Manoeuvre through Adaptive Dispersed Operations (ManADO) Explosive Hazard Avoidance (EHA) Improved Neutralization

02DA02.07 Implementation Plan

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Reference Document
DRDC-RDDC-2016-D039
May 2016

Abstract

The “Improved Neutralization” activity under ManADO Explosive Hazard Avoidance 02DA02.07 examines ways to enhance the Canadian Armed Forces Counter-IED system by addressing explosive hazard neutralization with a path towards exploitation (impact) while seeking to avoid duplication of efforts through systems available from our allies, or which are being addressed by another DRDC activity.

The explosive hazard neutralization capabilities of High Energy Lasers are being addressed under the Land Weapon Systems project by DRDC – Valcartier Research Centre. A complementary effort is herein proposed which will access the knowledge base of our allies through a modest investment in explosive hazard neutralization using Radio Frequency Directed Energy Weapons (RF DEW).

Significance to Defence and Security

This project will gather evidence to support or reject the military utility of RF DEW for the purposes of explosive hazard neutralization. This will guide doctrine, create concept(s) of operations, provide training needs analysis, etc, and will include S&T analysis of any vulnerability that may exist within the CAF capability that could be realistically addressed by RF DEW in the mounted Counter-IED role.

Résumé

Dans le cadre de l'activité "d'amélioration de la neutralisation" du projet Manœuvre through Adaptive Dispersed Operations (ManADO) sur l'évitement des risques d'explosion 02DA02.07, on examine différentes façons d'améliorer le système utilisé par les Forces armées canadiennes dans la lutte contre les engins explosifs improvisés (EEI). On aborde la question de la neutralisation des risques d'explosion dans une perspective d'exploitation (incidence) tout en cherchant à éviter les dédoublements d'efforts au moyen de systèmes disponibles chez nos alliés ou encore à l'étude dans le cadre d'une autre activité de RDDC.

La capacité de neutralisation des risques d'explosion par les lasers à haute énergie est abordée dans le cadre des projets sur les systèmes d'armes terrestres de RDDC – Centre de recherches de Valcartier. Un effort supplémentaire est suggéré, ceci afin de permettre l'accès à la base de connaissances de nos alliés grâce à un modeste investissement dans la neutralisation des risques d'explosion au moyen d'armes à énergie dirigée par radiofréquence (AED RF).

Importance pour la défense et la sécurité

Ce projet vise à recueillir des données probantes afin de confirmer ou infirmer l'utilité des AED RF dans la neutralisation des risques d'explosion. Il servira notamment à l'orientation de la doctrine, à la création de concepts d'opération, à l'analyse des besoins en formation et comportera une analyse de S&T des vulnérabilités potentielles de la capacité des FAC qui pourrait être abordée de façon réaliste par les AED RF dans la lutte contre les EEI embarqués.

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1 Introduction

1.1 Introduction

A thorough description of the background scope study approach, resources, constraints and study plan for this activity are provided by Faust [1]. While that document addresses improved detection, the discussions are equally applicable to improved neutralization, and are briefly summarized below.

The "Improved Neutralization" activity under Manoeuvre through Adaptive Dispersed Operations (ManADO) Explosive Hazard Avoidance Neutralization (EHA(N)) work breakdown element (WBE) 02DA02.07 focusses on the DtD (Defeat the Device) CIED (Counter Improvised Explosive Device) line of operation. The proposed Courses of Action which fall out of this exercise are those that:

- enhance the Canadian Armed Forces (CAF) CIED system by addressing explosive hazard neutralization with a path towards exploitation (impact);
- are not available as Commercial or Military Off-The-Shelf or from our allies; and
- are not being addressed by another DRDC activity.

Given the 02DA02.07 timeline and resources, efforts will focus on higher Technology Readiness Level (TRL) technologies by ensuring sufficient development of knowledge, expertise, and facilities to advise the CAF on existing technologies, or those available in the near near-term.

The original ManADO EHA(N) team comprised Geoff Coley and Kevin Russell of Defence Research and Development Canada's Suffield Research Centre, and Jean Fortin of Defence Research and Development Canada's Valcartier Research Centre, with the Valcartier Centre's contribution chiefly addressing High Energy Laser (HEL) neutralization. The way DRDC activities have developed, HEL is already being covered under the Land Weapon Systems project. There is little or nothing to be gained by spending ManADO resources on HEL outside of Valcartier Centre's Land Weapon System work. Hence, ManADO EHA(N) will simply observe the Valcartier Centre's HEL information and recommendations, but will not expend resources on parallel efforts on HEL.

1.2 Consultations

An ideal method of defining the scope of the EHA(N) work would have been to gather all stakeholders together in one place at one time and to work out a common understanding, a common list of priorities, and a commonly agreed scope for the EHA(N) activities. For a number of reasons there were delays in approving the start of the ManADO EHA(N) work, and this was compounded by limited availability of some of the primary stakeholders. It became clear that it would be difficult to schedule two or three players together, much less a full slate of all players. In addition, expecting to obtain a universally agreed upon set of priorities at a single meeting would probably be a bit naive.

As a result, contact was made by DRDC with what were considered to be the major stakeholders, and discussions were held via whatever means could be arranged—telephone, video conference, in-person, etc. A strawman proposal for the ManADO EHA(N) activity was circulated to those major stakeholders for consideration, criticism, and recommendations. The following organizations were identified as major stakeholders for the purposes of ManADO EHA(N). It is a certainty that others should have been included, and there is, of course, much uncertainty about what constitutes a "major" stakeholder as compared with a "minor" stakeholder. As such, the parties listed below were encouraged to identify additional stakeholders who should be consulted, or to make their own additional consultations and to include that information in the feedback on the strawman proposal:

- CALWC (LCol R.C. Rankin);
- DLR (Capt N. Malazdrewicz, DLR 7-9);
- CADTC (Maj M. R. Dunning, A/CG SHIELD);
- JCET TF (Maj D. Hilliker, Tech Eval/S&T Coord); and
- DSTAR 4 (Andrew Plater) was included in his role as Project Director of the ManADO EHA effort.

The initial discussions attempted to address the requirements in a "technology-agnostic" manner. That is, the discussion focused on "what" needed to be accomplished, and not on "how" it could or should be accomplished. Thus, "we need an improved ability to neutralize artillery shells without high-order detonation from greater than 200 metres" rather than "we need a high power laser to open up and low-order burn artillery shells from greater than 200 metres." The question of "how" would be addressed later.

A preliminary list of EHA neutralization tasks with perceived capability gaps was presented which included the discussion starters shown below in Table 1. The terminology was left intentionally vague so as to invite discussion and interpretation rather than guiding it.

Table 1: *Discussion starter topics.*

Task	Possible Considerations
Rapid standoff neutralization of visible EH; Neutralization of visible EH from distance > x.	Collateral damage to be minimized. Smoking hole to be avoided. • Immediate, visible evidence of neutralization is essential. Smoking hole ok.
Slow non-energetic standoff neutralization of visible EH; Mechanical disruption of visible EH from distance > x.	Permissive environment allows slow-time action. Smoking hole to be avoided.

Task	Possible Considerations
Standoff neutralization of visible off-route EH	An off-route EH threat has been found (perhaps using WOLF assets) and which can be visually pinpointed. Cannot be approached (due to terrain? in a tree?) and must be neutralized from distance > x. • Sparsely populated areas • Built-up areas
Standoff neutralization of invisible off-route EH	An off-route EH threat has been detected (perhaps using WOLF assets) and narrowed down to a small area but which cannot be visually located or identified. • Sparsely populated areas • Built-up areas
Rapid neutralization of buried but located EH	Buried EH which has been located and marked (perhaps by Husky), which cannot be avoided and must be quickly neutralized. • Smoking hole to be avoided • Smoking hole ok
Safe excavation of buried but located EH for traditional disruption	Buried EH which has been located and marked (perhaps by EROC), which cannot be avoided but which can be dealt with in slow-time but which first needs to be safely excavated and exposed.
Pre-detonation of unknown or unseen EH fuzes	Unknown, unseen threats, buried, concealed or off-route. No indication that any EH exists; Pre-detonation/pre-trigger of fuzes in areas where pre-det is permissible. • low collateral damage likely • risk of indirect fratricide (causing the EH to fire on friendly forces) is acceptable for reasons of op-tempo or other.
Jamming of unknown or unseen EH fuzes	Unknown, unseen threats, buried, concealed or off-route. No indication that any EH exists. • Pre-det/pre-trigger of fuzes not acceptable but jamming or disabling fuzes ok.

Based on the general discussion areas outlined above, a matrix (Figure 1) was developed which was circulated to the major stakeholders. The stakeholders were presented with almost 100 combinations of conditions and asked to consider whether each combination presented a capability gap. In some cases, the matrix served simply as a conversation generator, and feedback was provided outside of the matrix. In other cases, parts of the matrix were filled out, but not the whole thing. The DRDC personnel had no direct visibility into the decisions or the consultations that may have led to the decisions but there was no need for that visibility. Between the phone calls, emails, and video conference calls, four main themes started to emerge.

Ser	Location	Speed	Located?	Approach	Predet OK?	Smoking Hole?	Capability Gap?
1	OnRoute	SlowEOD	Located	Standoff	Predet	BangOK	
2	OnRoute	SlowEOD	Located	Standoff	Predet	BangNotOK	
3	OnRoute	SlowEOD	Located	Standoff	NoPredet	BangOK	
4	OnRoute	SlowEOD	Located	Standoff	NoPredet	BangNotOK	
5	OnRoute	SlowEOD	Located	Robot	Predet	BangOK	
6	OnRoute	SlowEOD	Located	Robot	Predet	BangNotOK	
7	OnRoute	SlowEOD	Located	Robot	NoPredet	BangOK	
8	OnRoute	SlowEOD	Located	Robot	NoPredet	BangNotOK	
9	OnRoute	SlowEOD	Located	PersApproach	Predet	BangOK	
10	OnRoute	SlowEOD	Located	PersApproach	Predet	BangNotOK	
11	OnRoute	SlowEOD	Located	PersApproach	NoPredet	BangOK	
12	OnRoute	SlowEOD	Located	PersApproach	NoPredet	BangNotOK	
13	OnRoute	SlowEOD	NotLocated	Standoff	Predet	BangOK	
14	OnRoute	SlowEOD	NotLocated	Standoff	Predet	BangNotOK	
15	OnRoute	SlowEOD	NotLocated	Standoff	NoPredet	BangOK	
16	OnRoute	SlowEOD	NotLocated	Standoff	NoPredet	BangNotOK	
17	OnRoute	SlowEOD	NotLocated	Robot	Predet	BangOK	
18	OnRoute	SlowEOD	NotLocated	Robot	Predet	BangNotOK	
19	OnRoute	SlowEOD	NotLocated	Robot	NoPredet	BangOK	
20	OnRoute	SlowEOD	NotLocated	Robot	NoPredet	BangNotOK	
21	OnRoute	SlowEOD	NotLocated	PersApproach	Predet	BangOK	
22	OnRoute	SlowEOD	NotLocated	PersApproach	Predet	BangNotOK	
23	OnRoute	SlowEOD	NotLocated	PersApproach	NoPredet	BangOK	
24	OnRoute	SlowEOD	NotLocated	PersApproach	NoPredet	BangNotOK	
25	OnRoute	HastyBreach	Located	Standoff	Predet	BangOK	
26	OnRoute	HastyBreach	Located	Standoff	Predet	BangNotOK	

Figure 1: *Partial matrix for capability gap discussion.*

1.2.1 Peripheral Concerns

A few of the observations suggested a desire for better personal protective equipment (PPE) or other topics related to explosive hazards but not directly related to explosive hazard neutralization.

1.2.2 “EOD is Fine”

The existing EOD methods and equipment are seen as being largely satisfactory. Incremental improvements will be gladly accepted but based on the feedback received there was no appetite for revolutionary changes to EOD equipment or tactics, techniques and procedures (TTPs). Even the EOD requirement for standoff seemed to have been adequately addressed through the use of remotely controlled robotic systems.

Further, 02DA02.11 is addressing specific areas of EOD technology in which further work is merited (HME render safe, advances in render safe technology, novel explosive threats).

1.2.3 Standoff Neutralization

The primary area of interest, expressed in one form or another by all participants was the desire for improved standoff neutralization. What was unclear, however, was what exactly was meant by either ‘standoff’ or ‘neutralization.’ This will be discussed in more detail below.

1.2.4 Rules and Doctrine and Who Gets to Do It

Any time a discussion includes a new technology, a new application of an existing technology, or changes to TTPs, there will be—and must be—concerns about rules of engagement (ROE), training, certification, doctrine, and so on. There are very real concerns about legal issues, rules of engagement and enabling unqualified people to do things they should not be doing, but the objective of this exercise is to imagine new/other ways to accomplish neutralization, not to imagine doing the same things in the same ways as we currently do them. There may also be a tendency to confuse (sometimes intentionally) legitimate ROE difficulties with simple resistance along the lines of “that’s not how we do it” or “it would be too complicated to change that.”

The discussion must therefore be open to considering different ideas with the understanding that due consideration must be given to doctrine, training, certification and so on, if these new approaches are eventually to be adopted.

Finally, the very fact that a technology can accomplish a task does not necessarily mean that it should or should not be used to accomplish the task. While it is tempting to think that simply throwing additional resources or technologies at a problem will lead to better results—faster operations, fewer friendly force losses, greater opposing force losses, etc.—an exercise done in 1996 under the direction of the Night Vision Electronic Sensors Division, Ft Belvoir, VA and the Engineer Battle Testbed, Ft Leonard Wood, MO [2] came to some interesting conclusions summarized as follows:

When an advanced mine detection system was included in a particular countermine mission, friendly force losses due to mine strikes decreased but losses from direct and indirect fire increased, with a net increase in overall losses. It was postulated that this was due to the friendly force sitting exposed while the system searched for the edge of the minefield or a way around. When an advanced, highly effective explosive minefield breaching system was included in the exercise, friendly force losses actually increased. The suggestion was that there was a tendency to breach rather than avoid a minefield.

The first of these may be analogous to a CAF operation in which a convoy is required to wait for conventional EOD operations to deal with an EH. It may well be the safest in terms of friendly force losses from the EH, but in some cases it may leave the friendly forces vulnerable to other threats during the EOD operation. The second illustrates the perils of using something just because it is there, not because it represents the best overall solution. It may also be noted that EROC, or other route clearance assets may not always be deployed with a full EOD capability, and that existing doctrine requires that force protection be made available to clearance teams.

The discussion above is almost trivial and self-evident; it is used simply to acknowledge that there are pitfalls to adopting a new technology or set of tactics, just as there are pitfalls to clinging tightly to the “that’s not the way we do it” mindset. In all cases, no matter what technologies or

techniques are available, it will be necessary to exercise intelligent, well informed decision making at all levels but especially by those commanding an operation.

Work in 02DA02.07 should include not only the technological considerations but also operational considerations—how to turn a technically functional tool into an operationally useable, acceptable tool.

1.3 Courses of Action

The goal of this exercise is to recommend a way forward in the neutralization of explosive hazards under ManADO. In general terms, there are three basic directions that could be considered:

- *Refocus elsewhere*: This option suggests that (i) there are no real areas of EHA(N) for DRDC to invest in or (ii) the available time, material resources, funding, and DRDC expertise are simply insufficient to make a useable difference. Under this option, the resources available to ManADO EHA(N) would have more of an impact if they were diverted to another ManADO EHA focus.
- *Dispersed attention (pursue breadth)*: This approach suggests that several areas within ManADO EHA(N) should each receive a relatively low level of funding and activity with the intent of (i) maintaining a technology watch in promising areas, and (ii) maintaining access to the technology development programs of our allies. This is unlikely to yield a functioning capability based solely on our own work, but cooperation with allied programs might provide access to their information and development activities.
- *Tightly focused attention (pursue depth)*: This suggests that all of the ManADO EHA(N) resources be tightly focussed on a single, narrowly defined goal. This necessarily requires that we would reduce our involvement in other areas which might have had promise. As with the wider "breadth" approach, it is also possible that a direct, focussed involvement in one part of an allied program might provide indirect access to the other areas in which we are not actually involved.

2 Analysis

2.1 Definitions and Semantics

2.1.1 Standoff Neutralization

In one context, ‘standoff’ could mean keeping personnel several hundred metres from an explosive hazard while sending a remotely controlled EOD robot into direct contact with the hazard. In another context ‘standoff’ could be interpreted as keeping all personnel and all equipment far from the threat and attacking the threat from a distance using bullets, mortars, lasers, etc. Alternately, a mine/IED roller, pushed ahead of a vehicle, provides a few metres of standoff as compared with detonating a pressure-plate explosive threat with the wheel of a vehicle.

‘Standoff’ may mean different things in different circumstances, all of which may be completely contradictory, but all of which may also be relevant and acceptable in certain circumstances; it is impossible to define a standoff distance which is universally acceptable. Instead, the degree of standoff provided (or required, depending on the context) needs to be described, and this can be applied as appropriate to different scenarios.

Similarly, an EOD operator will generally be attempting to ‘neutralize’ an explosive threat through render-safe techniques which will disable an identifiable device without detonation so that potential for collateral damage and human injury is minimized and viable evidence remains for forensic analyses if called for by operational needs. This also has the benefit of minimizing collateral damage and risk of human injury. In contrast, a military engineer tasked with rapid, explosive breaching of a minefield is neutralizing an explosive hazard—either the whole area or explosive devices within that area—by causing the detonation of detected or undetected devices which may or may not even be present.

Like ‘standoff,’ multiple definitions of ‘neutralization’ exist. According to NATO terminology definitions for ‘neutralization’ [3][4][5]:

- “In mine warfare, a mine is said to be neutralized when it has been rendered, by external means, incapable of firing on passage of a target, although it may remain dangerous to handle.” (Domain: Military operations – Land operations – Military engineering).
- “In countering improvised explosive devices, action intended to render an explosive ordnance either temporarily or permanently ineffective.” (Domain: Military operations – Land operations – Military engineering – Countering improvised explosive devices)

Either of the above NATO definitions allow for a device to be considered neutralized whether detonated, rendered safe, or even temporarily disabled. There is also no requirement that the device be located, detected, or identified prior to neutralization. The broadest interpretations of both standoff and neutralization will therefore be adopted for this discussion, with the understanding that a particular type of neutralization and a particular type and distance of standoff may not be acceptable in all situations. This is not an attempt to redefine what is acceptable for an EOD operation or the roles of the operators, or indeed for any other specific application. Keep in

mind that, as already acknowledged in Section 1.2.4, a change to who is permitted to conduct various neutralization tasks will almost certainly cause a ripple effect in training, doctrine, and so on.

2.1.2 Explosive Hazard

Historically an EH was often thought of as a pressure plate landmine buried on a road, a booby-trap, or a UXO. This was broadened to include IEDs, off-route mines or IEDs, and non-pressure plate devices of many types. One of the common characteristics, however was that all of these threats were stationary.

The VBIED (Vehicle-Borne IED), an explosive-laden vehicle with a human driver, created a class of EH that was both mobile, and included a human as part of the device. The human component created a complication well beyond the requirements for dealing with purely technological EH threats. Aside from the human element, the other complicating aspect of the VBIED is mobility. An incoming rocket, missile or bomb is certainly an explosive hazard, but would not normally have been grouped with mines or IEDs as explosive hazards. It is unclear whether the ManADO definition of EH should include these devices, but it is assumed that this was outside of the original intent.

With the recent surge in availability and capability of unmanned vehicles, especially unmanned air vehicles, there is the very real possibility of an unmanned, remotely controlled airborne platform carrying some kind of explosive device toward a convoy or a base camp. It would be easy to call this moving vehicle an EH but the difference between this unmanned air system (UAS) and an incoming guided missile seems artificial. This question is further complicated by the possibility of a UAV equipped only with cameras and GPS, but which is providing targeting data for a missile or mortar. In effect, this UAS is simply the EH sensor system in the same way that an IR detector is part of the sensor of an off-route mine or IED; the IR sensor on the stationary IED would be considered a legitimate part of the EH, and would be a legitimate target for EH neutralization.

Following the same logical argument, the camera/GPS equipped UAS should also be considered as a legitimate neutralization target but it is unclear whether the ManADO definition of EH should include these devices. The issue of EH-UAS is relatively new and complicated, and will require considerable attention. DRDC Activity outside of ManADO is ramping up to address counter-UAS, and will be addressing all aspects of counter-UAS including technical, legal, operational, etc. As such, ManADO EHA(N) will observe the Land Weapon Systems counter-UAS work but will not include it under 02DA02.07.

Although water-based explosive hazards could be encountered by land-based CAF members, the neutralization of naval mines and unmanned underwater vehicle bearing explosive devices is considered to fall outside of the scope of 02DA02.07.

2.1.3 Pre-detonation

The problem with discussing pre-detonation, or predet, is that these conversations can quickly devolve into an unspoken assumption of RF energy being randomly broadcast in all directions

and in all circumstances, with resulting rejections along the lines of “we don’t do that” or “we can’t do that – rules of engagement” or “we don’t do neutralization unless we can see the threat and can identify what it is.” While this may be true, and doubtless, is particularly necessary in the world of EOD neutralization, it is not, however, universally true.

Pre-detonation or “predet” can be thought of as simply something that causes an EH to function before its designer intended. A mine roller triggers a pressure plate before the host vehicle wheels reach the threat. A “Rhino” hotplate causes an IED’s IR sensor to function before the hot engine or exhaust of the host vehicle does. Even a remotely controlled vehicle at the front of a convoy to fool a human IED operator into acting prematurely, could reasonably be called a predet technique. In principle, none of these are materially different from broadcasting RF energy to prematurely detonate an unseen IED.

2.1.4 Definitions in General

In a more general sense, definitions need to be approached with some care. Narrowly conceived definitions may hinder the consideration of different neutralization concepts. For example, an EOD operation will generally require that the threat device be visible and identified or at least identifiable before neutralization operations commence. Hence, the idea of broadcasting an RF neutralizer to over an area “just in case there is something to detonate” may not be considered acceptable to some. “We don’t do that” may be the response to blindly applying a neutralizer to unseen, unidentified, or simply undetected explosive threats. A mine roller is used “just in case there are unseen, unidentified, or simply undetected explosive threats to be neutralized,” and this is an operation which the CAF explicitly accepts.

2.1.5 Semantics

Semantics will play a part in any discussion, and will be important in nailing down final positions, but getting bogged down in semantics too early can needlessly restrict the range of possibilities being considered. Is a mine roller on the front of a wheeled military vehicle providing protection or is it being used for neutralization? Or is it even a detector; identifying the presence of hitherto undetected EH threats? Such arguments may be intellectually stimulating but for the present purposes are largely pointless. If a device, system, technology, or method accomplishes the NATO definition of “neutralize” (see above), then it will continue to be included in the discussion.

2.1.6 Final Nod to EOD

As noted above, traditional EOD is not being considered under 02DA02.07. Therefore, the need within EOD operations to locate and identify the EH before engaging in neutralization operations will not necessarily apply in all cases being considered here.

2.2 Technologies

2.2.1 High Energy Laser Neutralization

One of the technologies originally included in 02DA02.07 was EH neutralization through the use of HEL. As noted above, HEL neutralization work is being conducted by Valcartier Research Centre under Land Weapon Systems, and will not be pursued under 02DA02.07. The outputs (reports) will be monitored and communication with the HEL team will be kept active to discuss anything ManADO EHA(N) observes or can contribute to help turn a potentially useful technology into an operationally useable neutralization system.

2.2.2 EOD Neutralization

As discussed above, EOD neutralization will not be included in 02DA02.07.

2.2.3 HME Neutralization

Also noted above is that 02DA02.07 will not include work in the area of HME neutralization since this is covered elsewhere (02DA02.11). The activities in 02DA02.07 will be observed, and anything 02DA02.07 can contribute will be offered up.

2.2.4 Mechanized Neutralization

A 1994 CRAD report [6] addressed the problem of low metal content landmines. The main focus was on detection of low metal content mines, but the broader countermine problem was acknowledged. In terms of mechanized neutralization, the report suggested that "CRAD should investigate methods to neutralize individual mines once detected [and] Canada should continue to observe developments and procure as necessary rather than develop systems on its own."

Approximately a decade after the 1994 CRAD report the detection problem was still proving to be extremely difficult to solve. The ILDS (Improved Landmine Detection System) Protection Vehicle was briefly used as a remotely controlled, standoff neutralization system while the CAF was in Afghanistan. As an interim measure, DRDC commissioned a project to maximize the CAF's mechanized countermine and counter-IED neutralization capabilities. This project led to evolutionary improvements to the CAF's in-service rollers and flails, and also identified mechanical tools that could be developed with relatively low effort if there was a perceived need [7]. The net result is that, at the time of writing, the CAF has a standoff neutralization capability in the ROMECS (Remotely Operated Mechanical Explosive Clearance System), a multi-tool remotely controlled vehicle. In effect, however, the standoff provided by ROMECS is similar to the standoff provided by an EOD robot—it keeps personnel at a distance while taking physical resources close-in for inspection and/or neutralization. It is unlikely that DRDC can offer much in the way of dramatic improvements in mechanized neutralization. It is considered unlikely that there will be significant advances in the field of minefield clearing flails or other similar mechanical tools over the period of 02DA02.07, and little reason for 02DA02.07 resources to be expended in this area.

As part of Project L1112 Enhanced Counter-IED, the CAF is fielding lightweight rollers to be used with the WOLF (6x6 Cougar) vehicle. These are considered among the best-performing (most effective against pressure activated fuzes) lightweight rollers available [8]. Aside from providing occasional advice into a capital acquisition or roller employment or effectiveness, there is little DRDC should consider contributing in this area.

Previous work by DRDC informed the Force Mobility Enhancement project to evaluate the effectiveness of the original Mine Clearance Roller System (MCRS) used with the CAF Leopard tanks, to design an enhanced-capability version and to verify that the new design achieved the expected enhanced capability. This new version of the MCRS is currently (September 2015) in the early stages of production. It is unlikely that DRDC can offer any fundamental improvement to the design of heavy rollers any time in the near future.

Other mechanical systems including waterjet soil excavation tools have been tried but found wanting, even when proposed for slow, permissive operations other than war such as humanitarian minefield clearance. The probability of these techniques suddenly developing into something that requires DRDC involvement is considered small.

2.2.5 Explosive Breaching

The 1994 CRAD report [6] also spoke to explosive neutralization, saying that CRAD should "…continue R&D in this area … continue testing … and evaluate breaching system concepts while awaiting the defence policy review."

Explosive neutralization of individual threats is carried out routinely using well established blow-in-place techniques.

Explosive Minefield Breaching as a standoff neutralization of explosive hazards is specific to a small subset of military manoeuvre operations. The CAF used to have the UK Giant Viper for breaching a vehicle path. In the 1980's and 1990's DRDC developed advanced development models of a fuel-air line charge (FALCON) and two distributed high-explosive line charges (THOR and THOR II). The high-explosive models were predicted to have better performance than Giant Viper. Neither was pursued, and while the Giant Viper remains in the Canadian government cataloging system, it is listed as "item is inactive, i.e. no recorded Users." Python, the successor to Giant Viper, and other explosive breachers such as the American MICLIC are available off-the-shelf. If the enhanced capability of the 1990's Canadian high-explosive breacher is brought forward as a required high priority capability, further development would be necessary, which DRDC would be well poised to deliver, with some work being executed in-house and some by industry partner(s). Explosive breaching of vehicle paths through minefields makes sense in a countermine context, but it is difficult to imagine much widespread application to the problem of randomly encountered, individual IEDs. No CAF requirement for man-path (as compared with vehicle-path) explosive breaching has been communicated to the ManADO(N) team.

2.2.6 Kinetic Projectile Neutralization

Kinetic Projectile Neutralization (KPN) is used to describe using a weapon to fire some kind of ammunition to neutralize an EH from a safe distance. Whether the weapon is a rifle operated by a

sniper or a heavy machine gun installed in a remotely operated weapon station, or a turret-mounted 25mm cannon, all involve launching some kind of projectile at the threat device with the intention of creating some kind of reaction. The projectile may be as simple as standard ball ammunition or it may include a variety of energetic components. Attacking the EH with kinetic projectiles may result in anything from a high order detonation to a simple mechanical breakup of the EH. Like any other technique there is also the possibility of leaving the EH unaffected, or worse, more unstable than it was before the attempt.

KPN failure is easy to define when the attacking projectile has no apparent effect on neutralizing the EH, but success can be harder to define. In some cases, only a mechanical breakup of the EH can be acceptable—to minimize collateral damage, perhaps. In other cases, only a high order detonation may be acceptable—due to the highly visible proof of success. In yet other cases, any result from mechanical breakup all the way to a large, smoking hole may be considered a success. An added difficulty is that, according to the NATO definitions of neutralization, an attack which severs an IED's detonator lead wires but which otherwise leaves the IED intact, has technically succeeded in neutralizing the threat, but it will be impossible to verify this from any reasonable standoff distance.

The two main drawbacks of KPN are that (i) the EH has to be visible, and (ii) there is little control over the type of neutralization response; the target may detonate, burn, or simply break apart. On the flip side, an advantage of KPN is that, in an operation which demands speed and can tolerate a high order explosive reaction, the neutralization is achieved in a matter of seconds.

In the past several years the Suffield Centre has conducted five different KPN experiments using in-service weapons to shoot projectiles at exposed EH. In these experiments a variety of soft and hard targets was attacked at different standoff distances using off-the-shelf ammunition. Effectiveness depended on distance, aiming accuracy, and the type of weapon/ammunition, but in general, a weapon/ammunition combination was either completely unsuitable or was very highly effective [9][10][11][12].

Based on the Suffield Centre's data, even with work to develop a new weapon or new ammunition, the effectiveness of KPN would not actually improve measurably. Developing a projectile ammunition capable of avoiding high-order detonation, if even possible, is not considered feasible within the limitations of 02DA02.07.

The use of HEL to attack EH threats from a distance is essentially the same as KPN but without the physical projectile. There is the possibility that HEL neutralization might provide an opportunity to fine tune the type of response—from high order detonation on down—but the need for the EH to be visible remains. As noted, HEL EH neutralization is being dealt with outside of 02DA02.07.

Rather than KPN, the term Standoff Munitions Disruption or SMUD may be a more familiar term to some but the term is inaccurate in that it is not a reliable disruption tool (in the EOD sense of avoiding an energetic reaction), and it is also not just standard munitions that are the target in this discussion. Unfortunately, even using the term SMUD can be problematic. In the authors' experience an audience can be divided more or less into three groups—those who understand and accept SMUD for what it is, those who are unfamiliar with the term, and those who instantly enter a state of apoplexy at the mere use of the word.

Bridging the gap between explosive breaching and kinetic projectile neutralization would be a system such as a missile-delivered, point neutralization device in which there is a projectile, but where the neutralization effect is a function of the explosive charge and not the kinetic energy of the projectile. The arguments for and against such as system are similar to those articulated for explosive breaching and for kinetic projectile neutralization.

2.2.7 Thermal Neutralization

The 1994 CRAD report [6] also discussed thermal neutralization in countermine terms. This can be thought of as covering an EH with something like Thermite. It requires (i) the EH be at least partially exposed, (ii) a delivery mechanism, and (iii) significant time for the burn to be completed. Even in the context of humanitarian demining where time is more-or-less freely available, thermal neutralization was never widely adopted. In the ManADO EHA(N) context, the materials exist but this technique appears to be unlikely to provide any significant advantage to the CAF, even if pursued and perfected [9].

2.2.8 Chemical Neutralization

Similar to thermal neutralization, chemical neutralization assumes injecting some kind of chemical into or onto the EH in order to desensitize or activate the explosive material [6]. Again it requires exposure, delivery, and time, and like thermal neutralization, chemical neutralization was not widely adopted even in humanitarian demining.

2.2.9 Magnetic Signature Duplication

Discussed in the CRAD report [6], magnetic signature duplicators are now in-service with NATO forces worldwide, and are applicable only to a very small subset of the mine fuzes that operate based on the magnetic signature of a vehicle. For the needs of 02DA02.07, there is little to be gained by expending DRDC resources in this area.

2.2.10 Thermosetting Materials

The CRAD report [6] also discussed a technique of pouring or spraying thermosetting materials on/around an EH to isolate the mechanical, pressure-activated fuze. This requires exposure, delivery and time, and again, has not been widely adopted except perhaps in certain EOD operations.

2.2.11 Electric Arc Neutralization

When it was accessed in November 2015, the website for Applied Energetics [10] stated that "Applied Energetics is the sole and exclusive developer of Laser Guided Energy ('LGE™') and Laser Induced Plasma Channel ('LIPC®') technologies. … Through our counter-IED programs, we have amply demonstrated the effectiveness of electric discharge techniques for IED neutralization. Laser Guided Energy is the clear next step in addressing this urgent mission, and offers the capability for IED neutralization at safe standoff distances."

In 2012 Photonics Media stated that "Applied Energetics reported that its revenue decreased more than 60 percent — from $13 million to $5 million — between 2010 and 2011. The bulk of the decline, nearly $7 million, was in revenue for the company's counter-improvised explosive device (counter-IED) program, which slid to $2.2. It attributed the decline to a contract completion in the first half of 2011…'We are not investing company funds or resources to further develop and enhance our LGE (laser-guided energy), LIPC (laser-induced plasma channel), counter-IED and high-voltage technologies and systems,' the company said in a Securities and Exchange Commission (SEC) filing." [15]

In addition, a 2011 article [16] reads in part "Applied Energetics has been pilloried by critics who have cited its missteps, including a shareholder lawsuit and the recent cancellation of a Marine Corps program to use the company's technology to defeat improvised explosive devices, or IEDs. … The Navy, Air Force and a joint-services IED agency bankrolled the company's anti-IED device — to the tune of about $38 million. The Marine Corps took over the program but recently canceled its last, $3 million contract to develop the system. The Marines had the company install its high-voltage IED zapper on a mine-roller system pushed ahead of a truck. Ten of the units, called the Banshee, were delivered to troops in Afghanistan before the Marine Corps pulled the plug."

This concept of electric-arc discharge neutralization *as demonstrated in Banshee* does not seem to have gained much of a following despite the US having spent almost USD40M on it. The authors are unaware of any more recent work in this area, and even if there were interest, it is unlikely that the level of funding/resources that ManADO could provide would stir anyone's attention. Finally, as of late February 2016, the website appliedenergetics.com has vanished. This would appear to be a definitive statement about the immediate future of Banshee and Banshee-like neutralization technologies. Technologies such as the Valcartier Research Centre's ZAPLIGHT (Zone Active Protection Laser Ionization for Guidance of High-intensity Transients), which rely on using a laser to create an ionized channel for electrical discharge are left to the laser community's work, as discussed previously.

2.2.12 Particle Beam Neutralization

A 1993 draft concept paper for mounted breaching operations [17] addressed various neutralization technologies as they applied to the breaching or neutralization of minefields. Along with mechanical (ploughs, rollers, etc.) and explosive (line charges, demolition charges, Bangalore torpedoes, etc.) assets, the road-ahead identified directed energy weapons including lasers, high power microwave, and charged particle beams. As noted, lasers are being addressed in parallel work outside of ManADO EHA(N). High Power Microwave (HPM) is addressed later in this document.

One of the textbooks used at the Fermi National Accelerator Laboratory [18] addresses weaponized or weaponizing charged particle beams only briefly in Chapter 12 where the introduction reads "…In this section we shall discuss two examples of high-energy electron beam propagation … the second topic is the propagation of a self-contained electron beam a long distance through a weakly-ionized gas. This propagation mode is the basis of *recurring proposals for electron beam weapons*" (emphasis added). This phrase implies that the idea of particle beams as weapons is in the same category as light sabres—pretty cool, but still in the realm of science fiction.

At the time of writing of this report, the situation for particle beams appears to be essentially the same as described in the 1994 CRAD report [6]: "Experiments done in the 70s by Ft Belvoir… showed that existing electron beam generators had enough energy to initiate an exposed landmine at a standoff of 1.5 m. In spite of this favourable result follow on work on this method was not pursued at that time. The authors currently do not have any information on the present status of this work or on any work carried out during the 1980s on particle beams, specifically for the neutralization of mines." In the context of 02DA02.07, it is expected that the power requirements for a standoff in the tens or hundreds of metres would make this technique difficult or even impossible.

2.2.13 What Have We Missed?

Is any kind of DE weapon other than laser or HPM a reality that will have any relevance to ManADO EHA(N)? Particle beam weapons, for example, are the sexy stuff of science fiction, and one might reasonably assume that work on this technology would generate considerable attention in the public press. In fact, the only place that this kind of thing seemed to appear in multiple internet searches was in the domain of conspiracy theorists. Reputable, or even reputable-looking sites were largely silent on the topic:

- Despite the promising title of a June 2007 slide deck entitled "A Vision For Directed Energy and Electric Weapons in the Current and Future Navy," [19], the material focused exclusively on lasers.
- In December 2011 naval-technology.com [20] opened an article with the statement "Naval Technology profiles the technology likely to make the biggest waves in 2012, including concept weapons, such as the electromagnetic railgun and free electron laser to directed energy and micro satellites." Despite this opening, the article looked only at lasers and rail guns and included a passing, speculative, and unsubstantiated statement that implied that the Chinese military was working on projects that "… include coil guns, high power microwaves and particle beam weapons."
- The title of the 2013 "Selected Directed Energy Research and Development for U.S. Air Force Aircraft Applications: A Workshop Summary" [21] is quite specific, and so it may be unfair to read too much into what is not included in this document. First, it is US Air Force centric, and is therefore unlikely to be too concerned with the CIED issues that ManADO must face. Secondly, the title is quite clear about dealing with only "selected" DE applications, and not DE weapons generally. Notwithstanding these limitations, it is interesting to note that the main focus of the DE applications is on various forms of lasers with a relatively small emphasis on HPM technologies, and nothing whatsoever on any other type of DE weapon. That other DE weapon types are not included suggests that they are not being seriously worked on, or that they are not sufficiently mature to be of immediate importance.

The total absence of any credible information about US interest in particle beam weapons may suggest that either there is no significant US work being done in this area that ManADO needs to be concerned with, or that the work is so highly classified that even the existence of these programs is classified. As noted in the July 2015 issue of the online National Defense Magazine's "Directed Energy Weapons: Will They Ever Be Ready?" [22], "details are scarce at the

unclassified level." In any case, no research programs were uncovered in this area which could plausibly be linked to ManADO.

2.2.14 Radio Frequency Directed Energy Weapon Neutralization

Traditionally referred to as High Power Microwaves (HPM), within the context of this study, the term Radio Frequency Directed Energy Weapons (RF DEW) will be used to refer to a class of weapons where electromagnetic radiation in the range of 3 Hz to 3000 GHz is used to deliver energy to a target for the purpose of damaging or disrupting the target. This does not include particle beams other than what could be considered as a photon beam within the energy range of 1.2407e-14 to 1.2407e-2 electron-volts (photon energy equals Planck's constant multiplied by photon frequency). Also excluded from the RF DEW category are electro-static discharge devices (ESD) or devices that use electrical current to destroy or disrupt a target. This study will also not consider the use of RF energy to disrupt communications or to directly affect the ability of a radio receiver to receive a signal via the receiver's antenna. The use of RF energy in this manner is commonly referred to as "front-door" attack and is well covered in other sources.

This section will focus on the "back-door" attack vector and includes disrupting sensors and electro-mechanical devices that may be contained within the target.

On 8 Jul 1962, the United States executed Starfish Prime which was the detonation of 1.4 megaton high-altitude thermonuclear warhead. The pulse of microwave energy effected electronic systems more than 1,300 km from the detonation [23] and demonstrated the potential of using RF DEW as a weapon. The ability to disable computers, blind radars and stop vehicles without collateral damage is very seductive technology and has been the attention of a significant level of military research.

Historic military interest and research into RF DEW is well covered by the 2001 book, "High-Power Microwave Sources and Technologies", created under the FY94 High-Power Microwave (HPM) Multidisciplinary Research Program of the University Research Initiative (MURI). There have been numerous attempts to use RF DEW as a fielded military weapon with limited success. A notable example is MAXPOWER, a US Air Force developed higher-average-power, single-frequency, RF DEW system used to neutralize IEDs which was deployed for one year to theater in 2012 for evaluation [24]. Another source [23] suggests that JIEDDO ceased funding MAXPOWER in 2011. A possible reason for the cessation of funding is that countering improvised explosive devices is not an Air Force mission [21].

"This is clearly an area for [science and technology investments], but while in the past we could pursue five to six applications, now it will be one or two. HPM clearly has potential. There are others [like Russia in particular] that have done more in these areas than we have. Clearly this is an area for continuing efforts. The Air Force will be part of that." (From a July 2012 interview with now retired USAF Chief of Staff Gen. Norton Schwartz as reported in Aerospace Daily & Defense Report.)

In "Presentation on Directed Energy at the Crossroads" Ellis [25] makes the recommendation that the US should increase its investment into radio frequency technologies in the direct energy weapons portfolio by 5 to 10 times based on successful developments but unsuccessful fielding of system. Ellis suggests that the US should have the intent to capitalize on success. A candid and

objective assessment of directed-energy weapons is provided in [26] and includes recommendations for how the US DOD should proceed, while being mindful of past failed promises.

Besides the focus on using RF DEW as a weapon, some consideration should be given to defending against RF DEW attack. Both Gen. Norton Schwartz (ret) and Ellis [25] suggest that several non-American militaries are making a heavy investment into RF DEW. Military standards for radiated EM susceptibility exist and should be applied to critical military systems. Given that it is difficult to design, build and test a high power RF DEW weapon implies that these systems will only be used by an adversary that has a strong and well-funded military-industry capability. However, there is a potential for a less capable adversary to use lower power RF DEW devices that have to potential to affect commercial or non-hardened systems that are used by the Canadian military. Critical CAF systems should be constantly evaluated to ensure that vulnerabilities do not begin appear if heavy foreign investment into RF DEW produces deployable systems.

DRDC has produced several studies on the military use of RF DEW but does not currently maintain RF DEW as an active research area (meeting held at DRDC Ottawa 8 July 2015). The most recent contribution was to the CRTI project titled "Flash Render-safe of Improvised Explosive Devices (FRIED) System" where a variety of laboratory-based, fast-pulse sources were used to investigate their potential to safely disable simulated IED trigger circuitry [27]. There has been successful deployment of RF DEW systems by Canada's allies in the C-IED role, albeit to address a narrow, but high mortality attack vector. On behalf of DLR Project L1112, the Suffield Centre procured one of these systems in 2010 to determine if the technology should be added to the CAF expedient route opening capability (EROC).

2.3 Can We Raise a Pulse?

The resources available to 02DA02.07 are limited, and it is necessary to be realistic about what can be accomplished in EH neutralization for ManADO with that level of resources. Can DRDC mount a new activity that will bear fruit? Can DRDC partner with industry, academia or allied nations?

A highly critical piece appeared in the 12 September 2012 edition of nature.com [23] which was headlined with the provocative "Microwave Weapons: Wasted Energy / Despite 50 years of research on high-power microwaves, the us[sic] military has yet to produce a usable weapon." This article derided the HPM Active Denial System saying "… But that hasn't changed a fundamental reality for the Pentagon's only acknowledged, fully developed high-power microwave (HPM) weapon: no one seems to want it …." On the only real ManADO-related topic, the author wrote "The Air Force Research Laboratory developed an HPM system called MAXPOWER to detonate roadside bombs remotely, but it was the size of an articulated lorry—too unwieldy to be deployed in Afghanistan. The Joint Improvised Explosive Device Defeat Organization, the defence department's bomb-fighting agency, declined to discuss the system, citing classification issues. But it did say that, as of 2011, it was not funding MAXPOWER." This negative view is actually echoed in the opening paragraphs of the militarytimes.com article [21]: "In 2009, the National Defense University recommended that 'The DEW S&T community must work to overcome the perception of its unproductive legacy.'" Whether the nature.com article is correct, fair, or even fully informed (due to the possibility of information being classified and

therefore unavailable), it is probably fair to conclude from these sources that despite decades of work on DEW, only lasers have shown any real progress in being fielded. HPM development seems to be lagging far behind with little apparent chance of becoming a reality any time soon, and other DE weapon systems are all but non-existent. With the possibility of classified information being unavailable, it is quite possible that certain technologies may have been successfully deployed, particularly against specific classes of IED.

The December 2007 report "Defense Science Board Task Force on Directed Energy Weapons" [28] contains the statement "The task force believes that the range of potential applications is sufficient to warrant significantly increased attention to the scope and direction of efforts to assess, develop, and field appropriate laser, microwave, and millimeter wave weapons. But until the operational demand generates priorities, there is little reason to expect rapid progress in fielding such systems." It also cautions that "… current work is by too few people, with inadequate budgets, insufficient technical collection capabilities, and fragmented connection to the directions and achievements of U.S.-directed energy programs." Setting aside the discussions relating to lasers, excerpts from the Finding and Recommendations include:

- Directed energy employment needs to be clearly described in concepts of operation as the basis for decisions relating to technical, employment, policy planning and priorities.
- For each capability gap where directed energy is a proposed solution, the directed energy solution should be assessed against available kinetic or other approaches to filling the gap.
- Research and development funding should be focused on those directed energy solutions where rigorous analyses identify directed energy as the most promising solution to a priority need and concentrated for progress rather than spread over a large number of projects.
- S&T funding for HPM applications should be concentrated on a defined set of applications meeting high priority needs.

It is interesting to look at the above findings and apply them to ManADO EHA(N). To the best of the knowledge of the authors, there is no known, pre-existing "…concept of operation as the basis for decisions relating to technical, employment, policy planning and priorities," and there is no "defined set of applications meeting high priority needs." Further, the authors are not aware of any justifications or DE weapon development against available kinetic or other approaches.

The 2015 nationaldefensemagazine.org article [22] on directed energy weapons included the following observations:

- "There are still many unanswered questions, analysts agreed. That is why it will be another 10 years before the Pentagon actually starts to integrate the systems into the platforms…"
- "For fiscal year 2016, some of the Navy's directed energy research efforts, for example, are included in their budget line item 73, "Directed Energy and Electric Weapon Systems." About $9.5 million, out of the $67.3 million, was requested for solid-state lasers. There is an additional $26.9 million in a different section of the budget, under "Power Projection Applied Research." Other directed energy weapons funding is kept secret under the military's classified budget…."

Similarly, a February 2012 militaryaerospace.com article [29] reported that the 2013 US DoD budget for lasers and DE weapons was being cut by a third from the previous year but was still at $244M for 2014.

In the April 2015 "Directed-Energy Weapons: Promise and Prospects," [26] the author Jason Ellis states "Few weapons have held as much promise – and have consistently failed to live up to that promise – as directed-energy weapons. … In the 1990s and early 2000s, DOD spent billions in aggregate on high-energy lasers such as the Airborne Laser and Space-Based Laser, both of which ultimately failed to reach maturity. … After several decades of investment, billions of dollars and several canceled programs, DOD has yet to successfully field an operational directed-energy weapon system." This appears to echo, and to confirm the complaints in the 2012 nature.com article [23]. Ellis goes on however, to say that over the past few years some of the "… directed-energy technologies have steadily and quietly matured … to the point where an operationally relevant payload can be carried on a cruise missile." Despite this, he acknowledges that only "approximately 20 percent of national security specialists polled in February 2014 anticipate that DE weapon technologies will be fully integrated into relevant, stable military systems within the next six to 10 years, while an additional 30 percent agree this will happen within 20 years. But fully half anticipate that this will not materialize for at least 20 years or remain skeptical that DE will ever achieve this objective." Keeping in mind that this is a 2015 document, it is not unreasonable to wonder if DE technologies (even including HPM) which are relevant to ManADO are unlikely to surface in any significant way within the lifespan of the ManADO project, even if DRDC manages to find an eager partner in the US system.

3 Recommendation

3.1 Most Promising Technology Area

Of the technologies discussed in the previous section, the only area which looks likely to be a candidate for DRDC involvement in ManADO EHA(N) is RF DEW. The other areas are either (i) mature, (ii) being covered elsewhere (lasers and HME neutralization) or (iii) so undeveloped that there is no reason to believe that sufficient progress can be made within the ManADO timeframe.

3.2 The Three Possible Avenues

Referring back to Section 1.3, there are three general directions which could be pursued under 02DA02.07.

3.2.1 Refocus Elsewhere

The option of refocusing the neutralization resources elsewhere suggests that there is no neutralization problem to be solved or that there is no reasonable probability of achieving anything useful in this area.

The stakeholder consultations discussed in Section 1.2 very clearly showed that standoff neutralization of explosive hazards is still an unsatisfied requirement. This leaves the possibility that there is no real chance of satisfying that requirement.

With the limited resources available under 02DA02.07, it would be unreasonably optimistic to expect that 02DA02.07 *by itself* could solve the standoff neutralization problem. Fortunately, DRDC does not have to stand by itself on this. Our allies have been working in this area for some time, and there appears to be reason to believe that a DRDC contribution would be well received and would allow us access to some of what our partners have been developing as solutions.

The refocus elsewhere course of action is therefore not recommended.

3.2.2 Breadth

As noted, 02DA02.07 has very limited resources, and it would be unreasonable to expect much in the way of solutions by spreading the resources thinly across multiple areas. This course of action is also not recommended.

3.2.3 Depth

Given the large investment into RF DEW that has been made and is continuing to be made by Canada's allies, what possible contribution could Canada make to advance RF DEW? Canada does not have the financial resources to match or compete with allied efforts. Nor has Canada's

previous investment into HPM targeted research produced facilities or capabilities that could make a significant difference to our allies' efforts. However, Canada could benefit by accessing the results of our allies' effort in order to advise DND/CAF on the tactical utility of using RF DEW to defeat battlefield explosive devices. Given that defeating explosive threats within the battlespace will remain a component of the Shield doctrine, DRDC should take advantage of the efforts of our allies in order to properly advise DND/CAF concerning the potential (or lack thereof) of using RF DEW.

3.3 Recommended Course of Action

It is recommended that, with a modest investment under 02DA02.07, DRDC pursue the following activities to access the knowledge base of our allies on Explosive Hazard Avoidance (Neutralization):

- With the CAF and our allies, gather evidence to support or reject the military utility of RF DEW for the purposes of EHA(N) (Guide doctrine, create concept of operations, provide training needs analysis, etc). The intent is to provide advice, via a document, to the Canadian Army Land Warfare Centre to impact C-IED preparedness. This would include S&T analysis of any vulnerability that may exist within the CAF capability that could be realistically addressed by RF DEW in the mounted C-IED role.
- Review readiness of any technological implementation of the physics to be available for procurement by the CAF in the ManADO report "Improve Neutralization of Explosive Hazards for CLS 99—Evidence based report on improved neutralization capability to inform Project CLS 99 SOR" which is due by 31 March 2019. Specific focus will be given to classified information that is released to Canada from our allies.
- Foster a relationship with Canadian OGD and industrial partners to enable the use of their high power RF facilities if required for testing the defeat of explosive hazard devices. There does not seem to be a requirement for DRDC to build an extensive RF DEW capability, if the CAF is able to access the capability from other government departments, industry, or academia. The relationships would only be required if RF DEW became part of the CAF's C-IED preparedness.
- Maintain a limited capability (expertise and facility) in lower power RF to evaluate the susceptibility of various commercial components that are used in the construction of explosive hazards. This is not a specific C-IED capability, but would enable DRDC to provide rapid RF DEW answers to the CAF if requested. For example, the susceptibility of a specific unmanned air system or a specific device trigger to RF DEW attack; both in the defensive and offensive role.

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List of Symbols/Abbreviations/Acronyms/Initialisms

CADTC	Canadian Army Doctrine and Training Centre
CAF	Canadian Armed Forces
CALWC	Canadian Army Land Warfare Center
CIED	Counter-Improvised Explosive Device
COA	Course(s) of Action
COTS	Commercial Off The Shelf
CRAD	Chief Research and Development
DE / DEW	Directed Energy / Directed Energy Weapon(s)
DLR	Director/Directorate of Land Requirements
DND	Department of National Defence
DOD / DoD	Department of Defence
DRDC	Defence Research and Development Canada
DSTAR	Director/Directorate Science and Technology Army
DSTKIM	Director Science and Technology Knowledge and Information Management
EHA(N)	Explosive Hazard Avoidance (Neutralization)
EOD	Explosive Ordnance Disposal
EROC	Expedient Route Opening and Clearance
GHz	Gigharetz
GPS	Global Positioning System
HEL	High Energy Laser
HME	Homemade Explosive
HPM	High Power Microwave
IED	Improvised Explosive Device
IR	Infrared
JCET TF	Joint Counter Explosive Threat Task Force
KPN	Kinetic Projectile Neutralization
ManADO	Manoeuvre through Adaptive Dispersed Operations
MCRS	Mine Clearance Roller System
MOTS	Military Off The Shelf
NATO	North Atlantic Treaty Organization

OGD	Other Government Department(s)
PD	Project Director
PPE	Personal Protective Equipment
R&D	Research & Development
ROE	Rules of Engagement
ROMECS	Remotely Operated Mechanical Explosive Clearance System
SMUD	Surface Munitions Disruption
SOR	Statement of Requirements
TTP	Tactics, Techniques and Procedures
UAS	Unmanned/Uninhabited Air System
UXO	Unexploded Ordnance
VBIED	Vehicle-Borne Improvised Explosive Device
WBE	Work Breakdown Element
ZAPLIGHT	Zone Active Protection Laser Ionization for Guidance of High-intensity Transients

DOCUMENT CONTROL DATA

(Security markings for the title, abstract and indexing annotation must be entered when the document is Classified or Designated)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Centre sponsoring a contractor's report, or tasking agency, are entered in Section 8.)

DRDC – Suffield Research Centre
Defence Research and Development Canada
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Canada

2a. SECURITY MARKING (Overall security marking of the document including special supplemental markings if applicable.)

UNCLASSIFIED

2b. CONTROLLED GOODS

(NON-CONTROLLED GOODS)
DMC A
REVIEW: GCEC DECEMBER 2013

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.)

Manoeuvre through Adaptive Dispersed Operations (ManADO) Explosive Hazard Avoidance (EHA) Improved Neutralization : 02DA02.07 Implementation Plan

4. AUTHORS (last name, followed by initials – ranks, titles, etc., not to be used)

Coley, G.; Russell, K.

5. DATE OF PUBLICATION (Month and year of publication of document.)

May 2016

6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)

38

6b. NO. OF REFS (Total cited in document.)

29

7. DESCRIPTIVE NOTES (The category of the 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.)

Reference Document

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

DRDC – Suffield Research Centre
Defence Research and Development Canada
P.O. Box 4000, Station Main
Medicine Hat, Alberta T1A 8K6
Canada

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.)

9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)

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.)

DRDC-RDDC-2016-D039

10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

Unlimited

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

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The "Improved Neutralization" activity under ManADO Explosive Hazard Avoidance 02DA02.07 examines ways to enhance the Canadian Armed Forces Counter-IED system by addressing explosive hazard neutralization with a path towards exploitation (impact) while seeking to avoid duplication of efforts through systems available from our allies, or which are being addressed by another DRDC activity.

The explosive hazard neutralization capabilities of High Energy Lasers are being addressed under the Land Weapon Systems project by DRDC – Valcartier Research Centre. A complementary effort is herein proposed which will access the knowledge base of our allies through a modest investment in explosive hazard neutralization using Radio Frequency Directed Energy Weapons (RF DEW).

Dans le cadre de l'activité "d'amélioration de la neutralisation" du projet Manœuvre through Adaptive Dispersed Operations (ManADO) sur l'évitement des risques d'explosion 02DA02.07, on examine différentes façons d'améliorer le système utilisé par les Forces armées canadiennes dans la lutte contre les engins explosifs improvisés (EEI). On aborde la question de la neutralisation des risques d'explosion dans une perspective d'exploitation (incidence) tout en cherchant à éviter les dédoublements d'efforts au moyen de systèmes disponibles chez nos alliés ou encore à l'étude dans le cadre d'une autre activité de RDDC.

La capacité de neutralisation des risques d'explosion par les lasers à haute énergie est abordée dans le cadre des projets sur les systèmes d'armes terrestres de RDDC – Centre de recherches de Valcartier. Un effort supplémentaire est suggéré, ceci afin de permettre l'accès à la base de connaissances de nos alliés grâce à un modeste investissement dans la neutralisation des risques d'explosion au moyen d'armes à énergie dirigée par radiofréquence (AED RF).

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Improvised Explosive Device; IED; ManADO; Manoeuvre through Adaptive Dispersed Operations; Explosive Hazard Avoidance