DEPARTMENT OF NATIONAL DEFENCE

CANADA

LAND FORCES DOCTRINE AND TRAINING SYSTEM

OPERATIONAL RESEARCH ADVISOR

RESEARCH NOTE RN 0005

TACTICAL IMPACT OF REMOVING ANTIPERSONNEL LANDMINES

by

Roger L. Roy

November 2000

KINGSTON, ONT, CANADA

National Defence
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Senior Op Research Advisor

KINGSTON, ONTARIO November 2000

ABSTRACT

Canada has ratified the *Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Antipersonnel Mines and Their Destruction*. This convention imposes a number of limitations on the types and use of antipersonnel weapons. There is an essential requirement to retain Anti-Personnel obstacles to ensure the protection of our troops on operations, maximise the effectiveness of weapons in combat operations, and to inflict casualties on opposing forces. This research note addresses whether the current weapons mix can replace the capabilities that AP mines provided.

RÉSUMÉ

Le Canada a ratifié la *Convention sur la destruction et l'interdiction d'usage, de production et du transfert des mines antipersonnelles*. Cette convention impose un nombre de limites sur l'utilisation et les types d'armes antipersonnelles. Le besoin essentiel de garder des obstacles antipersonnels demeure pour assurer la protection de nos troupes, pour maximiser l'efficacité des armes dans les opérations de combat et pour effectuer des pertes chez l'ennemi. Cette note de recherche examine si l'utilisation de l'arsenal actuel peut remplacer les capacités des mines antipersonnelles.

ACKNOWLEDGEMENT

The author would like to thank Mr. Shaye K. Friesen for his work on the Military Utility of AP mines which was originally part of the research conducted but not published in DLSC Research Note 9906, "The Historical Uses of Antipersonnel Landmines: Impact on Land Force Operations", by Roger L. Roy and Shaye K. Friesen, October 1999.

EXECUTIVE SUMMARY

INTRODUCTION

The Anti-Personnel Mine Ban Treaty imposes a number of new limitations on the types and use of antipersonnel weapons available to Canadian commanders. These limitations are affecting the mix of offensive and defensive options available to a commander to ensure operational success. This report examines whether the current weapons mix can fulfil the delta in capability that needs to be replicated due to the loss of AP mines.

The central military argument in the debate over AP mines has been that such weapons constitute an irreplaceable military capability and are indispensable weapons of war. Efforts to prevent the use of specific weapons arouse antagonism among members of the military, who see the Mine Ban Treaty as an attempt to deprive them of tools to carry out war. However, an increasing number of armies are renouncing the use of AP mines on the grounds that other munitions (such as command-detonated Claymores) are an acceptable substitute with less long-term effects on the civilian population.

RESULTS

The fact that millions of AP mines are in the ground today attests to the military utility of landmines. AP mines were effectively used without restraint, pattern or discrimination by undisciplined unconventional forces (e.g. paramilitary, irregulars or guerrilla), that relied on the low cost and the easy use of AP mines to "level the playing field" against technologically superior forces. Specific attempts to completely replace the AP mine have proven extremely difficult and costly to implement.

Functions of AP mines fall under four broad categories:

a. Protect small units and installations,

b. Protect anti-tank (AT) minefields from rapid hand breaching,

c. Cover blind avenues of approach, and provide early warning of infiltration,

d. Deter removal of other types of obstacles and slow the enemy.

Protective obstacles are laid in restricted areas, relatively close to one’s own positions, to cover routes from which the enemy might attempt either a silent approach or a sudden mass assault. A mathematical model shows that Claymores may provide a cost-effective and legitimate solution to the replacement of AP mines. Furthermore, they are easier and faster to set up than having to dig, bury and mark a lot of mines.

Results of JANUS war game scenarios indicate that a field of remotely detonated Claymores up to 500m ahead of the defended position, and/or using 40mm Automatic Grenade Launchers (AGLs), along with wire obstacles, provide a capability that compensates for the loss of AP mines against a mass assault.

Tactical obstacles are laid across substantial tracts of country to serve defensive purposes. Tank Ditches, berms, fences, and spikes can be used to reinforce obstacles, delay advances and increase effects of other weapons. Anti-Tank mines equipped with Anti-Handling Devices (AHD) can slow a mounted advance and force the enemy to use hand breaching as the method of choice. The use of command-detonated AP mines or Claymores, long-range direct fire weapons

(e.g. AGLs, LAVs, Tanks, etc) or mortars with bursting anti-personnel rounds linked to improved sensors and signal repeaters can deter and delay hand breaching of AT minefields.

Recent developments of sensor systems (motion detectors, cameras or laser beams) have demonstrated automatic detection of intrusions and can provide a silent alert of an infiltration in static barrier obstacles. For perimeter demarcation, fences or other appropriate obstacles can be very useful in halting unwanted intrusions. Wire entanglements inside or outside the fences can further delay infiltration. Claymore-type fragmentation munitions, Mortars, machine guns and rifles can be used to deter armed infiltration across borders.

There are several existing and many potential systems that can perform most of the functions of AP mines. Continuous unattended electronic or Electro-optical sensors can improve the detection from hidden approaches and data links can trigger immediate response by long-range direct and indirect fire weapons, achieving both greater effectiveness and far fewer indiscriminate casualties than AP mines. Improved barbed-wire entanglements covered by co-ordinated use of Automated Grenade launchers, Claymores, machine guns and aimed fires can provide close protection, exert an equivalent deterrence effect on enemy troops and help delay hand-breaching by dismounted troops. However, there is the possibility of greater ammunition consumption levels, increased unit footprint, and greater manpower and logistics requirements that result from these AP mine alternatives.

RECOMMENDATIONS

It is recommended to amend doctrine within the current framework of surveillance, obstacles and weapons. There is a need to develop improved surveillance sensors that can detect and alert our troops about enemy movement, direction and hostile intent. Jam-resistant RF or IR links between the sensors and the man-in-the-loop will be required to decrease the latency in sensor-to-trigger decision cycles.

A concept of layered defence should be used to update obstacle doctrine. A first layer with increased use of obstacles, patrols and/or guard dogs could provide warning to turn away innocent civilians. A second layer consisting of non-lethal responses that can cause nausea or disorientation could enhance deterrence against determined criminal factions, and a final layer with lethal responses could prevent infiltration by combatants and belligerents. Methods to quickly erect fences, dig ditches, and lay improved wire entanglements should be investigated.

There is a need to increase the lethality at the small unit level. Use of command detonated mines and Claymore-type munitions, Automatic Grenade Launchers, and more direct access to indirect fires can provide the required lethal response to compensate for the loss of AP mines. This may require more combined arms training at the lowest possible level.

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TACTICAL IMPACT OF

REMOVING ANTIPERSONNEL LANDMINES

INTRODUCTION

1. Canada has ratified the *Convention on the Prohibition of the Use, Stockpiling, Production, and Transfer of Antipersonnel Mines and On Their Destruction* which calls for the elimination of antipersonnel (AP) landmines, and provides a framework for the removal of mines from the ground, the destruction of stockpiles and manufacturing, as well as assistance to victims. The Anti-Personnel Mine Ban Treaty imposes a number of new limitations on the types and use of antipersonnel weapons available to Canadian commanders. Limitations include a total ban on the use of non-discriminating, victim-initiated antipersonnel weapons and on the non-discriminating emplacement of any other lethal antipersonnel weapon in areas where non-combatants are either the primary targets or at risk due to their number in the target area. These limitations are affecting the mix of offensive and defensive options available to a commander to ensure operational success.

2. Militaries are understandably reluctant to suddenly forfeit a useful weapon that has been part of their doctrine and procedures for decades on humanitarian grounds alone. One of the dilemmas is to quantify the capabilities that the AP mine provided. There is still an essential requirement to retain antipersonnel obstacles as part of the overall antipersonnel system to ensure the protection of troops in combat and non-combat operations, and to optimise the effectiveness of weapons during combat operations. In recent years, new weapon systems, surveillance devices and smart mines have been introduced into the inventory of most armies, providing new and sometimes overlapping capabilities. Therefore, before replacement technologies can be identified and developed, a decision must be made if the capability requires replacement or if other current systems sufficiently fill the gap.[1]

AIM

3. The aim of this study is to determine the tactical impact on land force operations of removing the AP mine from the Commander's inventory.

4. A first report examined the historical uses of AP mines in order to identify the capabilities that they provided. This Research Note will examine the impact of removing AP mines and determine if a replacement system is necessary by addressing whether the current weapons mix can fulfil the delta in capability that needs to be replicated.

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[1] For discussion, see Canada, Directorate of Army Doctrine, "The Banning of the Antipersonnel Mine," *The Army Doctrine and Training Bulletin*, Vol. 2, no. 1, February 1999, pp. 6-8.

MATERIAL FOR THE BAN

5. There is far more material supporting the Ottawa Convention than there is opposing it. Much of this material is emotional and openly biased in support of the landmine ban. Much of this material is devoted to political action supporting the Ottawa process, to the many claims dealing with where the mine problems exist and the impacts that minefields are having on civilians and their communities. There are several internet sites devoted to banning landmines, including *Safelane* by the Canadian Department of Foreign Affairs, and the International Campaign to Ban Landmines detailing the history of the crusade to eliminate landmines as well as studies on the impacts of landmines on civilians.

6. In 1996, the International Committee of the Red Cross (ICRC), an organisation actively working for a ban on AP mines and influence security policies, published an analysis of the military use and effectiveness of AP mines that examined the weapon's employment since 1940 by professional armies, by insurgents or in counter-insurgency operations. In the 26 conflicts considered, the report maintains that the historical record demonstrates that: 1) few instances can be cited where AP mine use has been consistent with international law or, where it exists, military doctrine, and 2) even when they were used correctly by developed or third world armies or insurgents, AP mines have had little or no effect on the outcome of hostilities, even when deployed in large numbers. No case was found in which the use of AP mines played a major role in determining the outcome of a conflict. The report even suggested that, because AP mines did not dramatically hinder a professional army's mobility, they could even have a detrimental effect on the forces that use them:

> The price of properly laying, marking, observing and maintaining minefields is high, in both human and financial terms; it involves significant investment, risk to one's own forces and the loss of tactical flexibility. Even when these costs are assumed, the effects of anti-personnel mines are very limited and may even be counterproductive.[2]

7. The conclusions reached by the ICRC were unanimously agreed at a meeting of military experts and were endorsed by a number of additional military commanders from 19 countries (including Major-General (Ret'd) Lewis Mackenzie and former Chief of the Defence Staff (CDS) Paul Manson from Canada), each with personal experience in mine warfare as well as the conduct of military operations in conventional wars and counter-insurgency and defence against mine use.[3] The implicit assumption of these officers was that banning AP mines would not <u>seriously</u> undermine military effectiveness or compromise the safety of the armed forces of any nation by endorsing the conclusions of the ICRC in their personal capacity. The views of these officers directly contradict the view that AP mines have an extensive military utility. In the end, although the military value of the AT mine is acknowledged, the utility of AP mines is not well documented.

8. The proponents of AP mine use focus on the utility and cost-effectiveness of the weapon as a "force multiplier" in the context of regular and irregular armies. Active and retired military officers have challenged the claims that its effects magnify the usefulness

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[2] See International Committee of the Red Cross (ICRC), *Anti-personnel Landmines - Friend or Foe? A study of the military use and effectiveness of anti-personnel mines* (Geneva, 1996) at http://www.icrc.org/icrceng.nsf/Index/9E7F0DB680B63733412562FF00381071?Opendocument#20

[3] Annex I, "Meeting of Experts on the Military Use and Effectiveness of Anti-Personnel Mines, 12-13 February 1996, in ICRC, *Anti-personnel Landmines - Friend or Foe?*

of other weapons. One former US Marine Corps Commandant has stated that “I know of no situation in the Korean war, nor in the five years I served in Southeast Asia, nor in Panama, nor Desert Shield-Desert Storm where our use of mine warfare truly channelized the enemy and brought him into a destructive pattern… I’m not aware of any operational advantage from [the] broad deployment of mines.”[4]

9. Because AP mines cannot discriminate, and their destructive capacity does not end with the signing of a peace agreement, it is argued by humanitarian based international organisations and Non-Government Organisations (NGOs) that the long-term humanitarian and socio-economic costs of AP mines dwarfs their immediate military effectiveness. The issue for such organisations is not whether AP mines might under some circumstances have marginal utility. Rather, it is whether their use is not only essential but also proportional in relation to the utility they may provide.[5]

10. An increasing number of armies are renouncing the use of AP mines on the grounds that other munitions are an acceptable substitute with less long-term effects on the civilian population. The Claymore AP munition (otherwise known as a directional fragmentation device and widely produced under other names) lies on the borderline between a mine and a munition. If the Claymore-type munitions were only designed to be used by command detonation, and did not include a tripwire firing system, they would be an acceptable alternative to the normal blast and fragmentation-type mines. Such munitions are easily emplaced, and equally easy to remove when no longer tactically relevant.[6]

11. Questions were raised very recently about whether Canada is complying with the spirit of the treaty to ban land mines when it was revealed that Canadian peacekeepers in East Timor plan to use the Claymore. “Anti-landmine activists were surprised Canada is using the Claymore, saying they had been told the Canadian Forces have not used mines of any kind since the Korean War”.[7] However, Canada has modified its Claymores to only be used by command detonation, making them an acceptable alternative to AP mines. Thus, even when the Canadian Army is complying with the Ottawa convention and humanitarian organisations like the International Committee of the Red Cross (ICRC), anti-landmine activists and politicians still argue against their use. But as one columnist noted, "For serious countries facing serious risk, however, a land mine ban could prove to be a fatal luxury."[8]

MATERIAL AGAINST THE BAN

12. The central military argument in the debate over AP mines has been that such weapons constitute an irreplaceable military capability and are indispensable weapons of war. As quoted by Major Charles Heyman in the 1995 Jane’s Information Group study, *Trends in Land Mine Warfare*: “The presence of a handful of mines in a sensitive area can

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[4] Cited in Shawn Roberts and Jody Williams, *After the Guns Fall Silent: The Enduring Legacy of Landmines* (Washington: Vietnam Veterans Foundation of America, 1995), p. 5.

[5] Robert G. Gard Jr., “The Military Utility of Anti-Personnel Mines,” In *To Walk Without Fear: The Global Movement to Ban Landmines,* edited by Maxwell A. Cameron, Robert J. Lawson, and Brian W. Tomlin (Toronto: Oxford University Press, 1998), p. 137.

[6] ICRC, *Anti-personnel Landmines - Friend or Foe?*, p. 66.

[7] The Canadian Press, 14 February 2000.

[8] John F. Troxell, "Landmines," pp. 82-101.

change the whole nature and tempo of operations in an area at least 10 km in radius from the point where the mines were originally found."[9]

13. Some military planners argue that the AP mine has an important and legitimate military role and that the development of a new generation of mines is justifiable. In a 1992 report, the US Defense Intelligence Agency (DIA) said that "even with relatively costly new technologies, land mines are an affordable weapon for the entire range of military organisations, from terrorist groups to large, well-equipped armies…[and]…will continue to be a significant element in armed conflicts at all levels of intensity well into the foreseeable future."[10] Economic and social factors combine to ensure that AP mines will be used in increasing numbers in the future. The ability of AP mines to impose damage on the enemy with limited manpower in a cost-effective manner is the critical argument.[11]

14. Despite the introduction of arms control regimes, recent military actions in the Balkans and in Africa provide further evidence of AP mine use, including those by civilians on the receiving end of the fighting. With these activities taking place, many observers cannot foresee a future when AP mines will not be used on the battlefield or how AP mines will substantially degrade military performance. In fact, far from being redundant and obsolete, the demand for AP mines will continue and may become more significant in the future. "All mine types will be an important battlefield asset…and as the 'intelligent minefield' becomes a reality and delivery systems more mobile and more rapid, mines could assume a much higher priority."[12].

15. One study prepared by the Institute for Defense Analysis (IDA) assessed the usefulness of land mines in "high intensity, mechanized land warfare." The degree of influence varies strongly according to 1) the kind of combat engaged in, and 2) the type of mine used. First, defenders benefit most from the use of land mines. Second, AP mines are not nearly as useful as AT mines. Results using the JANUS combat model showed that in a dismounted attack scenario, in terrain emphasising the role of the AP mine, casualties for a US battalion deployed in a purely defensive position increased by about 10% when all AP mines were removed but by a massive 70% when both AT and AP mines were removed. The assumptions presented are that use occurs in a defensive posture in which (a) the attacker reaches close positions, (b) the attackers' infantry dismounts and conducts an assault on foot, and (c) the attacker manoeuvres its dismounted infantry and its accompanying armoured forces independently.[13]

16. The Pentagon has also stated that recent war games have demonstrated the ineffectiveness of other weapons, such as the AT mine, when not augmented by AP mines. They claim that more American lives would be lost without AP mines than with them. In a *1997 Report to Congress on the Anti-Personnel Land Mine Use Moratorium*, the Pentagon claimed that US casualties would rise by 35% in the European theatre and by 15% in Southwest Asia if the military was unable to use AP mines. The incoming Chair of the JCS defended the use of self-destructing mines, maintaining that they were "not

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[9] C. Heyman, *Trends in Land Mine Warfare, A Jane's Special Report*, August 1995.
[10] U.S., Defense Intelligence Agency and Army Foreign Science and Technology Center, *Landmine Warfare: Trends and Projections* DST-1160S-019-92 (December 1992) cited in Human Rights Watch, *Landmines: A Deadly Legacy* (1993), p. 45.
[11] Mike Croll, p. 143.
[12] C. Heyman, *Trends in Land Mine Warfare.*
[13] Stephen Biddle, Julia Klare and J. Rosenfeld, *The Military Utility of Landmines: Implications for Arms Control* (Alexandria, VA: Institute for Defense Analysis, IDA D-1559, 1994), pp. 70-71.

responsible for the humanitarian problem."[14] Without a credible alternative to offset the loss of the AP mine, the result would constitute an unacceptable military risk to allied forces.

17. If the AP mine has a debatable utility when used in tandem with the AT mine, European defence planners acknowledge that they come into their own when used in low-intensity conflicts, such as Afghanistan, Vietnam, and throughout Africa. Here, the AP mine had a devastating impact and was used by irregular forces as a valuable way of affecting morale and terrorising civilians in battle for hearts and minds. When used in a more formal military role, AP mines may be less useful, and soldiers can minimise the impact of the AP mine once they know where they are. Alternatives to AP mines (anything from better sensors, trip flares, fixed-line fire, remote / command detonated devices) may be equally effective at alerting small numbers of troops. Defence planners also recognised that AP mines create major hazards when used irresponsibly in pursuit denial and to prevent general occupation.[15]

18. Although the U.S. has not become a signatory to the Ottawa Treaty banning all AP mines, they have tempered the calls for elimination with concerns about maintaining the ability to deter conflict and reduce the risk to US armed forces. The *Report to the Secretary of Defense on the Status of DoD's Implementation of the U.S. Policy On Anti-Personnel Landmines,* acknowledges the U.S. reliance on AP mine to deter aggression against or, if necessary, successfully defend U.S. interests. In light of the current reliance, the U.S. policy states that any international agreement will need to protect and preserve the right of the U.S. to use AP mines necessary to meet security requirements, such as in the Korean Peninsula, until AP mine alternatives become available or the risk of aggression has been removed. Moreover, the policy states that, until such time as an international agreement takes effect, the United States will reserve the option to use self-destructing / self-deactivating AP mines in military hostilities in Korea--and elsewhere, if necessary--to safeguard American lives and hasten an end to fighting.[16] In the most recent policy refinements, the US has stated it will sign the Ottawa Convention by 2006 if suitable alternatives to AP mines and mixed AT systems can be identified.[17]

19. An open letter to President Clinton signed by twenty-four retired American four-star Generals (including a former Chairman of the Joint Chiefs of Staff, two former Chiefs of Staff of the Army, and a former Secretary of State) urged the US Government not to succumb to international pressure calling for the destruction of AP mines. They claimed that the responsible use of the AP mines was "not only consistent with the Nation's humanitarian responsibilities; it is indispensable to the safety of our troops in manual combat and peacekeeping situations."[18]

20. Efforts to prevent the use of specific weapons arouse antagonism among members of the military, who see the Mine Ban Treaty as an attempt to deprive them of tools to carry out war. When legislation was introduced in 1994 by the US Senate calling for a

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[14] Cited in David A. Lenarcic, *Knight-Errant? Canada and the Crusade to Ban Anti-Personnel Land Mines* (Toronto: Irwin Publishing, 1998), p. 51.
[15] Chris Smith (editor), *The Military Utility of Landmines…?* (University of London: North-South Defence and Security Programme, Center for Defence Studies, King's College, 1996), pp. 98-104.
[16] U.S., Department of Defense, *Report to the Secretary of Defense on the Status of DoD's Implementation of the U.S. Policy On Anti-Personnel Landmines,* Office of the Under Secretary of Defense for Policy, May 1997.
[17] John F. Troxell, "Landmines: Why the Korea Exception Should be the Rule," *Parameters* (Spring 2000), pp. 82-101.
[18] "An Open Letter to President Clinton," 21 July 1997, reprinted in David A. Lenarcic, Appendix 6.

moratorium on the production and procurement of landmines, the Chief of Staff of the US Army (Gordon Sullivan) wrote that "the precedent established—that of unilateral denial to U.S. forces of a legitimate, essential weapon based on potential post-conflict humanitarian concerns—threatens the use of a wide range of military weapons."[19]

MILITARY UTILITY

21. The debate on the utility of the AP mine cannot be considered an open and shut case on analytical grounds. The results from the first report examining the historical uses of AP mines may shed some light on the issue of military utility. In having identified the functions and capabilities of the AP mine, the first report showed that, even though its operational effectiveness was complicated by several factors, the overall cost of not using AP mines in combat operations should not be downplayed.[20] AP mines of various types have been a regular feature of war since the antiquities. Traditionally, AP mines were used to enhance combat effectiveness of one's own troops while imposing attrition on enemy forces. Although there are always uncertainties as to whether this is because of the limitations of static defences or because of poor execution and use of such defences, increasing numbers of countries systematically used AP mines to generate their military capabilities. To meet the growing requirement, more refined devices were developed. The advances in appropriate military mine technology were harnessed, including the use of trip wires, directional fragmentation devices, air-dropped munitions and scatterable mines, to increase operational effectiveness. This allowed for greater lethality and survivability, enabled armies to provide an economy on the defence and enhanced the psychological effects.

22. Essentially, AP mines used as tactical / protective fields were not very useful in long-range firefights and mobile warfare. Rather, they were more effective when they were part of an integrated defence system. That AP mines produced marginal increases in combat power did not prevent military forces from pursing the development of more sophisticated weapons, mass producing them and deploying them in combat conditions to produce casualties and dominate key terrain.

23. On many different occasions, military commanders believed that AP mines were useful weapons of war and chose to sow extensive minefields to shape the terrain to their advantage when given an opportunity to improve their defences. At the battle of El Alamein, Field Marshal Erwin Rommel constructed a vast defensive system of minefields (so-called Devil's Gardens) some five miles deep to wear down the Allied advance. On the Eastern Front, the German forces fought against the dense minefields laid by the Soviets in the Kursk salient. Millions of mines of all kinds were also laid in preparation for the Allied invasion of Europe in Normandy. Soldiers that ran up against mines took extra precaution, as one American officer wrote of his experiences later during the war: "By now, I had gone through aerial bombing, artillery and mortar shelling, open combat, direct

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[19] General Gordon Sullivan cited in Warren Strobel, "Pentagon Analysis Questions Usefulness of Land Mines," *The Washington Times* (28 August 1994).

[20] See Roger L. Roy and Shaye K. Friesen, *The Historical Uses of Antipersonnel Landmines: Impact on Land Force Operations* DLSC RN 9906 (Kingston: Department of National Defence, 1999).

fire and machine gun firing, night patrolling and ambush. Against all of this, we had some kind of chance; against mines we had none. The only defence was not to move at all"[21].

24. AP mines were effectively used without restraint, pattern or discrimination by undisciplined unconventional forces (e.g. paramilitary, irregulars or guerrilla) that relied on the low cost and the easy use of AP mines to "level the playing field" against technologically superior forces. In Vietnam, the Viet Cong took AP mines out of their traditional role and used them as weapons to continually attack and harass a technologically superior opponent. As a result, mines and booby traps caused up to 11% of US personnel being killed in action and up to 15% wounded (compared to less than 4% in WWII and the Korean War). In scenarios like these, AP mines posed a threat to land forces because a majority of the operations had to be conducted dismounted. While this caused casualties and delays in tactical operation, equally notable was their psychological effect: "Just the knowledge that a mine or booby trap could be placed anywhere slowed combat operations"[22]. A fearful respect for AP mines was created amongst American ground forces: "The enemy they found hardest to combat was not the VC; it was mines"[23].

25. Much work has been undertaken in the field of AP mine replacement, especially in the US.[24] A tremendous amount of effort has been devoted to the search for a one-for-one substitute device for the AP mine. This methodology fixates on employing non-lethal mechanisms in lieu of fragmentation or blast effects of AP mines. Specific attempts to completely replace the AP mine have proven extremely difficult and costly to implement. Solutions that have been put forward to end the reliance on AP mines have nurtured the idea that alternatives could not only perform similar functions, but would also eliminate the unwanted human suffering and destruction of the socio-economic fabric following a war.

26. The Office of the Secretary of Defense has sponsored an Integrated Products Team to look at the impact that the loss of the AP mine capability from the inventory will have and the alternatives that could be developed. A Requirements Team has been tasked to determine what missions AP mines or their alternatives must be capable to achieve. Functions of AP mines fall under four broad categories:

a. Protect small units and installations,

b. Protect anti-tank (AT) minefields from rapid hand breaching and dismounted reconnaissance,

c. Cover blind avenues of approach, deter infiltrators and provide early warning of infiltration,

d. Deter removal of other types of obstacles and slow the enemy in pursuit or a general withdrawal.

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[21] Stephen A. Ambrose, *Citizen Soldiers: The US Army from the Normandy Beaches to the Bulge, to the Surrender of Germany, June 7, 1944-May 7, 1945*, (New York, Simon and Schuster, 1997), p. 143.
[22] Lieutenant-General John H. Hay, *Tactical and Material Innovations,* (Washington, Department of the Army, 1974), p. 131.
[23] Captain Francis J. West, Jr., "Mines and Men," In *Small Unit Action in Vietnam*, (Washington, Historical Branch, US Marine Corps, 1967), p. 3.
[24] Background studies include: Canada, Department of Foreign Affairs and International Trade (DFAIT), *Anti-Personnel Land Mines: An Annotated Bibliography* (Ottawa: October 1996).

27. It has been a widely held assumption that an AP mine is a necessary part of military inventory because no satisfactory alternative has been found. All present and future mechanisms that will be available on the battlefield will need to be examined to determine how their integration can perform the functions of AP mines. Alternatives will need to include not only new technology, but also revised doctrine and improved training.

28. The question remains: does the removal of AP mines from the battlefield have to be compensated with greater amounts of other weaponry to maintain the same level of capability? The evidence of effective AP mine use in military operations point to an obvious and more immediate conclusion, that the removal of the AP mine from a defensive or offensive scheme requires an increase in other conventional weaponry to offset the loss of movement impairment capability that mines represent. That being said, this report will examine the cost and impact of removing mines, and determine if a replacement is necessary.

THE ANTIPERSONNEL SYSTEM

29. Preliminary work was conducted on a concept paper in the area of AP mine replacement. The current antipersonnel system is a mix of surveillance systems, weapons and obstacles. This triad was previously optimised through operational experience. The recent treaties have affected this optimisation.

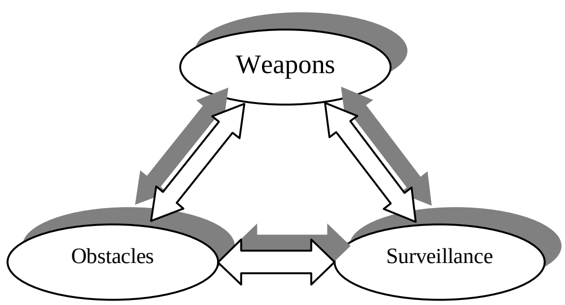

Figure 1: THE ANTIPERSONNEL SYSTEM

30. In light of this new situation, there is a requirement to re-optimise the balance between surveillance systems, obstacles and weapons used to achieve our operational goals. This will require that we look at the antipersonnel capability as an integrated system and no longer as a series of discrete systems.

31. We must be able to answer the following operational research question: What are the possible optimum mix of sensors, weapons and obstacles that will maximise the operational effectiveness of our anti-personnel system while minimising the logistical and financial burden? To this end we must establish a reference model, which should be based on the current system including antipersonnel mines and then modify the mix to establish a range of new optimum mixes.

32. There is an essential requirement to retain antipersonnel obstacles as a part of our overall antipersonnel system to ensure the protection of our troops in combat and non-

combat operations and the optimum effectiveness of our weapons during combat operations. Without obstacles the number of friendly casualties in any future conflict would be higher.

FUNCTIONS OF AP MINES

33. Defence leaders in Canada fought against the destruction of AP mines, arguing that if used properly against military targets they had a role to play in protecting troops.[25] The chief arguments in favour of landmines, and AP mines in particular, are reinforced by the fact that AP mines:

a. are cheap, lightweight, reliable, hard to detect and difficult to counter;

b. are simple to use, have a well-defined area of effect and are logistically easy to deploy;

c. provide an all weather, all terrain, continuous watch;

d. provide an economy of force enabling defensive positions to be held successfully by smaller forces;

e. inflict direct damage on the enemy, delay the attackers' closure and allow for increased effectiveness of other weapons; and

f. provide an important psychological effect causing fear, uncertainty and prudence in the minds of dismounted soldiers.

34. On the other hand, AP mines have several negative characteristics that make them undesirable:

a. They do not discriminate, are always active, restrict friendly mobility and cause friendly casualties;

b. The use, marking and mapping of mines is extremely difficult. History indicates that effective marking and mapping of mines has rarely occurred;

c. They are not tactically easy to re-use and quite often are not removed. Due to their inflexible active life, they are a residual hazard for years.

35. AP mine functions can be organised as subsets of four main capabilities: surveillance, deterrence, lethality and cost. As a means of surveillance, the AP mine provides early warning and an economy of force in all types of terrain, particularly in ground hidden from view (dead ground). In terms of deterrence, the AP mine inhibits hand breaching of obstacles, instils caution and adversely affects enemy morale. Its lethal nature includes inflicting personnel casualties, providing close protection and increasing effects of other weapons and hindering the use of landing zones. Finally, AP mines have low employment costs, which make them very desirable.

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[25] Canadian Press, "Landmine Ban had Military Brass up in Arms," *Edmonton Journal* (14 March 1999), A3.

36. In addition to the uses of AP mines described above, scatterable mines have been used by different nations in defensive operations to assist troops fighting in the covering force area, to complement and thicken existing obstacles, to close breaches and gaps, to prevent or delay reinforcements and to interdict and disrupt the enemy. Scatterable mines used in a nuisance-mining role could be particularly effective.

37. Replacing the AP mine is a matter of delivering its capabilities by other means. It was agreed at an Engineers Workshop that most operational applications of mines could be categorised as four types of obstacles. Each can be quantified by the number of mines, the distribution of mines and by the means to detonate them.

Tactical Employment	
Protective Obstacles	(e.g. Protect small units and installations)
Tactical Obstacles	(e.g. Protect AT minefields)
Static barrier	(e.g. Cover blind avenues of approach, prevent Border/Perimeter infiltration)
Other Obstacles	(e.g. Deter removal of craters/abatis)

PROTECTIVE OBSTACLES

38. Protective obstacles are laid in restricted areas, relatively close to one's own positions, to cover routes from which the enemy might attempt a silent approach or a sudden mass assault. AP mines are certainly a kind of ever-alert and invulnerable sentry providing early warning. However, to be legal they must be laid within a perimeter-marked and guarded area, and removed when the unit moves on. This requires extensive training and meticulous recording and laying procedures. This could prove very difficult if the mines were dispensed mechanically. They may not fall exactly where you want them and thus cannot be marked accurately. More seriously, on many forms of ground (long grass, heather, and undergrowth) AP mines are very hard indeed to spot, making the lifting process slow and hazardous.

39. The primary types of AP mines available in Canada were the C3A1/A2 (ELSIE), a pressure operated mine that can easily be emplaced by driving it into the ground with your foot; and the M16A2 bounding fragmentation mine, triggered by pressure or a trip wire, which detonates 0.6 to 1.2 meters above the ground, and sends fragments over a large lethal radius (up to 30 meters). The standard spacing of mines is 6 meters apart, with mines alternating 3 meters to the left or right of the row (a denser row can be created by spacing mines 2 meters apart). Due to the small size of the detonators on the mines (51mm diameter for ELSIE and 103 mm for the M16A2), the probability of causing personnel casualties with these mines is very low as shown in the following table (Probabilities are calculated based on the diameter of the mines divided by the distance between mines). For the M16A2 with a trip wire, it is assumed that they are laid no closer than 30 meters apart. The probability of causing personnel casualties is thus calculated here as the probability of tripping the wire, if the wire is in the line of advance. The probability will be the width of the lethal line (14m) divided by the distance between mines (30m).

TABLE I

PROBABILITY OF AP MINES CAUSING PERSONNEL CASUALTIES

MINE	SPACING	PROBABILITY OF DETONATING A MINE		
		1 Row	3 Rows	6 Rows
C3A1/A2 (ELSIE)	6 meters	0.3%	0.9%	1.7%
	2 meters	0.85%	2.5%	5%
M16A1	6 meters (no wire)	0.6%	1.7%	3.4%
M16A2	30 meters w/trip wire	47%	85%	97%

MODELLING KILLS BY FRAGMENTATION DEVICES

40. Fragmentation-type mines like the M16A2 propel fragments over a large lethal area and can cause more than one casualty per detonation. In order to determine the number of casualties, a mathematical model was developed to determine the probability of a kill against standing personnel for the M16A2 as well as for other Claymore-type directional fragmentation devices. Based on the number of fragments, the mass of metal and the weight of the explosive charge, the fragment striking velocity can be determined. This velocity is used to determine the single hit kill probability against standing personnel. The spreading of the fragments in range then determines the expected number of hits which gives the probability of a kill versus range for the different devices (See Annex A for details). Figure 2 shows the probability curves for the M16A2 and the Claymore.

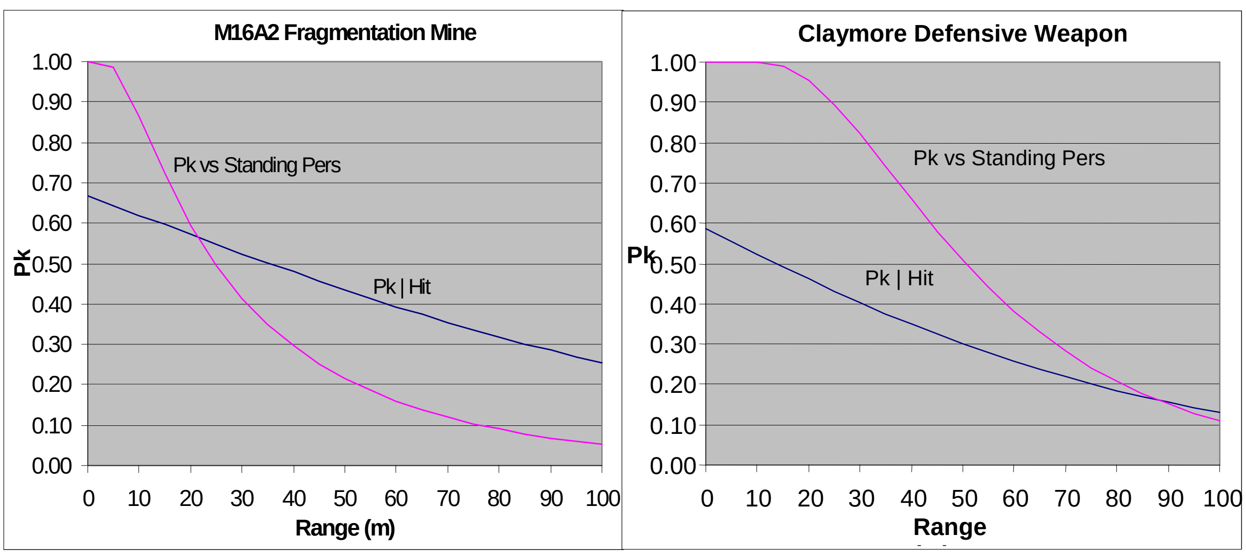

Figure 2: Probability of Kill versus Standing Personnel

41. Results for different fragmentation devices are shown in the following table. The M19, for example, uses explosive cords with detonators instead of electrical wire. This allows any length of cable and any number of devices to be arranged in series and command detonated at one location.

TABLE II

LETHAL RADIUS OF DIFFERENT FRAGMENTATION DEVICES

DEVICE	Fragments	EXPL. WEIGHT	TOTAL WEIGHT	Lethal Radius (m)	Angular Pattern
		kg	kg	at 50% Pk	
M16A2		0.59	2.83	25	360
Claymore	700	0.682	1.58	50	60
M19	923	0.9	1.9	55	60
M100	842	5.4	10	100	60
FFW013	1200	14	20	145	50

MASS INFANTRY ATTACK

42. One of the most frightening infantry problems is that of a mass infantry attack from about 300 dismounted enemy rushing your defended position under cover from artillery. At 300-400 meters, the enemy moves in 3-5 second rushes making it very difficult to engage effectively. Furthermore, the probability of hitting moving targets at that range is less than 5%. When the enemy reaches effective rifle range (200 meters), they assault. Artillery smoke rounds cover the attack and the assaulting force moves at a fast rush firing as they come. The defenders have few opportunities to engage and very low probability of achieving any significant levels of casualties without some form of obstacles.

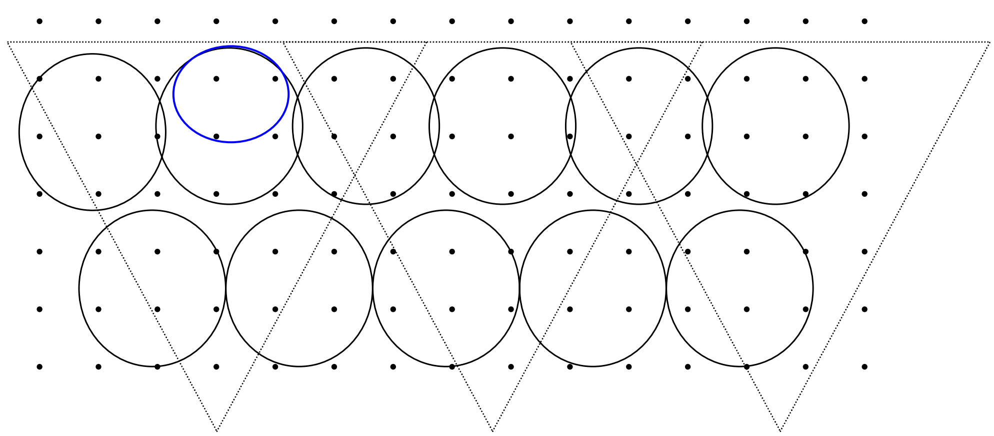

Figure 3: Potential Number of Casualties Against a Mass Infantry Attack

43. Assuming the enemy soldiers are spaced 10 meters apart, a comparison of the potential number of casualties by M16A1 fragmentation AP mines versus Claymore-type munitions is shown in figure 3. The M16A1 AP mines will be detonated before the lead soldier passes within 10 meters of the mine. Fragments are expected to hit 3 (ellipse) and kill 2 enemy on average calculated from the probability of kill curve above. The Claymore

can hit up to 21 enemy in a 60-degree arc out to about 60 meters if a human confirms the threat and fires the weapon when the lead enemy is close to the Claymore. This can cause up to 16 casualties (against standing personnel) based on the probability of kill curve above. Since the Claymore is command detonated and not all attacking infantry will be standing when it is fired, we will only use an expected 8 casualties per Claymore (half the potential value).

44. The expected number of casualties against a mass infantry attack (300 dismounted infantry) over a 400 meter wide protective AP minefield assuming one kill for each Elsie, two kills for each M16A1 or 8 kills per Claymore would be as shown in the table below.

TABLE III

NUMBER OF CASUALTIES IN A MASS INFANTRY ATTACK

		COST	**EXPECTED NUMBER OF CASUALTIES (TOTAL COST)**		
MINE	**SPACING (# of mines)**	**PER ROW**	**1 Row**	**3 Rows**	**6 Rows**
C3A1/A2 (ELSIE)	6 meters (66/row)	$2244	1 ($2244)	3 ($6732)	5 ($13464)
	2 meters (199/row)	$6766	3 ($6766)	8 ($20298)	15 ($40596)
M16A1	6 meters (no wire) (66/row)	$4290	4 ($4290)	10 ($12780)	20 ($25560)
M16A2	30 meters w/trip wire (13/row)	$845	12 ($845)	37 ($2535)	73 ($5070)
M18A1 Claymore	40 meters (10 Total)	$312 (each)			80 ($3120)

45. At about $300 per Claymore, the cost for the same number of expected kills is less than the cost of AP mines, and set up is easier and faster than having to dig, bury and mark a lot of mines.

SIMPLE SCENARIO ANALYSIS

46. In order to gain insights on the effectiveness of a different weapons mix to compensate for the loss of AP mines, a simple dismounted infantry scenario was run using the TACOPS computer game[26]. Blue defence consisted of a Platoon of Infantry with C7 rifles, C9 Machine Guns, M203 Grenade launchers, and a 60mm Mortar. The Red offence

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[26] TACOPS, A Game of Modern Tactical Warfare-Canadian Forces Edition, by Maj I.L. Holdridge, USMC.

consisted of 72 Infantry with AK74 rifles and RPK74 Machine guns in open terrain starting at about 500 m. When the scenario was run with and without mines, Red overran the Blue defensive position. When either a HMG or a Mk 19 AGL were used to compensate for the loss of mines, Blue wins overwhelmingly. Total time for the scenario varied between 13 and 23 minutes. It is important to note that the crew-served weapons must survive long enough to cause enough casualties to reduce the number of attacking infantry to a manageable level. In the scenario, all 400 rounds of HMG ammunition and over 125 Grenades from the 40mm AGL were used. The results of the scenarios are shown in figure 4.

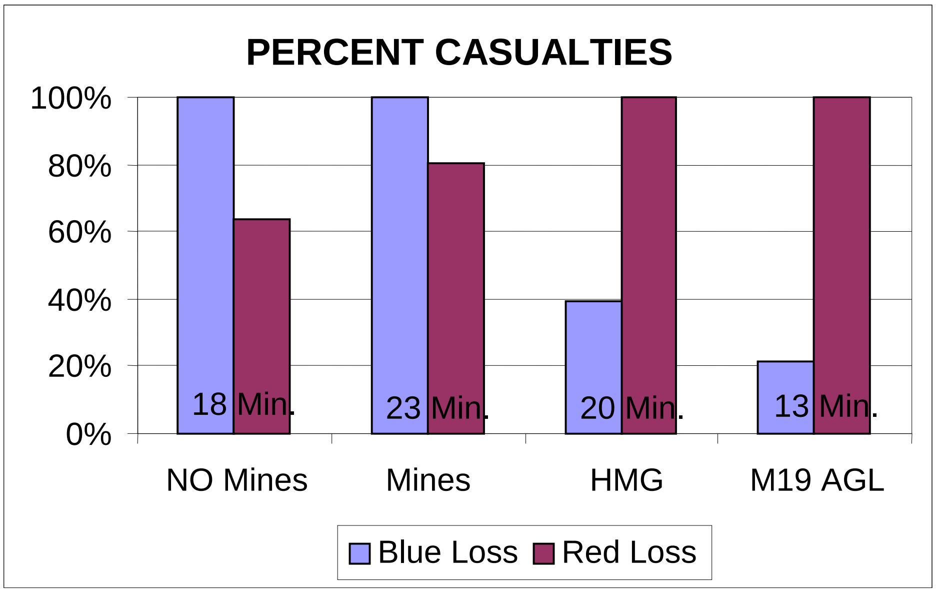

Figure 4: Results of a Small Dismounted Infantry Attack

JANUS WARGAMING

47. In order to validate the mathematical results and the preliminary results from the simple scenario above, a series of JANUS war games were conducted to determine the contribution that AP mines provided.

48. The scenarios consisted of a dismounted Battalion attack against a light Infantry Platoon in a prepared defence position. Two gaps in forested areas were chosen to evaluate mid and close range defensive options. For each option, 10 runs were conducted with no obstacles, with allowed obstacles including wire and remote-detonated Claymores, and with full obstacles which included M16A1 fragmentation mines. Since mines in JANUS can only have one kill, the mines were placed 1 meter apart to represent a dense minefield and to achieve the expected number of kills of the M16A1. Claymores with man-in-the-loop were represented as dual Artillery rounds each with 20-meter lethal areas impacting 15 meters and 35 meters ahead of the Claymore's location. Short and long preparation times were evaluated to test different densities of obstacles, but applying the same number of man-hours to each of the obstacle variables.

49. The close range scenarios sees the Battalion attack going through a forest where unattended ground sensors allowed the defender to launch 3 volleys of 81 mm mortars to

disrupt the advancing formations. Wires were placed at the edge of the forest, followed by a minefield and/or Claymores near the defended positions (figure 5). Both Red and Blue have Artillery support, with Red switching to smoke when the attack breaks out of the forest into the clearing. Blue fires 5 volleys of Mortars and M109 Artillery as Prep Fire, then brings the defenders out of full defilade (i.e. out of trenches) and fights his defence.

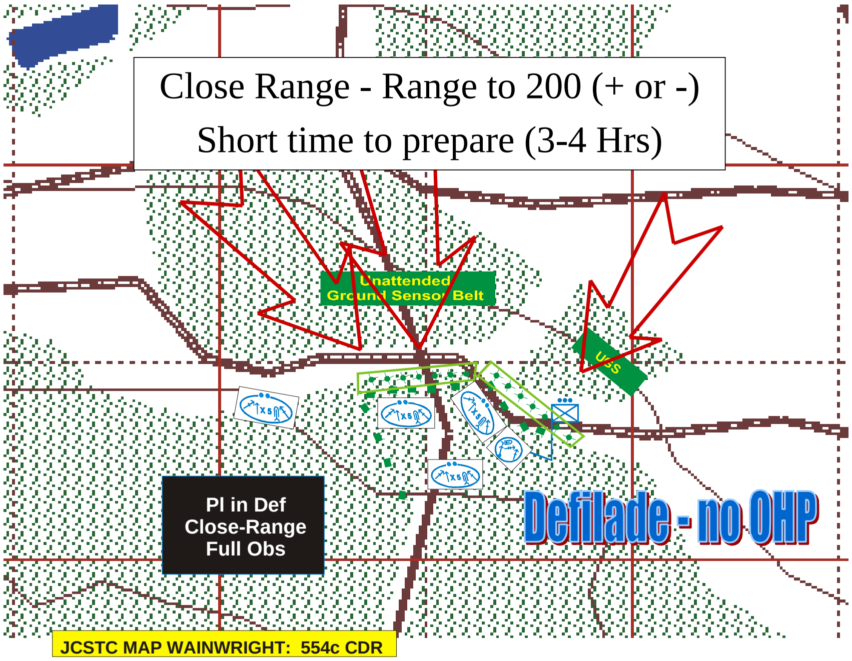

Figure 5: Close Range Scenarios

50. Red always managed to overrun the Blue defence because of their overwhelming numbers and the use of smoke to limit the line of sight of the defenders. However, the scenarios were run to determine the relative number of casualties with mines, with no obstacles and with allowed obstacles (e.g. wire and Claymores). The average results of ten repetitions of each scenario are shown in Figure 5.

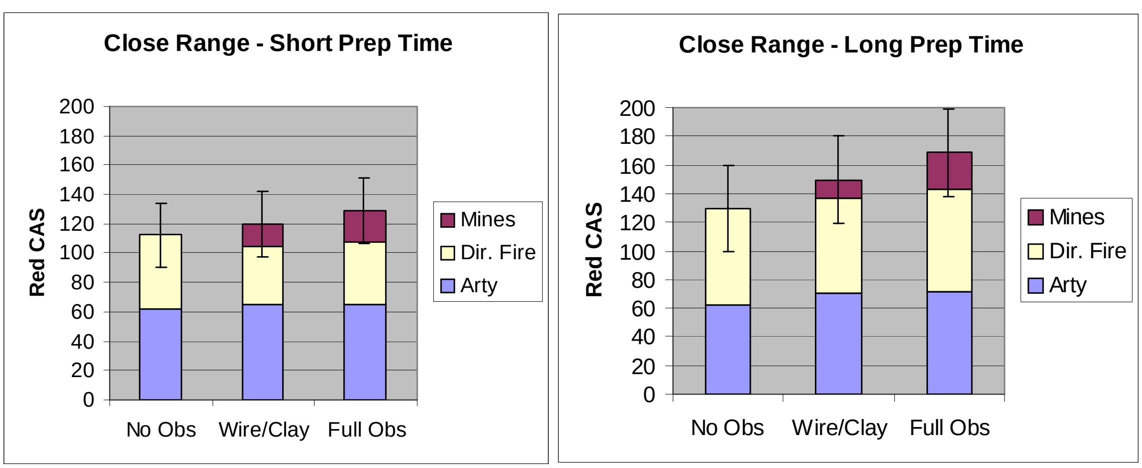

Figure 6: Results of a Close Range Dismounted Infantry Attack

51. Results indicate that wire obstacles and Claymores do better that no obstacles but not as well as mines. The contribution due to mines is not statistically significant because, in the short gap between forested areas in this scenario, Red had difficulty in achieving a

good smoke screen to block line of sight of direct fire weapons. Claymores only contributed a small percentage of the total casualties as seen in the top of the middle bars.

52. The mid range scenarios also sees the Battalion attack through a forest where unattended ground sensors allows the defender to launch 3 volleys of 81 mm mortars to disrupt the advancing formations. Again, wires are placed at the edge of the forest but also in front of the Claymores, with a minefield in between (see figure 7).

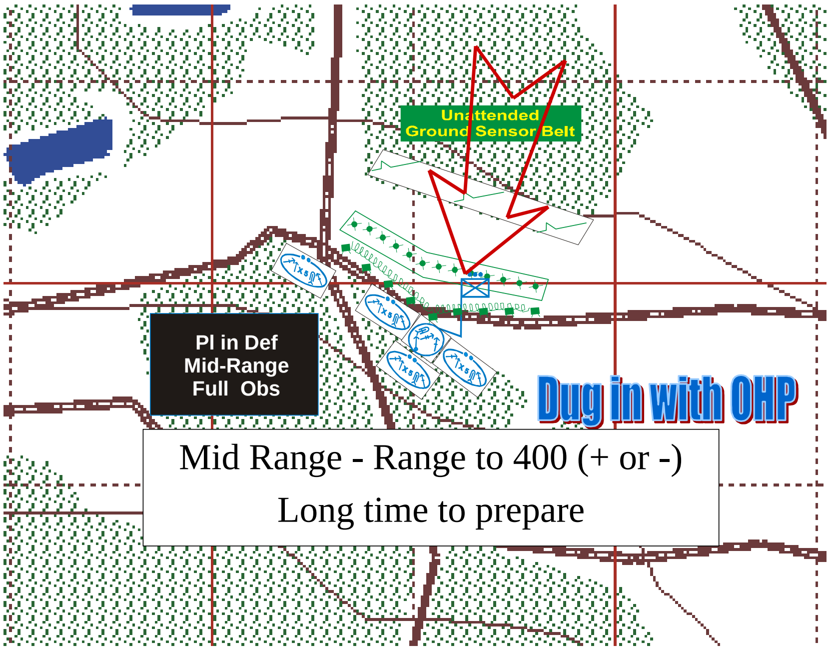

Figure 7: Mid Range Scenarios

53. Both Red and Blue have Artillery support, with Red switching to smoke when the attack breaks out of the forest into the clearing. Blue fires 5 volleys of Mortars and M109 Artillery as Prep Fire, then brings the defenders out of full defilade (i.e. out of trenches) and fights his defence. The exercise stops after the Red Bn crosses the road in front of the defended position or when Red is destroyed. Results of 10 runs of each scenario are shown in Figure 8.

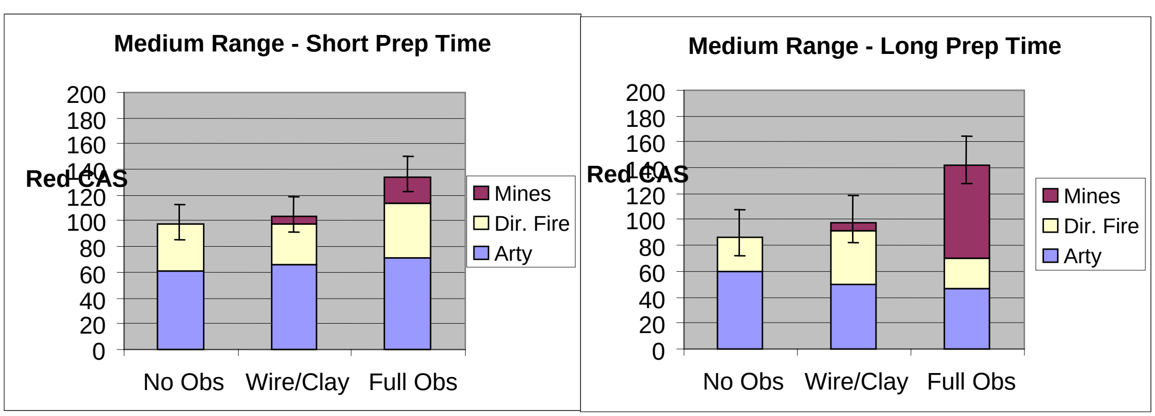

Figure 8: Results of a Medium Range Dismounted Infantry Attack

54. In the mid range gap scenarios, Red achieves a better smoke screen preventing the defender from achieving very many kills using direct fire weapons. Here mines achieve a

significant effect in the number of kills (90% win for Blue) compared to wire obstacles and Claymores (only 10% win for Blue). The contribution of the Claymores is even less than in the Short-range scenarios.

55. As a result of these JANUS wargames, it was shown that AP mines have a significant effect against Mass Infantry attacks when there is a medium range gap (about 400 meters) between forested areas but not as significant in close ranges (<200 meters). Two main effects are the fact that Red can have a more effective smoke screen in the larger open area so Blue must depend on mines to provide the kill mechanism, while in the shorter ranges, Blue can have more effective and accurate direct fire effects and mines do not contribute to as many kills in the region beyond the 150m effective direct fire range. One interesting result from some of these scenarios is the fact that the total number of kills from 40mm Grenades correlate fairly well with the number of grenades fired from rifle-mounted M203 grenade launchers (about 1 extra kill per round).

56. However, one striking result from all the above JANUS scenarios was the ineffectiveness of Claymores because they were unusable when the enemy broke through the defence. It was found that Claymores laid near the defended positions are vulnerable to Indirect fire because both the Claymores and the Man-in-the-loop (MITL) become one target for Indirect fire rounds, and Red has time to launch more rounds and adjust his fires to achieve more hits on the Claymores/MITL. Only 25% of the Claymores were detonated on average. There are several possible reasons:

a. The Claymore itself was destroyed or toppled by indirect fire;

b. The trip wire was damaged by indirect fire; or

c. The man-in-the-loop was killed by either direct or indirect fire.

57. Assuming that an Indirect fire round can destroy a mine/Claymore or a trip wire within 1 meter of its impact point and that it can be corrected to impact within a 50mx50m grid, the following table shows that even though losses are about the same, the percentage effective obstacle lost to Indirect fire is about 10 times more for Claymores than AP mines:

TABLE IV

EXPECTED INDIRECT FIRE DESTRUCTION OF OBSTACLES

Type/Number of mines in 400 m minefield	Probability of Hitting 1 mine/trip wire/cable	Expected number of Mines destroyed (% of protective obstacle)		
	# of Rounds->	10	20	50
C3A1 or M16A1 / 400	0.04	.4 (0.1%)	.8 (0.2%)	2 (0.5%)
M16A2-trip wire / 80	0.05	.5 (0.625%)	1 (1.25%)	2.5 (3.12%)
M18A1 Claymore with 35 m cable /10	0.06	.6 (6%)	1.2. (12%)	3 (30%)

58. Claymores need to be made more resistant to Indirect Fire. By eliminating the cable and using coded radio or IR signals to remotely command detonate the Claymores from a number of positions, it would be possible to reduce the time to prepare an obstacle and reduce their vulnerability to indirect fire.

59. Given that Automated Grenade Launchers can fire at a much higher rate, and that remotely command detonated Claymores could be laid further from the defended position, the mid-range scenario was repeated with different weapons usage by the defender. First, instead of using Claymores only as a last line of defence, a field of Claymores was laid in the gap, using 45 Claymores instead of the 10 to 16 from the previous scenarios. Another option replaced the 60mm Mortar in the Platoon with an Automatic Grenade Launcher (AGL), with a second AGL located in the supporting Section from a flanking Platoon. Different combinations of Claymores, wire obstacles and Mk 19 AGL were run. Average results from 12 runs of each scenario are shown in figure 9.

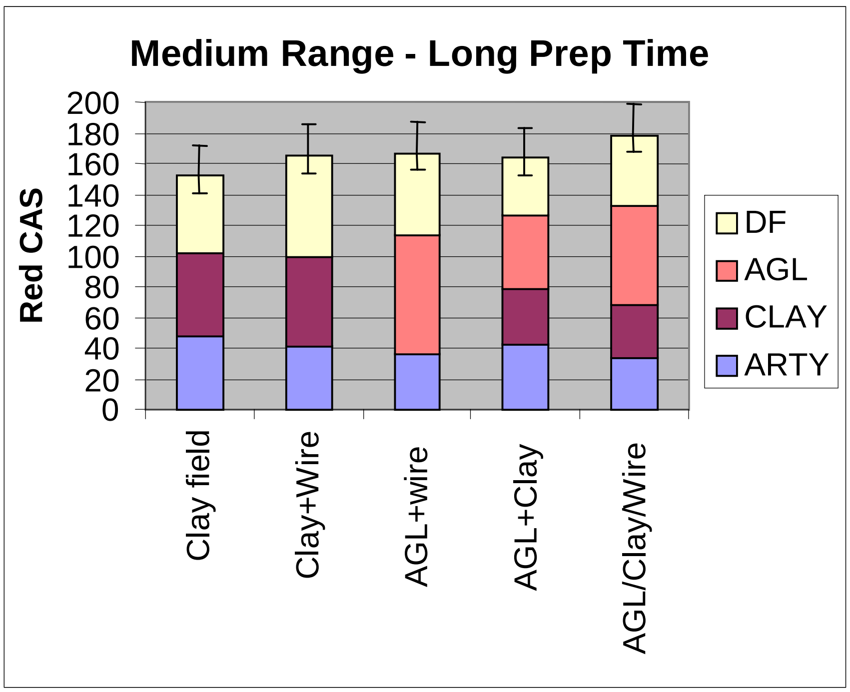

Figure 9: Results Using Claymores and/or AGL

60. In the first option using a field of Claymores with RF/IR links to reduce their vulnerability, the average number of Red casualties is about 152 (with over 80% win for Blue), higher than the average of 141 found with AP mines. When wire obstacles are used to slow down the attack (second option), Blue causes more Red casualties with his direct fire weapons and with the Claymores (achieving over 90% wins).

61. Similarly, when replacing the 60mm Mortar in the Platoon with an Automatic Grenade Launcher (AGL), the major contribution to Red casualties is the AGL. The players observed that the AGL becomes a priority target and must be protected. In almost every run, however, at least one of the two AGLs survives for most of the attack.

62. When both the field of Claymores and the AGL are used, but no wire obstacles, then the average number of Red casualties is about the same as each used with wire obstacles.

63. The best result (Average of 178 Red casualties and 100% win for Blue) is achieved when Claymores, the AGL, and wire obstacles are used together. The wire obstacles slow down the attack, permitting more lethal effects from direct fire weapons, providing the man-in-the-loop enough time to detonate the Claymores against more dispersed attackers and allowing the AGL to be aimed and fired at more stationary targets.

64. It was shown with these scenarios that using Claymores (with no wire connections) further ahead of the defended position (similar to the way mines were laid) or using 40mm Automatic Grenade Launchers (AGLs) along with wire obstacles provide a capability that helps to compensate for the loss of AP mines. In the JANUS wargames, players were able to manually target the approaching enemy even when there was an effective smoke screen because they were provided with an overhead view. Whether these results can be achieved on the battlefield will depend on sensors being able to see through smoke.

65. Recent improvements to AGLs will make these weapons effective in poor visibility and bad weather conditions. One example is the Striker 40mm Advanced Lightweight Grenade Launcher. It is about half the weight of the Mk19 and requires about half the total charge pull of the Mk19. Striker features include rapid slew and traverse, high-stability recoil design and downward ejection for reduced thermal battlefield signature. The most significant modification over the Mk19 is Striker's enhanced fire control system and air-bursting munitions. The Striker has a Generation III image-intensified night-vision capability as well as a sensor suite for measuring pressure and temperature. The electronic fire-control system coupled with an integral eye-safe laser rangefinder allows programming rounds for air-burst at the intended target range, giving the operator a much improved first-round burst lethality.[27]

Figure 10: Striker 40mm Advanced lightweight AGL

66. Thus, defence of a Platoon-size position against a mass infantry attack is possible by increasing the lethality (volume, range, and precision) of small units in the direct fire fight, by using improved wire obstacles, trip flares, and night vision equipment to provide early warning and detect attempts at breaching and infiltration and by introducing improved sensors and displays to provide target discrimination especially in dead ground

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[27] Jane's Defence Weekly, Vol, 34 No. 11, 13 September 2000, p.29 "USSOCOM set to test new grenade launcher"

several hundred meters ahead of the defenders. It is important to decrease the latency in sensor-to-trigger decision cycles with C4 fully linked to sensors (ISR).

TACTICAL OBSTACLES

67. Tactical obstacles are laid across substantial tracts of country to serve defensive purposes. Pattern laying drills, by hand or mechanically, are used for tactical minefields and occasionally protective minefields, if time and resources permitted. Minefields laid in a pattern produced a better obstacle (i.e. greater stopping power) than random laying, and could be located and lifted quicker. Almost invariably Anti-Tank mines are their principal component, laid in some depth over several hundred metres from front to rear. AP mines are normally laid among the few rows of the minefield nearest to the enemy to:

a. deter the enemy from rushing the minefield by infantry assault to gain control and make hand clearance more feasible; and

b. cause casualties, demoralise and further delay the progress of the dismounted clearing parties.

68. Scatterable mines are often used to complement and thicken existing obstacles, to close breaches and gaps, to prevent or delay reinforcements and to interdict and disrupt the enemy. Before the Ottawa Convention, scatterable AP mines could have been used legally and effectively provided they could be made to self-destruct reliably, be located with pin-point accuracy (and thus recorded), be continuously covered by observation and fire, and that civilians could be effectively warned. Since scatterable mines are surface laid, they are easier to detect and to breach. Thus it has been the practice in the US to include both AT and AP mines in a mix in order to make rapid hand-breaching more difficult.

69. Since tactical minefields are classically used to block routes of expected enemy mechanised advance, they are almost certain to be laid in terrain that favours mechanical breaching. The AP mines however forced the attacker to change his breaching method. Although mechanical breaching (required in the presence of AP mines) is faster than dismounted breaching, the number and width of resulting lanes reduces the speed which armour can traverse the minefield. Dismounted breaching also allows armoured vehicles to remain protected until lanes are completed. Thus it is important to continue to provide means to prevent or severely disrupt dismounted breaching operations.

70. Anti-Tank mines can be equipped with Anti-Handling Devices (AHD) to slow the mounted advance and to make mechanical breaching more hazardous (detonation of the mine if it is moved). AHD installed on scatterable AT mines would also prevent their removal and allow the closing of breaches and gaps. To make dismounted breaching difficult, trip flares can provide early warning in detecting dismounted attempts at breaching and infiltration, while Forward Observers equipped with night vision equipment can call for rapid response by long-range direct fire weapons (e.g. AGLs with a range of up to 2000m), Mortars (range up to 8.5 km) and Artillery fire (range beyond 8 km). Continuous electronic or Electro-optical sensors can further improve the detection from hidden approaches and data links can trigger immediate response by long-range direct and indirect fire weapons. Tank Ditches, berms, fences, and spikes can be used as adjunct obstacles to slow down vehicles and dismounted infantry. Finally, barbed-wire

entanglements can exert delays and make hand breaching by dismounted troops more difficult.

71. The US conducted a quick look study to examine the use of anti-handling devices to replace the protective functions of AP mines in mixed minefields.[28] Examination of breaching techniques provided by the Engineer School quickly showed that the two capabilities attack different threats to the minefield, and that one cannot be substituted for another. The anti-handling (or anti-disturbance) device causes the mine to detonate if it should be picked up or disturbed. This is designed to prevent mines from being moved or stolen. Normal dismounted breaching destroys the mines by placing demolition charges beside them. The soldier is very careful not to disturb the mine, as he is aware of the possibility of anti-handling devices being present. Consequently, anti-handling devices have negligible impact on a dismounted breach.

72. A secondary outcome of this quick-look study was data that clearly showed the contribution of AP Mines to AT minefield effectiveness. Table V shows the results of an analysis of the time required executing a daylight dismounted breach of AP/AT minefields and AT-only minefields. (A dismounted breach is one whereby soldiers work to clear the minefield by hand, as opposed to a mechanical breach, wherein specialised breaching equipment mounted on a tank or armoured vehicle chassis is used.)

TABLE V
ESTIMATED TIME FOR DISMOUNTED BREACH (MINUTES)
(5-m wide, 100-m long lane)

	Buried		Surface	
Dismounted Task	AT/AP	AT only	AT/AP	AT only
Grapple†	20	0	80	0
Sweep (two operators)	15	12	8	4
Mark/place charges	1	1	1	1
Back-out/detonate	3	3	3	3
Check lane	2	2	2	2
Total	41 minutes	18 minutes	94 minutes	10 minutes

† Four 25-m throws used for buried mines, 16 20-m throws used for surface mines

Underlying assumptions, consistent with Bosnia experience and with Army Field Manual FM 20-32 are:
· Probing, necessary for buried mines, is not necessary in a surface minefield since the mines are visible;
· The dismounted breach clears a lane 5-m wide by 100-m long;
· In the AT-only case the enemy knows only AT mines are in use;
· Marking and placing charges are done concurrently with sweeping;
· Six soldiers are required for the dismounted breach (two to sweep and mark, one to place demolition charges, two to connect charges to the firing circuit, and one to provide security).

The initial analysis looked at some alternatives to the AP mine that could ensure that dismounted breaching times would remain fairly high. The initial analysis of an APL alternative with tripwire and radio controlled detonation showed a clear advantage when compared to the other alternatives. The use of a motion detector instead of trip wires would

[28] Greenwalt, R.J. and D.E. Magnoli, Examination of the Battlefield Utility of Antipersonnel Landmines and the Comparative Value of Proposed Alternatives, LLNL, UCRL-ID-130004, 23 December 1997.

negate the use of grapple hooks and would increase breaching times even more. The concept should be examined in detail using realistic assumptions / models for the features identified.

73. Improved sensors that could recognise movement and heat signatures as well as detecting metal and explosives would help to discriminate combatants from non-combatants and provide some decision support for the man-in-the-loop. Signal repeaters / amplifiers would reduce the risk of jamming and allow for more remote observer locations, reducing operator vulnerability. The same technologies (improved sensors, repeaters, etc) could be used to produce improved remotely triggered Claymores and/or AP mine alternatives allowing for the protection of AT minefields.

74. Thus, enhanced tactical obstacles can be achieved with the use of modified AP mines using improved sensors, signal repeaters and radio-controlled detonation. Improved Claymores with similar capabilities could also be used. If a rapid response, cyclic firing capability is required, then long-range direct fire weapons (e.g. AGLs, LAVs, Tanks, etc) or mortars with bursting anti-personnel rounds can be used. Trip flares, and night vision equipment can also provide early warning similar to that of mines in detecting attempts at breaching and infiltration. Improved sensors and displays are also needed to provide target discrimination especially if the Mines / Claymores are located in dead ground several hundred meters ahead of the defenders. Tank Ditches, berms, fences, and spikes can be used as adjunct obstacles to slow down vehicles and dismounted infantry. Finally, barbed-wire entanglements can exert delays and make hand breaching by dismounted troops more difficult.

STATIC BARRIER

75. As a static barrier, the mines serve two main purposes. The first is to deter potential adversaries from crossing the barrier; the second is to provide early warning during infiltration. The early warning function can be provided reliably when using motion detectors, cameras or laser beams, which can detect infiltration without providing any indication to the adversary. If deterrence is desired, then alarms, trip flares or non-lethal effects can be set when the "invisible" barrier is crossed. For perimeter demarcation, fences or other appropriate obstacles can be erected. Wire entanglements inside or outside the fences can further delay enemy infiltration. Finally Claymore-type fragmentation munitions, Mortars, machine guns and rifles can be used to stop infiltration across borders.

76. South African forces, in the struggle against insurgents, used such a border system which is claimed to have resulted in no accidental killings or civilian casualties. This involved the use of perimeter demarcation, harmless mechanical and electronic sensors, and command-detonated Claymore-type directional fragmentation munitions visibly mounted on posts 6 meters above the ground. The link between the sensors and the weapons was a soldier in an armoured control post outside the "minefield" who confirmed the firing command initiated by the triggering of a sensor. This system eliminated the traditional risks associated with minefield maintenance, as the system could simply be switched off. It thus allowed for safe passage by forces, civilians and cattle under appropriate conditions.[29]

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[29] ICRC, *Anti-personnel Landmines - Friend or Foe?*, p. 66.

77. Recent developments of sensor systems have demonstrated automatic detection of intrusions. Norway has conducted research on their OPAK camera surveillance system and demonstrated automatic detection with only one false alarm per day over 176 camera days of testing. Arkonia Systems, a small UK company, has developed its Hornet radar sensor, a handheld or tripod-mounted detector triggered by an external or remote sensor, to provide perimeter surveillance and transmitting its output data over an RF link. The initial variant of the radar has a maximum range of 100m, but a new version will have a range of 400-500m.[30]

OTHER OBSTACLES

78. To enhance craters and/or abatis, both Anti-Tank mines and AP mines are useful. The AT mines prevent easy repair with plows or backhoes, and the AP mines deter manual repairs thus forcing a delay. Since these obstacles are obviously military in nature, one option is to replace the function of AP mines with booby traps. Booby traps are not specifically banned by the Ottawa Convention. A booby trap can be as simple as a hand grenade with a trip wire attached to the pull ring. Since these obstacles are not usually under observation, there is no need to provide sensors and/or weapons to enhance their effectiveness.

79. Booby traps can replace some of the functions of AP mines, but not in all situations. In protective and tactical minefields, they can deter infiltration and provide early warning of infiltration. They can deter hand breaching and reconnaissance of minefields. They are not generally as effective as AP mines since they do not have a large lethal radius and do not have safety features like AP mines to protect soldiers when emplacing them. Therefore, more time and training is required to safely employ booby traps than to employ AP mines.

POSSIBLE SOLUTIONS

80. **Near term**. The near term solution is to amend the current doctrine within the current framework of surveillance, obstacles and weapons. Better sensors can be used to detect intrusions. Fences, spikes, and barbed wire can be used as adjuncts to the obstacles, and command detonated mines, Claymore-type munitions or Automated Grenade Launchers can provide the lethal response. It must be noted that in the case of the command detonated munitions, a non-line of sight capability will not be possible unless an associated non line of sight surveillance and target acquisition system can be provided. For example, a cheap IR camera installed near the munition with a display at the command firing position could provide a limited non-line of sight capability.

81. **Mid term**. The mid term solution could see the integration of non line of sight ground surveillance systems with RF links, command detonated antipersonnel munitions and the introduction of a more logistically effective reduced lethality antipersonnel obstacle system.

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[30] Jane's International Defense Review, Vol 32, December 1999, p. 19.

82. **Long term**. The long-term solution could see the total sensor to shooter integration of the indirect and direct fire systems with the surveillance and unattended munitions to create an optimum antipersonnel system. This could also include the introduction of brilliant munitions that could automatically discriminate between friendly forces, enemy forces or belligerents and non-combatants while retaining full operational effectiveness.

CONCLUSION

83. The central military argument in the debate over AP mines has been that such weapons constitute an irreplaceable military capability and are indispensable weapons of war. Once deployed, mines require very few personnel to monitor them, they function 24 hours a day under all weather and visibility conditions, and are cheap and simple to manufacture. However, mines provide a low probability of hit at a relatively large cost of labour and stores. The price of properly laying, marking, observing and maintaining minefields is high in both personnel and logistic terms, and involves significant investment, risk to one's own forces and the loss of tactical flexibility. They are single shot weapons and have no cyclic firing capability.

84. In many cases, Claymores provide an economical and legitimate solution to the replacement of AP mines and appear to be more cost-effective than several rows of AP mines. Furthermore, set up is easier and faster than having to dig, bury and mark a lot of mines. Improved sensors and displays are needed however to provide target discrimination especially if remotely detonated Mine alternatives / Claymores are located in dead ground several hundred meters ahead of the defenders. A cheap camera, automatic IR or radar sensors near the remote alternatives / Claymores with a display at the command firing position could provide the required non-line of sight capability to cover hidden approaches and dead ground.

85. It was shown, with JANUS war game scenarios, that using a field of remotely detonated Claymores (with no wire connections) further ahead of the defended position (similar to the way AP mines were laid), and/or using 40mm Automatic Grenade Launchers (AGLs) along with wire obstacles, provide a capability that compensates for the loss of AP mines in protective obstacles. Whether these results can be achieved on the battlefield will depend on sensors being able to see through smoke and ensuring that the AGL team is well protected from indirect fire.

86. Although mechanical breaching of tactical obstacles is faster, dismounted breaching allows armoured vehicles to remain protected until lanes are completed. Anti-Tank mines equipped with Anti-Handling Devices (AHD) will slow a mounted advance and force the enemy to use hand breaching as the method of choice. Using improved sensors, signal repeaters and a direct link to command-detonated AP alternatives or Claymores, long-range direct fire weapons (e.g. AGLs, LAVs, Tanks, etc) or mortars with bursting anti-personnel rounds can deter hand breaching of AT minefields.

87. Motion detectors, cameras or laser beams can provide early warning, automatic detection of intrusions and a silent alert of an infiltration in static barrier obstacles. For perimeter demarcation or to protect fixed installations, fences or other appropriate obstacles can be very useful in stopping unwanted intrusions. Wire entanglements inside or outside the fences can further delay infiltration. Claymore-type fragmentation munitions,

mortars, machine guns and rifles can be used to deter armed infiltration across borders. If politically feasible, soldiers should be equipped with booby trap kits and trained in making booby traps from existing munitions such as hand grenades and mortar rounds.

88. There are several existing and many potential systems that can at least in part perform the functions of AP mines. However, there is the possibility of greater consumption levels, increased unit footprint, and greater manpower and logistics requirements that result from APL alternatives.

RECOMMENDATIONS

89. It is recommended to amend doctrine within the current framework of surveillance, obstacles and weapons. There is a need to develop improved surveillance sensors that can detect and alert our troops about enemy movement, direction and hostile intent. Jam-resistant RF or IR links between the sensors and the man-in-the-loop will be required to decrease the latency in sensor-to-trigger decision cycles. Synchronisation of ISTAR (intelligence, surveillance, target acquisition and reconnaissance) assets, decentralised allocation of sensors and early warning systems to tactical units and dissemination of intelligence to commanders at all levels will be required to develop a robust Common Operating Picture.

90. A concept of layered defence should be considered to update obstacle doctrine. A first layer with increased use of obstacles, patrols and/or guard dogs could provide warning to turn away innocent civilians. A second layer consisting of non-lethal responses that can cause nausea or disorientation could enhance deterrence against determined criminal factions, and a final layer with lethal responses could prevent infiltration by combatants and belligerents. Methods to quickly erect fences, dig ditches, and lay improved wire entanglements should be investigated.

91. There is a need to increase the lethality at the small unit level. Use of command detonated mine alternatives and Claymore-type munitions, physical barriers (including non-lethal), Automatic Grenade Launchers, and more direct access to indirect fires can provide the required lethal response to compensate for the loss of AP mines.

ANNEX A

Calculation Of Personnel Casualty Chances[31]

Consider a fragmenting munition that contains M kg of metal and C kg of charge with chemical energy per unit mass of E joules per kg. Then Gurney's Law gives the velocity of ejection of the fragments on detonation

$$V_0 = \sqrt{\frac{2EC}{(M + 1/2C)}} \qquad (1)$$

Typically for small warheads such as mines and grenades, 80% of the munition's metal is dispersed as fragments. For simplicity, assume that all the fragments have the same mass. For Claymore-type warheads, the number and mass of fragments (steel balls) is usually known. If the munition generates N fragments, the mass of a fragment will be

$$m = \frac{800M}{N} \quad \text{(gm)} \qquad (2)$$

To compute the velocity at which a fragment strikes the target, we must take account of fragment deceleration due to air drag. This deceleration is

$$2\rho_A C_D A_F v^2 \qquad (3)$$

where

ρ_A is air density (about 0.00122 gm/cc at sea level)
C_D is the fragment's drag coefficient (about 1.0)
A_F is the presented area of the fragment (in sq.cm.)
v is the fragment velocity in cm/sec

If the fragment has moved a distance r (cm) from the detonation point by time t, the equation of motion of the fragment of mass m (gm) is therefore

$$m\frac{dv}{dt} = mv\frac{dv}{dr} = -2\rho_A C_D A_F v^2 \qquad (4)$$

$$v = v_0 \text{ and } r = 0 \text{ when } t = 0 \qquad (5)$$

The solution of (4) subject to (5) is easily found to be

$$v = v_0 \exp\left(-\frac{\rho_A C_D A_F r}{2m}\right) = v_0 \exp(-r/r_1) \quad (6)$$

$$\text{where } r_1 = \frac{2m}{\rho_A C_D A_F} \text{ or } R_1 = \frac{2m}{100\rho_A C_D A_F} \text{ in meters.}$$

[31] The formulas in this Annex are taken from the unclassified portions of an Annex in DLOR Staff Note 90/6, A Rough Estimate of the Effectiveness of a Dual Purpose 120mm Mortar Round, by Eric Leese, July 1990.

If we express the fragment initial velocity V_0 in meters/sec, and fragment velocity after distance R in meters as V meters/sec, then

$$V = V_0 \exp(-R/R_1) \qquad (7)$$

An estimate of the presented area A of an unprotected standing person when engaged by a fragmenting warhead that detonates at range R and at height of 1 meter above the ground can be calculated as follows:

$$A = 0.4281 - 0.0016\,R \qquad (8)$$

For a warhead with N fragments, which are expelled horizontally in all directions, attacking a target with presented area A at range R, the expected number of lethal fragment hits is

$$H = \frac{NAP_{KH}}{4\pi R} \qquad (9)$$

P_{KH} is the probability of a kill given that the fragment strikes the target.

For a directional fragmentation warhead (like the Claymores), the expected number of lethal fragment hits is

$$H = \frac{NAP_{KH}}{b/90\pi R}$$ where b is the angular spreading of the fragments

The probability of a "kill" is thus

$$P_K = 1 - \exp(-H) \qquad (10)$$

Probabilities of kill versus range curves can thus be produced and lethal ranges of different fragmentation warheads calculated.

ANNEX B

RESULTS OF JANUS WARGAMES

NUMBER OF RED CASUALTIES

CLOSE RANGE – SHORT PREP. TIME

serial201 **NO OBSTACLES**

RUN#	ARTY		DF	TOTAL
1	86		32	118
2	89		30	119
3	62		122	184
4	59		20	79
5	39		72	111
6	63		60	123
7	58		18	76
8	59		54	113
9	42		39	81
10	67		51	118
AVE	62.4		49.8	112.2
St Dev	15.95967		30.82856	31.2225

serial202 **ALLOWED OBSTACLES**

RUN#	ARTY	CLAYMORE	DF	TOTAL
1	58	8	18	84
2	65	24	58	147
3	75	12	29	116
4	37	21	44	102
5	38	17	30	85
6	73	16	61	150
7				
8	96	12	32	140
9	77	19	44	140
10	66	8	41	115
AVE	65	15.22222	39.66667	119.8889
St Dev	18.81489	5.629782	13.99107	25.7752

serial203 **FULL OBSTABLES**

RUN#	ARTY	MINES	DF	TOTAL
1	74	21	32	127
2	54	27	28	109
3	54	28	43	125
4	84	19	19	122
5	34	25	75	134
6	81	22	33	136
7	73	22	57	152
8	54	12	49	115
9	70	18	49	137
10	73	18	37	128
AVE	65.1	21.2	42.2	128.5
St Dev	15.54527	4.779586	16.13691	12.15867

RESULTS OF JANUS WARGAMES

NUMBER OF RED CASUALTIES

CLOSE RANGE – LONG PREP. TIME

serial211 NO OBSTACLES

RUN#	ARTY	MINES	DF	TOTAL
1				
2	58		130	188
3				
4	36		71	107
5	61		35	96
6	77		92	169
7	81		75	156
8	60		15	75
9	77		103	180
10	56		69	125
AVE	63.25	0	73.75	137
St Dev	14.791	#DIV/0!	36.523	42.095

serial212 ALLOWED OBSTACLES

RUN#	ARTY	CLAYMORE	DF	TOTAL
1	69	1	121	191
2	55	17	31	103
3	77	17	68	162
4	74	36	23	133
5	73	11	91	175
6	89	2	75	166
7	70	7	24	101
8	67	7	96	170
9	57	6	86	149
10	70	18	55	143
AVE	70.1	12.2	67	149.3
St Dev	9.6546	10.379	33.307	29.907

serial213 FULL OBSTABLES

RUN#	ARTY	MINES	DF	TOTAL
1	101	31	22	154
2	56	0	137	193
3	66	35	23	124
4	75	4	97	176
5	48	56	59	163
6	104	0	60	164
7	86	32	53	171
8	55	29	91	175
9	60	38	76	174
10	66	32	92	190
AVE	71.7	25.7	71	168.4
St Dev	19.454	18.457	35.264	19.546

RESULTS OF JANUS WARGAMES

NUMBER OF RED CASUALTIES

MEDIUM RANGE – SHORT PREP. TIME

serial221 **NO OBSTACLES**

RUN#	ARTY		DF	TOTAL
1	46		19	65
2	66		51	117
3	82		22	104
4	69		16	85
5	62		27	89
6	47		72	119
7	33		65	98
8	54		24	78
9	62		32	94
10	89		34	123
AVE	61	0	36.2	97.2
St Dev	16.89839		19.69659	18.89033

serial222 **ALLOWED OBSTACLES**

RUN#	ARTY	CLAYMORE	DF	TOTAL
1	55	10	27	92
2	59	5	63	127
3	64	17	56	137
4	68	3	32	103
5	52	5	36	93
6	83	1	11	95
7	64	1	42	107
8	61	4	4	69
9	37	11	28	76
10	120	0	15	135
AVE	66.3	5.7	31.4	103.4
St Dev	22.23136	5.396501	18.86914	23.42933

serial223 **FULL OBSTABLES**

RUN#	ART	MINES	DF	TOTAL
1	43	23	45	111
2	64	27	34	125
3	57	17	85	159
4	74	23	35	132
5	64	14	76	154
6	63	17	48	128
7	81	26	24	131
8	97	15	15	127
9	71	25	36	132
10	92	19	34	145
AVE	70.6	20.6	43.2	134.4
St Dev	16.21522	4.765618	21.86219	14.36199

RESULTS OF JANUS WARGAMES

NUMBER OF RED CASUALTIES

MEDIUM RANGE – LONG PREP. TIME

serial231 **NO OBSTACLES**

RUN#	ARTY		DF	TOTAL
1	61		9	70
2	99		30	129
3	60		27	87
4	56		16	72
5	52		39	91
6	51		7	58
7	47		26	73
8	55		14	69
9	66		36	102
10	54		57	111
AVE	60.1	0	26.1	86.2
St Dev	14.72		15.4	22.235

serial232 **ALLOWED OBSTACLES**

RUN#	ARTY	CLAYMORE	DF	TOTAL
1	53	2	73	128
2	36	13	48	97
3	23	3	85	111
4	58	3	33	94
5	73	3	44	120
6	48	7	64	119
7	60	1	14	75
8	64	4	37	105
9	42	2	18	62
10	39	20	2	61
AVE	49.6	5.8	41.8	97.2
St Dev	14.95	6.0882	26.7	24.147

serial233 **FULL OBSTABLES**

RUN#	ARTY	MINES	DF	TOTAL
1	40	87	27	154
2	38	85	29	152
3	61	62	47	170
4	51	49	30	130
5	35	65	26	126
6	53	68	18	139
7	10	86	29	125
8	64	64	9	137
9	68	80	9	157
10	51	80	5	136
AVE	47.1	72.6	22.9	142.6
St Dev	17.12	12.791	12.7	14.938

RESULTS OF JANUS WARGAMES

NUMBER OF RED CASUALTIES

MEDIUM RANGE – LONG PREP. TIME

serial301 **AGL + CLAYMORES**

RUN#	AGL	ARTY	DF	CLAYMORE	TOTAL
1	57	76	24	31	188
2	33	41	28	53	155
3	1	60	29	16	106
4	6	18	66	47	137
5	51	71	34	33	189
6	45	45	41	54	185
7	16	33	47	36	132
8	100	19	40	23	182
9	68	81	17	16	182
10	50	27	55	45	177
11	104	20	28	32	184
12	47	26	32	37	142
AVE	48.17	43.083	36.8	35.25	163.25
St Dev	32.43	23.333	13.9	12.89	27.854

serial302 **AGL + WIRE**

RUN#	AGL	ARTY	DF		TOTAL
1	58	48	81		187
2	73	44	60		177
3	54	20	76		150
4	48	43	55		146
5	97	53	33		183
6	104	61	20		185
7	18	19	69		106
8	95	11	57		163
9	78	71	38		187
10	143	19	27		189
11	63	26	66		155
12	105	18	45		168
AVE	78	36.083	52.3		166.33
St Dev	33.04	19.723	19.7		24.44

serial303 **CLAYMORES**

RUN#		ARTY	DF	CLAYMORE	TOTAL
1		82	21	64	167
2		34	61	72	167
3		28	50	33	111
4		34	47	79	160
5		67	37	72	176
6		53	76	55	184
7		35	31	20	86
8		31	40	55	126
9		75	62	50	187
10		62	48	50	160
11		35	56	41	132
12		43	64	57	164
AVE		48.25	49.4	54	151.67
St Dev		18.854	15.5	17.01	31.128

RESULTS OF JANUS WARGAMES

NUMBER OF RED CASUALTIES

serial304 **CLAYMORES + WIRE**

RUN#	ARTY	DF	CLAYMORE	TOTAL
1	72	72	43	187
2	63	73	43	179
3	27	59	80	166
4	26	42	78	146
5	68	61	52	181
6	11	73	64	148
7	36	85	40	161
8	28	74	65	167
9	60	75	44	179
10	54	63	46	163
11	23	53	77	153
12	31	54	62	147
AVE	41.583	65.3	57.83	164.75
St Dev	20.536	12.1	15.06	14.379

Serial305 **AGL+Claymores+WIRE**

RUN#	AGL	ART	DF	CLAYMORE	TOTAL
1	70	56	23	40	189
2	73	62	17	36	188
3	24	21	56	53	154
4	71	16	53	39	179
5	92	52	21	22	187
6	97	33	29	30	189
7	8	23	94	53	178
8	90	20	37	24	171
9	76	55	34	22	187
10	81	32	54	22	189
11	27	12	76	44	159
12	70	13	47	34	164
AVE	64.92	32.917	45.1	34.92	177.83
St Dev	29.04	18.486	23.2	11.38	12.819

UNCLASSIFIED
SECURITY CLASSIFICATION OF FORM
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1. ORIGINATOR (the name and address of the organisation preparing the document. Organisations for whom the document was prepared e.g. Establishment Sponsoring a contractor's report, or tasking agency, is entered in Section 8). Operational Research Advisor Fort Frontenac, PO BOX 17000, Station Forces Kingston, Ontario, Canada, K7K 7B4	2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable) UNCLASSIFIED	
3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title) Tactical Impact Of Removing Antipersonnel Landmines (U)		
4. AUTHORS (last name, first name, middle initial) Roy, Roger L.		
5. DATE OF PUBLICATION (month Year of Publication of document) November 2000	6a. NO OF PAGES (total containing information. Include Annexes, Appendices, etc.) 36	6b. NO OF REFS (total cited in document) 31
7. DESCRIPTIVE NOTES (the category of document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.) Research Note		
8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address). Directorate of Army Doctrine		
9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.) N/A	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written.) N/A	
10a. ORIGINATOR's document number (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) RESEARCH NOTE RN 0005	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor.) N/A	

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Canada has ratified the *Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Antipersonnel Mines and Their Destruction*. This convention imposes a number of limitations on the types and use of antipersonnel weapons. There is an essential requirement to retain Anti-Personnel obstacles to ensure the protection of our troops on operations, maximise the effectiveness of weapons in combat operations, and to inflict casualties on opposing forces. This research note addresses whether the current weapons mix can replace the capabilities that AP mines provided.

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- Antipersonnel Landmines
- Obstacles
- Land Operations
- Operational Research
- Weapons Mix

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