohen, Target Recognition for Autonomous Smart Weapons, 39

An important element of discussion in Cohen's paper on ATR is redundancy in sensors. Using sensors or effectors that have multiple sensor modes from the host of other

[108] *Ibid*.

active and passive capabilities[109] gives greater capability in multiple domains and across a variety of environmental conditions, not to mention greater resilience to countermeasures.[110] In a complex environment, a sense network could be quickly overwhelmed by artificial and natural signals in the area of operations.[111] Layering of sense within the ISTAR network will yield better definition, providing more feeds and enabling cross-referencing as well. AAC has the potential to provide the commander with additional, and potentially better refined, understanding of the battlespace.

Command

C2 is the central building block of an AAC system. It is the brain, whether it is human or not. The C2 block and communication are analogous. "Its function is to provide the operator the ability to plan, maintain, and manage the AAC obstacle systems."[112] In addition to providing a user interface required to control the system, it allows the operator to maintain situational awareness of the system and to communicate with other systems in the network. Once something has been identified by the sensor network, the principle of discrimination implies that a decision needs to be made as to whether it is a legitimate target or not, and this message needs to be relayed to the respective effectors. Maintaining this communication link is critical to the integrity of the overall AAC system.

This building block of the AAC network is the likely choke point in terms of the system's ability to identify a target and then apply the appropriate effects. With the

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[109] NIAG, 23.

[110] Cohen, 39.

[111] National Research Council, *Avoiding Surprise in an Era of Global Technology Advances*, (Washington, DC: The National Academies Press, 2005), 41.

[112] NATO, Allied Procedural Publication 34…, 1-2.

development of artificial intelligence technology, it is possible that this choke point could be reduced or eliminated depending on the level of human interaction in the system. The level of human interaction and control of the AAC system can vary, including: "Human-in-the-Loop" (humans select and engage targets); "Human-on-the-Loop" (robots select and engage targets, but a supervising human can override); and "Human-out-of-the-Loop Weapons" (fully autonomous weapon system (AWS)).[113] The level of autonomy does not need to remain consistent throughout a mission. An AWS may at any given point have differing levels of control over different aspects of a mission.[114] The RQ-9 Reaper UAS can self-navigate and seek out targets, but it is the human operator that makes the decision to fire the Reaper's missiles.[115] While armed and fully autonomous systems exist, such as the Robart 3 which can identify and engage targets with a Gatling gun-type weapon,[116] there is great debate with respect to the ethics of such systems. These systems, much like landmines, still do not meet the requirements of international human law with respect to discrimination. To be compliant, AWS need to be able to discriminate between friend and foe, combatants and non-combatants, and assess proportionality of attack options, among others.[117] Although extremely challenging, it is very likely that such a task could be achieved, but an international consensus on AWS has not been achieved so full autonomy should not be considered for an AAC system at this time.[118]

[113] Leys, 50-51. For clarity, "a weapon system is autonomous if its initiation and use of force - i.e. firing of a weapon - cannot reasonably be traced back to one or a small group of human beings." Egeland, 94.

[114] Leys, 51.

[115] Egeland, 99.

[116] Landmine Action, 52.

[117] Egeland, 103; Leys, 53.

[118] Ismay; Trevithick; Project Manager – Close Combat Systems, "2018 Munitions Executive Summit: PM Acquisition Panel," Briefing (18 April 2018), slide 8.
US efforts are focused on keeping a human in the loop for a number of its projects. "The Army, as well as the U.S. military as a whole, has focused heavily on plans to incorporate some kind of 'man-in-the-loop'

Full autonomy may be out of the question for now, but just as with the sensor building block, some level of HRI would benefit the overall system. Information overload is a regular concern for commanders. Automation could relieve some of this burden, freeing commanders up for other tasks. This also mitigates the risk of fatigued human operators missing significant details or from becoming distracted.[119] Low-risk tasks could be conducted autonomously, leaving the high-risk tasks for the now much more available human controller. An auto-pilot system on an aircraft is an example. A human can decide from moment to moment what level of autonomy the system has.[120] A balance needs to be achieved between risk and autonomy, but consideration should be given to incorporating a level of flexibility into an AAC system.

APP-34 identifies a number of recommendations for the command function of an AAC system. Some are quite obvious, such as interoperability. Most conflicts are fought by coalitions, so AAC systems need to be plug and play as well as transferable between allies and coalition partners. [121] Other key recommendations include the ability to maintain system awareness through obstacle status requests, obstacle feedback to the operator, and network security.[122] Although these specific details are not critical to this discussion, the bottom line is that command is a complex undertaking and central to this system. The command architecture needs to be robust yet flexible, and a fine balance between each must be achieved.

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control scheme into future landmine designs as a counter to criticism about its continued use of these kinds of weapons. Opponents of landmine use point primarily to the dangers these weapons, especially if emplaced indiscriminately, can present to civilians well after a conflict has come to an end." Trevithick

[119] Schacter, 43.

[120] *Ibid*.

[121] Department of National Defence, *Advancing With Purpose: The Canadian Army Modernization Strategy*... 27.

[122] NATO, Allied Procedural Publication 34…, 1-10 – 1-15.

Effector

An effector system engages targets with either lethal or non-lethal effects based on said target being identified by the sensor network and a command to engage being acknowledged.[123] This does not necessarily mean destroying or killing the target. Effects need to be applied to the target such that the enemy's behaviour is affected.[124] It may constitute fixing or striking the enemy on either the physical or psychological plan, if not both.[125] That said, the effects need to be discriminate and proportional to the threat, and this is where landmines become an issue. They are fully autonomous in that there is no human in the loop so the escalation of force in most cases moves immediately to lethal effects. This does not need to be the case. When designing and employing AAC systems, consideration of the target and the commander's intent should dictate the nature of the effector being employed within the system. This implies that the AAC system is adaptable, potentially with plug and play functionality for the effector systems. This could mean that the AAC system is non-lethal in some cases, lethal in others, or potentially a mix in yet others.

In this context, lethality is defined as

> a combined function of the probability of encounter (e.g. effector density and lethal engagement area), the probability of hitting a target in a vulnerable area (e.g. sensing/targeting and firing accuracy), and the probability of kill (e.g. the impact of the effector against the target).[126]

Varying levels of lethality within a system can be achieved by balancing these factors. For instance, a country may choose many effectors with a lower probability of killing a

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[123] *Ibid*., 1-1.
[124] Department of National Defence, B-GL-320-000/FP-001, *Act: The Operational Function* (Ottawa: DND Canada, 2013), 10.
[125] *Ibid*., 21.
[126] NATO, Allied Procedural Publication 34…, 1-9.

target, while another may choose fewer effectors with a higher probability of a kill. Mines, when considered individually, have a high probability of striking and killing a target but only a low probability of encounter, and as such, must be employed in deep fields consisting of many mines. This overall medium level of lethality is offset by their low production costs, historically making them a popular choice. Mines could be used in the system, but the *Ottawa Treaty* has created an international stigma associated with the word "mine."[127] Finland has signed the *Ottawa Treaty* and has removed AP mines from its inventory, but it still employs a "smart" system with an AVM as the central effector.[128] Whereas traditional experience is that smart mine technology is too unreliable and indiscriminate to be deployed,[129] the Finnish defence company FORCIT advertises that its AVM is "programmable, radio-controlled, and features an integrated map function, under which it is impossible to lose an A[V]M."[130] The company is confident that its mines are completely discriminate, but only the future can tell if it can truly do what all others before it have failed to do. Although Canada championed the *Ottawa Treaty*, it does retain a limited AVM mine capability. If there is political concern with further procurement of AVM, there is some legal latitude when it comes to defining weapons. Canada maintains the C19 command-detonated defensive weapon in its inventory (in a command detonated role only), and these were classified as mines in the

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[127] Erin Hunt, "International Day of Mine Awareness and Assistance in Mine Action," *Mine Action Canada*, last modified 4 April 2016. https://www.minesactioncanada.org/international_day_for_mine_action

[128] Marek Dąbrowski and Jakub Palowski, "Poland Gets Rid of Its Landmines Inventory. Time for "Smart" Defence Systems?" last modified 22 December 2016. https://defence24.com/geopolitics/poland-gets-rid-of-its-landmines-inventory-time-for-smart-defence-systems

[129] Human Rights Watch, *V. Epilogue*.

[130] Curtis Hand, "New Land Mine Option," last modified 24 April 2020. https://euro-sd.com/2020/04/news/17056/new-land-mine-option/

past.[131] It is now classified as an area defence weapon.[132] Canada could procure AVM-like area defence or area denial weapons to be employed within AAC, but there are other options as well.

Tactical area denial is also achieved through other means. Cluster munitions - bomblets delivered remotely in a non-reusable tactical munition dispenser - litter the ground to deny its use, or depending on the specific bomblets, can target armoured vehicles through a top attack.[133] They provide an effective capability, with a single howitzer-launched cluster munition providing an equivalent lethal effectiveness of 15 high-explosive rounds.[134] That said, cluster munitions have had a problematic history, similar to the history of AP mines, in that the bomblets are indiscriminate and, regardless of attempts to rectify the issue of duds, persistent.[135] As such, an international commitment was made to eliminate the use of cluster munitions in the *Convention on Cluster Munitions*.[136] Unless significant improvements are achieved in their design, cluster munitions are clearly not a viable option for AAC systems.

Non-persistent and discriminate lethality is achievable on the battlefield, and as such, battlefield commanders can retain the capability to shape enemy manoeuvre as they historically did with traditional obstacles. A more promising lethal option that could be

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[131] Landmine and Cluster Munition Monitor. To ensure compliance with the Mine Ban Treaty, Claymores are produced without the built-in tripwire capability. The Canadian Armed Forces do not consider the Claymore in command-detonated mode to be a mine as defined by the treaty.

[132] *Ibid*.

[133] Mike Jacobson, "Cluster Munitions No More: What This Means for the U.S. Military," *eArmour,* (n.d.) https://www.benning.army.mil/armor/earmor/content/issues/2014/OCT_DEC/Jacobson.html

[134] *Ibid*.

[135] *Ibid*.

[136] *Ibid*. Canada is a State Party of this Treaty. The US, China, and Russia are not Parties or Signatories.

considered are loitering munitions.[137] A significant difference between a landmine and a loitering munition is the level of control required for an operator to guide the kamikaze UAS in to the target and as such, this option has the potential to be personnel intensive. Loitering munitions

> may not have a pre-designated target before launch, but will have a bank of valid target signatures, and will then find a match and strike within a defined area. The value of such systems is that they drastically reduce the fidelity of track data required to successfully strike a target, and thereby reduce the exposure of reconnaissance platforms.[138]

There is a lot of potential to use such an effector in an AAC system as a means to achieve area denial. That said, they differ from mines in that they are expensive, some on the scale of hundreds of thousands of dollars per round.[139] Further, because of their terminal nature, BDA cannot be given without the layering of ISR assets.[140] There are a variety of options on the market. The Isreali Harop for example, has a 50-pound high explosive charge.[141] These and similar systems were employed in Nagorno-Karabakh to "destroy heavy ground units, including T-72 tanks and advanced S-300 air defenses."[142] Smaller systems, such as the individual soldier-launched Switchblade system, have a smaller

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[137] Dan Gettinger and Arthur Holland Michel, "Loitering Munitions," last modified 2017, https://dronecenter.bard.edu/files/2017/02/CSD-Loitering-Munitions.pdf.
A loitering munition is a type of unmanned aerial vehicle designed to engage beyond line-of-sight ground targets with an explosive warhead… A defining characteristic of loitering munitions is the ability to "loiter" in the air for an extended period of time before striking, giving the targeter time to decide when and what to strike. Gettinger and Michel.

[138] Watling, 32.

[139] Neil Hauer, "Turkish and Israeli Military Tech in the Nagorno-Karabakh War," last modified 12 January 2021. https://www.timesnownews.com/columns/article/turkish-and-israeli-military-tech-in-the-nagorno-karabakh-war/706217; Gettinger and Michel.

[140] Tuan Nguyen, "Tiny missile hunts down, destroys enemies," *ZDNet,* last modified 16 November 2011. https://www.zdnet.com/article/tiny-missile-hunts-down-destroys-enemies-video/

[141] Tyler Rogoway, "Meet Israel's 'Suicide Squad' of Self-Sacrificing Drones," *The Warzone,* last modified 8 August 2016. https://www.thedrive.com/the-war-zone/4760/meet-israels-suicide-squad-of-self-sacrificing-drones

[142] Shaikh and Rumbaugh.

explosive payload but also a smaller cost of approximately $70,000 per round.[143] Loitering munitions have an advantage over their more vulnerable conventional ISR/strike UAS peers.[144] Loitering munitions such as they Israeli Harop have a "radar signature of a small bird and virtually no infrared signature whatsoever," making them extremely difficult to detect and counter.[145] Although traditional kinetic energy projectiles (i.e. artillery rounds) are even more difficult to intercept and far cheaper than loitering munitions, their trajectory is more difficult to correct than a human controlled, slower moving, loitering munition.[146] Many loitering munitions can even be return home autonomously to be refueled and relaunched.[147] Such systems should be given serious consideration at being the lethal effectors within AAC systems.

There are a host of non-lethal options on the market or in development that could meet a commander's requirement. They have the distinct advantage that they can be used "in situations where the threat is unclear, such as peace operations, or if large noncombatant populations were in the immediate tactical area."[148] Time is always of the essence on the battlefield, and discrimination can be expensive from a time perspective. "Non-lethal effectors can provide warning not to enter an area, and aide in the determination of intent to make an escalation of force decision."[149] Autonomous non-

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[143] Nguyen; Gettinger and Michel; Rich Smith, "Does Russia's New Drone Pose a Threat to AeroVironment's Switchblade?" *The Motley Fool*, last modified 9 March 2019. https://ca.finance.yahoo.com/news/does-russia-apos-drone-pose-121300946.html

[144] Gettinger and Michel.

[145] Rogoway.

[146] National Research Council, *Reducing the Logistics Burden*…, 99.

[147] Rogoway.

[148] National Research Council, *Alternative Technologies*…, 7.
Nonlethal weapons have several other advantages: they can be used in a broad variety of circumstances; they can be triggered automatically; and they do not require man-in-the-loop operation to be Ottawa compliant, which could improve the timeliness of a response and lessen the burden on the soldier/operator.

[149] NATO, Allied Procedural Publication 34…, 1-9.

lethal effectors can enable the commander to make more important decisions while monitoring the incursion. Effectors such as tasers, obscurants, calmatives, entanglements, acoustics, among others, can provide early warning and deterrence, and many can be, or are in development to be, remotely deliverable.[150] Non-lethal effectors are not a panacea. There are concerns with some technologies that need to be resolved. The first is the controversy with acoustic weapons and their potential to stun and nauseate victims. One Pentagon official professed their ability to 'liquefy their bowels and reduce them to quivering diarrheic messes."[151] Another concern is with anti-personnel expanding sticky foams which can potentially suffocate victims.[152] AAC system designers have many options available to deter adversaries or potential threats, but they must work through the second order effects of using each effector to ensure that non-lethal effectors do not have the potential to inadvertently become lethal.

The command block of an AAC system allows for flexibility. The system can be lethal and non-lethal. Whereas minefields escalate immediately to lethal effects, an AAC system could layer effects from non-lethal to lethal, allowing commanders to "make a measured response to an attack or provocation, facilitate the control of opposing forces, and avoid collateral casualties."[153] An "'onion' or 'layered defence' model… describes entering the outer layers as inviting a punitive response whilst the central core is lethal."[154] This concept could consist of single effector that offers a "potential rheostatic or tunable response from less-lethal to lethal, operating at the speed of light, as so-called

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[150] John Stanton, "Uncertainty Remains about U.S. Landmine Policy," *National Defense* 88, no. 602 (January 2004): 40; NIAG, 26-27; Landmine Action, 8-10; National Research Council. *Alternative Technologies to…*, 46-50.

[151] *Ibid*., 50.

[152] Landmine Action, 9.

[153] National Research Council, *Reducing the Logistics Burden…*, 107.

[154] Landmine Action, 9.

'progressive penalty munitions.'"[155] This concept could also employ a variety of effectors, with non-lethal effectors to provide warning at the periphery, and lethal but discriminate effectors at the core. The Polish Jarzębina-S remotely controlled anti-personnel barrier is an example of a system that could be provide an AAC defence model. This system consists of layered effectors, a sense system, and a decision-making sub system.[156] Such a layered defence system could have the potential to be discriminate and non-persistent, providing commanders with great ethical flexibility.

The Network

The AAC system described above as having sense, command, and effector components must be integrated on a network such that each component can interact and effect the others. Each component, down to the individual effector or sensor, needs to be networked so that complete situational awareness is achieved. Networking, for instance, will enable the concept of a self-healing effector field being explored by the US[157] where the thousands of effectors can "dynamically reconfigure itself to better protect military forces during warfare and also be deactivated and safely removed post bellum, preventing needless tragedies to civilians in ensuing years."[158] Ideally, an effector field would also be able to reconfigure itself following breaches to reestablish its integrity. In addition to maintaining integrity, networking can also enable the concept of swarming, where effectors such as loitering munitions could "be able to independently identify, target, and engage opponents in large numbers, or 'swarms.'"[159] Cheaper but more numerous

[155] *Ibid.*

[156] Dąbrowski and Palowski. This program was cancelled due to budget constraints

[157] Note that their specific concept is a self-healing minefield.

[158] William M. Merrill *et al*, "Dynamic Networking and Smart Sensing Enable Next-Generation Landmines," *Pervasive Computing* (October–December 2004): 84.

[159] Gettinger and Michel.

effectors, networked in such a way to conduct swarming attacks, could be considered as a lethal physical (and potentially psychological) effector option for AAC. Although self-healing and swarming technologies do provide excellent potential, they also increase the complexity of the system. It is recommended that such technologies be incorporated in to AAC once the concept has been proven.

Existing concepts

Research, and in some cases fielding, has been done on a number of systems that resemble this concept of AAC. First is the Wide Area Munition (WAM),[160] also known as the M93 Hornet, a system developed by the US in the late 1980s. It is described as a

> smart, autonomous top attack anti-tank/anti-vehicle munition, designed to defeat armored combat vehicles from a standoff distance. The WAM utilizes acoustic and seismic sensors in its ground platform to detect, track, and classify potential targets, and then launches an infrared detecting submunition or "sublet" over the top of the selected target. Once the sublet detects the target, it fires an explosively formed penetrator (EFP) to defeat the target…It consists of a communications module, a ground platform module, and a smart submunition/warhead (sublet) module.[161]

The sensors of the WAM are short range and are designed to track a target. Formation ISTAR assets are required to cue the commander to where and when to emplace the WAM system itself. The effectors are autonomous in nature, although it has a level of discrimination in its acoustic sensors. The algorithms would theoretically prevent the system from attacking civilians, but it is likely that there still is residual risk from employing a lethal effector without a human in the loop. The system is notably versatile in that it could be hand-emplaced, emplaced as a SM obstacle with a dispenser, or

[160] The M in WAM is reported in some literature as munition, in others as mine. It is possible that this was changed in response to *Ottawa*.

[161] Global Security, "M93 Hornet [Family of Wide Area Munitions – WAM]," last accessed 16 April 2021. https://www.globalsecurity.org/military/systems/munitions/m93.htm

emplaced as a RDM obstacle. The drawbacks of the system are that each unit costs $52,400 and the system capability development stopped at hand-emplaced systems in 2002 as further development was cancelled in 2002 to reallocate funding for the Stryker and Future Combat Systems project.[162] This system has many of the characteristics of an AAC system and its technology could be incorporated into future systems.

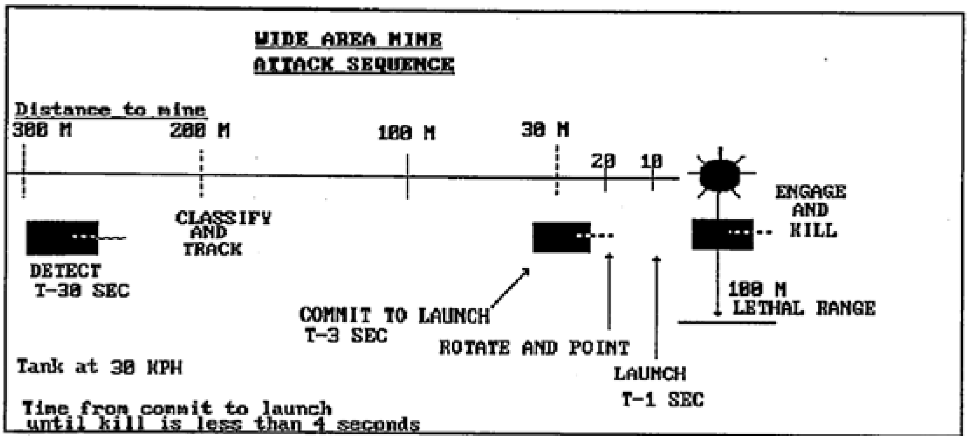

Figure 6 -- Wide Area Munition Attack Sequence
Source: Natynczyk, *Technology in Battle: Smart Mines*, 10.

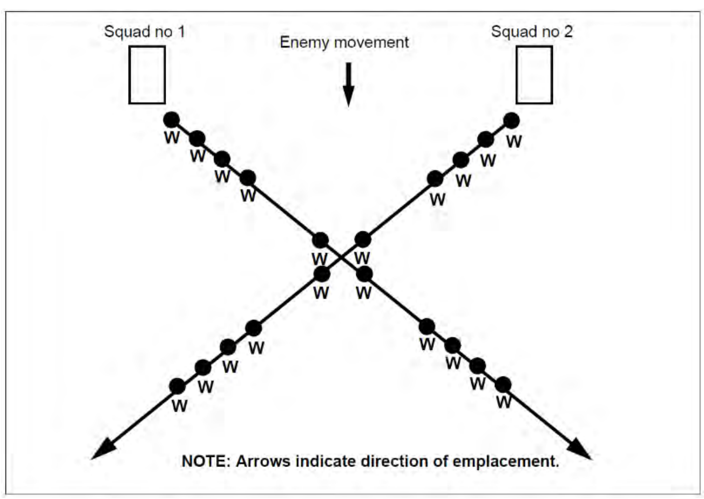

Figure 7 -- Area Disruption obstacle with a M93 Hornet
Source: Department of the Army, FM 20-32…, 4-11.

[162] *Ibid*.; Trevithick.

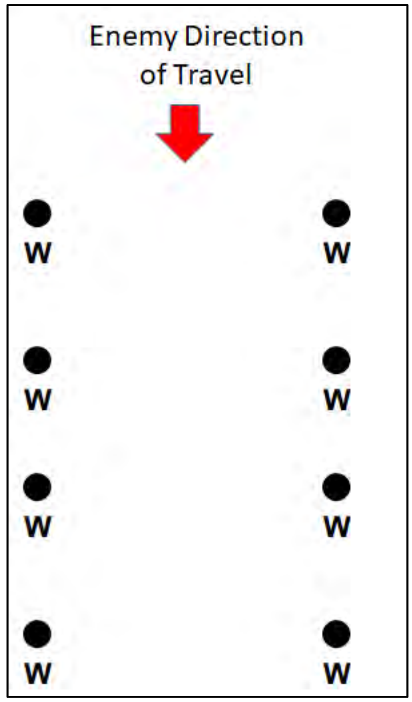

Figure 8 -- Gauntlet type obstacle with M93 Hornet
Source: Adapted from Department of the Army, FM 20-32…, 4-12.

More recently, the US has been pursuing a Gator Landmine Replacement (GLMR) under its Close Combat Systems program to update its area denial capability with a more discriminate effector.[163] The proposed system consists of two subsystems. The first, a vehicle or air-emplaced (scatterable system) would be a networked bottom attack/top attack common anti-vehicle munition (CAVM) system, which the DoD has classified as a Close Terrain Shaping Obstacle (TSO).[164] The aim of this system is to

> deploy a series of mines connected by a wireless network, far removed from American troops, who would monitor sensors attached to the weapons[…] When a vehicle approaches, the sensors would alert the operator, who would then decide whether to detonate the mine.[165]

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[163] Tucker; Audra Calloway, "PEO Ammo stands up new product management office," US Army, last modified 1 April 2016. https://www.army.mil/article/165263/peo_ammo_stands_up_new_product_management_office; Project Manager – Close Combat Systems.

[164] *Ibid*. TSO is noted as the top tech priority for the Close Combat Systems project

[165] Tucker.

This system is similar in concept to the WAM, though in this case the launch of the effector is controlled by a human-in-the-loop. It also doesn't appear to have a remote firing capability, which does put personnel and equipment at risk when emplacing the system. The second part of this system is the M7 Spider, which is very similar to the CAVM but it is a hand emplaced networked system.[166] In general, and like the WAM, these systems have some component characteristics that could be employed in an AAC system.

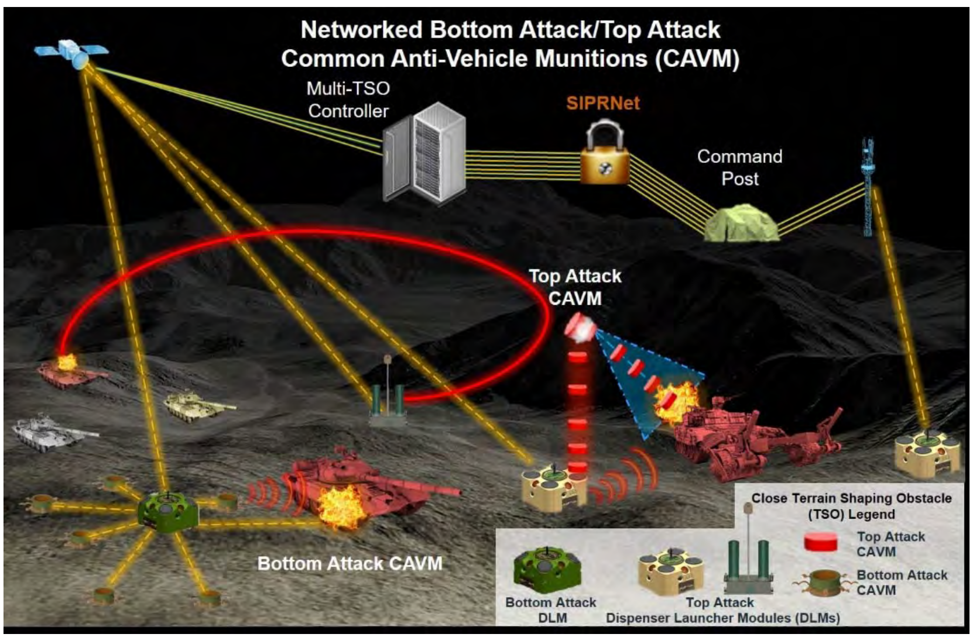

Figure 9 -- Common Anti-Vehicle Munitions
Source: Tucker, "US Expected to Loosen Restrictions on Land Mines…"

[166] Calloway.

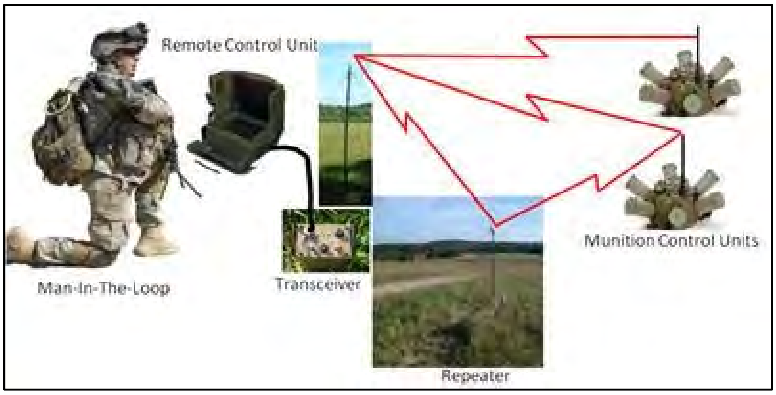

Figure 10 -- Man-in-the-Loop Systems
Source: Mizokami, "The U.S. Army Is Trying to Design…"

These, in addition to the previously mentioned Polish system, are just a few of a number of initiatives to increase discrimination and decrease persistence on the battlefield. There is a clear need for a system that networks sense, command, and effectors in such a way that the risk to civilians on the battlefield is decreased, and the commander's ability to shape, attrit, and/or deter an enemy is improved. The US is actively engaged in replacing traditional mines with advanced discriminatory munition systems. NATO needs to remain actively engaged with its American partners to develop a capability that not only meets the needs of the US military, by NATO writ large.

AAC SYSTEM DESIGN

APP-34 provides a good start state for AAC system development. A networked system of sensors, C2, and effectors could have the ability to provide commanders with the discriminate and non-persistent replacement to minefields in order to control movement in non-line of sight areas. Figure 11 shows the proposed logical architecture prepared during the 2014 NIAG study. This architecture, as well as the following significant considerations will aid in the development of a draft AAC system that can be tested in a theoretical case study.

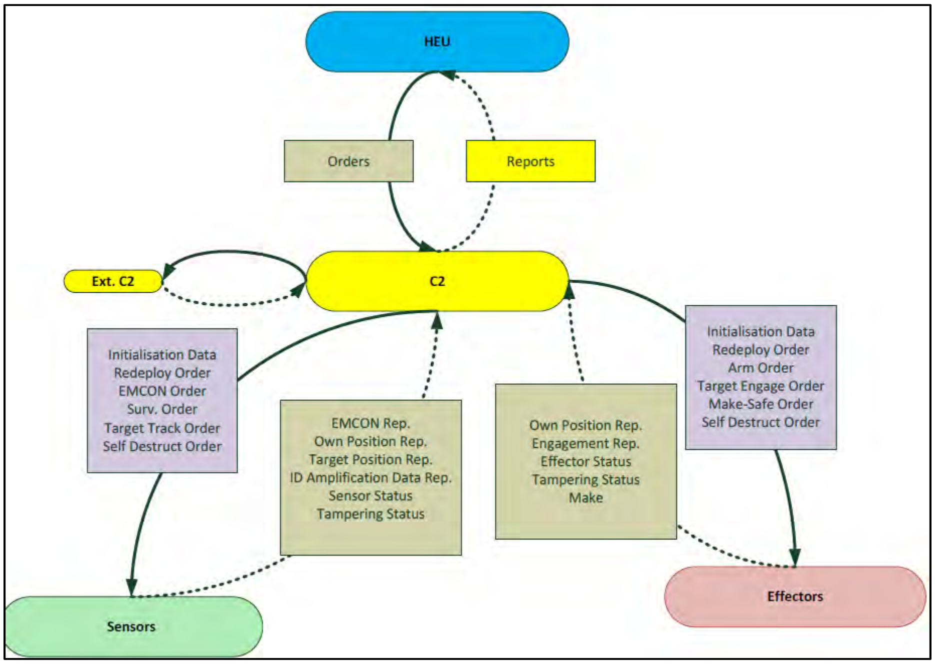

Figure 11 -- AAC System Logical Architecture. This figure demonstrates the logical architecture of a potential AAC system. A central C2 node controls the system, providing direction and receiving feedback from its higher echelon unit (HEU), the sensor array, and the effectors. Examples of what type of information could be relayed between each component are provided along the arrows.
Source: NIAG, 13.

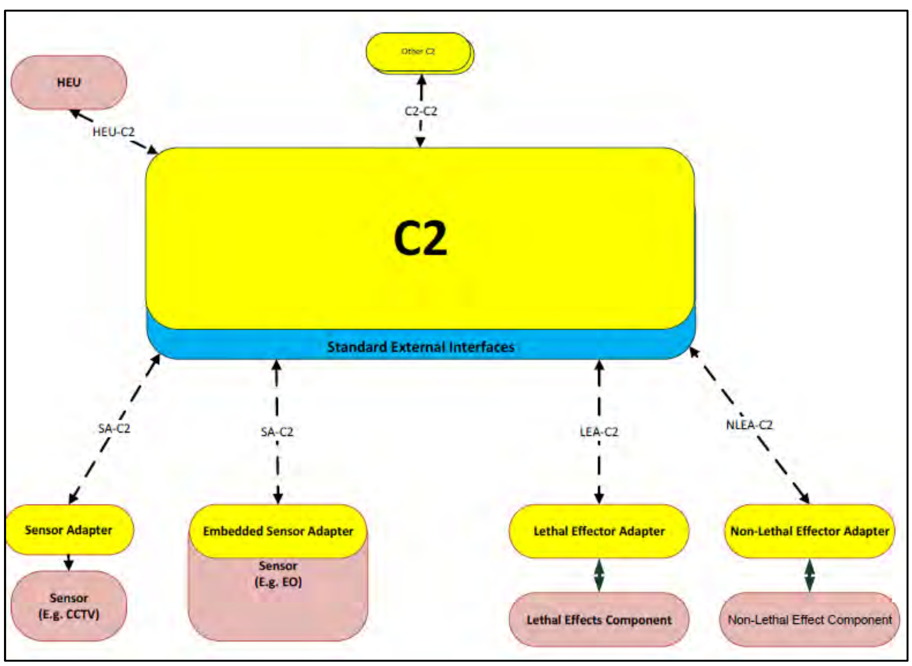

Figure 12 – AAC Physical Architecture
Source: NIAG, 19.

Layered Defence Design. Non-lethal security should be considered for lethal effectors. Non-lethal effectors will apply sufficient warning to direct civilians from the area. That said, warnings go both ways. While autonomous non-lethal effectors cue the AAC operator to the threat so that lethal action may be taken if required, it also alerts the enemy to the presence of the obstacle. It could be argued that keeping a human in the loop is burdensome, but obstacles are doctrinally covered by observation and fire as they are emplaced where the enemy is expected to manoeuvre.[167]

Level of Lethality. The level of lethality required within an AAC system will depend upon the nature of the target anticipated. A system that is shaping armoured formations will require effectors designed to defeat armour, whereas a system placed in the manoeuvre corridor of dismounted infantry would require a much different effector. Effectors will need to be refined over time as there is a continual battle between effector and mitigation techniques (such as the development of active armour to defeat anti-armour weapons.)[168] As such, the effectors within the AAC system will need to be regularly reviewed.

Stopping Power. There are complex calculations that can be made to establish relative stopping powers between various types of minefields, but these calculations rely on numerous constants that have been determined depending upon the nature of the mine being used.[169] In this study, a specific effector is not being assigned to the AAC system, so calculation of stopping power is not feasible. That said, very generally, stopping power

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[167] Kyle Mizokami, "The U.S. Army Is Trying to Design a Civilian-Safe Land Mine," *Popular Mechanics*, last modified 14 November 2018, https://www.popularmechanics.com/military/weapons/a25064634/better-land-mine-us-army-gator/

[168] A penetrator velocity of 1.7km/second is required to defeat current armour technologies such as ceramics. National Research Council, *Reducing the Logistics Burden*…, 92.

[169] F.V. Davies, *Rational Performance Indices for Mine and Minefield Assessment* (Ministry of Defence, 1971), 1-10.

can be simplified and discussed as a function of effector lethality and probability of an effector striking a target.[170] For instance, the more lethal and more accurate the effector, the higher the stopping power of the obstacle. When there is a decrease in either lethality or probability of striking the target, the number of effectors will need to be increased to maintain the desired stopping power, which will be related to the desired effect of the obstacle.

HRI. Although fully autonomous lethal systems are not recommended, there are options to incorporate HRI into AAC. First, fully autonomous sensors can assist operators in classifying targets and can cue non-lethal effectors. While a human-in-the-loop is recommended for lethal effectors, autonomy in the command system, even if only at certain stage of the engagement, will assist the human operator in triaging targets and should lead to more timely and effective target engagements.

Effector Restrictions. There are many options for effectors in an AAC system, such as loitering munitions, smart munitions, among others, but AAC system designers need to be cognizant of international law. Although AVM are technically still authorized for use, and great efforts have been made to make them less persistent and more discriminate, they still pose a risk to civilians both during and post-conflict. Cluster munitions have been used extensively throughout recent decades, but are banned for use by the Canadian Armed Forces for the same reasons as AP mines. Where possible, use of non-lethal effectors should be maximized if the commander’s intent can still be achieved.

Deployment Options. Much like traditional obstacles, the AAC system could theoretically be emplaced as a directed obstacle or delivered as a scatterable or remotely

[170] Department of the Army, FM 20-32…, 2-8.

delivered obstacle. Existing tactical doctrine provides some examples of how the system could be emplaced and deployed. Of note, the system does not necessarily need to be deployed once it is emplaced. It can be left dormant and deployed to an operational status once the commander deems it necessary (a situational obstacle). The effectors could be dispersed much like the area disruption or gauntlet methods above, or they could be left consolidated much like a MOPMs system. There are numerous design and employment strategies that could be developed in to AAC doctrine.

Sense Capabilities. The AAC system must receive two sources of information. The first is external to the AAC system and cues the commander to where and when to deliver or emplace the system and when to deploy it (if required). For efficiency, this should be drawn from the ISTAR assets of employing formation. The second sense source is internal to the AAC system and it will acquire the target and enable the firing of the effectors. The command unit should be able to fuse this information into a common operating picture so that the enemy can be accurately engaged.

Self-healing. The effectors should have a self-healing capability to mitigate the effects of adversarial attempts at breaching or reducing the AAC obstacle.

Battle Damage Assessment (BDA). An element of an engagement is confirming that the engagement, whether lethal or non-lethal, actually achieved its intended effects. As such, BDA must be conducted. To enable BDA, the AAC system should incorporate a residual sense function, but this can also be achieved through formation ISTAR assets.

System Readiness/Availability. Minefields are complete once mines are emplaced and armed, marking systems are in place, and reporting is complete. AAC is similar, but there is an additional requirement for testing the communication links as well as the individual component blocks of sense, command, and effectors. Due to the electronic nature, and depending on the length of time that an AAC system is emplaced, there could be a requirement for system maintenance. Systems could become bogged down, misfire, jam, etc., and such, assets such as combat engineers will need to be allocated to maintain the capability of the system.[171] One way of quantifying the readiness of an AAC system is measuring its availability, defined as the "probability that a system will be able to perform its mission profile."[172] *APP-34* has set a milestone requirement of 90 percent availability or greater.

Issues. AAC, unlike a traditional minefield, is highly networked and can be neutralized in additional ways. The communication link between sensor, command, and effector is vulnerable and must be protected.

Draft AAC System

Much progress has been made in the field of AAC, and based upon the above review, a refined draft AAC system can now be proposed and tested. The logical and physical architecture presented by the NIAG provide a very good baseline and require only some minor refinements. First, the AAC system needs to delineate the roles of formation ISTAR and AAC sensors. Specific to the AAC sensors, technologies have advanced significantly over the past number of decades and there are numerous examples of sensor/effector integration that would work very well within AAC. Redundancy built within the sensor and targeting suite, such as that seen in WAM, will reduce the system's vulnerability to countermeasures. When the local sense function is incorporated into a

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[171] Watling, 32.

[172] The availability of the system can be calculated by dividing the time it is operational by the total time it was supposed to be. NATO, Allied Procedural Publication 34…, 1-4.

terminal effector such as the WAM or a loitering munition, BDA needs to be conducted and as such, the command system and a residual sense function needs to remain independent to see the targeting cycle through to completion.

Second, a layered defence should be incorporated, and where possible, non-lethal effects should be autonomous. There are numerous options available on the market or in development, and one’s creativity seems to be the only limit to what could be done to prevent the deaths and injuries that are the issue of current indiscriminate obstacles.

Finally, this system hinges on its communication network. EW could bring this system to a standstill and as such, network security is an absolute must. The technical details and procedures for network security require a study of their own, but suffice to say, this is not an issue unique to AAC, and as such, network security measures can be drawn from other existing or emerging technologies.

CASE STUDY

This draft AAC system needs to be tested to determine if it meets the requirements of shaping a contemporary land adversary. A case study will be employed, with NATO forces employing AAC as a component of their overall counter-mobility plan to delay a Russian attack on Latvia, all while under a Russian strategic A2AD bubble.[173] This case study analysis will be qualitative in nature, comparing unclassified Russian capabilities against the AAC system to determine where the AAC system could potentially fail. A number of specific factors will be analyzed to determine the efficacy of the system. These include time, in terms of comparing the ability to get the system in place and operational in comparison to the Russian mobilization and advance. The next factor is efficacy in achieving its aim. The third is the AAC system's impact on the civilian population, specifically in terms of discrimination and persistence. This case study will identify strengths and shortfalls in the AAC system so that they can be reinforced or mitigated, and enable the proposal of a prototype AAC system for further capability development by nations wishing to develop a non-persistent and discriminate terrain enhancing capability.

A resurgent Russia is challenging the existing western international security order in an effort to replace it with one where Russia has regained the authority and influence that it enjoyed during the Cold War.[174] In 2017, NATO deployed four multinational battlegroups (BGs) (known as the Enhanced Forward Presence (eFP)) to the three Baltic

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[173] It is beyond the scope of this paper to discuss whether Russia would actually attack the Baltics or not.

[174] V. Veebel and Z. Sliwa, "The Suwalki Gap, Kaliningrad and Russia's Baltic Ambitions," *Scandinavian Journal of Military Studies* 2, no. 1, (2019): 111.

Nations of Estonia, Latvia, Lithuania, as well as the fourth to Poland.[175] It has been noted by numerous notable figures that the intent of eFP may not be met. US General Ben Hodges, a former commander of US Forces in Europe, was blunt in saying "Russia could take over the Baltic States faster than we would be able to defend them."[176] These assertions were echoed by a 2016 RAND Corporation study which noted that Russian forces could overrun the Baltic States in fewer than three days.[177] In short, Russia as the aggressor is a significant threat to NATO, especially in the Baltic States, and counter-mobility and AAC would be a significant factor in buying NATO time to react appropriately.

NATO's operational problems are exacerbated by Russia's ongoing development of a robust strategic A2AD network, increasing the risk to NATO's strategic lines of communication.[178] Although it can be argued that NATO far outmatches Russia in global conventional military power,[179] locally Russia is the more powerful of the two parties.[180] Further, Russia's A2AD capability mitigates its limited power-projection capabilities and supports its ability and credibility to seize and hold territory in its traditional areas of

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[175] Steve Maguire, "The Positive Impact of NATO's Enhanced Forward Presence," *The Strategy Bridge,* last modified 3 September 2019. https://thestrategybridge.org/the-bridge/2019/9/3/the-positive-impact-of-natos-enhanced-forward-presence

[176] Global Security, "Suwalki Gap," (n.d.) https://www.globalsecurity.org/military/world/europe/suwalki-gap.htm
General Sir Richard Barrons (retired) similarly notes that Russia could be ready for action within 48 hours and could take control of some land, airspace, and territorial waters before NATO could agree to respond. Veebel and Sliwa, 118.

[177] David A. Shlapak and Michael W. Johnson, *Reinforcing Deterrence on NATO's Eastern Flank: Wargaming the Defense of the Baltics* (Santa Monica: RAND, 2016), 1; Robert M. Klein *et al*, "Baltics Left of Bang: The Role of NATO with Partners in Denial-Based Deterrence." *Institute for National Strategic Studies*, no. 301 (Nov 2019): 1.

[178] Veebel and Sliwa, 118.

[179] E. R. Lucas and T. Crosbie, "Anti-Access/Area Denial in the Baltic Sea Region," *Scandinavian Journal of Military Studies* 2, no. 1, (2019): 72; Wesley Clark *et al*, *Closing NATO's Baltic Gap* (Tallinn: International Centre for Defence and Security, May 2016), 10-11.

[180] Shlapak and Johnson; 1.

influence within the former Soviet Union/Warsaw Pact nations.[181] NATO will need to provide ground troops to defend the Baltics, but it could struggle to effectively resupply and reinforce these troops in a prolonged ground campaign as a result of Russia's A2AD threat.[182] From an AAC perspective, the systems need to be prepositioned in theatre so that the defending forces have guaranteed access to them, otherwise there is a risk of them being delayed or destroyed along the lines of communication. NATO faces significant challenges in mounting a credible deterrent and reactionary force, so capabilities such as AAC will be required to enhance NATO's ability to defend the Baltics.

Figure 13 -- The Baltic States

[181] Tangredi, 21; Alexander Lanoszka and Michael A Hunzeker, "Confronting the Anti-Access/Area Denial and Precision Strike Challenge in the Baltic Region," *The RUSI Journal* 161, no. 5 (2016): 12-13; Veebel and Sliwa, 116.
In a conflict, NATO should expect to face air forces and air defence to deny local NATO air superiority, shorter range anti-ship missiles and submarines to deny NATO maritime superiority in the objective area, precision fires that will degrade land forces, cyber attacks that will degrade C2, disruption by Spetsnaz, amongst a host of other unclassified capabilities within the A2AD construct. US Department of Defence, *Joint Operational Access…*, 7.
[182] Lanoszka and Hunzeker, 14.

Source: R.D. Hooker, Jr, *How to Defend the Baltic States*, 25

Environment

The Baltic States share a 1,400km land border with Russia and Belarus and lack strategic depth.[183] The Baltic States simply do not have enough open room to absorb a Russian attack before their defending forces would be fighting from within an urban environment. Further, they are largely isolated from the rest of NATO, with only the 65km wide Suwalki gap between Kaliningrad and Belarus providing a ground line of communication with NATO in Western Europe.[184] In short, the Baltics are conceptually afloat on an island isolated from the bulk of NATO.

Although the Baltic States lack strategic depth, the terrain in general is in their favour as the defending force.[185] It is generally flat lowland, but its advantages include "forested areas, crisscrossed by numerous rivers and streams. The terrain is also dotted by lakes and marshlands that limit the number of avenues of approach from which defenders could channelize, divert, and otherwise impede any Russian attack."[186] More detailed ground analysis would need to be done by ground commanders, but in general, reinforcing obstacles should shape Russian manoeuvre and buy NATO time.

Physical terrain is not the only point of consideration. In the event of a Russian invasion, it must be assumed that the Baltic population will be in their homes or trying to leave the region. This has the potential to create a significant challenge for NATO in the defence of the region, as it will need to identify not only friend from foe (who may or may not be in Russian uniform), but it will also need to potentially contend with a civil

[183] Clark *et al*, 10.
[184] *Ibid.*, 12.
[185] Klein *et al*, 8.
[186] *Ibid*.

population moving throughout the region.[187] Further, when these populations are interwoven within an urban environment, lines of sight are short, reducing the reaction time to positively identify and discriminate targets.[188] Discriminate weapons would significantly reduce the potential for collateral damage to resident populations.

Threat

Russia enjoys the advantage of a conventional military overmatch in the Baltic region.[189] NATO needs to find creative ways to deter Russia and achieve an overmatch in relative capability. NATO has numerous challenges, as Russia could launch a pre-emptive conventional invasion, and Russia also has the option of increasing its advantage in the region through the use of hybrid warfare, executed by partisan and volunteer forces and supported by its conventional units.[190] The hybrid option would be harder for NATO to initially detect, thereby delaying a NATO response. It would also make it more difficult for NATO to discriminate between adversaries and civilians, and is popular among theorists as Russia's best option for seizing the Baltics.[191] Russia has many options for attack and continues to improve its situation on NATO's eastern flank by improving a number of capabilities that warrant further examination.

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[187] Veebel and Sliwa, 118; National Research Council, *Avoiding Surprise…,* 64-65.

[188] *Ibid*., 63.

[189] It is estimated that NATO needs to assign an additional 18 brigades to match the Russian capability. Veebel and Sliwa, 112.
This does not consider the additional brigades that would be required for NATO to wrest the initiative from Russia, (RAND recommends seven additional brigades plus the associated enablers). Global Security, "Suwalki Gap."
The Baltics could not logistically support such a force, and NATO would need to do the almost impossible task of gaining commitment from member nations in time of peace. Shlapak and Johnson; 4.

[190] Lanoszka and Hunzeker, 15.

[191] R.D. Hooker, Jr, *How to Defend the Baltic States* (Washington, DC: The Jamestown Foundation, October 2019), 1.

In addition to the A2AD bubble that Russia has established, it also has other capabilities that must be taken into consideration when defending the Baltic nations. First, Russia has a significant space satellite infrastructure that it can draw upon for detection, surveillance, and reconnaissance.[192] As such, NATO should assume that its footprint in the Baltics is well understood, and any subsequent attempts to shape the anticipated invasion axes or to reinforce with additional forces would not go unseen by the Russian intelligence network. Next, Russia has a proven and effective cyberwarfare capability.[193] During the Nagorno-Karabakh war, Armenia employed its Russian-supplied Polye-21 electronic warfare systems to disrupt Azerbaijani drone operations.[194] While these drone operations were only disrupted for four days,[195] NATO must assume its networks (including those within semi or fully autonomous systems) and critical infrastructure will be targeted and degraded. In the most general sense, it must be assumed that Russian agents have provided Moscow with comprehensive knowledge of NATO's military plans and capabilities,[196] reinforcing the requirement for flexibility in planning and execution. A combination of situational and directed tactical obstacles must be considered so that NATO can actually impose some surprise and therefore shaping effects upon the advancing Russian columns, and ISTAR cuing of AAC will be absolutely necessary. All of this will fail for NATO though if it does not use redundant and EW-protected networks.

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[192] Tangredi, 99.
[193] *Ibid*.
[194] Shaikh and Rumbaugh.
[195] *Ibid*.
[196] Benjamin B Fischer, "CANOPY WING: The U.S. War Plan That Gave the East Germans Goose Bumps," *International Journal of Intelligence and CounterIntelligence* 27, no. 3, (2014): 432.

The conventional force attacking the Baltics would be from the Russian Western Military District (WMD) as well as from the Kaliningrad Oblast. For simplicity's sake, US Army Colonel (Retired) Richard Hooker's analysis in *How Russia Fights* will be used, with NATO facing the Russian 4th Guards Tank Division (4 GTD), the main effort of the First Tank Guards Army (1 TGA) thrust into the Baltics.[197] In line with the Russian doctrine of maintaining tempo and reinforcing success, this force writ large is predominantly armoured and will be supported by significant fires in the form of self-propelled howitzers and multiple rocket launcher systems, and likely additional layers of assets allocated from 1 TGA.[198] Of note from a mobility perspective, Russian armoured personnel carriers, infantry fighting vehicles and even tanks can independently cross water obstacles.[199] Finally, and in addition to the 4 GTD noted in Colonel Hooker's scenario, the three Spetsnaz Special Forces brigades that are in WMD must be brought into consideration to enable a hybrid scenario.[200] In short, the defending NATO force is facing a sizeable armoured threat supported by massed fires and will be operating in a degraded C2 environment due to the EW threat.

The Russian military is a commendable adversary, especially in consideration of the lessons it has learned in Georgia, Syria, and Ukraine.[201] That said, it has vulnerabilities which NATO needs to exploit. The AAC system could assist in this

[197] 4 GTD has two of its three tank regiments and is supported by an additional two airbourne regiments, plus supporting fires, engineers, and other enablers including EW, close air support, attack helicopters, and air defence. A defending force could expect to face approximately 186 tanks of the T-72B3 or T-80U variants, as well as approximately 248 infantry fighting vehicles consisting of a mix of BMP-2 or BMP-3 as well as BTR-80s. The airbourne units will have BMD-4s. R.D. Hooker, Jr., *How to Defend the Baltics,* 1-4.

[198] *Ibid*., 29; R.D. Hooker Jr., *How to Fight the Russians* (Arlington: Association of the United States Army, 2020), 2-3.

[199] Global Security, "Suwalki Gap."

[200] R.D. Hooker, Jr, *How to Defend the Baltics*, 2.

[201] Clark *et al*, 11.

regard. In many cases, explosive threats such as mines and ATGMs have led Russia to protect its armoured vehicles with complex reactive armour[202] and active missile defence systems.[203] That said, despite these improvements, Russian armour and soft skin vehicles remain vulnerable to top-attack munitions.[204] Russia is in the process of fitting its vehicles with IR dazzlers to disrupt the ATGM's laser designator, in turn, providing protection to the vehicle that no level of armour protection could ever achieve.[205] Regardless, in the Nagorno-Karabakh war, top-attack weapons such as missiles launched from drones and loitering munitions are confirmed to have killed at least 124 Armenian T-72 tanks.[206] These vulnerabilities are of key importance when choosing an effector for an AAC system.

Friendly

NATO has much to consider in terms of the Russian threat to the Baltics, but unfortunately Russia is not the only issue NATO has to deal with. With flashpoints around the world, member states having national priorities, and new issues such as COVID-19, the Baltic region is just one of NATO's priorities.[207] That said, it has

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[202] Watling, 26.

[203] The Economist, "Tanks have rarely been more vulnerable," *The Economist,* last modified 10 Sep 2020. https://www-economist-com.cfc.idm.oclc.org/science-and-technology/2020/09/10/tanks-have-rarely-been-more-vulnerable

[204] Klein *et al*, 9.
A top attack ATGM: "After launch the missile follows a lofted trajectory and as it approaches the target it dives down to impact the target. The lofted trajectory and the tandem high explosive warhead enables the missile to penetrate tanks equipped with explosive reactive armour (ERA)." Army Technology, "Spike Anti-Tank Missile," last accessed 16 April 2021. https://www.army-technology.com/projects/gill/

[205] Stijn and Oliemans.

[206] *Ibid*.

[207] Heinrich Brauß and András Rácz, "Russia's Strategic Interests and Actions in the Baltic Region," *German Council on Foreign Relations*, no. 1, (January 2021): 29.
The three Baltic States are of particular importance as they are NATO members and their protection by the alliance is theoretically assured by Chapter 5. At the 2016 Warsaw Summit, NATO leaders recognized this endorsed a strategy to enhance resilience in the Baltics. Stephen J Flanagan *et al., Deterring Russian Aggression in the Baltic States Through Resilience and Resistance* (Santa Monica: RAND, 2019), 4-6.

mustered the aforementioned four BGs as a deterrence force. Further, it has established a 5,000 troop Very High Readiness Joint Task Force (VJTF) which is ready to move within days.[208] However, considering Russia's options at launching a surprise attack under the guise of a snap exercise, or its ability to engage in hybrid conflict, compounded with the A2AD bubble and NATO's vulnerability of the Suwalki Gap, it must be assumed that any help to the Baltic States could be some time away. The Baltic States and the eFP BGs must deal with Russia on their own with their integral resources in order to buy as much time as possible for the follow on forces to arrive.

From a friendly force perspective, the biggest issue for NATO to address is interoperability. This issue would be of particular concern the AAC C2 network. Interoperability is a high priority for NATO, and it is addressed in *APP-34*. Each country could use its own sensors and effectors, but the processes within the command node as well as how the sensors, command, and effectors all interact need to be standardized. Processes are largely in place with respect to counter-mobility through STANAGs and are covered in detail in *APP-34*, so the network spine itself is what needs to be a priority. NATO needs to focus efforts on ensuring network resilience and venues such as NATO exercises and the eFP will help work through this issue.

For the purposes of this paper, the AAC system has a generic network and can communicate between the sensor, the effector, the command hub, and a higher HQ, in this case the Canadian eFP BG in Latvia. This BG consists of a Canadian BG HQ and elements from seven other countries. [209] This eFP BG is truly complex and

[208] *Ibid*., 20.

[209] Specifically, a reconnaissance platoon from Canada, infantry companies from Canada, Italy, Slovakia, and Spain (Spain and Italy's company's reinforced with a troop of tanks each) a tank squadron from Poland, a mortar platoon from the Czech republic, a combat engineer squadron from Spain, an

interoperability is a primary concern, but it does have the capability resident within it to plan and execute counter-mobility operations, and as such, could employ AAC within its defensive plan.

Case Study Analysis

The following is a qualitative analysis of how the draft AAC system would be used in the case study. A number of specific questions will be individually addressed and a series of conclusions will be made. This analysis is qualitative and is limited in that all analysis is based on unclassified material.

Question 1: Will AAC be able to apply an effect to a target in a timely manner?[210]

Question 1 Discussion: The AAC system must be in theatre, otherwise it will not be operational in time to defend against an attack. Even with sufficient warning of a Russian attack, the Russian A2AD bubble will make supplying the Baltics extremely challenging until NATO neutralizes this capability. Assuming the BG has the requisite resources, it could choose to emplace the AAC obstacles in a directed (pre-emplaced) or situational (either scatterable or remotely-delivered) manner within the larger counter-mobility plan. Note that emplacement speaks to getting the system where it needs to be, deployment consists of any actions to bring the system to an operational state.

Directed Emplacement. If the eFP BG decides to pre-emplace its obstacles in accordance with their assessment of Russian intent, the AAC system will be in

explosive ordnance disposal platoon from Albania, and a nuclear, biological, chemical defence platoon from Slovenia. NATO, "NATO's Enhanced Forward Presence Fact Sheet," last modified March 2021. https://www.nato.int/nato_static_fl2014/assets/pdf/2021/3/pdf/2103-factsheet_efp_en.pdf

[210] Assumptions: NATO will likely have some warning of a Russian attack; exactly how much will depend on intelligence indications and warnings. That said, if Russia employs an asymmetric concept for its attack, a NATO response will likely be delayed as politicians debate whether or not to respond. As such, this analysis will consider only the forces currently in the Baltics and that they have minimal warning of Russia's offensive actions.

place and operational when needed. It would need to be activated, maintained, and tested to confirm its operational status. The drawback of it being emplaced in such a manner is it must be assumed that the Russian intelligence network will have developed an understanding of the eFP BG defensive plan and 4 GTD will be able to design its manoeuvre accordingly. Further, directed obstacles are at risk of sabotage by the Spetsnaz, although this can be mitigated by surveillance and maintainance. The system could also be targeted by preparatory fires and destroyed prior to the arrival of the enemy ground forces.

Situational Emplacement. The AAC system can be emplaced in either a scatterable[211] or remote[212] manner. In general, situational obstacles have the benefit of concealing the defensive plan from the enemy, but they run the risk of not actually being emplaced when needed. This could happen as a result of destruction of the emplacement capability (i.e. the vehicle) or disruption of the communication link that was to order the emplacement of the obstacle.

Scatterable. The time required to emplace the AAC obstacle will depend on the location of the delivery vehicle relative to the obstacle location. The delivery vehicles must remain covert, otherwise the Russian intelligence network will be able to assess the likely defensive plan. The emplacement time will also depend on the size of the obstacle, and thus the number of sensors and effectors required to have the desired effect upon the enemy. If executed properly, the obstacle will be emplaced in sufficient time to have an effect on the enemy, but fire support needs to be coordinated to assist the emplacement vehicle with its

[211] short-range (vehicle or helicopter delivery)
[212] Long-range (artillery, aircraft delivery)

egress, potentially under fire from the enemy. As such, a ground emplacement vehicle would need to be armoured, and a helicopter asset would need to consider the air defence threat.

Remotely Delivered. The AAC system can be delivered by aircraft or artillery. The emplacement would need to be deconflicted so that the AAC is prioritized against other weapons systems that are competing for the delivering mechanism. If properly rehearsed and deconflicted, the AAC system could be emplaced in the TAI within minutes. A further advantage of remote delivery is Russian reconnaissance will have less chance of determining the eFP BG defensive plan, increasing the probability that the Russian force can be shaped in accordance with the defensive plan. This expedience does come with associated risk. There is a risk that Russian preparatory fires will neutralize the eFP BG fires or destroy the emplacement aircraft prior to them being able to emplace the AAC system.

Question 1 Conclusions: First and foremost, planning is essential to ensuring sufficient resources are available. The employment of directed obstacles has a higher risk of allowing the enemy force to define the defensive plan, but it has the advantage that it is guaranteed to be in place and operational when it is required (although this does not consider the risk of sabotage or EW disrupting or disabling the system). This could be mitigated through concealment. Situational obstacles need to have armoured emplacement vehicles and redundant communications or clear emplacement criteria to ensure that the obstacle is emplaced when needed. Remotely delivered obstacles require redundancy in delivery platform.

Question 2: What effects will the AAC system likely have on the Russian forces?[213]

Question 2 Discussion: This questions should be considered from both a physical and a psychological perspective.

> *Physical Effects.* Numerous effectors are available for use within the AAC system and the US in particular is actively developing new technologies. For the AAC effectors to be effective against the vehicles of 4 TGD, they need to be top-attack in nature to target the vulnerable top of Russian vehicles. Russia is mitigating the threat of ATGM by incorporating laser defence technologies. The precision guidance system of the AAC effectors must defeat these mitigation strategies. The human in the loop component of the command system allows for prioritization of destruction of Russian capabilities, so the true concern comes down to ensuring that enough effectors are emplaced within a TAI to have the desired effect on the enemy and that the sensors have the requisite redundancy to counter Russian camouflage and deception measures. This is very much the same as traditional calculations of fix, turn, disrupt, and block obstacles in relation to obstacle stopping power.
>
> *Psychological Effects*. The presence of mines makes an enemy commander reconsider their situation. The AAC system, with its escalatory lethality, lacks much of this psychological effect as dismounted soldiers or vehicle crews will know that they will be warned before lethal effects are a

[213] Assumptions: To answer this question, it must be assumed that the AAC system has been emplaced and is fully deployed. It should be assumed that elements of the system will be destroyed by Russian fires.

threat. This psychological effect needs replaced with effectiveness and lethality of the system overall. The enemy must know that when they encounter the obstacle and choose not to redirect their manouevre, they will be engaged and they will be destroyed.

Question 2 Conclusion: From a physical perspective, the lethality of the chosen effectors will determine how many effectors need to be within a TAI to have the desired effect. Psychologically, the AAC system will only be truly effective once it has proved itself. NATO needs to put the concept into action and demonstrate its capabilities so that potential adversaries will know what could happen to their forces once the system is deployed. This could also have a deterrent effect at the strategic level if a significant enough impact could me made upon the adversaries intentions.

Question 3: What will be the impact of the AAC system upon the civilian population?[214]

Question 3 Discussion: Discrimination between friend and foe and/or civilian and combatant is crucial. It has been discussed that area denial systems such as landmines are indiscriminate as they autonomously maim or kill no matter what triggers them. There is a second factor to this question and it relates to persistence. Regardless of the efforts that have been made in improving the technology, it cannot be guaranteed that a battlefield will be 100 percent safe from unexploded ordnance once the combatants lay down their arms. The AAC system needs to be non-persistent and pose little risk to civilians post-

[214] Assumptions: The population of the Baltics will not have sufficient time to evacuate the conflict zone. Further, it would be presumptuous to assume a winning side in this conflict, but the persistence of the system and post-conflict remediation need to be considered and the matter can be made irrelevant by simply looking at the end state from both perspective – first with NATO as the victor, and then again but with Russia as the victor.

conflict. Again, this question should be addressed in consideration of how the AAC obstacle is emplaced.

> *Directed*. If an obstacle is pre-emplaced and deployed, there is the potential that a civilian, whether suspecting or oblivious to the threat, could enter the AAC obstacle and be harmed or worse. This situation reinforces the requirements for a layered defence, as an escalation of effect from the lethal to the non-lethal would mitigate the chances of the civilian from being hurt. Marking the perimeter of the obstacle would also mitigate this threat but make it overt. As such, it is now susceptible to the concerns listed in question one with respect to sabotage and the enemy deciphering the defensive plan.
>
> *Situational*. The impact of a situational obstacle on the civilian population will depend upon the emplacement mechanism.
>
> *Scatterable*. If a scatterable obstacle is being emplaced, it means that the commander has deemed it necessary to apply an effect in the TAI. Contact with the enemy is likely imminent and the priority needs to be on obstacle emplacement. An AAC system emplaced in a scatterable manner, whether it be via a land based vehicle or a helicopter, will have control in that the operator will generally have observation of the target area and as such will know when civilians are present. There is a limited risk of a civilian being injured during emplacement, but there is a more significant risk of civilians moving through the AAC obstacle area as they flee the advancing enemy.
>
> *Remotely Delivered*. The difference between scatterable emplacement and a remotely delivered system is the level of observation of the target area

> during emplacement. Although there should be observation of some sort during the emplacement, this is not always possible. The TAI will be prerecorded during planning and the mission may be conducted blindly once certain criteria are met. There is some risk that a civilian in the area could be struck by components of the system during deployment, but this cannot be avoided and must be considered collateral damage. Getting the system in place to effect the enemy is the priority.

The second part of this question relates to the persistence of the system. If NATO is responsible for the post-conflict remediation, the process is straight forward as the system is designed such that it can be turned on and off, making the risk of remediating the systems negligible. The situation is different if Russia is responsible for the remediation (as they have won the conflict). If left deployed, the batteries in the system would eventually die, rendering the system inoperable. This creates a risk the non-lethal layered protection being inoperable, making the system persistent. A command initiated self-destruct mechanism would enable NATO to destroy its AAC systems post-conflict.

Question 3 Conclusion: The AAC system could have some negative consequences on the civilian population but this can be mitigated with a layered defence so that a civilian cannot actually get to the lethal area of the obstacle. Scatterable and remotely delivered systems would provide less risk to the civilian population as the obstacle is not emplaced until absolutely necessary, but mitigation measures will limit the risk of directed obstacle emplacement and deployment. Any threat of persistence in the system should be mitigated and considerations of a command initiated self-destruct should be incorporated into the system.

Question 4: What are the perceived weaknesses of the AAC system?

Question 4 Discussion: The AAC system has a single point of failure: its command network. Russia has a very capable EW capability and as such, could jam the network and prevent the commander from emplacing or deploying the system, block the relaying the order to the operator to fire the system (if required), or prevent the operator from firing the system when a threat is observed. This must be mitigated with redundancy within the network. This could be partially mitigated by having components within the AAC system hardwired together. This has a number of drawbacks that will impact how the system could be employed. A hardwired system would likely need to be an emplaced directed system as situational systems risk remaining connected during deployment. The network brings another weakness - the system could be quite technical from a signals perspective. The system must be robust enough to withstand a Russian EW attack but also be intuitive enough for a soldier with limited specialized training to operate.

Another concern is that the attacking force of the 4 TGD will be supported by significant fires capability. Force protection of the AAC system is crucial to ensure that it remains operational throughout any bombardments. This can be achieved through redundancy, depth, dispersion, hardening, maintenance, and concealment.

> *Redundancy.* If the command node is destroyed by fires, the operator will lose the ability to synthesize the information flowing from the sensors and may not launch the effectors when required. The command node must be duplicated within the network so that a backup system can take over if the primary is destroyed. This backup system could potentially also take over in the event of an EW attack on the primary command unit.

Depth. Obstacles are effective when they are layered so that an enemy must repeatedly commit its breaching assets. Depth also provides some force protection to the obstacles as although some obstacles could be damaged or destroyed by preparatory fires, obstacles in depth could remain effective.

Dispersion. Consolidating all components of an AAC system in one location, a sea can for instance, makes the system vulnerable to precision or massed fires. A dispersed system, such as the WAM discussed earlier, however, would make the system more difficult to target.

Hardening. If a consolidated sea can system was chosen vice a dispersed system, hardening could make it less susceptible to fires. The sea can could be made from ballistic resistant materials. Another option would be to dig the sea cans into the ground. This would require additional resource support such as heavy equipment, but it would make the system harder to hit and would improve its concealment.

Maintenance. It must be assumed that enemy forces will commit assets to breach or degrade an obstacle system. In this case, it is likely that Spetsnaz forces would attempt to sabotage those systems that had been identified by Russian reconnaissance or intelligence. In addition to having the layered defense system that keeps civilians out, it could deter enemy saboteurs and alert the eFP BG to the presence of a threat. Just as combat engineers are assigned the task of maintaining minefields as they are degraded, forces such as combat engineers need to be allocated to maintain the AAC system. Further, a self-healing capability could be incorporated into the system, especially those that are dispersed, so that less personnel resources are required to maintain the system, or there is less physical risk to the personnel assigned this task.

Concealment. Physical concealment should be a feature of the AAC system. Further, operational security of the existence and location of these systems must be maintained.

Question 4 Conclusion: The network of an AAC system is its weakness. Significant effort needs to be taken to ensure that the system is resilient in an EW environment. The system is vulnerable to physical fires and as such needs to be physically protected.

Question 5. What are some advantages of AAC over traditional minefields in this situation?

Question 5 Discussion. The AAC system provides many advantages over minefields in this scenario. First and foremost is flexibility. The counter-attack is a critical element of a defensive battle as this is how the defending force attempts to regain the initiative. With minefields, lanes and gaps must be left and maintained by the engineers so that the countermoves force can move through the defensive position to attack the enemy. The countermoves force needs to find these lanes and gaps and there is a risk that the countermoves force enters the minefield. An AAC system on the other hand has a human-in-the-loop to control the firing of the effectors. As such, the countermoves force can pass through the area without concern of fratricide. This consideration also applies to the opening phases of a defensive battle where the covering force of reconnaissance and armour elements need to break clean from the Russian attacking force as it withdraws and do a rearward passage of lines. This rearward movement requires the covering force to move through the defensive position, including any minefields. As such, the eFP commander has significantly more manoevure flexibility with AAC obstacles.

Question 5 Conclusion. AAC provides a commander with more flexibility that they would have when employing minefields.

Case Study Summary

This case study demonstrates that the refined NIAG model for AAC could be employed effectively to counter a Russian threat. It could enable the NATO eFP BGs in buying time for the NATO follow on forces to arrive in theatre. Although minefields could do the job, they are indiscriminate and persistent. AAC on the other hand, if resourced in accordance with an effective barrier plan, could assist NATO in delaying the Russian advance in a much more discriminate and non-persistent manner. The caveat is that a robust network is critical to the success of this system. If Russia can jam the system, they will advance unimpeded. Although the Russian military has a number of other resources, such as Spetznaz, fires, and breaching TTPs, that could reduce the AAC impact on its manoeuvre, EW is the single system that requires the most mitigation.

A robust communication network will provide AAC designers significant flexibility in system design. This case study has highlighted some advantages and disadvantages of emplacing and deploying the AAC system in different manners. The EW threat to the communications link limits these options, but once mitigated, a detailed AAC doctrine can be developed.

The success of AAC will be truly measured by its deterrent capability. It will only deter potential adversaries such as Russia through lethality. AAC as a capability needs to be demonstrated. There are numerous lethal effectors available or in development that could make AAC a battlefield factor that will make commanders and politicians alike think twice before choosing their actions. AAC has the potential to mass a significant quantity of discriminate precision effectors, and when this is combined with the intelligence and fires inherent in the current NATO force structure, adversaries will think twice.

While lethal, the refined NIAG model for AAC is discriminate and non-persistent, and as such, will not cause the humanitarian crises that are created by minefields or other non-discriminate and persistent area denial weapons. The lethality of the system is held within its core, and the human-in-the-loop function further ensures that the targets engaged have military value. The strategic effect of AAC will therefore be twofold – it will deter adversaries and the emplacing nation will not be deterred from employing the system. The political and military frictions that arise from the use of systems such as minefields or cluster munitions will no longer have to occur. In short, AAC will bring flexibility to battlefield commanders and politicians alike.

Final AAC Architecture

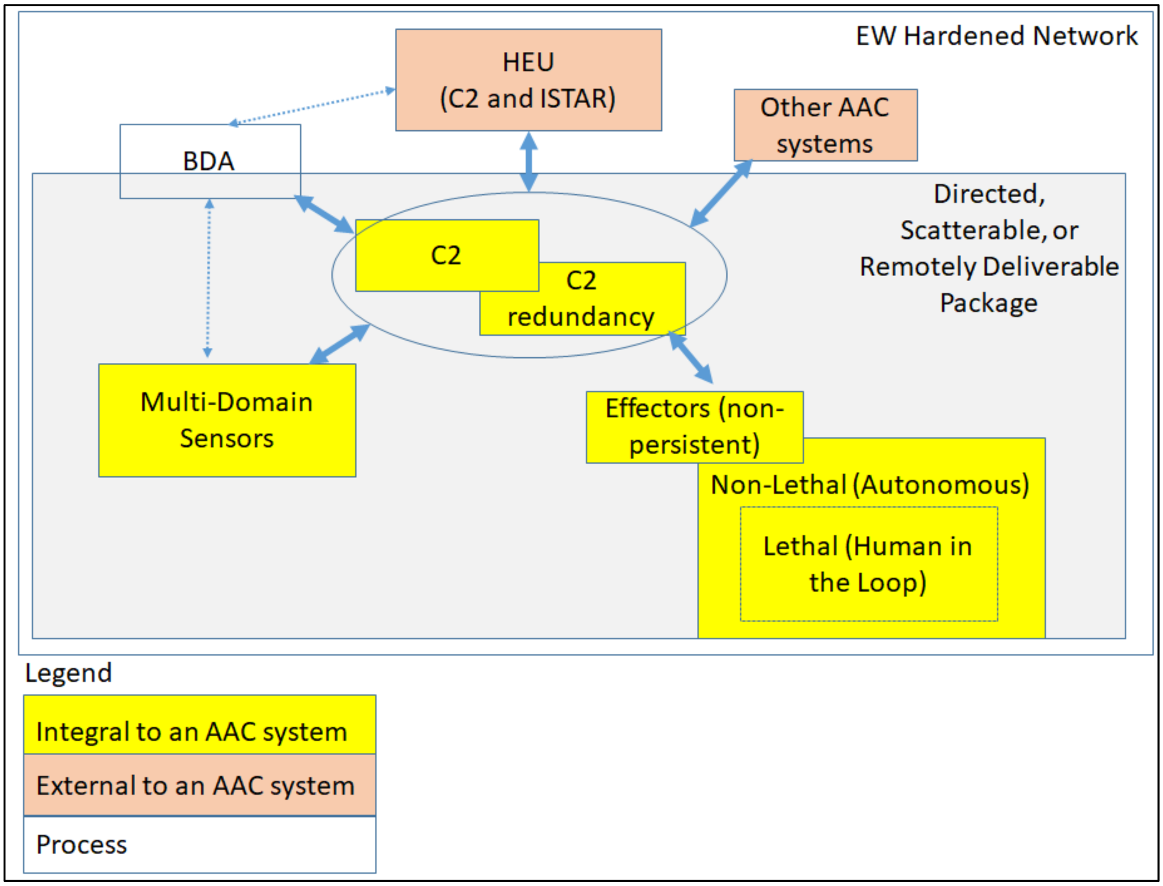

Figure 14 -- Final AAC System Architecture. This architecture has been refined from the original structure presented by the NIAG and represents the key observations of this paper. Of note, BDA has been kept external to AAC, but this task could be completed by either AAC itself of by formation ISTAR. Individual NATO nations can use this architectural prototype to enable their AAC capability development. The choice of command node, sensors, and effectors is left to their discretion, but for interoperability sake, the network spine must be compatible between nations and coordinated by NATO as the central agency.

CONCLUSION

The international community has a moral, and in many cases, a legal obligation, to destroy its stocks of indiscriminate and persistent weapons, including landmines. NATO has taken action to do so through the studies of the NIAG and the publication of *APP-34*, and its work has made it clear that these weapons could be replaced with a discriminate and non-persistent system such as AAC. The AAC architecture and logic presented by the NIAG provided an excellent start state for this study, and further analysis and testing against a Russian adversary in the case study demonstrated that the results of the NIAG study require only minor modifications. These include layering non-lethal and lethal effectors, ensuring that a human is in the loop for lethal effectors, using multi-domain targeting sensors, clearly highlighting the relationship between the multi-domain sensors of the AAC system and those of formation ISTAR, and reinforcing the requirement for the system to be on an EW-hardened network.

Although this study is limited in that it was conducted in the unclassified sphere, AAC provides a number of advantages over traditional indiscriminate weapon systems. AAC emplacement and deployment options, including directed, scatterable, and RDM, highlight the flexibility provided to nations and military commanders through the use of AAC. Manoeuvre on the battlefield will no longer be restricted due to emplaced autonomous mines. The system is plug and play. There are many effectors available on the market or in development, including WAM/X93 Hornet, CAVM, loitering munitions, just to highlight some that were discussed in this paper, that could effectively shape and attrit the enemy, and they will likely do so in a more efficient manner than traditional mines thanks to their precision top-attack technologies. Although the individual effectors cost more than individual mines, far fewer of the more lethal effectors will be required overall. Each NATO nation needs to conduct their own studies to determine which components will make AAC truly useful for the situations they expect to face in the coming decades.

The AAC system has a number of strengths, but this paper highlights the vulnerability of the system's communication network. Enemy EW could very likely jam the system, especially when operating in an A2AD environment, preventing the effectors from being launched at the required time. Further study and empirical testing is required to ensure that the AAC network spine will be effective against a peer adversary while still linking sensors and effectors over a potentially widely dispersed system. NATO needs to lead these efforts and provide guidance to its member nations on the specifications for such a network.

AAC is a tactical tool that will support the ground commander's counter-mobility plan. Strategically, AAC will form a component of a nation's area denial in its A2AD system. It can deter enemy commanders and politicians alike, but it can only do this once it is a proven capability. Landmines have a significant psychological and deterrent effect, but AAC can only match this through proven lethality. NATO nations need to aggressively develop and demonstrate their AAC capability so that nations who currently fighting a conflict below the threshold of conflict will think twice about their actions. Further, Russia needs to be deterred from invading the Baltic States and undermining NATO's credibility. Although they have not termed their projects as AAC, the US is working hard to develop an affective TSO in an effort to transition away from non-discriminate weapon systems; other NATO nations need to catch up. The efforts of

Finland and Poland were also highlighted in this paper, but these examples are the exception to the general rule that NATO nations are either relying on archaic landmine technology or are not addressing their capability gaps in area denial.

This paper has not identified a specific AAC system for use by NATO nations but has instead continued the discussion from a practitioner's perspective. This discussion must continue, and capability development needs to transition from ideas to physical prototypes. There is an appetite for modernization by NATO nations, and there is a clear need for AAC to fill the capability gap left from banning AP mines. There are nations flexing their muscles, intent on disrupting the liberal western order. The time is now to take action and develop discriminate and non-persistent weapons systems so that future conflicts are safer for civilians and more effective for military commanders. Armies need mobility to win wars, and this will not change in future conflicts. Counter-mobility is a significant capability for nations seeking overmatch of their peers, and NATO needs this to deter and defeat its potential adversaries. Great efforts have been made thus far, NATO and its member nations need to carry these efforts through to completion.

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