GICHD

IMPROVISED EXPLOSIVE DEVICE CLEARANCE GOOD PRACTICE GUIDE

2021 EDITION

The GICHD works towards reducing risk to communities caused by explosive ordnance, with a focus on landmines, cluster munitions and ammunition stockpiles.

We help national authorities, international and regional organisations, NGOs and commercial operators to develop and professionalise mine action and ammunition management. The GICHD supports around 40 affected states and territories every year.

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GENEVA INTERNATIONAL CENTRE FOR HUMANITARIAN DEMINING
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INTRODUCTION

An improvised explosive device (IED) is "a device placed or fabricated in an improvised manner incorporating explosive material, destructive, lethal, noxious, incendiary, pyrotechnic materials or chemicals designed to destroy, disfigure, distract or harass. They may incorporate military stores but are normally devised from non-military components."[1]

> **NOTE. When IEDs meet the definition of anti-personnel (AP) mines, this must be recorded and reported, as they are also subject to the Anti-Personnel Mine Ban Convention (APMBC).**

Over the last decade a clear trend has been witnessed in the increased use of IEDs by armed groups. This increase has been simultaneous to a worldwide decline in the production, storage and use of commercially manufactured anti-personnel and anti-vehicle mines. These two factors working together have magnified the impact that IEDs as a category of explosive ordnance (EO) has on post-conflict settings. In many post-conflict environments, such as Afghanistan or Iraq, IEDs now cause more civilian casualties than commercially manufactured landmines.[2]

Enduring post-conflict IED contamination creates an environment of sustained insecurity and hinders recovery. The use of IEDs against civilians affects the entire spectrum of their human rights, including the right to life, physical security, education and health. Moreover, the socio-economic impact on goals for sustainable development can be significant given that IEDs impede commerce, contribute to internal displacement and refugee flows, obstruct humanitarian responses and civil society activity, and the practice of good governance and reconstruction. Reducing the impact of IEDs involves close cooperation and coordination between the diplomatic, rule of law, economic and information levers of power to restrict or undermine their use, protect the population, enhance their security freedoms, and restore confidence. Mine action (MA) therefore plays a significant part in facilitating the recovery of communities experiencing IED contamination in the wake of conflict.

The GICHD has developed this IED Clearance Good Practice Guide with the aim of sharing information across the MA sector to assist in safe, effective and efficient IED search and disposal activities as part of a broader MA IED clearance process. The guide provides technical content related to specific techniques and procedures but is not intended to replace training or technical publications supplied by equipment providers.

1 IMAS 04.10 February 2019. Glossary of mine action terms, definitions and abbreviations.

2 In Afghanistan, mines of an improvised nature were responsible for more than 17 times the casualties as conventionally manufactured mines in 2019 (62 antipersonnel mines; 21 antivehicle mine; 1,093 improvised mines). http://www.the-monitor.org/en-gb/reports/2020/afghanistan/casualties.aspx In Iraq during 2019, improvised mines cause almost 6 times the casualties of the conventionally manufactured mines, where a large number of mines are of unknown nature (of 242 casualties from mines in 2020, 28 were caused by antipersonnel mines; 161 by improvised mines; and 53 as a result of unspecified mines). http://www.the-monitor.org/en-gb/reports/2020/iraq/casualties.aspx

A single MA worksite contaminated with IEDs can encompass multiple different types of ‘space’; from buildings and other man-made structures, to open areas, roads and confined spaces. Secondary hazards (such as oil and gas pipelines, fuel stations, chemical containers, human waste and electricity lines) can also contaminate these spaces, making survey and clearance challenging tasks. IEDs can be laid in defined patterns, such as those associated with conventional minefields, or in a more focused manner to deny specific areas, protect supply routes, degrade clearance operations or instil fear within the local community. The technical ‘threat’ of IEDs may also vary from ‘simple’ to ‘complex’ within a relatively small geographical area (complexity depends on the capability of an armed group and the availability of material), or it can be relatively consistent over a much larger geographical area, such as improvised minefields designed to slow the advance of security forces during a conflict.

This guide provides tools to mitigate risk and exploit opportunities in order to maximise efficiency during MA operations where IED clearance is being conducted. With such improvisation in design and complexity comes a requirement to employ techniques and procedures which provide confidence that “all reasonable effort” has been achieved and that the specified clearance parameters will and ultimately have been met. Although not a quality management (QM) guide, this publication provides a link to help explain “all reasonable effort” in relation to IED clearance.

This guide is intended to be used to inform the development of National Mine Action Standards (NMAS) and organisational level Standard Operating Procedures (SOPs), including staff training and policy related to IEDs. Critically, due to the ‘improvised’ nature of IEDs, the activities associated with a clearance process must also incorporate effective threat assessment to form part of a wider platform from which nationally led responses can be established. This is not just a threat assessment of the device itself, but also the potential threat surrounding the team task site. Nor is threat assessment bound to the tactical level – it must also be considered at the operational and national levels, such as determining the security environment in which MA operates, and if national support mechanisms are in place to sustain the activities. Based on information collected and analysed by MA organisations, the ‘threat assessment’ provides confidence in decision-making at all levels.

Image 1. Mine action operator using optics to enhance visual search

SCOPE

The GICHD IED Clearance Good Practice Guide is a technical publication intended for use by MA staff that are suitably trained and qualified in IED search and / or disposal. The intention is to help 'operationalise' and 'institutionalise' IED clearance as part of the MA response.

The guide complies with International Mine Action Standards (IMAS), which provide the framework for response to all explosive ordnance contamination, under the conditions of humanitarian principles. It is intended for use by MA organisations, national authorities, operational implementers and training providers. It may be used by such staff as a source of reference in the delivery of training, but it is not intended as a training manual in itself.

This guide complements the IMAS released in early 2019 for IED Disposal (IMAS 09.31), Building Clearance (IMAS 09.13) and Risk Management in Mine Action (IMAS 07.14). It acknowledges that post-conflict IED contamination occurs in urban, semi-urban and rural locations. It seeks to communicate sectorial good practice as part of an IED clearance process of interlinked activities including operational planning, survey, search and disposal in order to 'clear' IED contamination. It concentrates on providing good practice guidance on the latter two of these activities: IED search and IED disposal.

DISCLAIMER. This publication makes reference to non-technical and technical survey and complements the associated IMAS for these activities. It DOES NOT contain technical guidance on the use of demining machines or animal detection systems as part of an IED clearance process, or provide explicit detail on MA 'systems' to release IED contaminated areas. The user should therefore refer to IMAS 07.11 Land Release and the complementary GICHD urban approach model.

WARNING. This guide is NOT intended for use outside of a humanitarian mine action context.

Image 2. Mine action IEDD operator checking both ends of a tripwire

GUIDANCE ON USING THIS PUBLICATION

CHAPTER 1 – INTRODUCTION TO IEDs IN MINE ACTION

This chapter provides a general description of the following considerations: IED clearance in MA; high-level IED tactics; and the use of threat assessment to provide confidence in decision-making.

> **RECOMMENDATION. This section is intended to be read by all staff involved in the management of IED clearance operations.**

CHAPTER 2 – IED SEARCH

This chapter provides guidance on IED search activities as part of an MA IED clearance process. It explains the principles described in IMAS 09.13 for Building Clearance, and provides detailed guidance on the following: search-related training, planning and information gathering; threat assessment; collective and individual techniques and procedures (including the use of tools and aids) to detect and locate IEDs in both urban and rural environments.

> **RECOMMENDATION. This section should be read by all staff involved in the management of search activities related to the clearance of IEDs.**

CHAPTER 3 – IED DISPOSAL

This chapter provides guidance on IED disposal (IEDD) as an activity within an MA clearance process. It explains the following: IEDD principles, mandatory actions and conventions as described in IMAS 09.31 on IEDD; detailed IED tactics of armed groups; IEDD planning and task conduct; MA IEDD operator techniques and procedures that are internationally recognised as 'good practice'.

> **RECOMMENDATION. This section should be read by all staff involved in the management of disposal activities related to the clearance of IED contamination.**

CHAPTER 4 – IED INDICATORS AND GROUND SIGN AWARENESS HANDBOOK

This chapter provides guidance on the use of indicators and signs to assist in the identification of IEDs and other EO during survey and clearance. It should also inform explosive ordnance risk education practitioners in the development of methodologies, approaches and tools that are specific to environments contaminated with IEDs and other EO. Chapter 4 explains IED indicators, categories of signs, types of signs and methods for their interpretation. It includes 3 scenarios.

> **RECOMMENDATION. This section should be read by all staff involved in the management of disposal activities related to survey and the clearance of IED contamination, as well as by explosive ordnance risk education practitioners.**

CHAPTER 1
INTRODUCTION TO IEDs IN MINE ACTION

1. GENERAL CONSIDERATIONS FOR IED CLEARANCE

Image 3. Location of a detonator lead by a mine action IEDD operator

IED search and disposal operations have traditionally been activities conducted by security forces during armed conflict. MA organisations must carefully consider the security envelope in which they operate at the cessation of hostilities, to maintain the humanitarian principle of neutrality. If the security environment is not understood, then MA staff could become the target of state / non-state armed groups.

While it is recognised that MA organisations may be present in places where there is a risk of attack from a NSAG, the intended target has passed (surveillance is highly unlikely) and the IED becomes an obstacle to development and humanitarian goals. Only when there is a combination of an adequately secure environment (within which it is possible to operate in accordance with established humanitarian principles), and a type of IED for which the organisation has the necessary skills, equipment and procedures to render safe, is it appropriate to proceed. Decisions about when it is appropriate for MA organisations to engage with IEDs, and about what types of IED they are equipped and competent to address, relate to the MA operating envelope described above. This is wholly dependent upon threat assessment.

MA IED clearance organisations should be acutely aware of the previous actions of other operators and agencies such as security forces, and how these may have been observed and targeted during the conflict. For example, if security forces were regularly conducting manual actions such as moving IED components by hand, or manually cutting explosive or electrical links, these patterns may have provided an opportunity for them to be targeted.

WARNING. If at any stage an MA organisation believes that it is being deliberately targeted, operations should immediately cease until it can be confirmed it is no longer under direct threat.

COMMUNITY ACCEPTANCE

IEDs are frequently used in asymmetric conflicts involving various armed groups. These conflicts tend to be cyclic and enforcing international treaties can be problematic. Establishing and maintaining community consent is therefore critical to avoid breaches of neutrality. It may not be immediately evident whether an armed group still maintains an active interest in IEDs that were placed during the conflict, especially when fighting continues in neighbouring areas. The community is likely to be the best source of indicators on the presence of suitable conditions.

WARNING. If these conditions are not achieved, then the risk of an MA organisation being deliberately targeted increases and this guide cannot be effectively or safely applied.

MA organisations operating in an IED-affected, asymmetric conflict space, should consider developing and implementing community liaison plans that identify potential changes in the humanitarian space. These should cut across functional areas from strategic to tactical, and involve programme, operational, risk education and survey staff.

1.1. TECHNICAL OVERVIEW OF AN IED

There are five component parts common to most modern IEDs:

- **Main charge**. This contains the explosives (low or high) intended to function and deliver a specific effect. The explosives may be home made, military or commercial. High explosives will detonate whether confined or unconfined, whereas low explosives will burn when unconfined and produce a higher-pressure event if suitably confined. Armed groups will often try to configure a main charge to a desired effect, which falls into two categories: a directional blast effect or an omnidirectional blast effect. A directional blast effect is used specifically to focus the power of the explosive and/or fragmentation in a particular direction, whilst an omnidirectional blast effect is used when a radial effect is desirable.

- **Initiator**. This is the component designed to initiate the main charge. High explosives require a detonator, whereas low explosives can be initiated by a heat source such as the bridge wire from a light bulb. The initiator can be home made, commercially or military manufactured or it can be converted; for example, a plain detonator can be converted to an electrical one.

- **Firing switch**. This component passes energy (power) to the initiator to complete initiation. This could be kinetic energy from a cocked striker, heat from a burning fuse or electrical energy from a battery.

- **Power source**. This stores the energy (power) that is released through the method of initiation and then transferred to the initiator. Frequently, this will be a battery (electrical) but could be chemical (heat) in a safety fuse, or potential energy (kinetic) in a compressed spring.

- **Container**. The means by which all or some of the other IED components are encased. It may include the object that holds the main charge or the packaging that surrounds the battery. It may camouflage the device and / or generate fragmentation including directional effects.

Some IEDs may also include enhancements such as a safe-to-arm switch that increases safety for the person that emplaces the device. Safe-to-arm switches include timers (mechanical and electronic), twisted electrical leads, command wire and radio control receivers. Safe-to-arm switches should be considered during the planning of render safe procedures (RSPs).

REMEMBER. Like all explosive ordnance, an IED contains an explosive train, which is a succession of initiating and igniting elements arranged in such a way as to cause a charge to function. The normal configuration is: initiator > booster charge (if required) > main charge. A thorough understanding of the explosive train used in an IED can inform an effective RSP, thereby minimising risk to the MA IEDD operator.

1.2. IED CATEGORISATION

There are three main categories of IED associated with MA IED clearance: time, command and victim operated (VO). There are an additional three categories that are worth noting, for reporting purposes: combination / multi switch, hoax and false. Details are as follows:

- **Time**. This is an IED designed to function at a predetermined moment in time. It could be a short delay for an improvised hand-thrown grenade or long delay targeting a high-profile event.
- **Command**. This is an IED that remains under the control of an armed actor and is activated by them completing a specific action. Often, this means that the device can be activated 'at the optimum moment'. It may be physically linked (e.g. command wire, command pull) or non-physically linked (e.g. a radio-controlled device).
- **Victim operated**. This is an IED that functions through an action made by the victim, normally either through contact (e.g. a pressure plate or tripwire) or influence (e.g. passive infrared (PIR) sensor). Victim operated IEDs (VOIED) can cause a significant number of unintended casualties as they can remain viable for a long period of time after the conflict has ended. This category of device is the one most likely to be encountered in significant numbers during MA operations. **It should be noted that a VOIED may also fall under the definition of an AP mine.**
- **Combination / multi switch**. This type of IED incorporates multiple types of firing switches (e.g. a victim operated IED armed by a radio control that enables specific targeting and mitigates against jamming). A single IED can also have multiple switches of the same type (e.g. two or more different pressure plates or multiple crush wires).
- **Hoax**. These are designed to resemble a viable IED in order to achieve a desired effect. Normally they are physical (i.e. an actual object) but can also be non physical and simply rely on fear (e.g. a coded warning for a prominent event). MA organisations may encounter physical hoax devices during survey and clearance operations.
- **False**. Not all suspect items turn out to be viable devices. Searchers / deminers will regularly identify wires and other objects that resemble components of IEDs but turn out to be innocuous after more detailed investigation by an MA IEDD operator.

2. IED THREAT ASSESSMENT

Image 4. A mine action IEDD operator using a window to observe the inside of a building

This section aims to assist MA organisations in the development of national threat analysis and operational threat assessment in accordance with Annex C of IMAS 07.14 Risk Management in Mine Action.

Both national threat analysis and operational threat assessment provide MA organisations with processes to systematically and consistently analyse IED threats. The intention is that this consistency adds confidence to decision-making associated with the IED threat. In IMAS, threat and risk are closely related, with threat being a risk that includes malicious human intent that will influence its nature and severity. This is a distinction made in multiple sectors that are involved in areas such as cyber and physical security.

REMEMBER. These processes are part of broader MA risk management systems that also include non-explosive risks.

WHAT IS NATIONAL THREAT ANALYSIS?

National threat analysis considers the macro situation with respect to how IED contamination affects MA programming. MA organisations operating in states that suffer from cyclic conflict, often involving non-state armed groups, can also use national threat analysis to make an assessment of the security situation. The GICHD's Guide to Mine Action outlines five phases in MA programming:

1. Conflict
2. Immediate post-conflict stabilisation
3. Priority reconstruction
4. Assisted development
5. Development

National threat analysis will be of particular use in phases 2 and 3, during which there is an increased risk of recurrence of violence, as well as a rapid expansion of operational areas, as conditions evolve to facilitate MA.

WARNING. This guide does not provide detailed guidance on national threat analysis.

WHAT IS OPERATIONAL THREAT ASSESSMENT?

Operational threat assessment is focused at the task site and on the individual activity (detection, location, disposal, etc). At the task site level it adds confidence to the decision-making processes related to IMAS 07.11 Land Release and at the activity level to functions such as IMAS 09.31 IEDD and IMAS 09.13 Building Clearance.

WHAT DO NATIONAL THREAT ANALYSIS AND OPERATIONAL THREAT ASSESSMENT ENABLE?

Neither are intended to have a defined end point, and this means that as new information is obtained it should be inputted to enable continual refinement. Both enable better informed decision-making to improve the safety, effectiveness and efficiency of MA operations.

A national threat analysis is conducted at the strategic level and helps ensure that an MA response is staffed with people with appropriate competencies, and that equipment and procedures are developed, tested and employed to conduct the required activities to achieve the outputs that are needed. Ultimately, this will enable the outcomes that are most needed and valued by the community.

At the task level, an operational threat assessment enables the selection of a suitably qualified survey team prior to survey and the accurate classification, categorisation and identification of boundaries of confirmed hazardous areas (CHAs) containing IED contamination and to release them safely and efficiently. For example, it will enable the reduction and cancellation of suspected hazardous areas (SHAs) by providing a consistent method for the analysis of new information from both new key informants and through technical survey activities. It will also enable the most efficient clearance processes and procedures to release CHAs. This means that the appropriate level of effort can be applied to achieve the same minimum level of confidence no matter how an IED-contaminated hazardous area is released. The result will be that valuable resources are not wasted carrying out expensive clearance, if suitable evidence exists to demonstrate with confidence that IED contamination is not present.

At the individual level, an operational threat assessment will ensure that search is conducted in a manner that is as safe as possible. For example, the operational threat assessment process can be used to make informed decisions on the probable locations of main charges or electrical links, and to enable the avoidance of firing switch locations when there is a VOIED threat. For an MA IEDD operator it also means that they can plan and execute the safest possible RSP by understanding the most likely, best-case and worst-case scenarios prior to leaving the contact point.

2.1. INFORMATION SOURCES

Information sources provide the primary input to operational threat assessment and national threat analysis. They can be gathered intrusively (via technical survey and / or clearance activities) or non-intrusively (via non-technical survey).

NON-INTRUSIVE

Image 5. Observing hazard area marking during non-technical survey (NTS) is an example of evidence gathered by non-intrusive means

- **Key informants.** Members of affected communities, including ex-combatants, that can be interviewed to provide information.
- **Monitoring of movements of internally displaced persons.** This can be achieved through tools such as the Displacement Tracking Matrix.
- **Social media.** This can be particularly useful at the national threat analysis level when an MA response is being established or broadened in scope.
- **Casualty data.** This can come from government departments and NGOs.
- **Previous NTS, TS and clearance reports.** Held by the National Mine Action Authority (NMAA) and other agencies, as well as by the MA organisation conducting an operational threat assessment.
- **Satellite images.** Accurate satellite imagery is critically important at the macro level to compare pre- and post-conflict battle damage, critical infrastructure and likely defensive locations, and at the task-specific level for planning clearance.
- **Unmanned aerial vehicle (UAV) imagery.** This can be taken from outside a defined SHA / CHA to provide 360 degree and current imagery of the site. There is potential that other sensors, not just cameras, can be fitted.

INTRUSIVE

Image 6. Building clearance is an intrusive information source

Where intrusive operations have been conducted, reports should include technical information on IEDs that have been removed or destroyed. This should be reported in a consistent manner to enable inter-organisational analysis to establish trends and ensure that procedures remain appropriate.

TECHNICAL INFORMATION

Technical information should be recorded in detail for IED components. An example below:

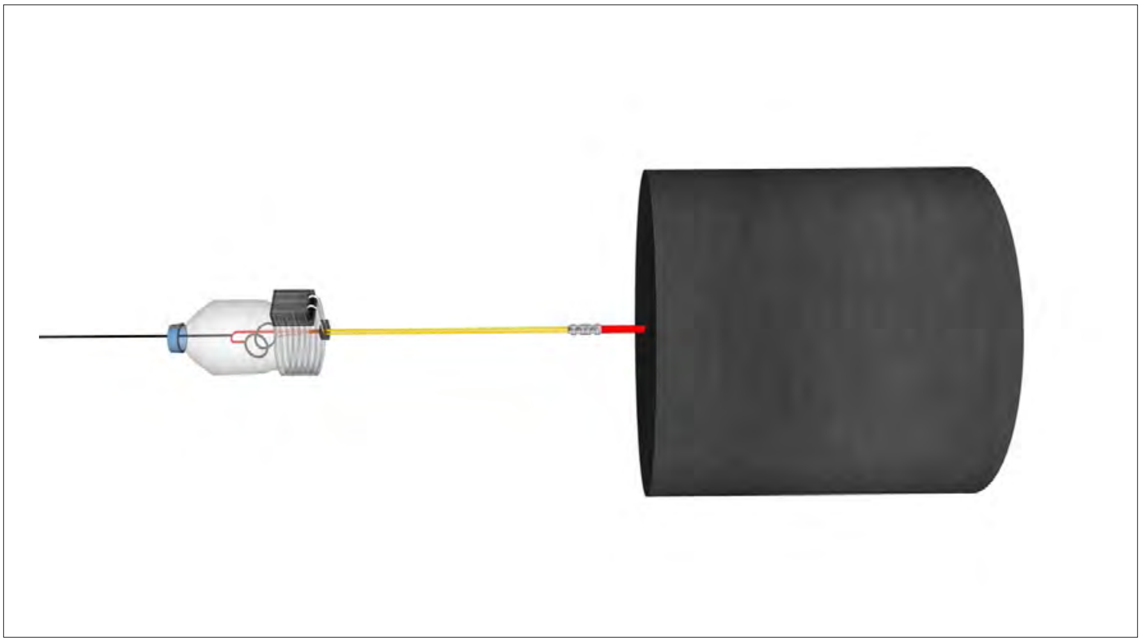

Image 7. A tripwire IED, the components of which are described in Table 1

SWITCH(ES)	A bare wire loop switch contained in a clear 500 ml (200 mm x 95 mm) drinking bottle and consisting of two electrical wires, one red and one brown. A length of fishing line was attached to the red wire which had been laid across the adjacent track.
MAIN CHARGE	The main charge consisted of a black metal (probable steel) cylinder with an outside diameter of approximately 300 mm and 350 mm in length. The wall thickness was approximately 5 mm. A section of flat steel of the same thickness was welded on to one end with approximately 100 mm of red detonating cord protruding through a centrally located hole. At the other end there was a fragmentation matrix consisting of a mixture of nuts and bolts. The main charge contained approximately 10 kg of probable ammonium nitrate-based home-made explosive (HME).
POWER SOURCE	1 x black and silver PP3 9V battery with "ENERGY" stencilling, wrapped in black adhesive tape with a length of white electrical wire secured to each terminal. The battery was secured to the outside of the bare wire switch using clear adhesive tape.
INITIATOR	The initiator was a commercial detonator measuring approximately 55 mm in length and 9 mm in diameter. Two yellow electrical leads protruded from a yellow plastic bung at the base of the detonator, each measuring approximately 400 mm in length. **"DANGER BLASTING CAP"** was stencilled in black on the detonator's body.
CONTAINER	The IED components had not been placed in a container but camouflaged in long grass.

Table 1. Example of IED reporting details for a tripwire IED

It will not always be possible or necessary to record this level of descriptive free text detail for every single IED. This volume of information could make effective information management difficult and laborious.

HINT. In the case of technical reports of new, novel or significant IEDs, however, this level of detail may need to be exceeded.

A better method may be predetermined fields, ideally specified by the NMAA, or at least with a broad consensus between MA implementers that are conducting IED survey and clearance.

Annex B of IMAS 05.10 on Information Management for Mine Action provides minimum data requirements for EO, but due to the improvised nature and novel ways in which IEDs can be employed, there is a requirement for more detailed reporting. An example of how set fields could be used to report the minimum requirements for the descriptive example above are in Table 2.

NOTE. When IEDs meet the definition of AP mines, this must be recorded and reported, as they are also subject to the APMBC.

	NUMBER	CATEGORY	SUB-CATEGORY	DIMENSIONS	PRIMARY COLOUR	PRIMARY MATERIAL	BOOSTER	NEQ	REMARKS (FREE TEXT)
SWITCH	1	VO	Tension	200 mm x 95 mm	Transparent	Plastic			500 ml drinks bottle Two electrical wires, one red and one brown
MAIN CHARGE	1	Fragmentation	Directional	300 mm x 350 mm	Black	Steel	Commercial detonating cord	HME	Yellow electrical leads and bung
POWER SOURCE	1	Electrical	9V	N/A	Black	Aluminium			PP3
INITIATOR	1	Detonator	Commercial	55 mm x 9 mm	Silver	Aluminium			**"DANGER BLASTING CAP"**
CONTAINER	N/A	N/A	N/A	N/A	N/A	N/A			N/A

Table 2. Minimum IED component reporting requirements

2.2. OPERATIONAL THREAT ASSESSMENT PROCESS TRIAD

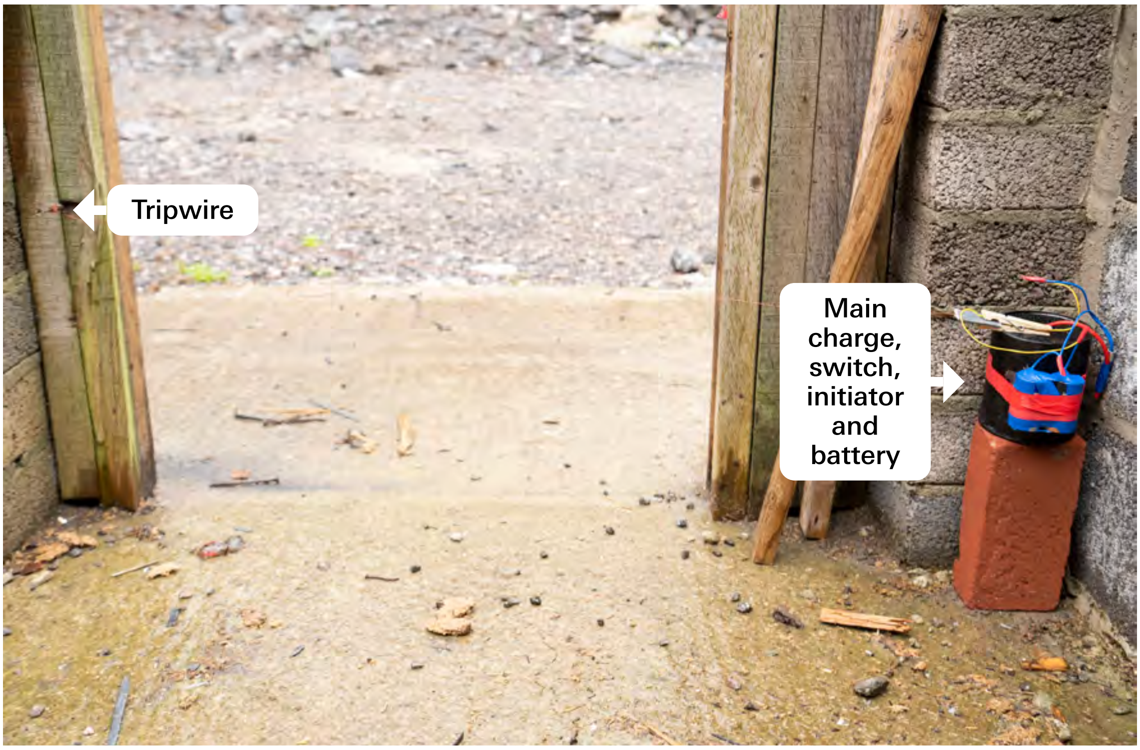

Image 8. How do MA staff make the decision on whether to tripwire 'feel' or not?

The threat triad interlinks three factors:

Figure 1. Threat triad, IMAS 07.14 Annex C

The primary output of the threat triad tool is a threat summary that describes the nature of the assessed IED contamination.

2.2.1. INTENT

Intent is the effect that an armed actor 'wanted' to achieve. The past tense is used here to reflect the importance in MA of considering the intent at the time the IED was placed, dropped or thrown. The intent of different armed groups will vary between strategic, operational and tactical. At the strategic level, an armed group will establish an overall goal or purpose that drives their involvement in armed conflict. This will in turn drive (or not), the use of IEDs. If an armed group intends to use IEDs as a weapons system, then it does not mean they will use every option that is available. For example, some armed groups would not use suicide IEDs as this may not correspond to cultural or religious values.

Some armed groups also have significantly less tolerance for inflicting civilian casualties than others. If this is the case, then the use of VOIEDs and / or landmines of an improvised nature will be subject to controls. Some armed groups will be indifferent or only take on board minor considerations related to civilian casualties, viewing them as a necessary part of the conflict. Other groups will deliberately target civilians. This may be specific ethnic groups or simply to create fear and instability.

The value that armed groups place on their own personnel and communities will be reflected in their intent and therefore how they use IEDs. For example, safe-to-arm switches (such as timers) may be incorporated in VOIEDs to provide a delay in the circuit becoming 'active' and therefore increasing the safety of the person making the emplacement. Such switches allow time to retreat to a safe distance from the IED after it has been laid. Some armed groups will even use time IEDs to target infrastructure and issue a warning so that civilians can be moved out of harm's way.

Examples of an armed group's differing intents include:

INTENT	SO WHAT?
An armed group wants to target road convoys yet maintain the popular support of the local population and leave the route open to other traffic.	Command-initiated devices may better match the intent than VOIEDs as they avoid unintentional casualties.
An armed group wants to persistently deny ground to an opponent.	VOIEDs or improvised landmines may match the intent better than command IEDs as the armed group does not need to constantly observe every IED day and night.
An armed group wants to stop personnel being captured alive and wants any personnel that is facing capture to have the ability to conduct a final act to inflict casualties.	Person-borne suicide IEDs may be commonly carried and not reserved only for spectacular attacks.

Table 3. Analysis of 'Intent'

2.2.2. CAPABILITY

Capability considers what IEDs an armed group will use, and will not use, to achieve its intent. Efficient use of resources is a critical factor for sustaining any armed campaign. The best 'quality' IED is the one that can achieve the required result with least amount of resources consumed. This means a 'good IED capability' does not have to be the most technically advanced, as a \$5 VOIED may be much 'better' from the perspective of an armed group than a \$100 radio-controlled IED (RCIED).

Consideration of capability will enable the following question to be answered:

How would an armed group have tried to best achieve their desired effect within the constraints they faced?

AVAILABILITY OF MATERIAL	Not all groups have access to all IED-related technology and material. Some materials are more scarce or costly than others and will be used sparingly, whereas others may be cheap and suitable for large-scale use.
PERSONNEL	The number of available personnel involved in a conflict will often relate to the scale of IED contamination that is left behind. This is not just the personnel that directly use IEDs but also those available in their manufacture and transportation through logistical chains.
TRAINING	Some IEDs require greater levels of knowledge and skill to deploy effectively than others. Some also require certain fundamental attitudes such as in the placement of VOIEDs inside civilian residences or the use of suicide IEDs.
FREEDOM OF MOVEMENT AND SUPPORT FROM THE LOCAL POPULATION	The emplacement of large numbers of IEDs, such as defensive belts consisting of hundreds of VOIEDs to deny freedom of movement, require access to large manufacturing facilities and associated real estate and logistical systems.

Table 4. Capability assessments

The assessment of capability, matched against the intent and opportunity, will enable the following to be assessed:

LOCATION	Where are the high-risk parts of an SHA / CHA? Will different types of IEDs be located in different places or will there be concentrations of multiple IEDs of the same type in a certain location?
FIRING SWITCH	Time, command or VO. These can also be broken down into subcategories such as with VO: high metal content or low metal content.
MAIN CHARGE	Different main charges provide different advantages and disadvantages. For example, an off-route main charge targeting vehicles may be more likely to be an explosively formed projectile (EFP) or 'platter' charge. Whereas if a blast main charge was used it would likely need to be much larger and located directly underneath the vehicle. People who have dismounted from a vehicle are more likely to be targeted by small blast or fragmentation, with the latter providing an advantage that multiple people can be targeted by a single IED.
COMPONENT LAYOUT	How can components be placed to best effect? For example, an opposing armed group uses metal detectors. Using a low metal content pressure plate, a plastic main charge container, and a power source several metres away from the anticipated direction of approach, will make the IED harder to detect.
OVERALL SCALE AND FREQUENCY	Some armed groups have more overall capacity to build and sustain the use of IEDs for longer than others. This will affect the overall scale but not all categories of IED will be used as frequently.

Table 5. Analysis of capability in consideration of intent and opportunity

2.2.3. OPPORTUNITY

Opportunity relates to an armed group identifying the vulnerabilities of an opponent and exploiting them. Armed groups often use IEDs to exploit weakness through observing patterns that have been set, assessing tactics and procedures, and analysing likely avenues of approach or vital ground (either symbolically, politically or tactically).

Assessment of opportunity can consider specific targeting. For example, a military convoy transiting a busy road being targeted by a command device at a specific point. It can also be used to assess wider-level operational plans, such as an armed group's defence of a city using IEDs to deny 'avenues of approach' created by open areas or multiple routes that afford an opposing group the ability to attack en masse.

Opportunity factors provide useful information on where a device will be located and how and what the armed actor will have emplaced. The following three factors are important to consider when analysing opportunity:

TERRAIN	What opportunities does the terrain provide? At the higher level this is an analysis of the make-up of urban, rural and interface areas, including water features and transportation networks. Further terrain analysis can then be conducted at the MA task site level to determine the high-risk parts of an SHA / CHA. For example, locations of choke points, slowdown and channelled areas.
LOCAL COMMUNITY	This can be split between two time frames: **Conflict**. Did the community remain in the area during the conflict or leave? **Post conflict**. Is the community providing direct or indirect evidence of IED contamination?
OPPONENT'S DOCTRINE AND TACTICS	At the strategic level this will be how an armed group fought their campaign against their opponent(s). At the operational level these are the specifics of how they operated. For example, did they use armoured vehicles, in what formations and how were these being deployed? At the tactical level this will aim to identify what the specific targetable actions were at the time of conflict. For example, poor procedures used by clearance teams or recurring actions such as assaulting forces always entering through obvious points.

Table 6. Analysis of opportunity-based factors

Opportunity factors can directly affect the make-up of an IED. For example, from an armed actor's perspective:

EXAMPLE OF OBSERVATION	OPPORTUNITY
If metal detectors were extensively used by an opponent.	Then an armed actor may have used low metal content IEDs.
If poor disposal procedures were employed by an opponent.	Then these may have been observed to deliberately target personnel conducting disposal.
If an opponent used heavily armoured vehicles.	Then an armed actor may have used an EFP main charge to try to penetrate the armour.
If the target was a dismounted patrol.	Then a directional fragmentation main charge might have caused the most casualties.

Table 7. How opportunity can affect the construction of an IED

2.3. OPERATIONAL THREAT ASSESSMENT OUTPUT

Operational threat assessment enables the following six Ws to be answered:

WHO?	Who placed, dropped or threw the IED(s)?
WHO?	Who was the target?
WHAT?	What are the components and layout of the IED?
WHEN?	When was the IED(s) placed, dropped or thrown?
WHERE?	Where is the IED(s) located?
WHY?	Why is the IED there? What was it intended to achieve or target?

THREAT SUMMARY

A primary means of communicating the output of the operational threat assessment is a threat summary, which can be fed into the planning process at a variety of levels. This means that whether decisions are being made at the strategic-, operational- or task-specific levels there will be consistency in the approach used in the analysis of the available information.

The information used in the threat assessment process should be recorded in an accessible and auditable way so that all stakeholders can have confidence in the threat summary. In general threat summaries can:

- Produce general assessments for programme-level planning;
- Make recommendations about the classification, categorisation and definition of SHAs / CHAs;
- Support priority setting at various levels;
- Inform decisions related to the release of hazardous areas.

2.4. OPERATIONAL THREAT ASSESSMENT – SCENARIO EXAMPLES

The following three examples explain the operational threat assessment process. Each scenario is fictitious and referred to in the present tense.

2.4.1. SCENARIO 1 – OPERATIONAL THREAT ASSESSMENT

Image 9. Suspected IED under road bridge (important infrastructure)

GENERAL DESCRIPTION

An MA operator receives a request to conduct NTS of a road bridge. The bridge is the primary crossing point over a 20 m-wide, fast-flowing river. It links two sides of a large city that was the scene of intense fighting between two armed groups, one of which made extensive use of IEDs.

DESKTOP INFORMATION

The following information is gathered through the desktop assessment:

- The last fighting in the area occurred 60 days prior to the tasking request being received.
- Critical infrastructure is known to have been targeted by time-initiated IEDs.
- The only command IEDs to be used were physically linked, i.e. command wire or command pull. No RCIEDs were reported.
- Civilian vehicles and people have been reported to be crossing the bridge in large numbers.
- The police checkpoint adjacent to the bridge has reported a suspect object under one of the bridge abutments.

NTS INFORMATION

The following information is gathered during NTS of the bridge:

- A police officer is questioned as a key informant. He reports a large blue drum on its side with cord protruding from it.
- A UAV is used to observe the bridge in detail and a blue drum is confirmed. It appears to have blue detonating cord protruding from it and what appears to be a black safety (burning) fuze.
- The police officer is questioned further and reports that a similar object was cleared by the army unit on the other side of the bridge approximately 40 days previously. The army unit has now left the area and cannot be contacted.
- A woman working as a local shopkeeper reports that she believes at least one explosion has occurred in the vicinity of the bridge in the last 60 days. A child that went down to swim under the bridge lost a leg.
- The police inform the NTS team that no one is currently allowed adjacent to, or under, the bridge.

The UAV is used to build a detailed picture of the terrain around the bridge. Each side of the bridge represents a channelled approach and a seat of an explosion can be observed on the left-hand side.

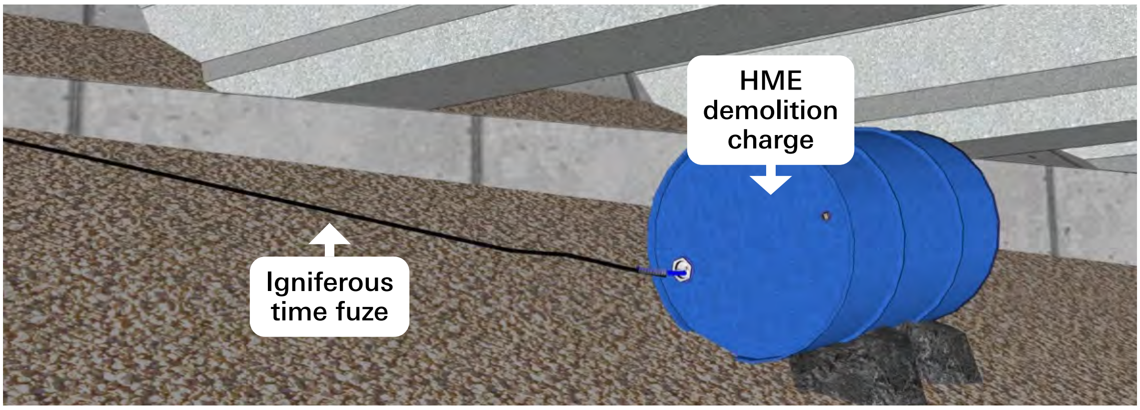

Image 10. Image taken by the UAV during NTS

OPERATIONAL THREAT SUMMARY

It is assessed that an igniferous time IED containing approximately 100 kg of HME is located directly under the bridge. It is probable that either the fuze was not ignited or a misfire occurred. It is assessed that the IED was not placed after the conflict in the area finished.

The explosion that occurred is assessed to have probably been the result of a VOIED containing 1–2 kg of HME in a plastic container. This had probably been placed to protect the primary time IED. It is possible that further VOIEDs may be present.

WHO?	A non-state armed group (NSAG) placed, dropped or threw the IED(s).
WHO?	State armed groups were the target.
WHAT?	Large igniferous time-initiated blast IED, with secondary VOIEDs and small main charges.
WHEN?	The IEDs were placed at least six months previously.
WHERE?	Directly under the bridge abutment with the VOIEDs protecting potential approach routes.
WHY?	The time IED is there to destroy the bridge, which was seen as critical infrastructure during the conflict. The VOIEDs are there to protect the time IED.

2.4.2. SCENARIO 2 – OPERATIONAL THREAT ASSESSMENT

GENERAL DESCRIPTION

An MA operator is requested to survey a route linking a village to a local market town. The villagers have reported an explosion occurring on the route but no casualties.

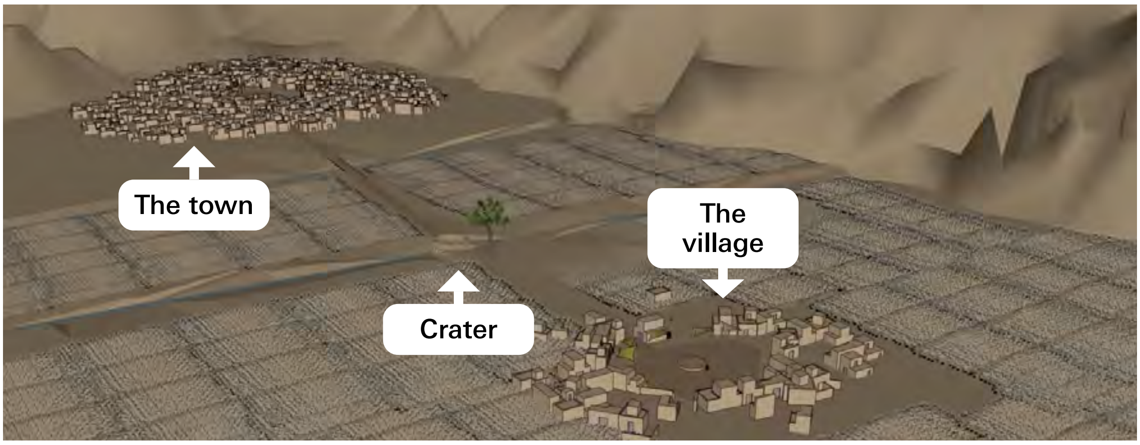

Image 11. Image showing the village on the right and the town on the left

DESKTOP INFORMATION

The following information is gathered through the desktop assessment:

- During the conflict an NSAG targeted a state armed group a number of times on the route between the village and the town. Conflict in the area ended six months previously.
- The NSAG was extremely careful not to cause civilian casualties and although numerous successful attacks were conducted, there were no reports of civilian casualties, with the route remaining open for civilian use throughout the conflict.
- The NSAG used a wide range of high metal content pressure plate VOIEDs.
- There were no reports of the NSAG using RCIEDs in this area, although other types of command IED may have been used.

NTS INFORMATION

The following information is gathered during NTS of the route:

- A number of key informant interviews were conducted and the route was discussed with a number of users, across different ages and genders. All users reported that the route has been regularly trafficked by pedestrians, vehicles, motorcycles and herds of sheep over the last six months and that no accidents have occurred.
- One week previously there was a large explosion at a culvert. It occurred approximately five minutes before a minibus full of children would have transited this point. Further investigation revealed that a shepherd had been working in the adjacent area when the explosion occurred. The shepherd stated that, at the time of the explosion, he had moved the herd into a field that had not been grazed since the conflict ended. Other than the explosion, the only thing he observed out of the ordinary was one of his sheep becoming entangled in 'kite string' that appeared to be running towards the road.
- The NTS team can access a known safe area 70 m from where the explosion occurred. Using binoculars, they can see a crater in the road consistent with the functioning of approximately 20 kg of explosives.

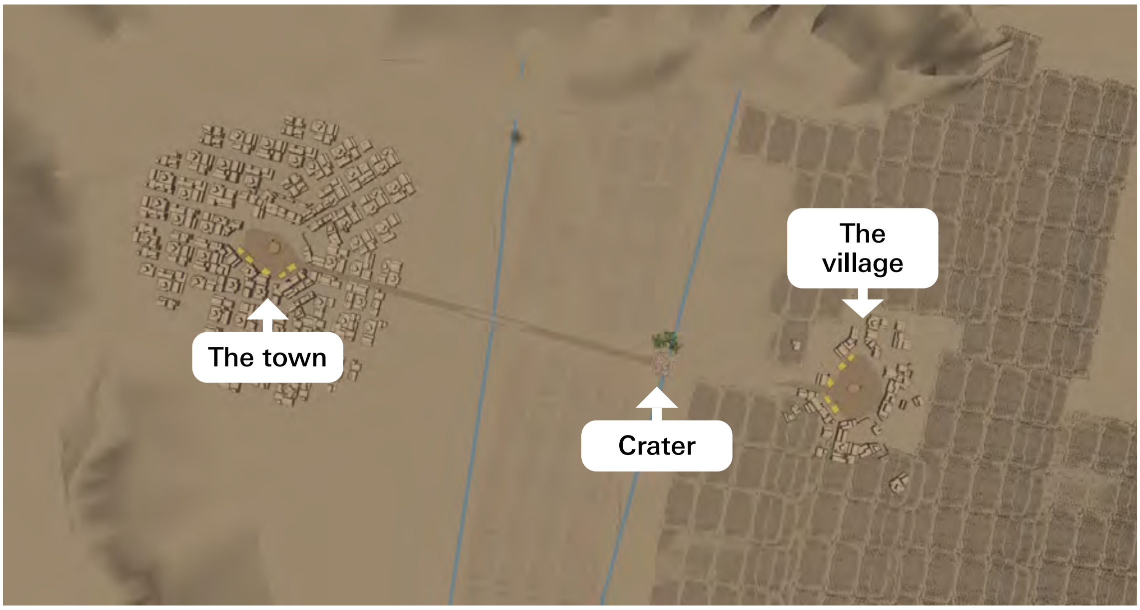

Image 12. Image taken by the UAV during NTS

OPERATIONAL THREAT SUMMARY

The explosion was probably the result of a command-pull IED with a 20 kg blast main charge. It is probable that it was inadvertently initiated as the herd of sheep was being moved into a field for the first time since the conflict ended. The IED that functioned was located at a prominent vulnerable point (VP), with a tree as an aiming marker and a culvert acting as a choke point slowing down vehicles moving along the route.

It is assessed as unlikely that VOIEDs have been emplaced on the route or that this explosion was the result of active conflict. Analysis of the route during NTS identified one further VP that would have provided the NSAG with an opportunity to use a command-pull IED.

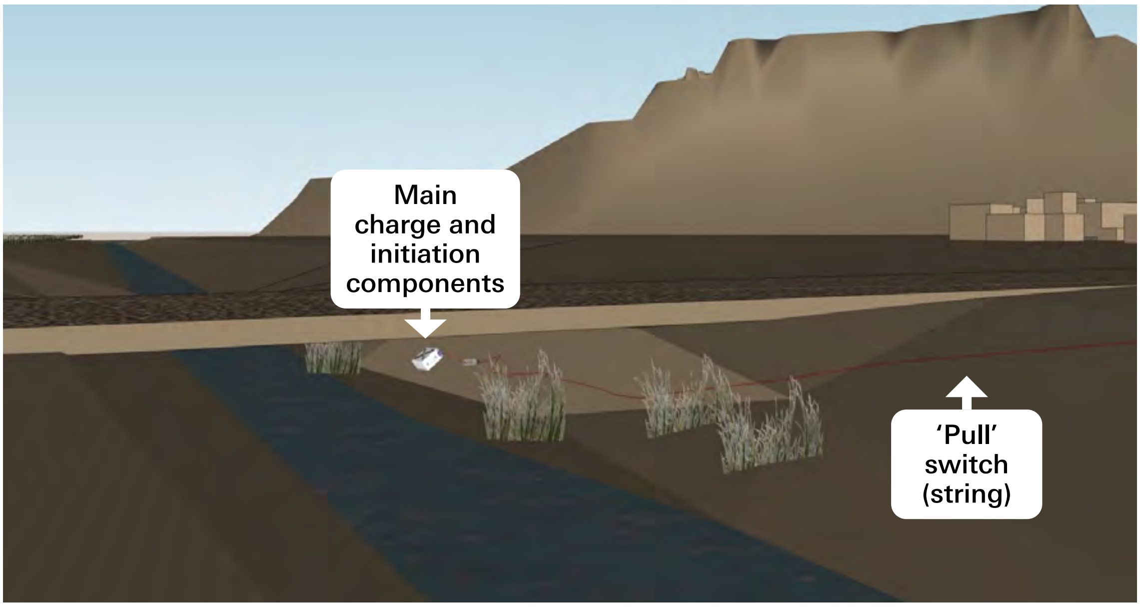

Image 13. An example of the assessed command-pull IED

WHO?	NSAG placed, dropped or threw the IED(s).
WHO?	State armed groups were the target.
WHAT?	Command-pull IEDs with large blast main charges.
WHEN?	The IEDs were placed at least six months previously.
WHERE?	Points on the route that afforded good opportunity to target vehicles with command IEDs.
WHY?	To target opposing armed groups' vehicles when the conflict was active.

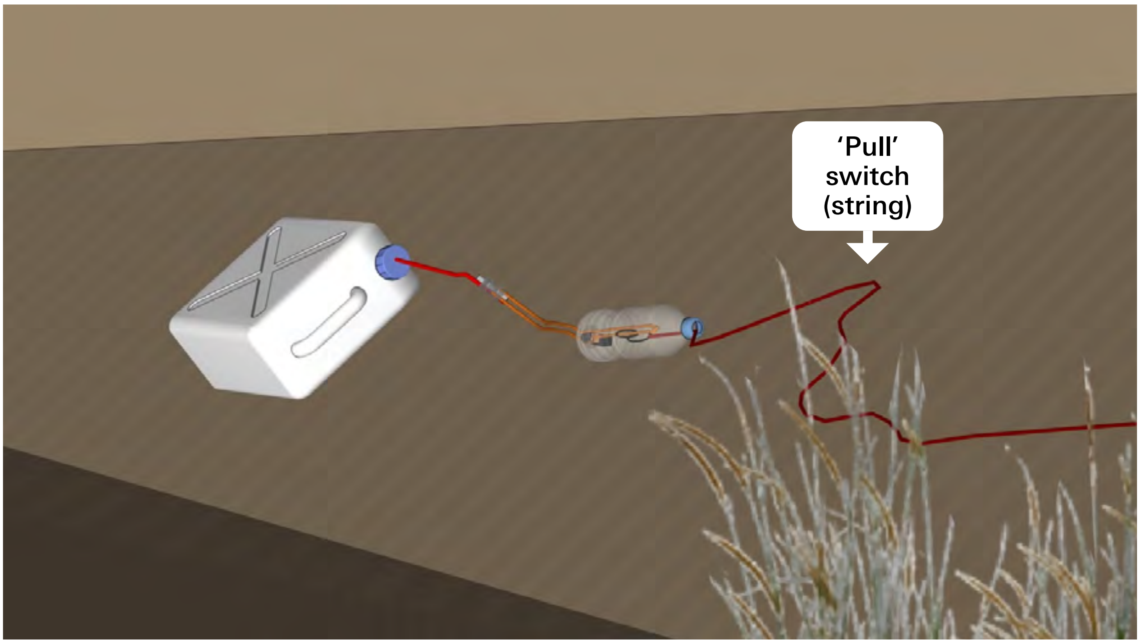

Image 14. Command-pull IED in detail

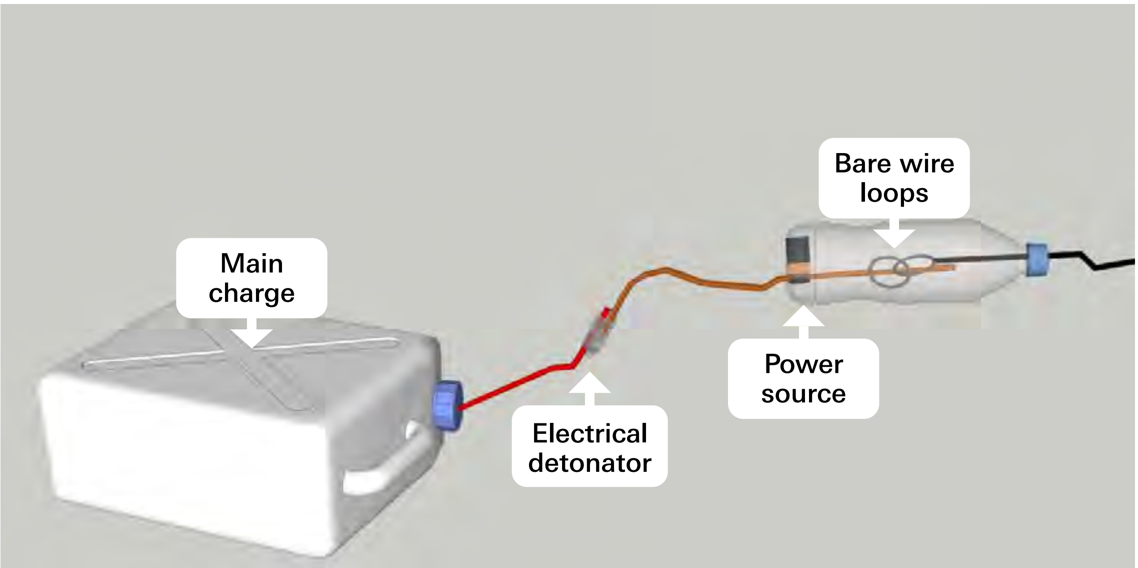

Image 15. Command-pull IED in detail

2.4.3. SCENARIO 3 – OPERATIONAL THREAT ASSESSMENT

GENERAL DESCRIPTION

An MA operator is requested by the NMAA to release a large SHA that encompasses a community-owned new-build housing complex and open surrounding areas. NTS has already been conducted by another MA operator.

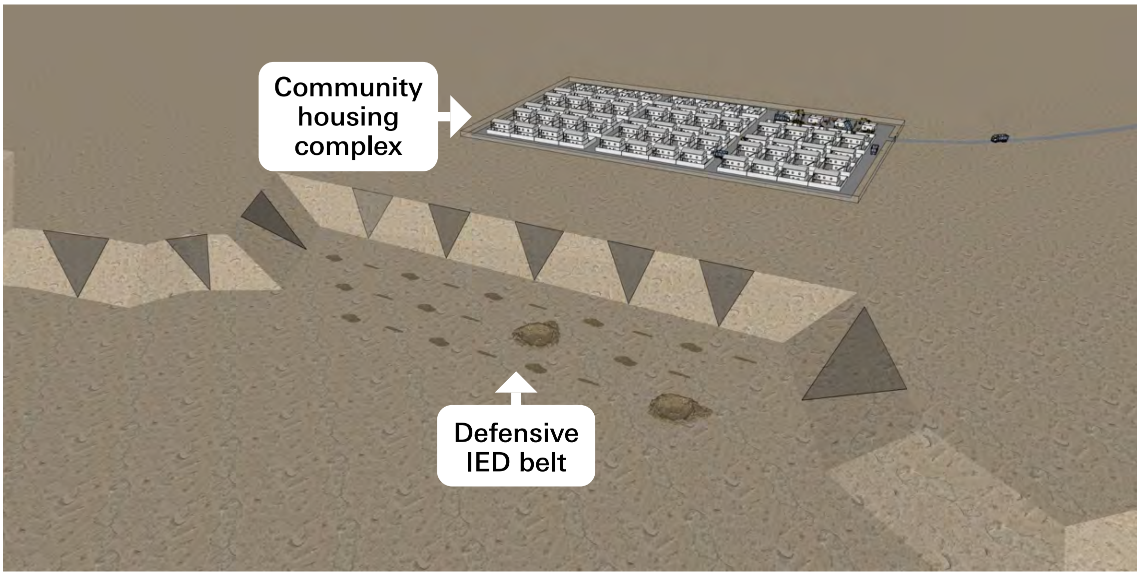

Image 16. Defensive IED belt in relation to a community housing complex

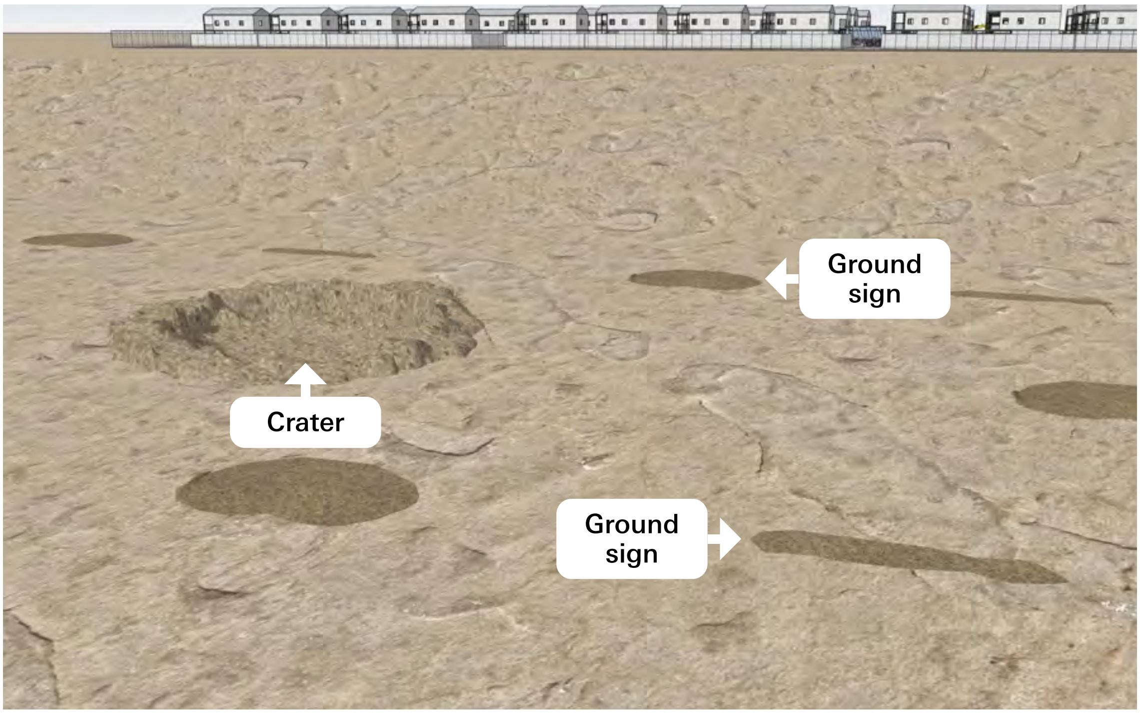

Image 17. Ground signs and crater from an explosion

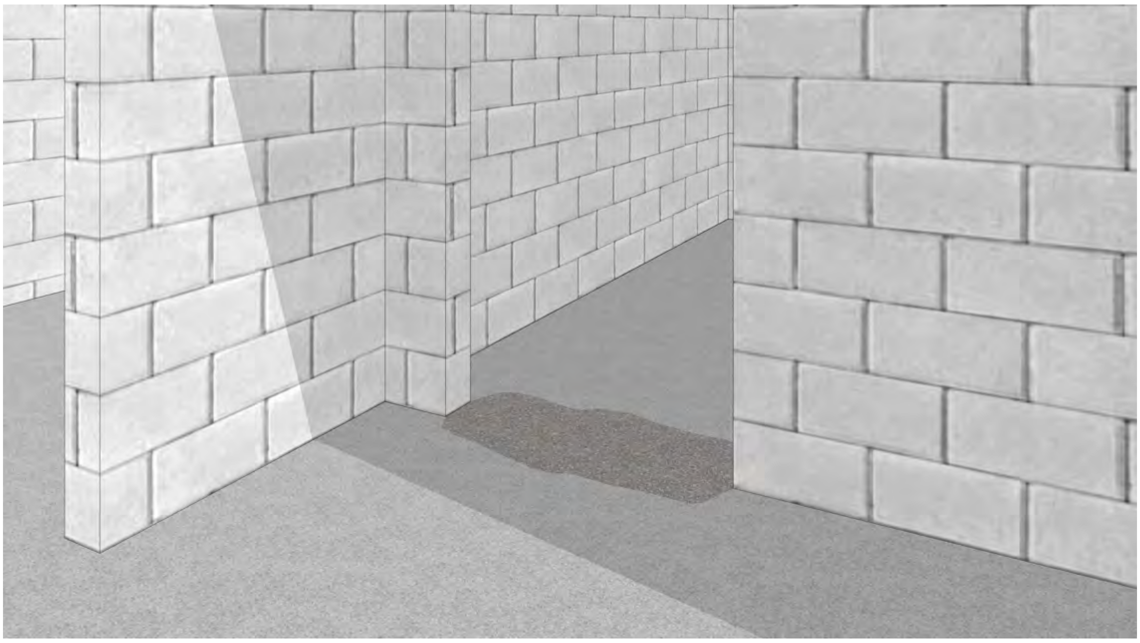

Image 18. Example of the ground sign observed at the entrance to some of the buildings

DESKTOP INFORMATION

The following information is gathered through the desktop assessment:

- The community-owned housing is on top of an area of high ground and was known to have been occupied by an NSAG during the conflict.
- The NSAG was known to make extensive use of VOIEDs.
- The NSAG was known to develop integrated defensive plans that incorporated physical terrain, with non-explosive obstacles and belts of VOIEDs.
- Other types of IEDs were regularly used at defined VPs such as doorways.

NTS INFORMATION

The following information is gathered during NTS:

- A local construction company has started work at the site with the intention of recommencing construction. During this they reported that one of their members of staff was killed when entering one of the partially-constructed houses.
- A local shepherd is identified as another key informant. He informs the NTS team that two of his flock were killed in separate incidents 100 m south of the housing complex in the last 30 days.
- A UAV is flown over the area where the shepherd reported the explosions occurring. Two craters are identified, each approximately 1 m in diameter and consistent with the functioning of 5–10 kg of HME.
- The seats of explosion are approximately 50 m apart between two areas of steep-sided slopes. Two rows of regular ground signs can be observed.
- The house in which the construction worker was killed has collapsed. Interviews with the other construction workers present, suggest that he simply stepped through a doorway.
- The construction staff have been at the site for 30 days and apart from not entering the partially-constructed houses they have driven machinery, including graders, across the whole of the site in preparation for work commencing.

Image 19. Construction work being carried out in the housing complex

OPERATIONAL THREAT SUMMARY

A defensive belt of pressure plate IEDs (PPIEDs) is probably located 100 m from the housing estate in the area between the two steep slopes. These probably consist of 8–10 kg of HME in metal containers directly adjacent to a high metal content pressure plate.

Inside the fenced area of the estate there are probably high metal content pressure plate VOIEDs located in the doorways and entrances to the houses. The routes inside the housing estate are probably free from IED contamination.

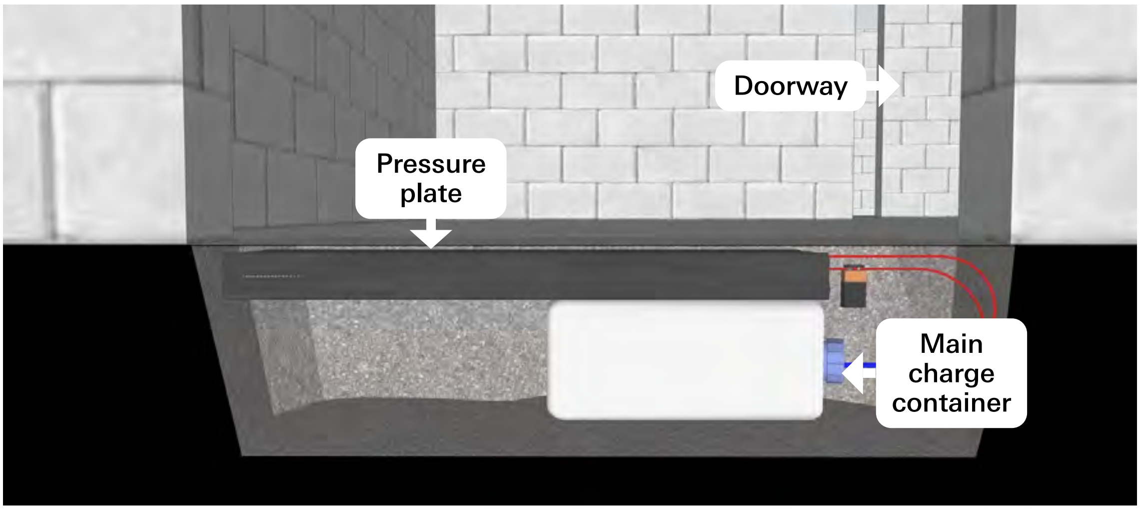

Image 20. VOIED placed in a doorway of a partially-completed house

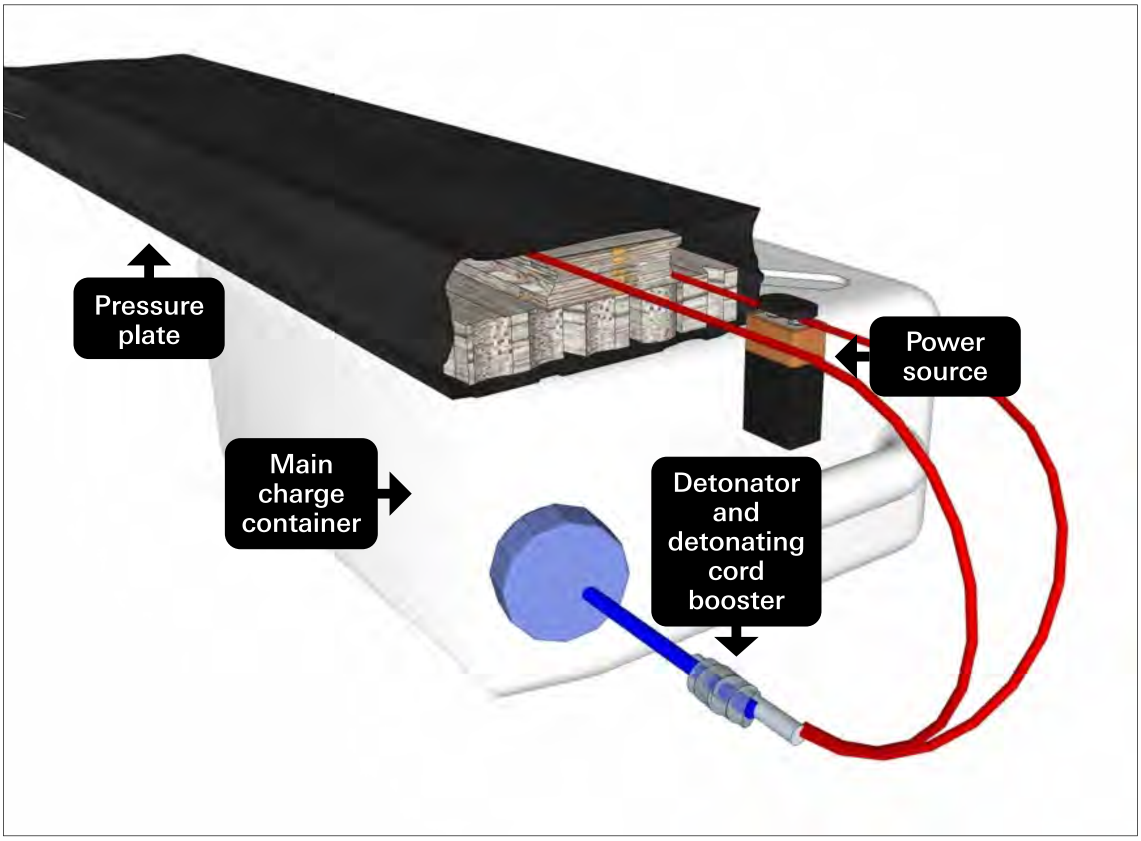

Image 21. Detail of the VOIED located in the doorway

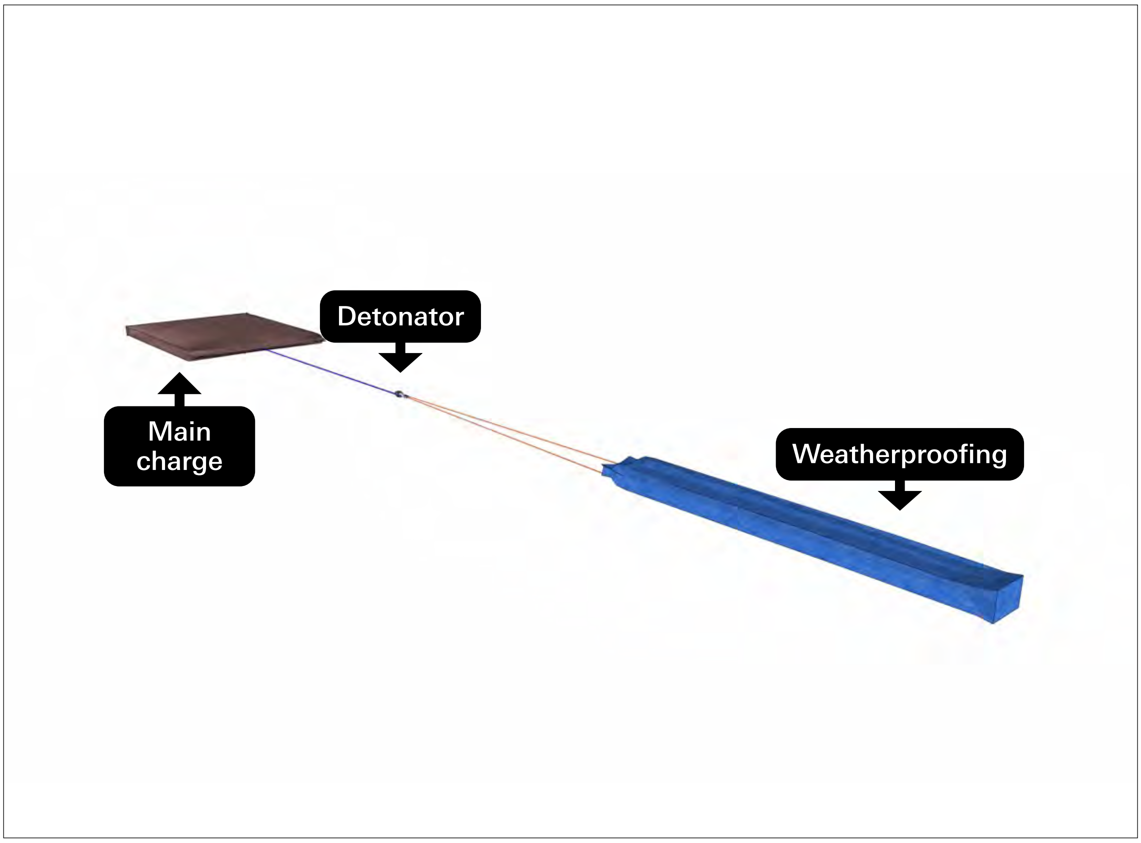

Image 22. PPIED variant (with blue weatherproofing) assessed to be located in the defensive belt

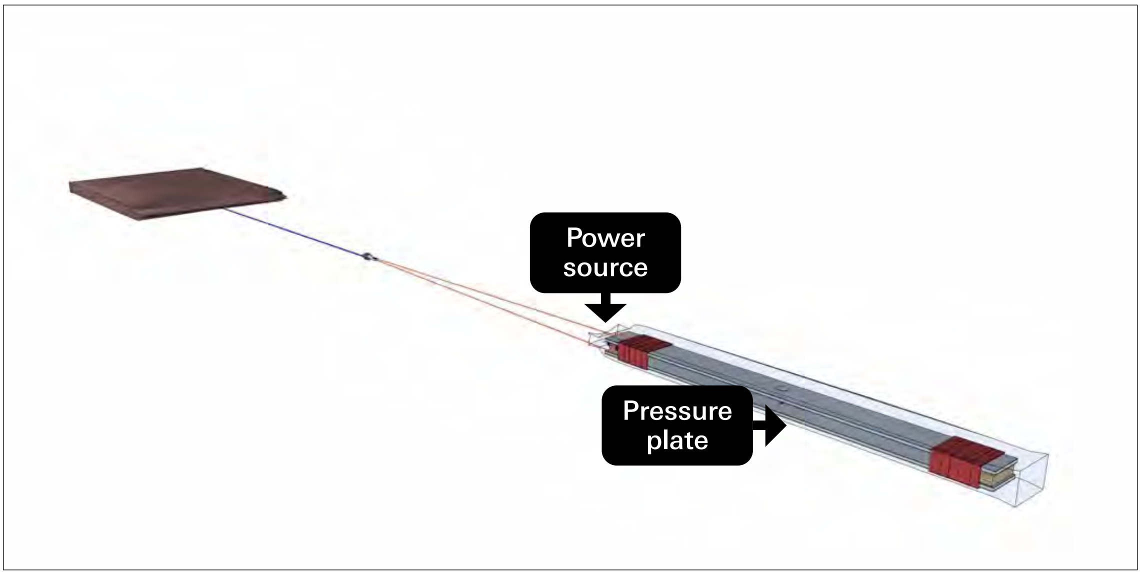

Image 23. PPIED variant (without blue weatherproofing) assessed to be located in the defensive belt

WHO?	NSAG placed, dropped or threw the IED(s).
WHO?	State armed groups were the target.
WHAT?	VOIEDs with blast main charges and high metal content pressure plates.
WHEN?	The IEDs were placed at least six months previously.
WHERE?	Potential approach routes between steep slopes and entrances to buildings.
WHY?	To target opposing armed groups’ vehicles on approach routes and individuals on foot entering buildings.

3. TECHNICAL IED CAPABILITIES

Image 24. Directional fragmentation charge camouflaged behind a tyre and vegetation

Due to their improvised nature, although they contain the same fundamental components, IED technical characteristics and employment can vary considerably. This section provides a global overview of the IED threat and how signs and indicators can be used to help assist in the development of IED threat assessment It is aimed at MA staff who are planning and implementing IED clearance at programme and operational task site levels. Section 3.2 (IEDD), provides detailed technical guidance on IED threats in the context of disposal operations.

At this level, IEDs have been subdivided into three main categories:

- Time
- Command
- Victim operated (VO)

An additional section on vehicle-borne IEDs (VBIEDs) and projected IEDs has also been included. Although these IEDs can normally be inserted into the time, command and VO categories, the MA sector often finds it useful to give them specific consideration.

3.1. TIME IEDs

Image 25. Failed electronic time IED, with conventional ordnance as a main charge

WARNING. If active time IEDs are anticipated as part of the threat assessment it is a non-permissive environment and the task is not suitable for a mine action organisation.

Time IEDs may be encountered by MA organisations having failed to function as intended or having been constructed but not deployed. There are numerous subcategories of time IEDs but the three that are encountered most frequently are:

- Mechanical
- Electronic
- Igniferous

ADVANTAGES OF TIME IEDs:

- Provide time to withdraw to a safe location after placing the IED before it detonates.
- Can be used in conjunction with a warning to enable civilians to be evacuated.
- Can incorporate a short delay to give safe separation between an IED that has been thrown or projected.

DISADVANTAGES OF TIME IEDs:

- No control after the means of initiation is activated (e.g. timer / burning fuze) unless additional switches have been incorporated.
- Very difficult to target anything that is moving.

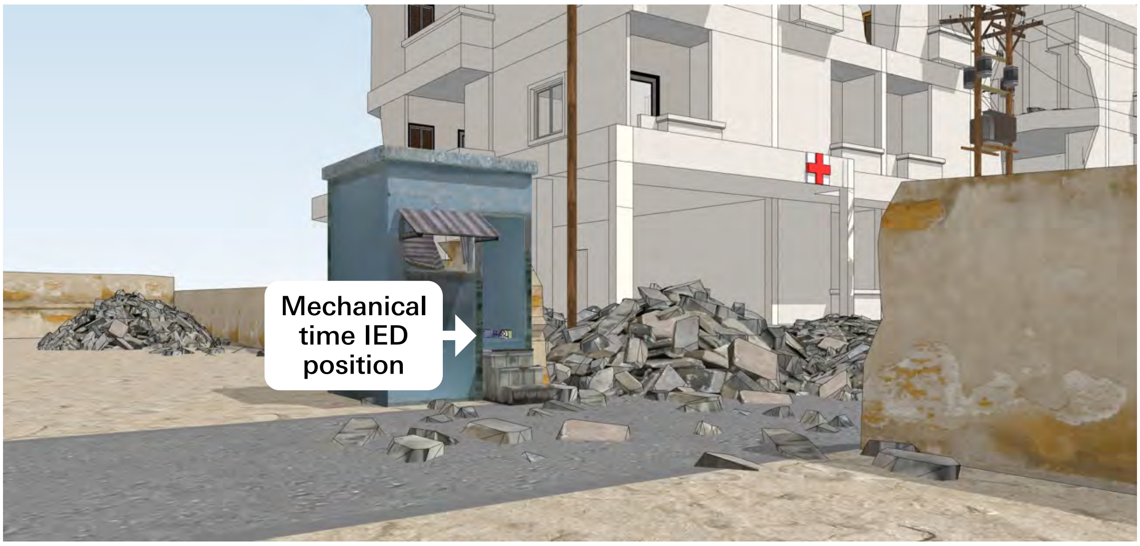

Image 26. An abandoned mechanical time IED

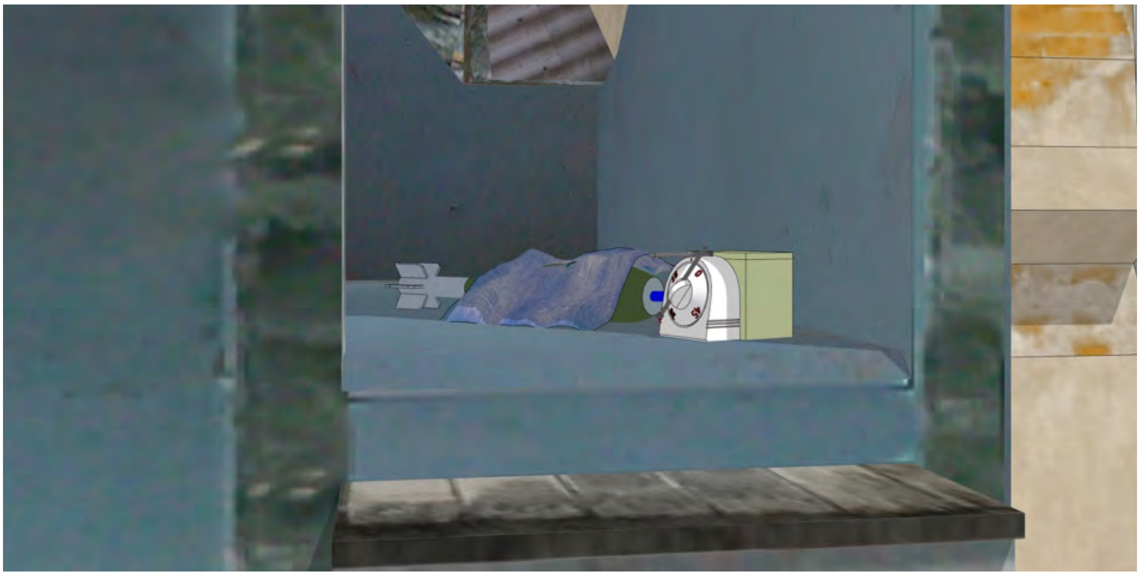
Image 27. A closer view of a mechanical time IED incorporating a conventional mortar main charge, electrical detonator and a modified 60 min cooking timer

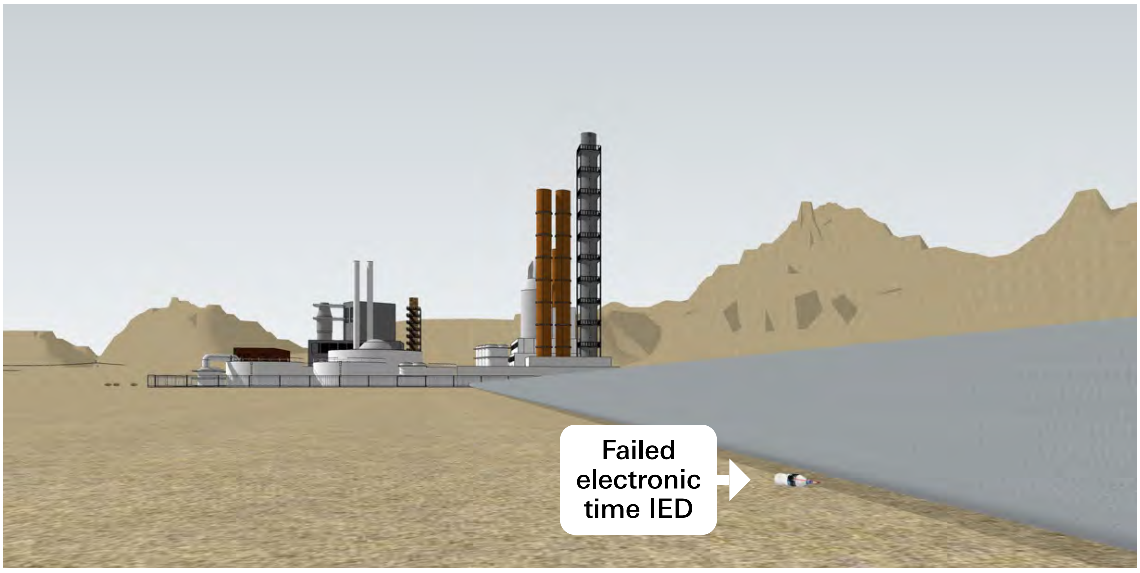

Image 28. A failed electronic time IED targeting critical infrastructure

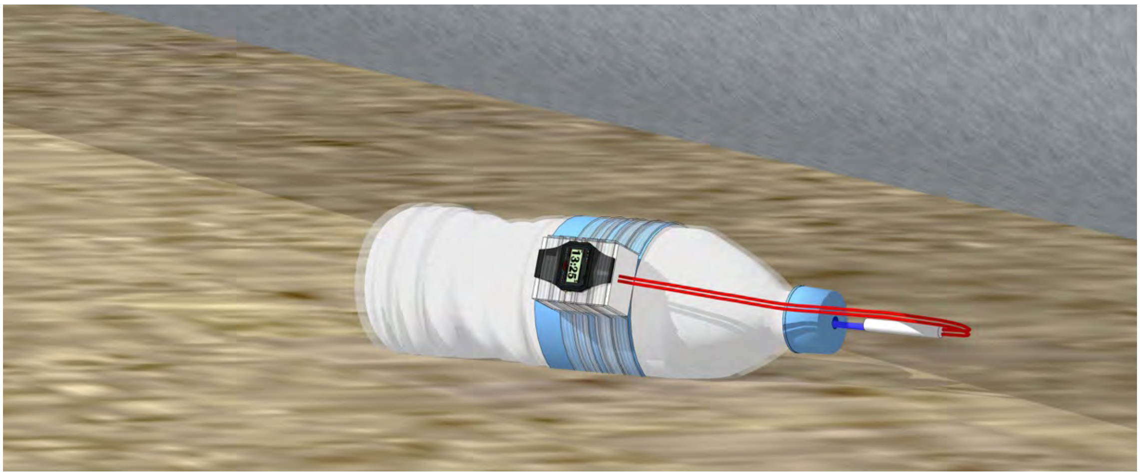

Image 29. A closer view of the failed electronic time IED incorporating a modified digital watch attached to a plastic box which contains additional step-up circuitry and a power source

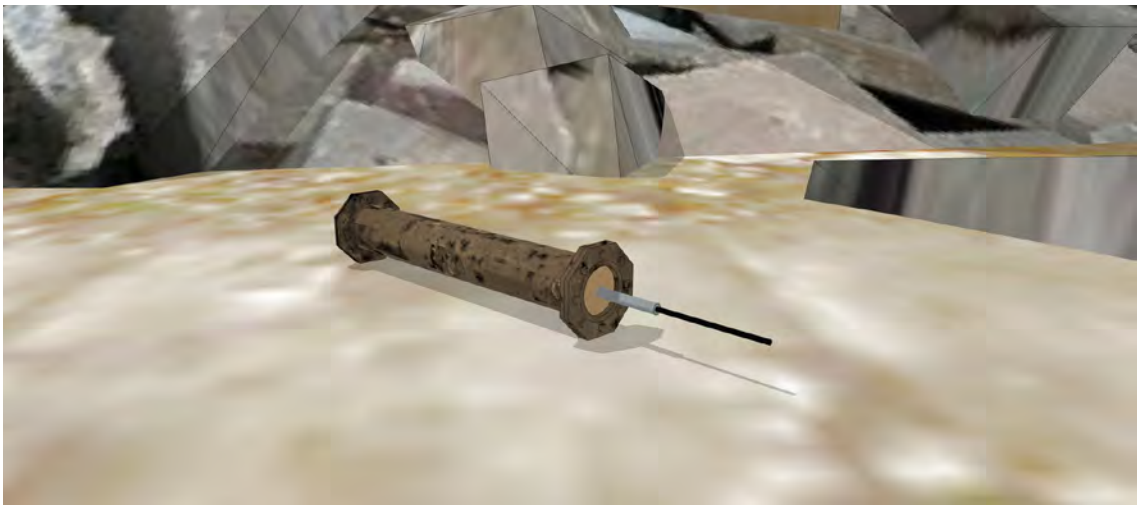

Image 30. Abandoned igniferous time IED that was thrown by hand during the conflict but failed to function as intended

3.2. COMMAND IEDs

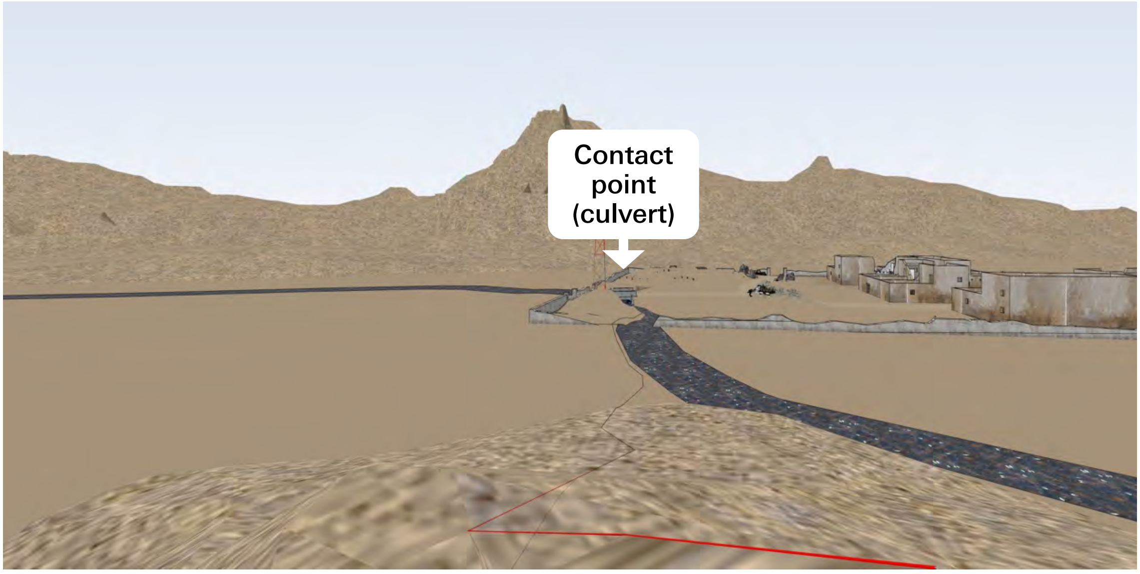

Image 31. Showing good line of sight between a firing point and contact point (culvert) where a target can be easily observed

Command IEDs provide the ability to retain full control over the IED until the moment of initiation. This reduces the possibility of an inadvertent initiation which would cause unintentional casualties and waste resources.

There are many different types of command IED. The main division is between physical and non-physical link devices. This guide provides specific details of:

- Non-physical link radio-controlled IEDs
- Physical link command-wire IEDs
- Physical link command-pull IEDs

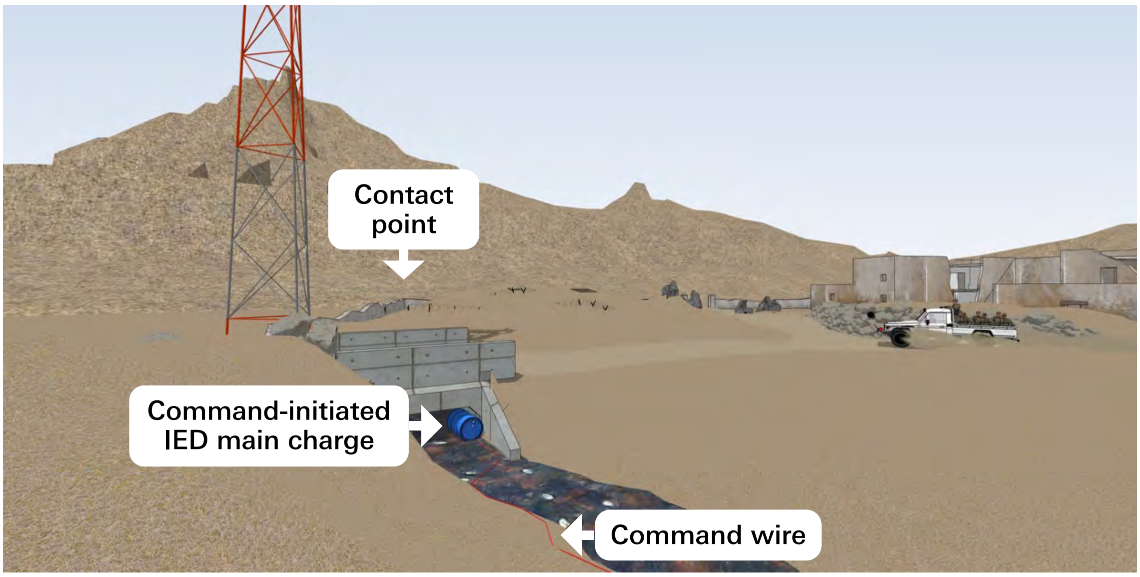

Image 32. Command-initiated IED that will be initiated when the target crosses the VP. (Note: this image is in the context in which the IED was originally emplaced to target the armed group using the route)

ADVANTAGES:

- Control of the IED enables armed actors to maintain freedom of movement, while denying it to opponents.
- The IED can be initiated at the optimum moment.

DISADVANTAGES:

- Continued observation is necessary in order to detonate the IED when a suitable target presents itself.

3.2.1. RADIO-CONTROLLED (RC) IEDs

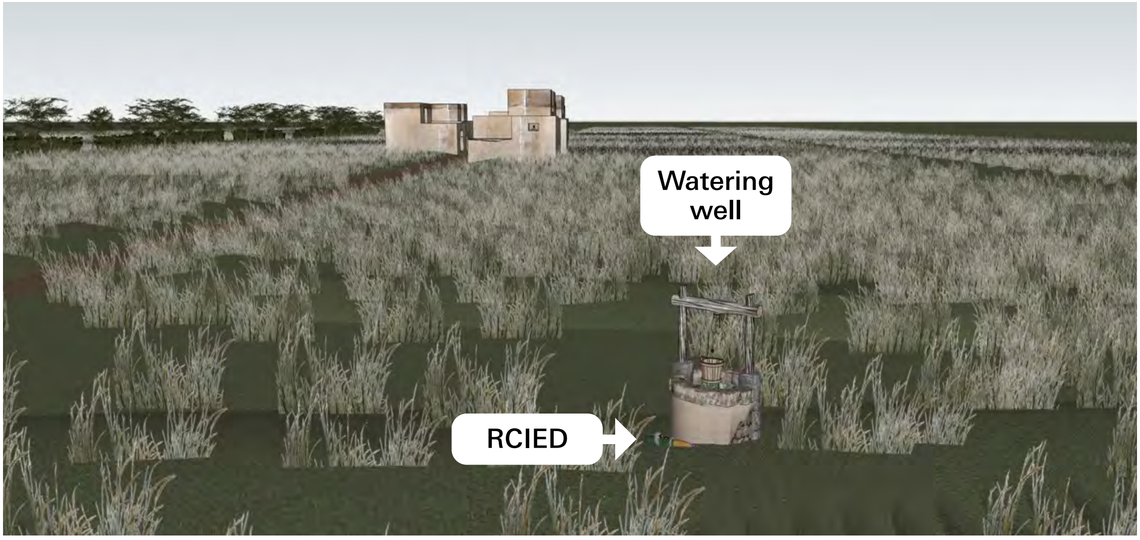

Image 33. An RCIED at the base of a watering well near a state armed group position with good line of sight from a nearby compound

This type of command IED has no physical link between the firing point and contact point. Instead it uses a radio frequency transmitter and receiver.

The following advantages and disadvantages of RCIEDs are considered in comparison to physically linked command-wire and command-pull IEDs.

ADVANTAGES:

- Not fixed to a single firing point.
- Reduces vulnerability of the firer to follow-up attacks.
- Can be quicker to emplace.
- Distance for observation can be considerable.

DISADVANTAGES:

- Can get jammed.
- Higher level of training is likely to be required to both construct and use effectively.
- Requires access to more technical resources and knowledge.

Image 34. A closer view of the RCIED at the base of the watering well (no camouflage has been used to help the reader see how compact it is and easy it would be to place this type of command device)

3.2.2. COMMAND-WIRE IEDs

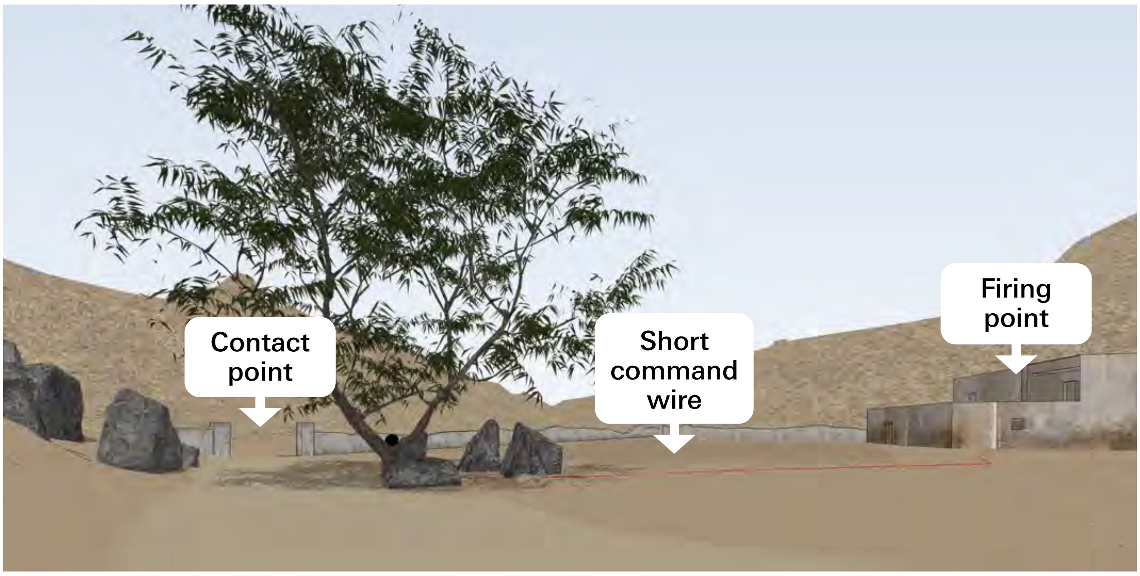

Image 35. Showing a short command wire attack with firing point in a compound

This type of command IED has an electrical wire as a physical link between the firing point and contact point. At the moment the device is to be initiated, the firer makes a connection that allows electrical current to flow down the wire to detonate the main charge.

The following advantages and disadvantages of command-wire IEDs are considered in comparison to RCIEDs.

ADVANTAGES:

- Resources and training requirements are straightforward.
- Not affected by jamming.

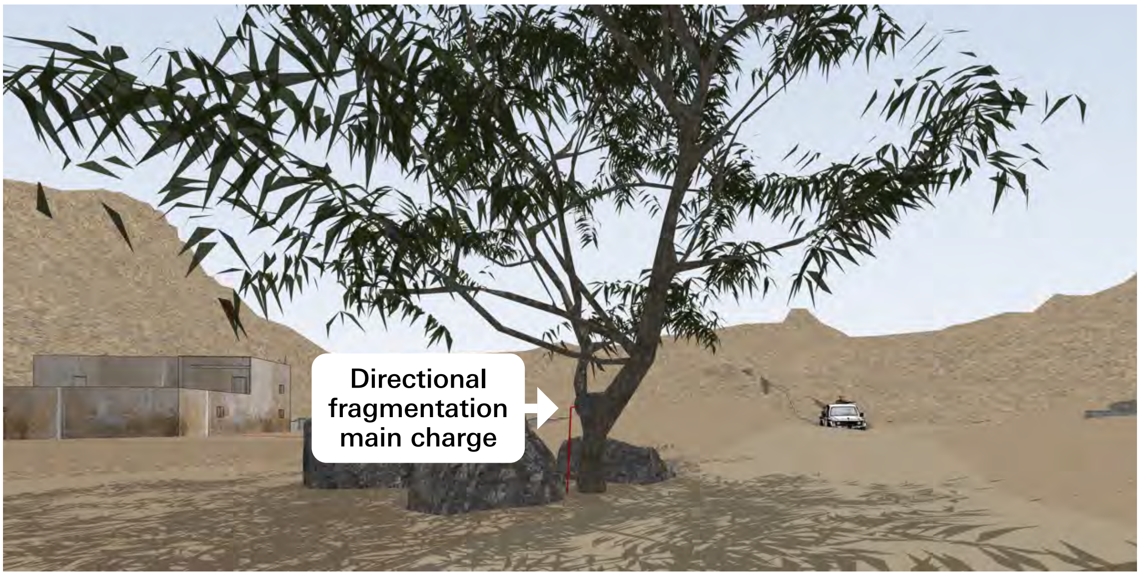

Image 36. Showing how the tree and rock form a slowdown point and aiming marker. The directional fragmentation main charge has also been elevated to cause maximum effect on the approaching target

DISADVANTAGES:

- Restricted to a single firing point.
- The physical link can make a follow-up attack on the firer easier to carry out.
- Can take time to lay the electrical wire, especially if the contact point and firing point are far apart.

3.2.3. COMMAND-PULL IEDs

This type of command IED has a non-electrical string or cord that physically links the firing point and contact point. When the link is pulled a switch is closed and the IED functions. There are many different options for command-pull switches. Some of the most common include:

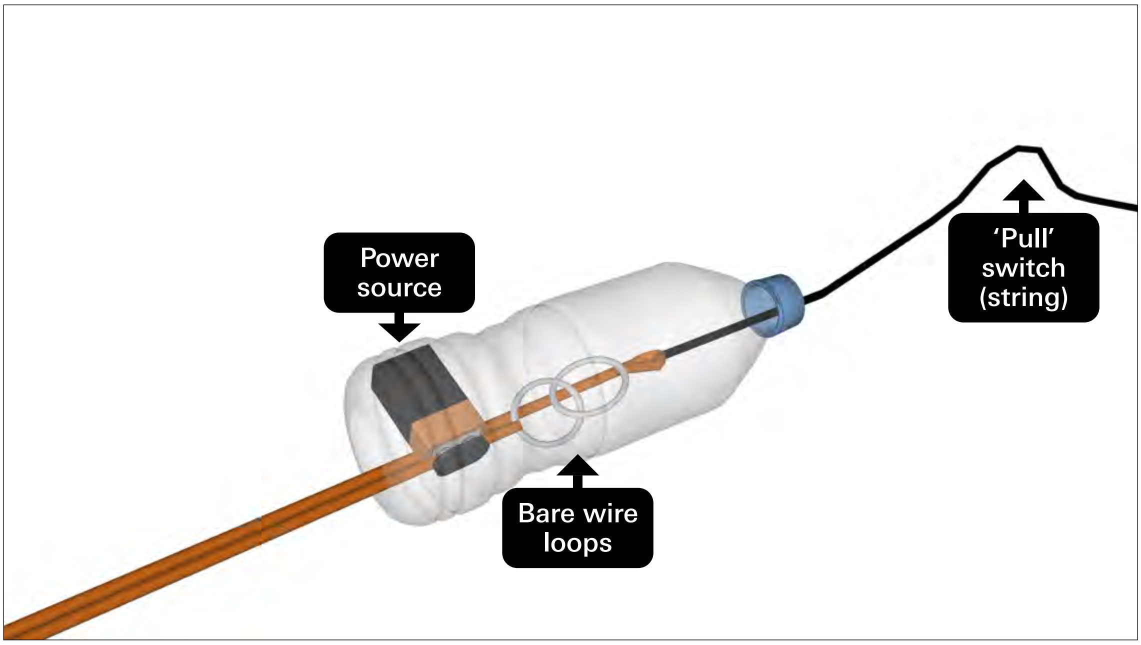

Image 37. An improvised command-pull switch made from two bare wire loops contained in a plastic drinks bottle

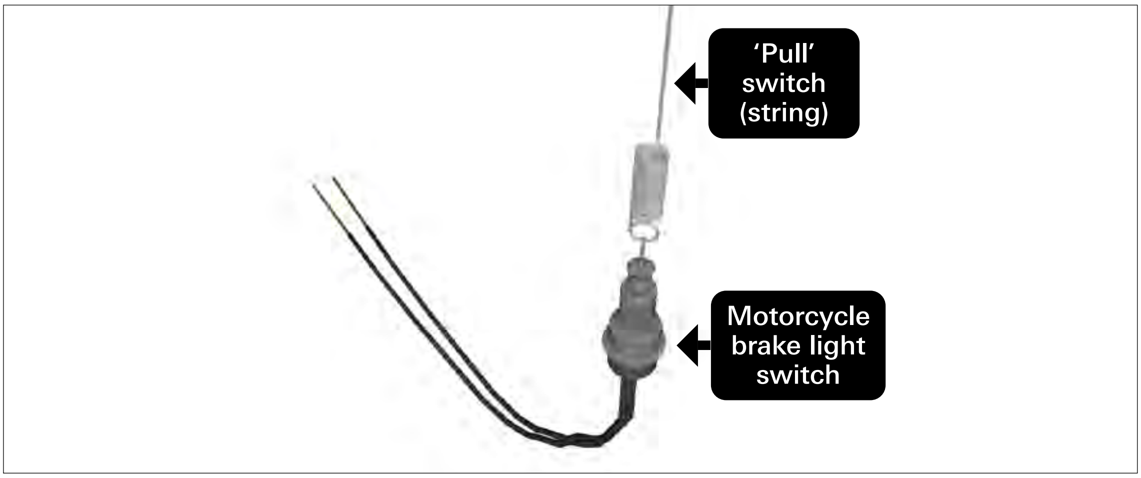

Image 38. A motorcycle brake light switch used as a command-pull switch. This is an example of a repurposed commercial switch used in an IED

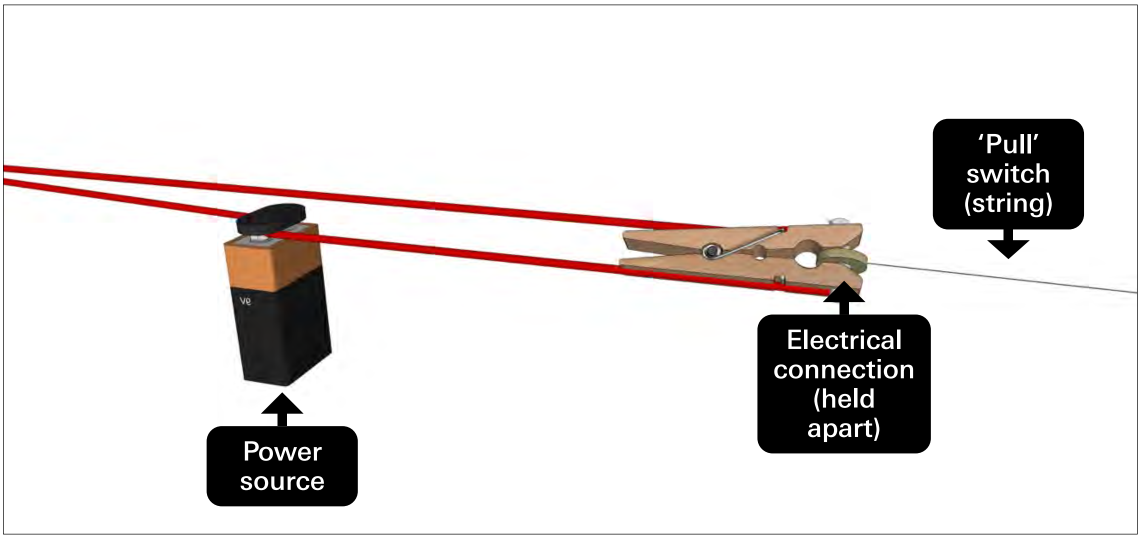

Image 39. A modified clothes peg used as a command-pull switch

WARNING. These same switches could be used in a VOIED (tension) tripwire type IED.

The following advantages and disadvantages of command-pull IEDs are considered in comparison to command-wire IEDs:

ADVANTAGES:

- Less expensive resources are required (string vs wire).
- The pull link can be hastily emplaced on the surface while still remaining difficult to detect.

DISADVANTAGES:

- Can act as a tripwire, significantly increasing the possibility of inadvertent initiation compared with other command IEDs.
- Harder to target fast-moving targets due to the time lag caused when 'taking up slack' in the pull cord.

3.3. VICTIM OPERATED IEDs

Image 40. A surface-laid pressure-activated switch

VOIEDs target victims when they carry out a normally safe act such as walking or opening a door. They can remain concealed for many years after a conflict has ended and can be split into two main subcategories:

- Contact
- Influence

Both of these main subcategories can be further subdivided and the UNMAS IED Lexicon provides a very useful breakdown.

Advantages and disadvantages of VOIEDs, when compared to time and command devices, include:

ADVANTAGES:

- Provide a persistent effect both day and night.
- Can be used effectively against moving targets.
- Can remain viable for many years after they are placed, with no need to observe their location.

DISADVANTAGES:

- Can cause accidental casualties, which can also occur long after the conflict has ended.
- Can reduce the armed group’s own mobility unless they have the ability to arm and disarm the device.
- Can be hazardous to emplace, unless there is a safe-to-arm switch incorporated.

MA organisations most frequently encounter contact VOIEDs which can be broken down as:

- Pressure
- Pressure release
- Tension
- Tension release

3.3.1. PRESSURE

This subcategory of contact VOIED functions when pressure is applied on the firing switch. There are many specific types, but the following two examples show mechanical and electrical firing switch variants.

> **NOTE. Chapter 3 provides further technical details on a number of other variants**

The first example is a pressure-initiated VOIED incorporating a mechanical firing switch. This is an improvised type grenade fuze incorporating a cocked striker. This striker is held back by a wooden matchstick that is intended to snap when weight is applied. To increase the contact area a car bulb cover has been positioned around the switch.

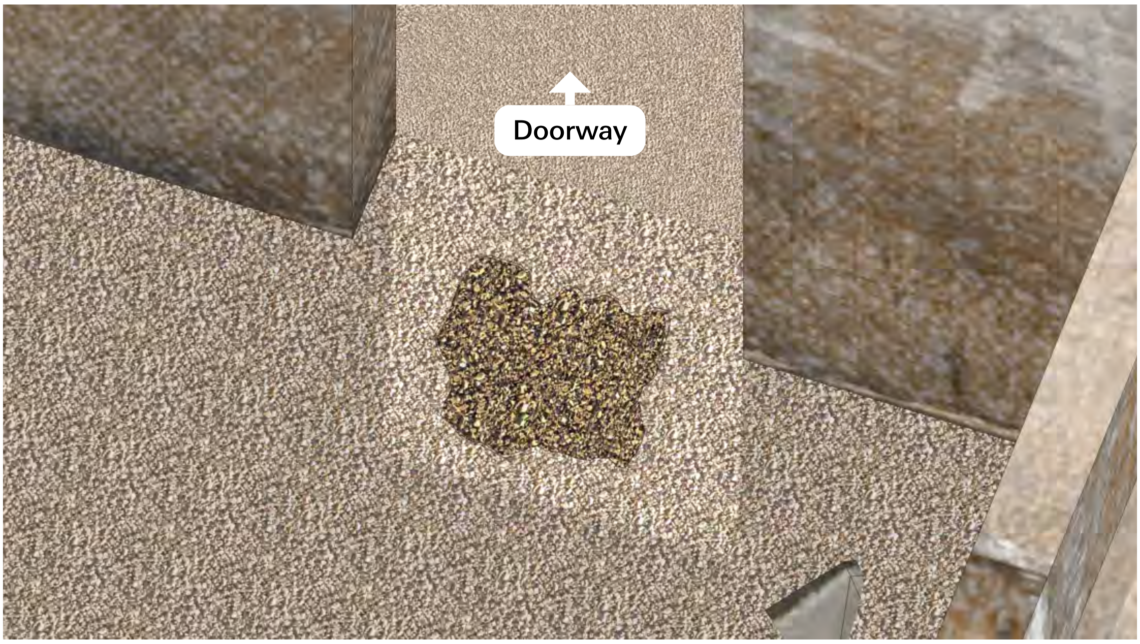

Image 41. Ground sign (disturbance) where a mechanical VOIED (pressure) is located

Image 42. Mechanical VOIED (pressure) in position

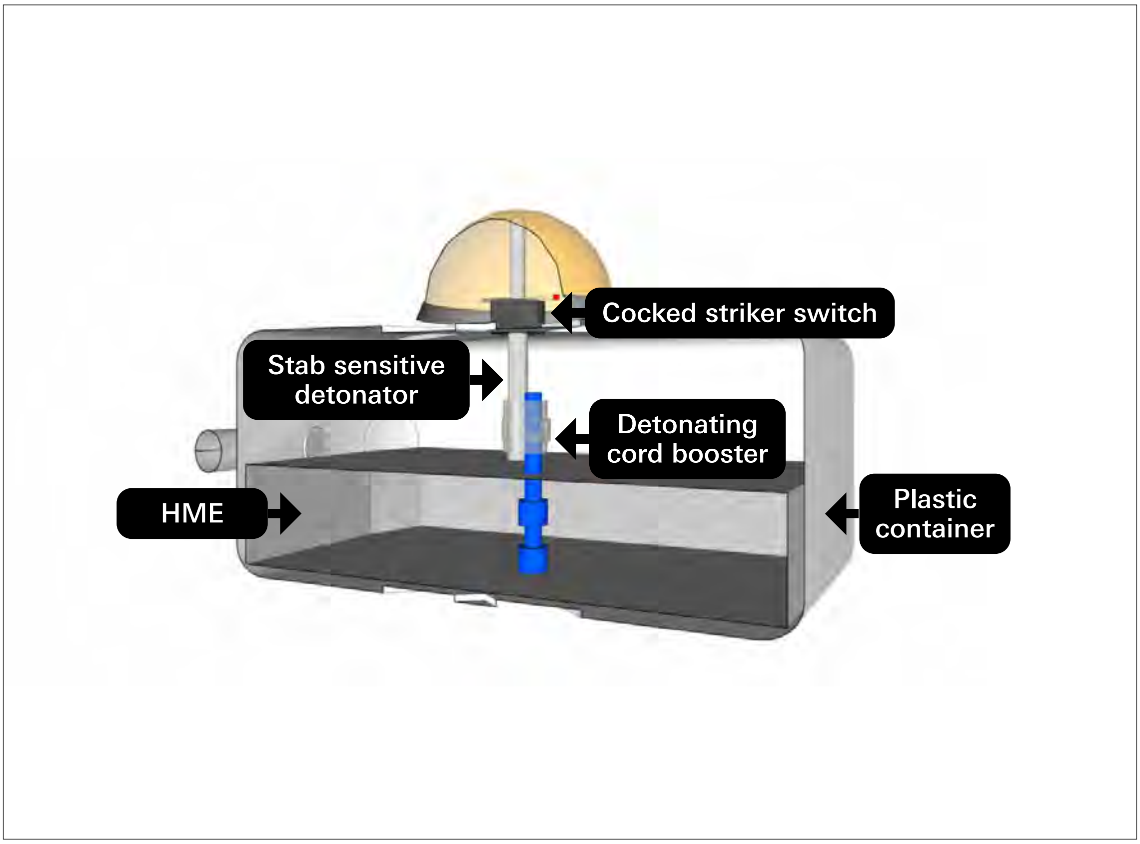

Image 43. VOIED (pressure) consisting of a mechanical cocked striker switch, stab sensitive detonator, detonating cord booster and HME in a plastic container

Pressure plates are an extremely common VOIED switch. In MA they can be divided into high metal content and low metal content (see Chapter 3). Both operate under the same concept of two electrical contacts that are held in an open position. When pressure is applied, these contacts close and the circuit is completed, allowing electrical current to flow in the circuit causing the IED's initiator / detonator(s) to function.

EXAMPLE OF A HIGH METAL CONTENT PRESSURE PLATE

Image 44. A high metal content pressure plate wrapped in rubber tubing to weatherproof the switch

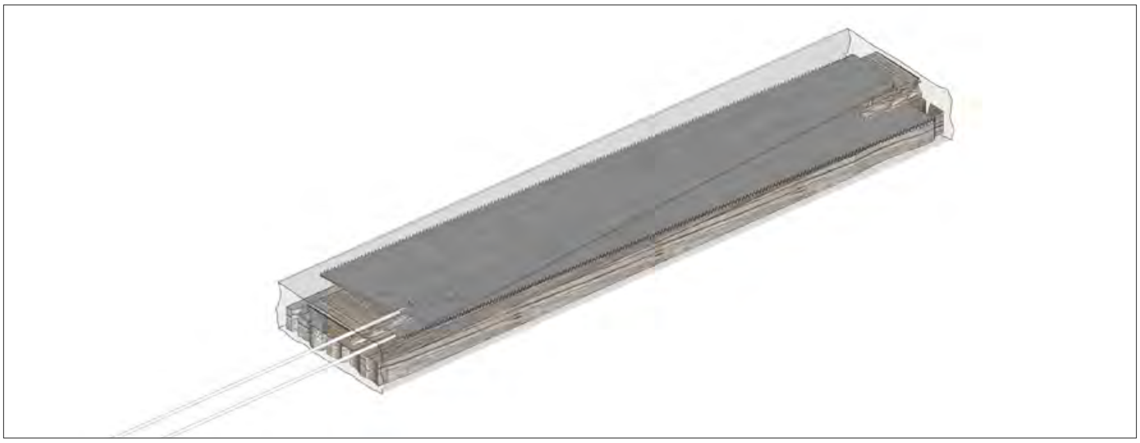

Image 45. View of the two metal saw blades used as electrical contacts

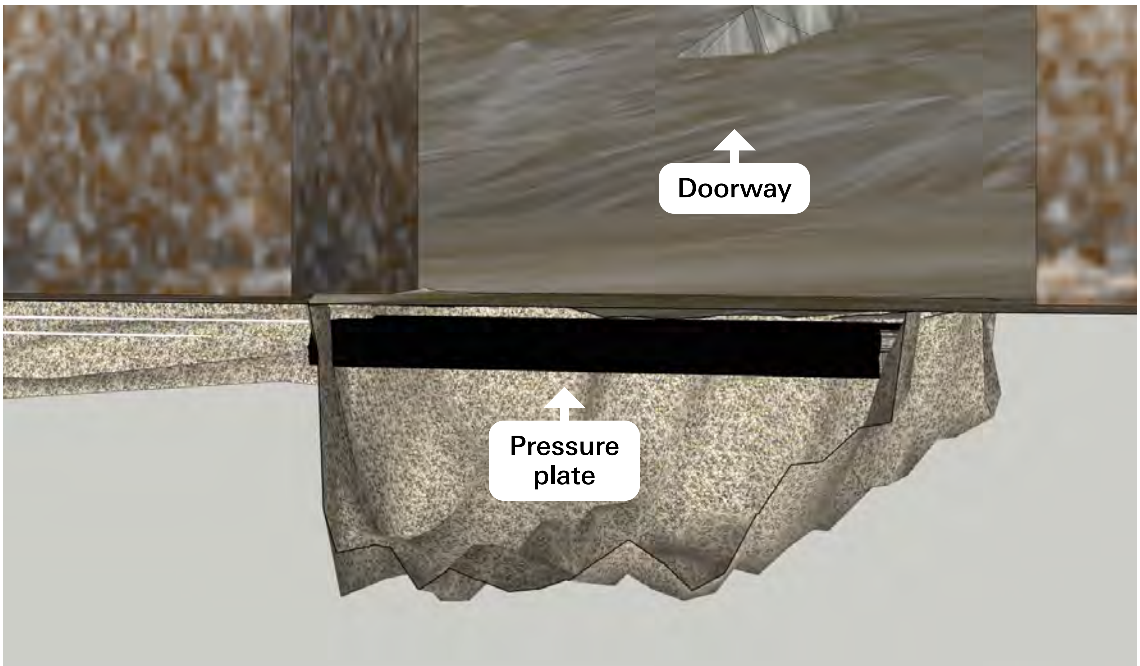

Image 46. View of a pressure plate located in a doorway

3.3.2. PRESSURE RELEASE

Pressure release VOIED switches operate when a weight is removed. This can be to target a victim when they carry out what they believe to be a normally safe act or when IED clearance personnel conduct poor procedures.

In the most basic form, a pressure release switch consists of two electrical contacts held apart by the weight of an object. When the weight is removed, the contacts come together and electricity flows to the detonator.

WARNING. More complex pressure release switches can work when electrical contacts come apart, stopping electrical current flowing in one part of the circuit, which in turn causes it to flow in another part.

Image 47. Weapon used in conjunction with a pressure release switch as an attractive item to pick up

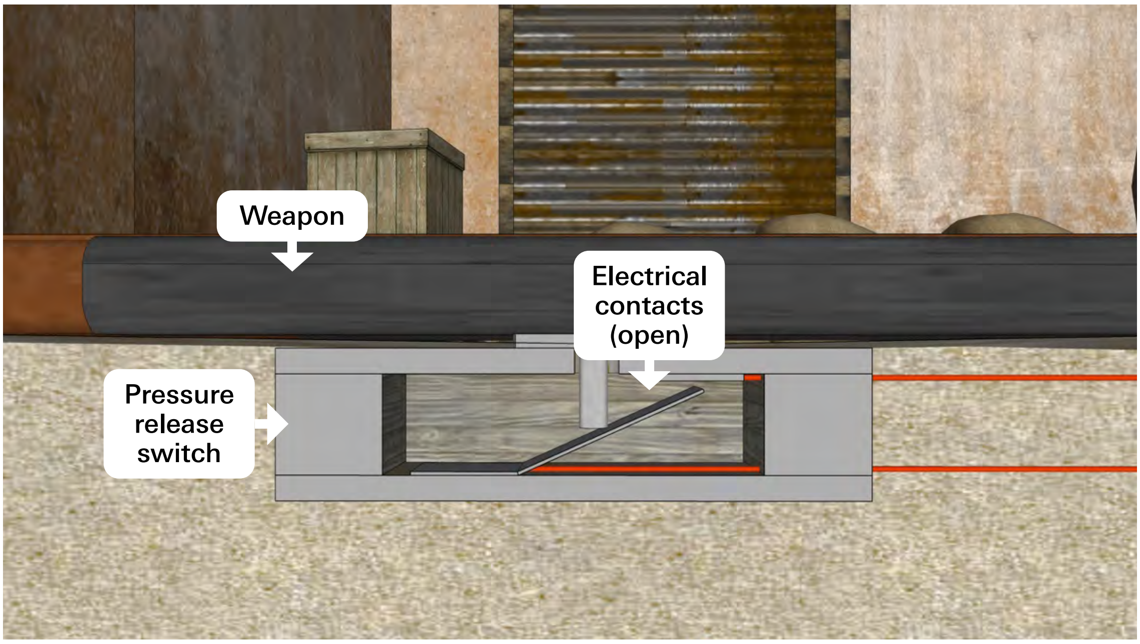

Image 48. A simple pressure release switch located under the weapon. Note that the electrical contacts are open and when the weight of the weapon is removed, they will close

3.3.3. TENSION

Tension VOIEDs are often referred to as pull or tripwire IEDs and work when the victim makes contact with the switch causing tension, normally through a string or wire.

The following example is a mechanical VOIED (tension). The IED is designed to function when a victim moves over a crossing point in a ditch adjacent to a tree line.

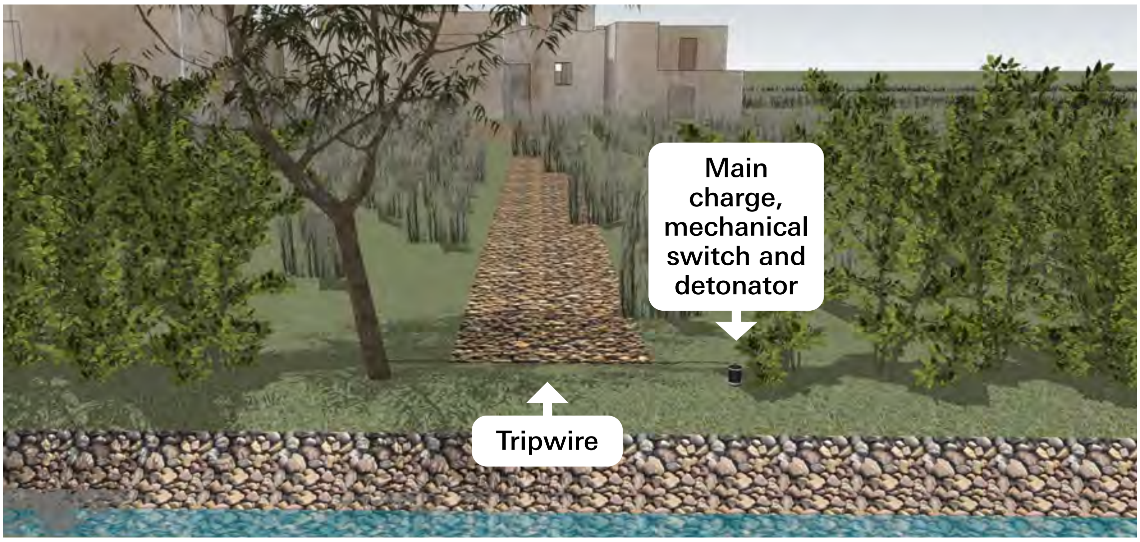

Image 49. A VP created by a crossing point over a ditch

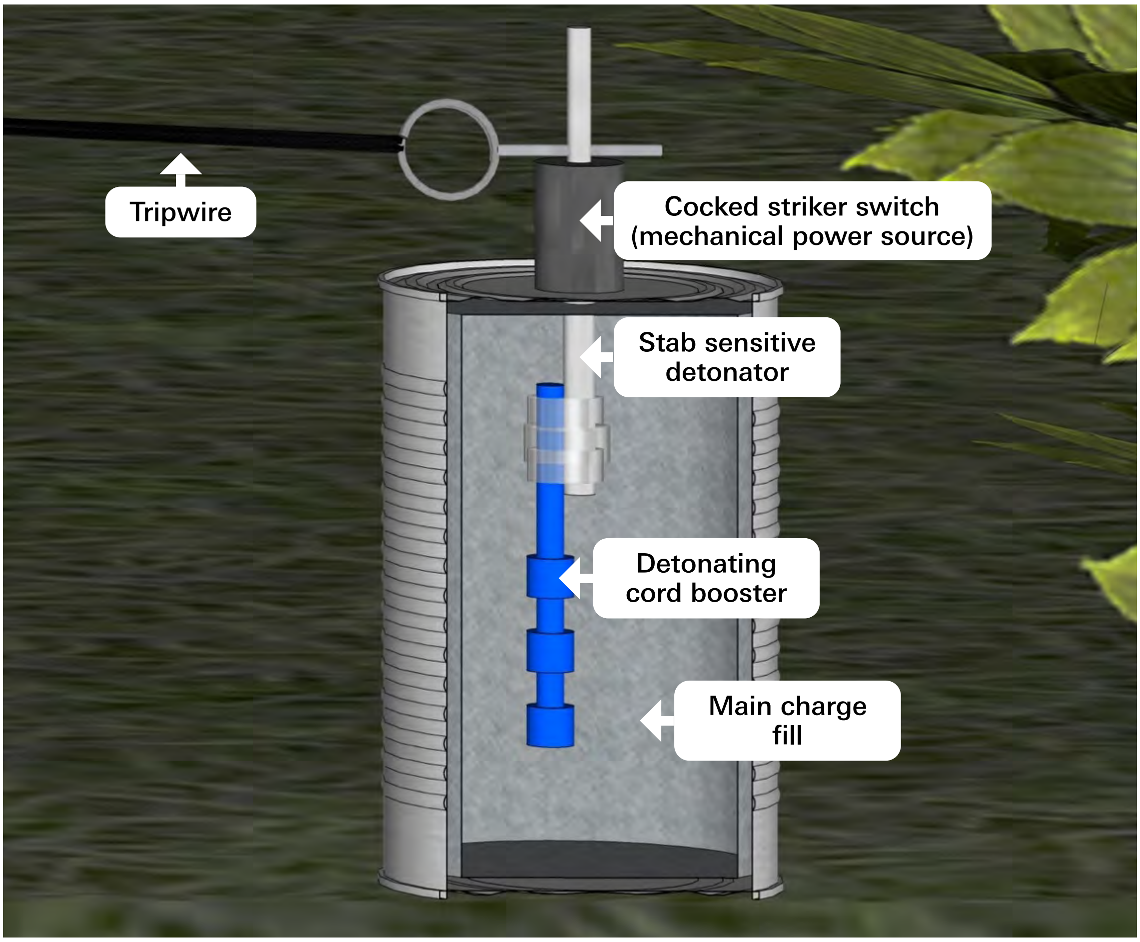

Image 50. VOIED (tension) in detail

3.4. VEHICLE-BORNE IEDs

Vehicle-borne IEDs use the mobility of a vehicle to the advantage of an armed group. They can utilise a range of vehicles from motorcycles and cars, to vans and trucks. They can be initiated by time, command or even VO switches. The VO switch is more often used as a secondary 'protection' switch, rather than the primary means of initiation.

The following example is a VBIED initiated by radio control (RC).

Image 51. An abandoned RC-initiated VBIED

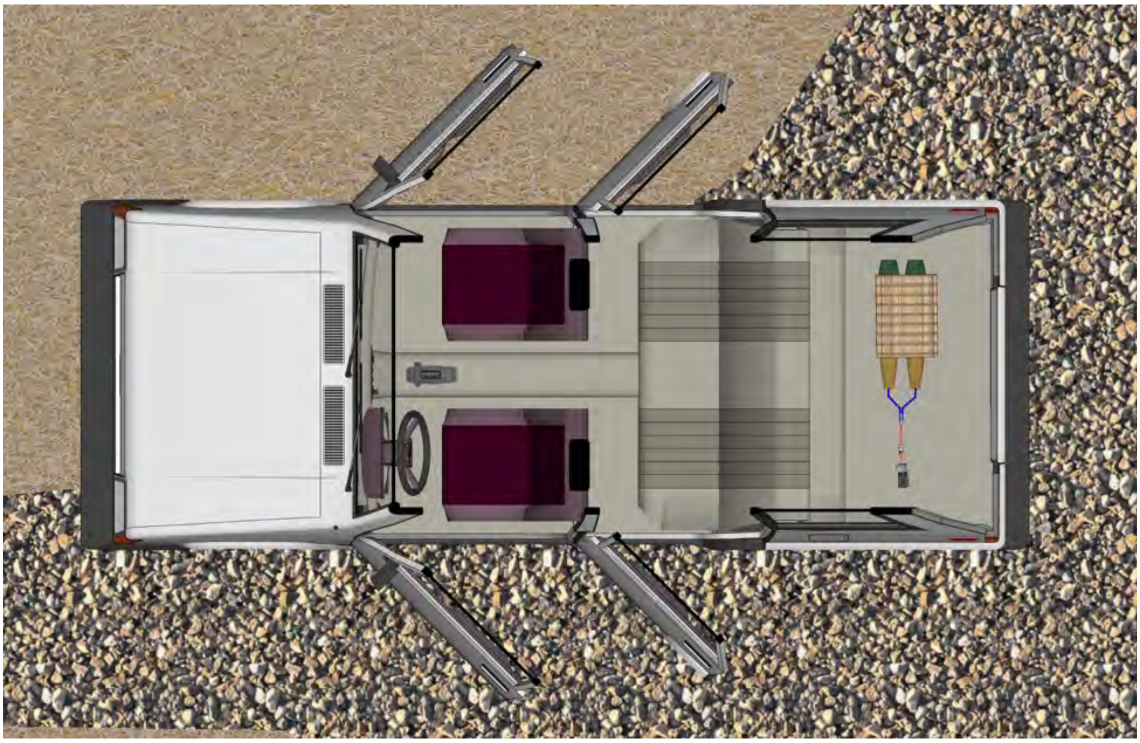

Image 52. The main charge (2 x 105 mm high explosive (HE) projectiles) co-located with the RC receiver (mobile phone), power source and detonator in the vehicle's main load carrying area

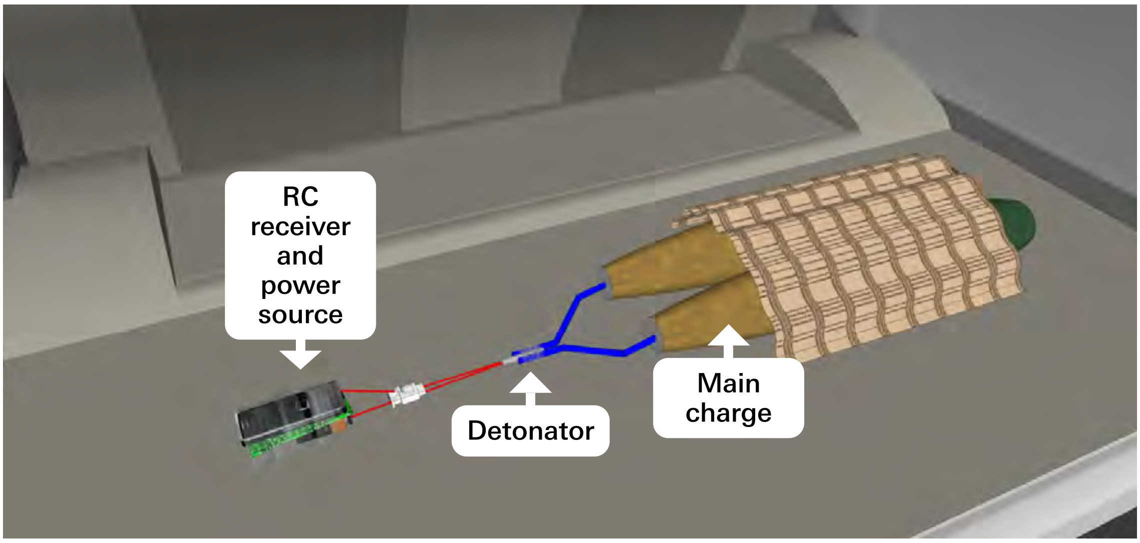

Image 53. Showing the RC-initiated VBIED's components in detail

The following example is a VBIED initiated by a modified mechanical timer.

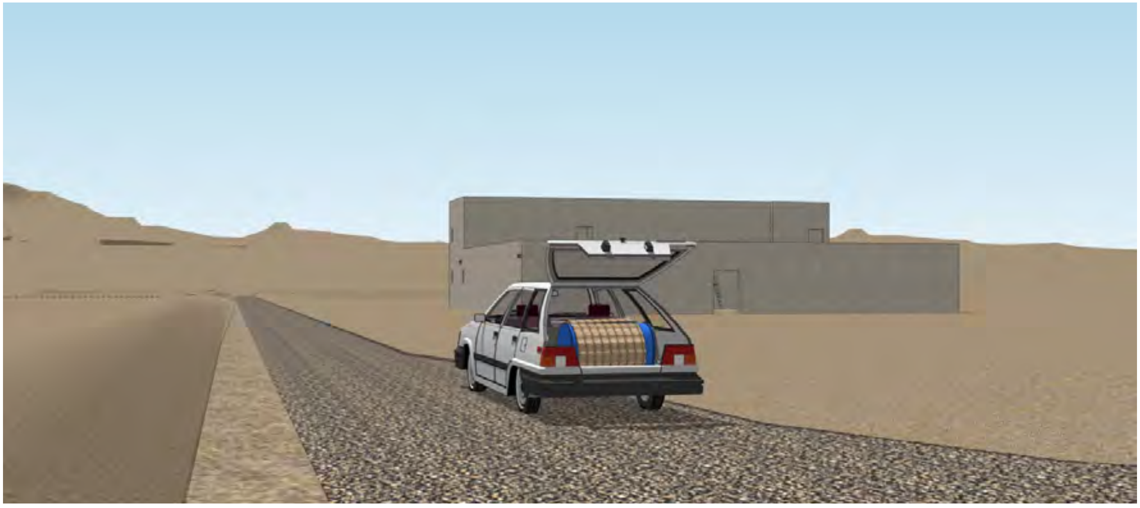

Image 54. An abandoned failed time-initiated VBIED

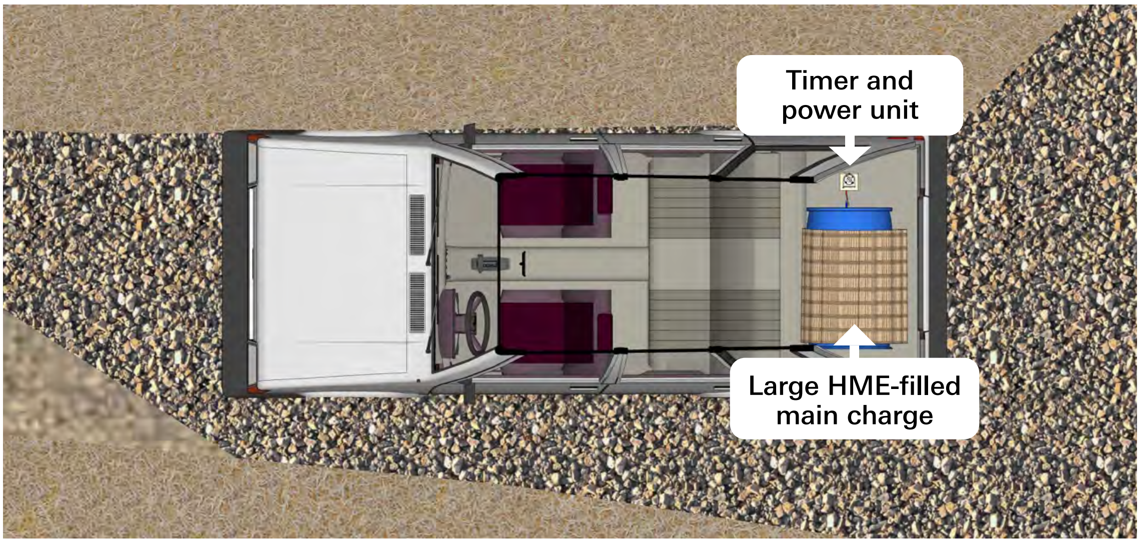

Image 55. The layout of the VBIED's components

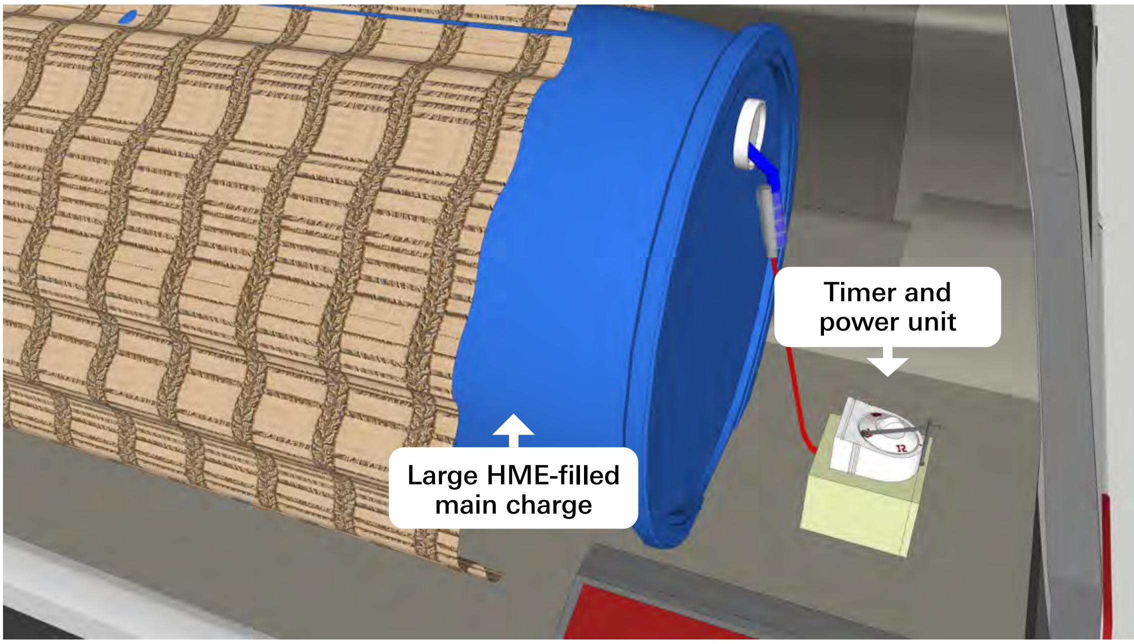

Image 56. The timer and power unit connected to an electrical detonator which in turn is attached to a blue detonating cord. This is the booster for the large HME-filled main charge

3.5. PROJECTED OR DROPPED IEDs

Projected IEDs are regularly encountered by MA organisations. They can often be categorised in a similar manner to conventional ordnance as projected (mortars and rockets) or dropped (most regularly from UAVs).

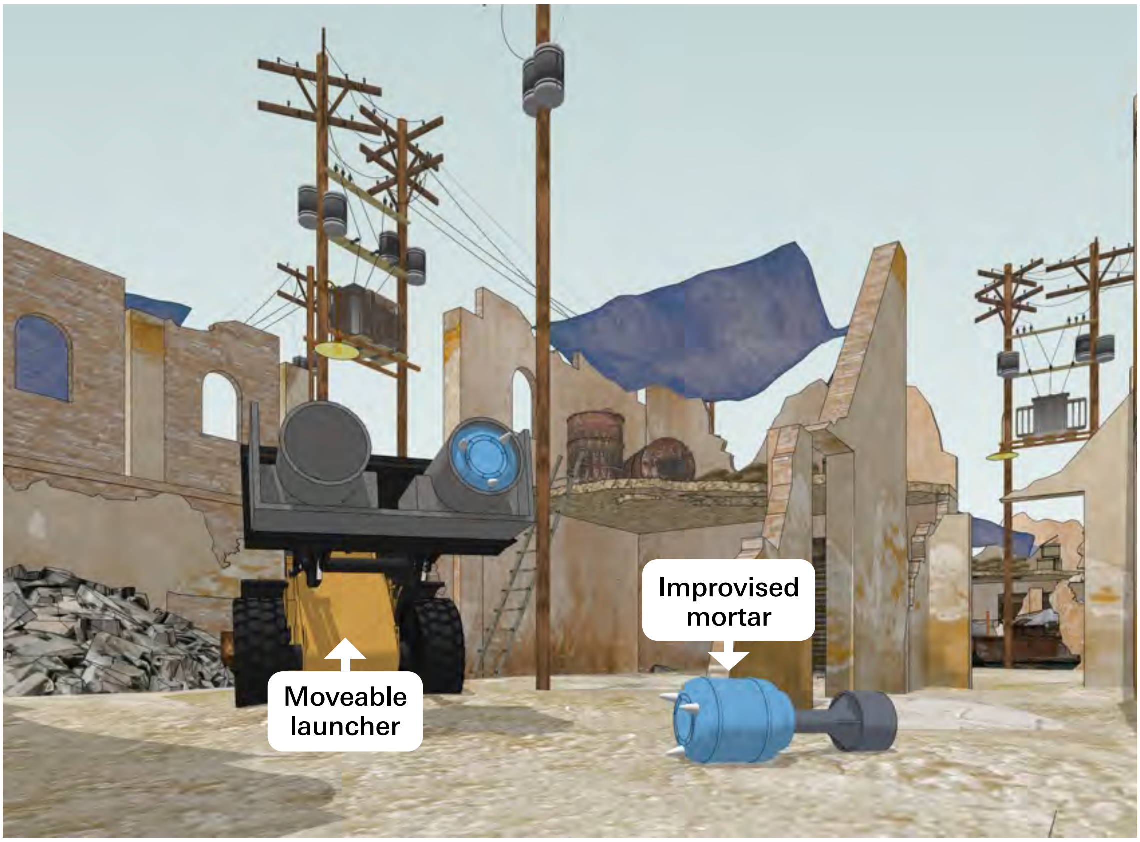

Image 57. Improvised mortar with modified plant machinery used as a moveable launcher

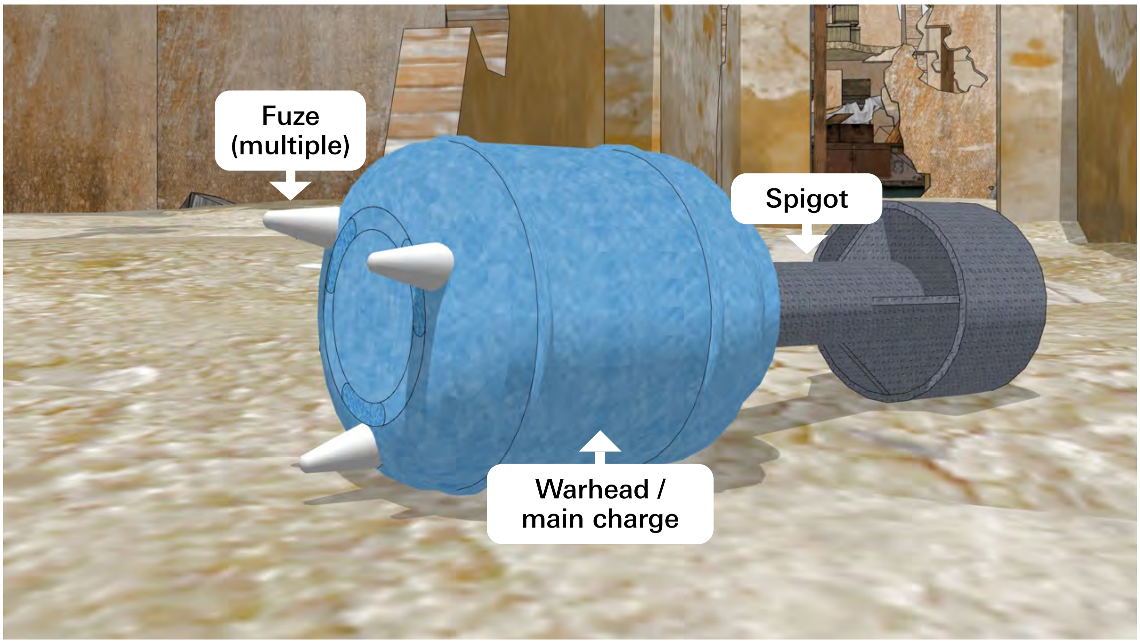

Image 58. An example of an improvised mortar

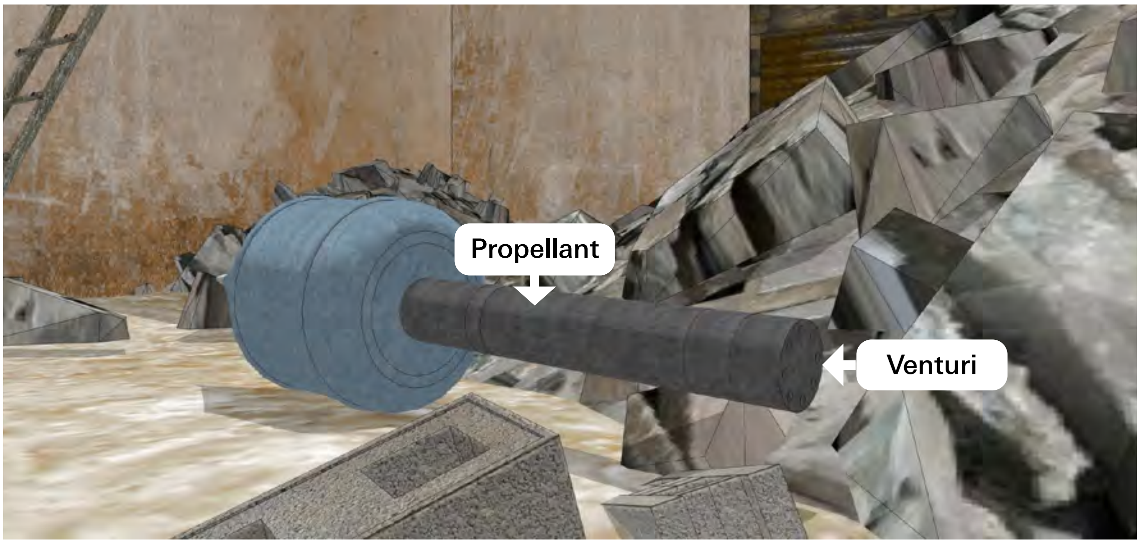

Image 59. An improvised rocket

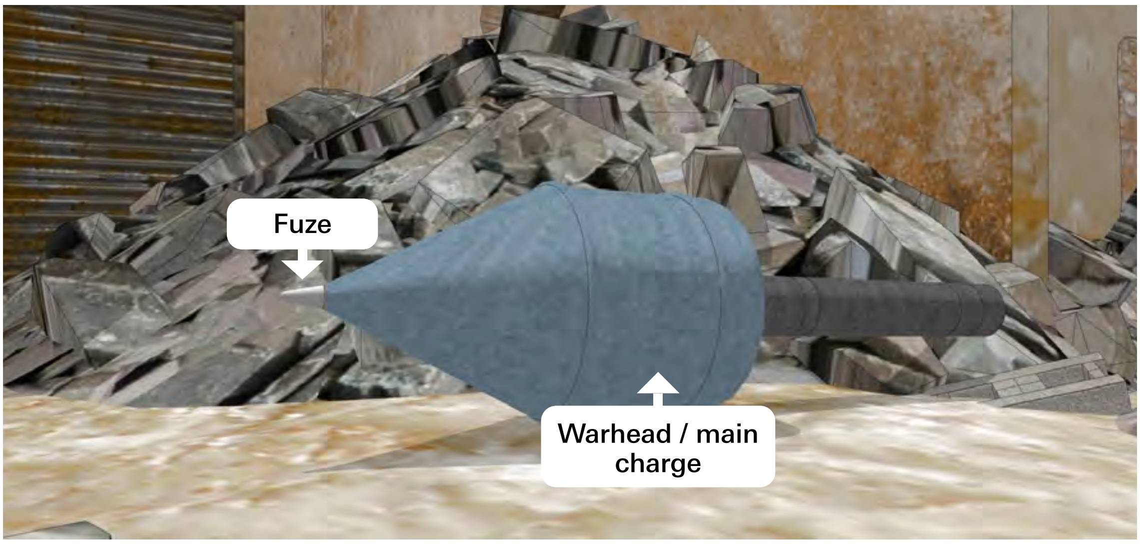

Image 60. An example of an improvised rocket

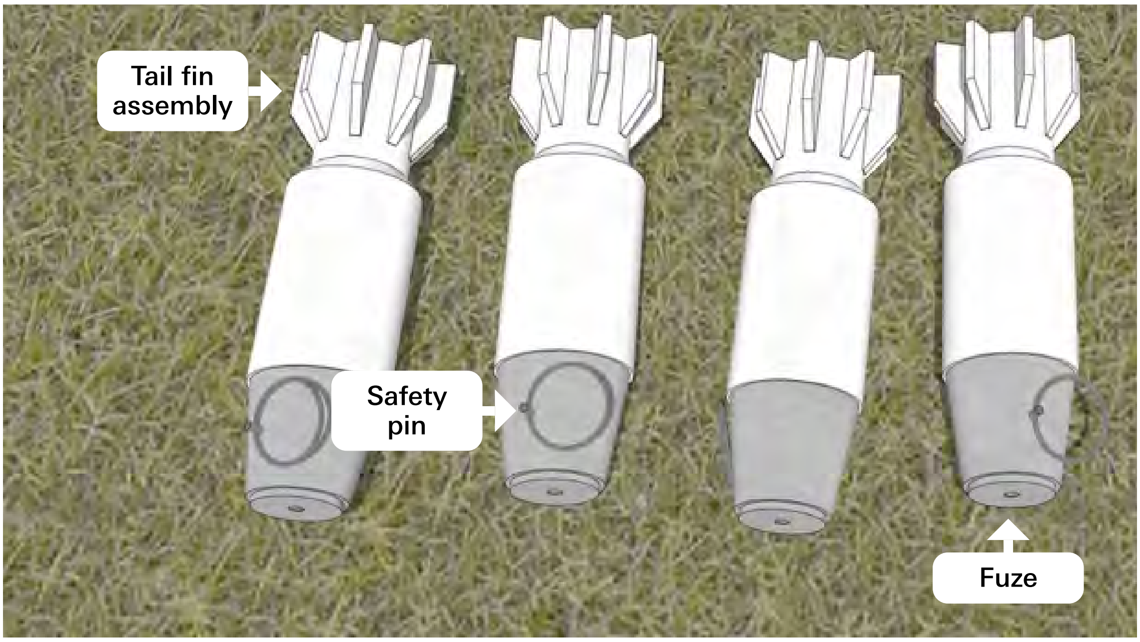

Image 61. Multiple UAV-dropped IEDs

3.6. SCENARIO EXAMPLES

3.6.1. SCENARIO 1 – TIME IED TARGETING A HOSPITAL

Image 62. Hospital containing IED contamination

SURVEY INFORMATION

The community reported to MA community liaison officers that a hospital contained a suspected IED. An MA organisation was then tasked and a survey team visited the hospital to gather information. The MA staff conducted a number of interviews, including with the hospital's lead caretaker who showed them images on his mobile phone of an IED located adjacent to a critical pillar inside a main hospital building. It was reported that the caretaker's staff had entered the hospital through all primary entrance points and had walked within all the interior rooms. They have even started to refurbish part of the building but are extremely worried about the suspicious object which they have avoided and not touched. The community want to have the hospital providing critical care which is much needed in the current post-conflict environment.

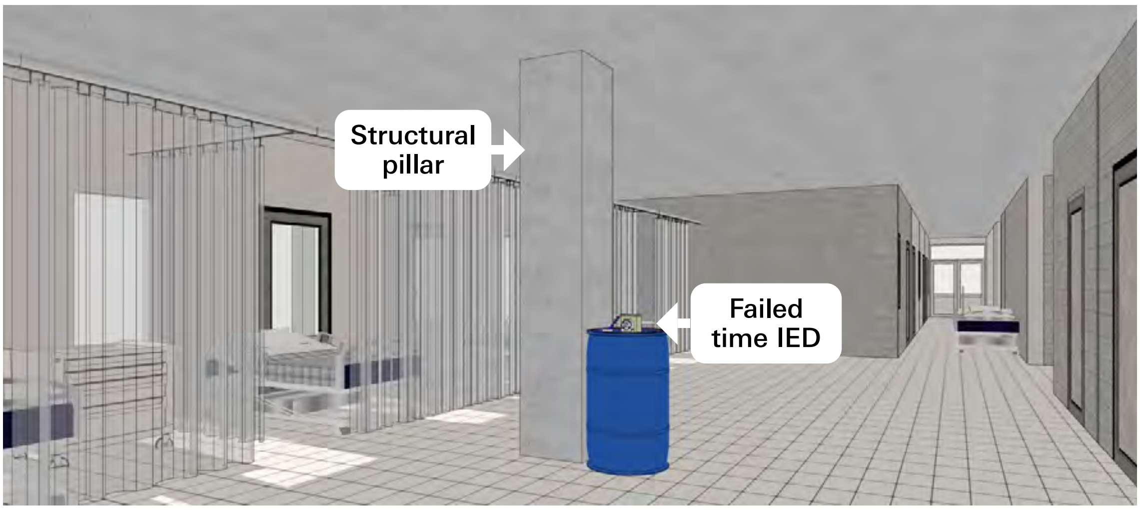

Image 63. Failed time IED placed to destroy critical infrastructure (hospital)

The intent of the armed group that placed this IED was to destroy critical infrastructure prior to their withdrawal. Their aim was to degrade the ability of the government to provide key services to the community, such as healthcare. This in turn would degrade the community's confidence in the government and encourage discontent, promoting conditions for armed conflict to return in the future.

CAPABILITY

The armed group has a wide range of IED capabilities, including mechanical, electronic and igniferous time-initiated devices. The photograph provided by the caretaker indicates that the armed group has selected a mechanical switch (cooking timer) that has been modified by attaching two metal nails as electrical contacts. The main charge contains approximately 200 kg of HME.

In addition, the armed group has a wide range of VOIEDs, although sensors such as PIRs have not been encountered.

OPPORTUNITY

The armed group has an understanding of structural engineering and construction methods. They have identified a crucial structural pillar inside the hospital that, if destroyed, would result in large-scale structural failure of the facility. They have selected a blast-effect main charge that will strip the concrete from the reinforcing bars inside the pillar, causing collapse.

THREAT SUMMARY

Probable failed mechanical time IED placed to destroy critical infrastructure. Possible anti-lift and secondary VOIEDs cannot be discounted but there is no direct evidence at this stage that anti-lift is present. Further IEDs are also assessed as unlikely due to the extensive activities of the hospital staff inside the building.

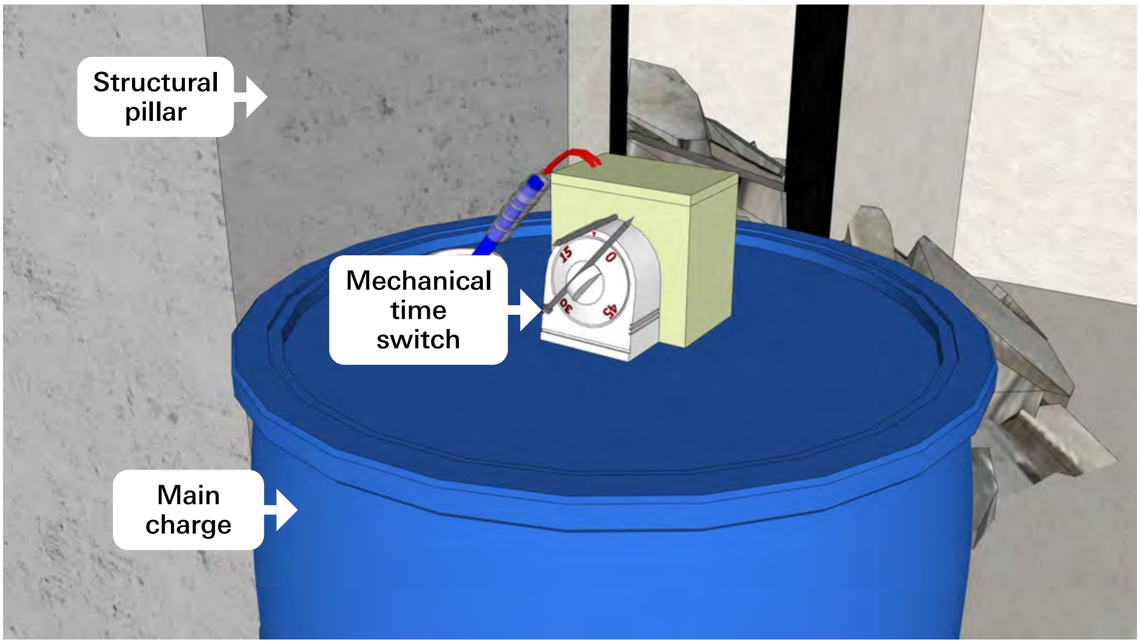

Image 64. Failed mechanical time IED adjacent to a structural pillar inside a hospital

3.6.2. SCENARIO 2 – MULTI-SWITCH VOIED TARGETING IED CLEARANCE

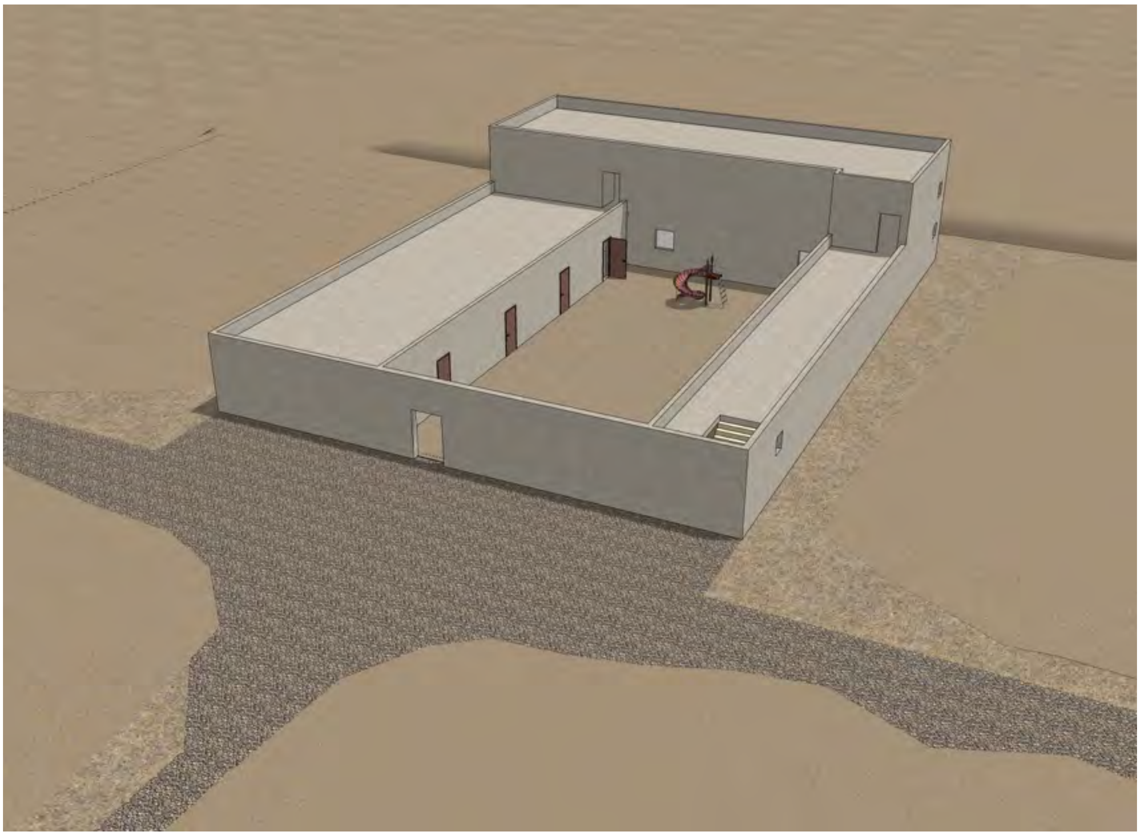

Image 65. A school contaminated with IEDs

SURVEY INFORMATION

An MA organisation conducted a survey of a school which an NSAG had used as a prison. A number of accidents had been reported by the local community, who had been trying to rehabilitate the school to enable it to be reopened.

When the survey team arrived at the school they were met by the school's principal, who informed them that they had remained in the area throughout the conflict. They knew that the NSAG had used IEDs to help defend key locations from opposing forces of a state armed group. The NSAG even reported to the community prior to their withdrawal from the area that only if they were able to return could the school be cleared of IEDs. They stated that they had made it impossible for anyone else to remove the IEDs without being killed.

The school's principal reported that one of the teachers had observed a suspicious object in the entrance to the main school building. They had been taken to this point by local police who told them to go no further. The survey team use a UAV to remotely observe the suspect object.

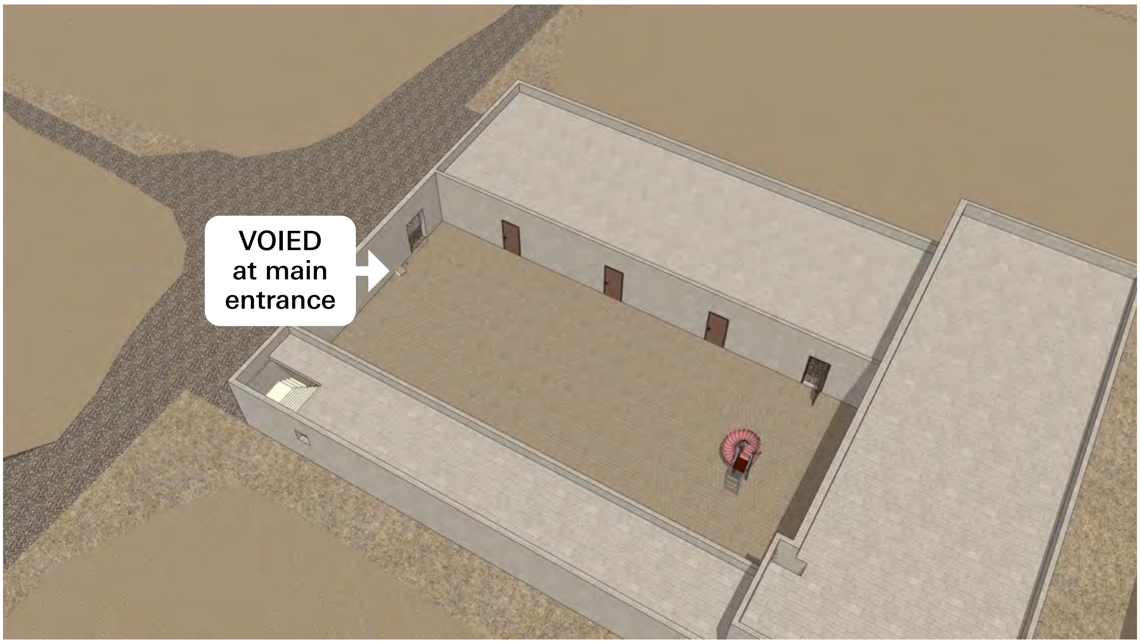

Image 66. VOIED at the main entrance observed by a UAV

The conflict in this area ended 12 months previously and since this time no new contamination has been placed or dropped.

INTENT

The assessed intent of the NSAG was to defend the school from attack and, in the event of a withdrawal, to prevent its clearance and rehabilitation.

CAPABILITY

The NSAG had access to a full spectrum of IED capabilities: time, command and VO IEDs. The NSAG would often use time-initiated demolition charges to destroy critical infrastructure. These would generally be large main charges placed near to supporting columns or beams and, due to their size, easily visible through windows and doorways.

If they intended to defend a location, they would then place command and VOIEDs at vulnerable access points. Command IEDs would normally be at specific locations where the NSAG wanted to maintain regular access themselves. VOIEDs would often be used on a larger scale when they were placed to deny potential approach routes, as opposed to inside or close to buildings where they would be used in a specific manner. To impede clearance, the NSAG would use IEDs that targeted observed vulnerabilities in the techniques and procedures used by the opposing armed group.

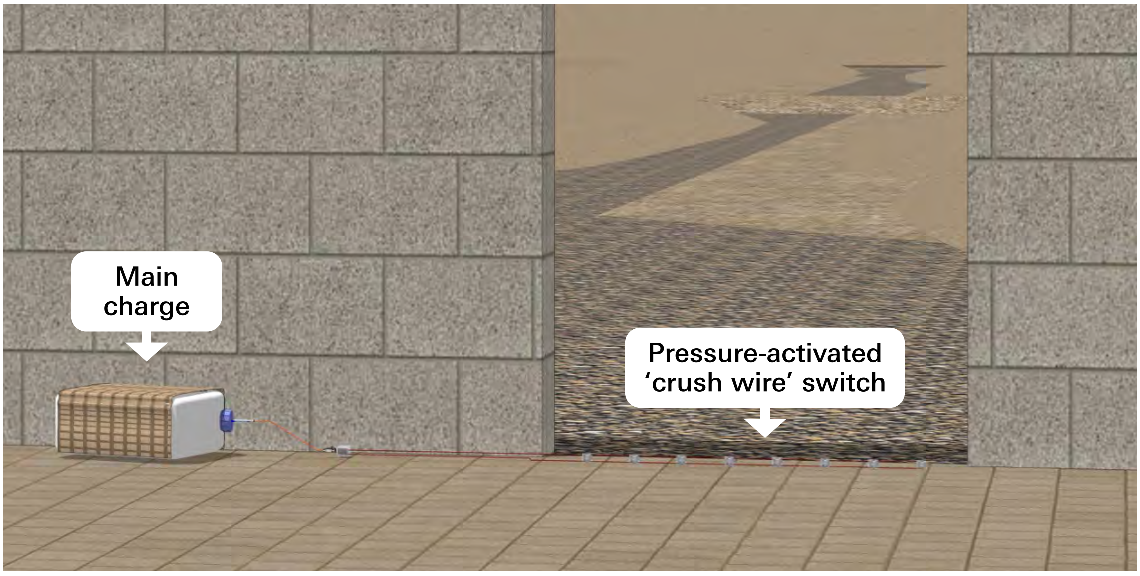

Image 67. VOIED observed by the UAV in the doorway

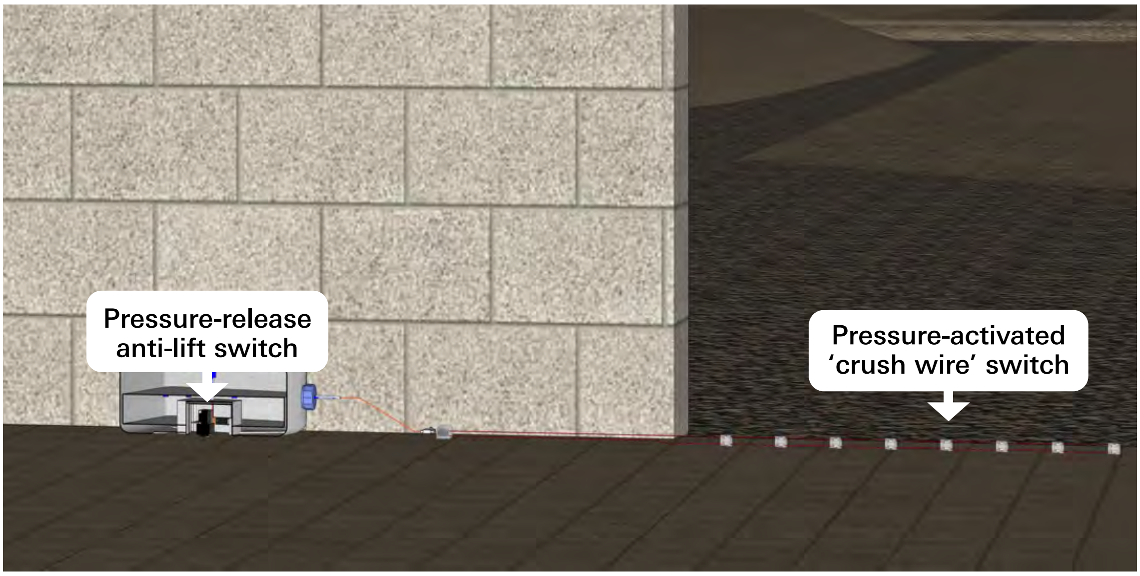

Image 68. Multi-switch VOIED with pressure-activated 'crush wire' and pressure-release anti-lift switch

OPPORTUNITY

The NSAG was aware that after their withdrawal the community would seek to rehabilitate the school in order to facilitate its use. If they could not achieve this due to the inability of the government to clear the IED contamination, then this would discredit the government, show them as weak and potentially support the case for the return of the NSAG. The state armed group had poor IEDD training and lacked equipment. This meant that they would 'deal' with IEDs manually.

THREAT SUMMARY

VOIEDs have probably been placed at numerous points throughout the school complex. In open areas these are likely to be subsurface high metal content pressure plates, with a main charge of up to 10 kg of HME in a plastic container located directly under the pressure plate.

On hardstanding paths and inside buildings the majority of the VOIEDs are probably crush wires, although tension (pull) switches may be encountered. This may include 'come on' scenarios deliberately targeting patterns that have been observed of clearance personnel by the opposing armed groups.

Command IEDs, either command wire or RC, are possibly located at the two main entry points. Failed time IEDs are assessed as unlikely as they would have probably been observed by the caretaker or the UAV.

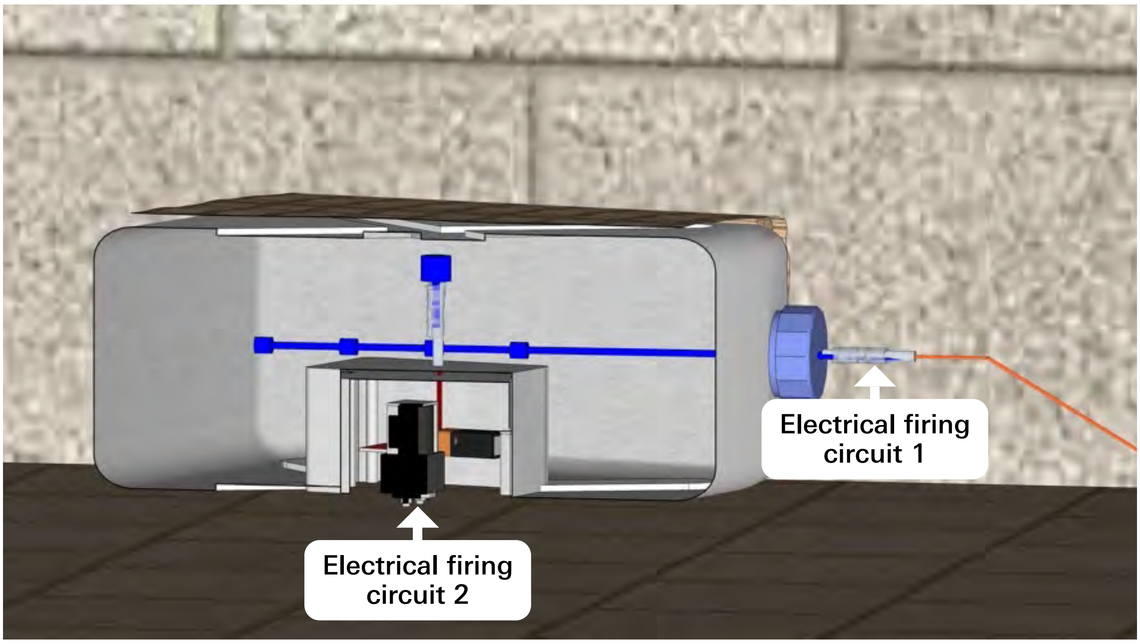

Image 69. A VOIED with two independent electrical firing circuits and explosive chains

3.6.3. SCENARIO 3 – LOW METAL CONTENT PRESSURE PLATES

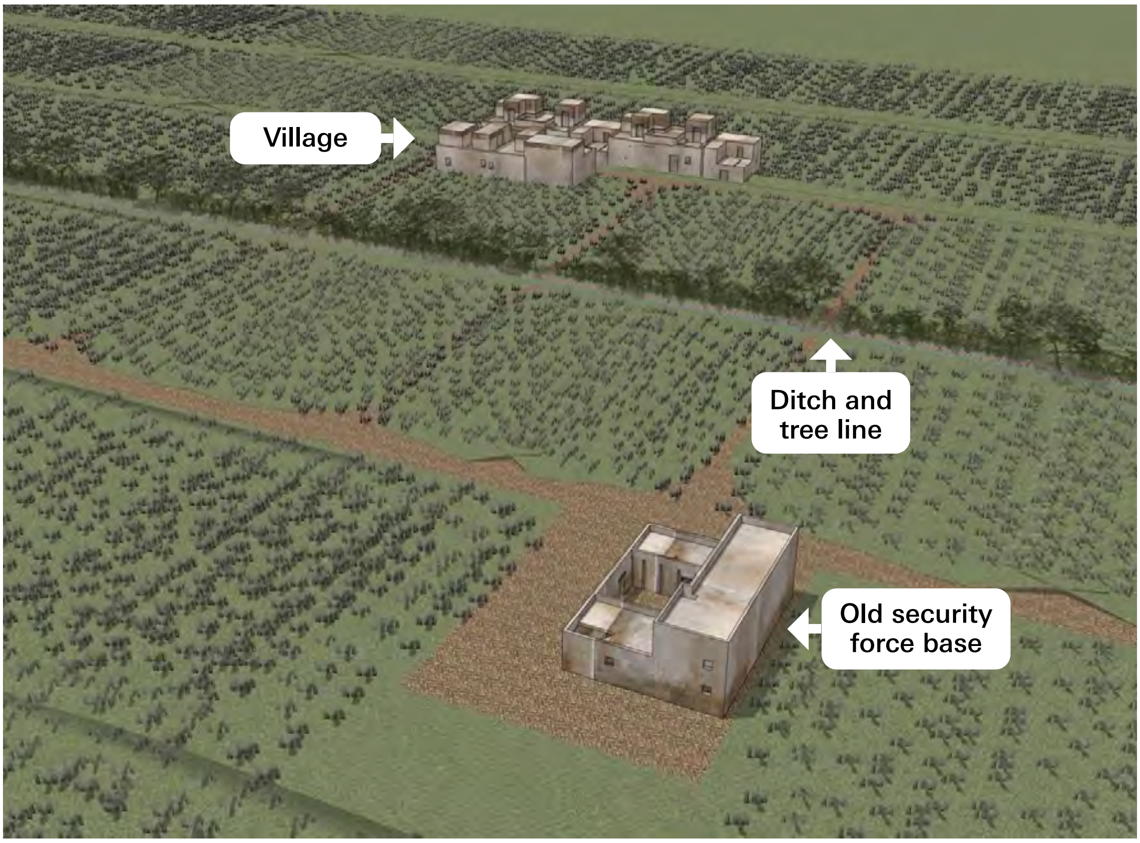

Image 70. An old security force base separated from the village by a ditch and a tree line

SURVEY INFORMATION

A tree line located near an old state armed group's (police) patrol base was reported by the community to contain IEDs. It was believed that the IEDs were placed by an NSAG to deny freedom of movement of foot patrols by the police when the conflict was active.

The MA survey team visited the community to gather information related to IED contamination. The community reported that they were able to use all buildings, routes and farmland in their area except a 100 m section of ditch / tree line. They reported that approximately 60 days previously an explosion occurred, killing one child and injuring a second. They showed the survey staff photographs of the deceased child and the injuries were consistent with 3–5 kg of HME functioning directly underneath the child's legs. The injured child suffered secondary fragmentation injuries from stones projected when the explosion occurred. No primary metal fragmentation was reported.

The conflict in this area ended six months previously and since this time no new contamination has been placed or dropped.

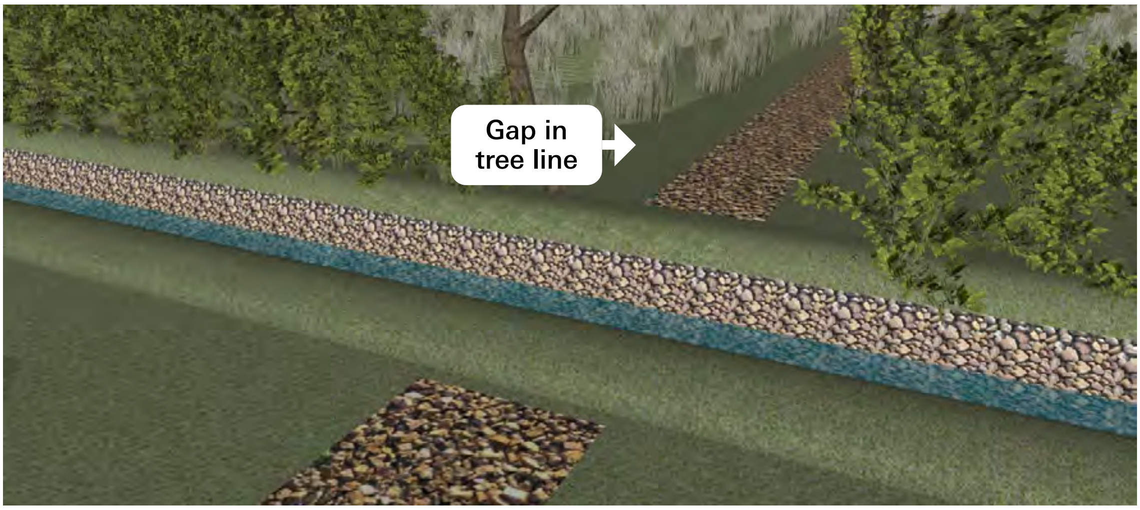

Image 71. A VP created by a possible crossing point and gap in the tree line

INTENT

When the conflict was active in the area, the NSAG sought to reduce the freedom of movement of the state armed group operating out of the patrol base.

CAPABILITY

The NSAG had access to command IEDs and VOIEDs. Command IEDs predominantly used directional fragmentation charges to target unarmoured vehicles or police foot patrols setting patterns on routes.

The NSAG's predominant VOIED switches were low metal content, carbon rod or bare wire pressure plates located directly above a plastic-cased main charge containing 3–5 kg of HME to target people on foot. The battery was normally located 3–4 m from the pressure plate / main charge.

OPPORTUNITY

The state armed group predominantly operated on foot and tried to avoid setting patterns. They did not follow tracks or paths unless absolutely necessary. If it was necessary to cross through a VP, then that VP would be searched using a metal detector. The tree line adjacent to the ditch restricted the number of crossing points and also made it difficult to search effectively.

THREAT SUMMARY

Low metal content PPIEDs are probably located in the gaps in the tree line which could have been used by the state armed group as crossing points. The main charge is probably 3–5 kg of HME in a plastic container located directly underneath the pressure plate. The batteries have probably been placed 2–3 m away from the anticipated direction of approach to make detection with a metal detector problematic.

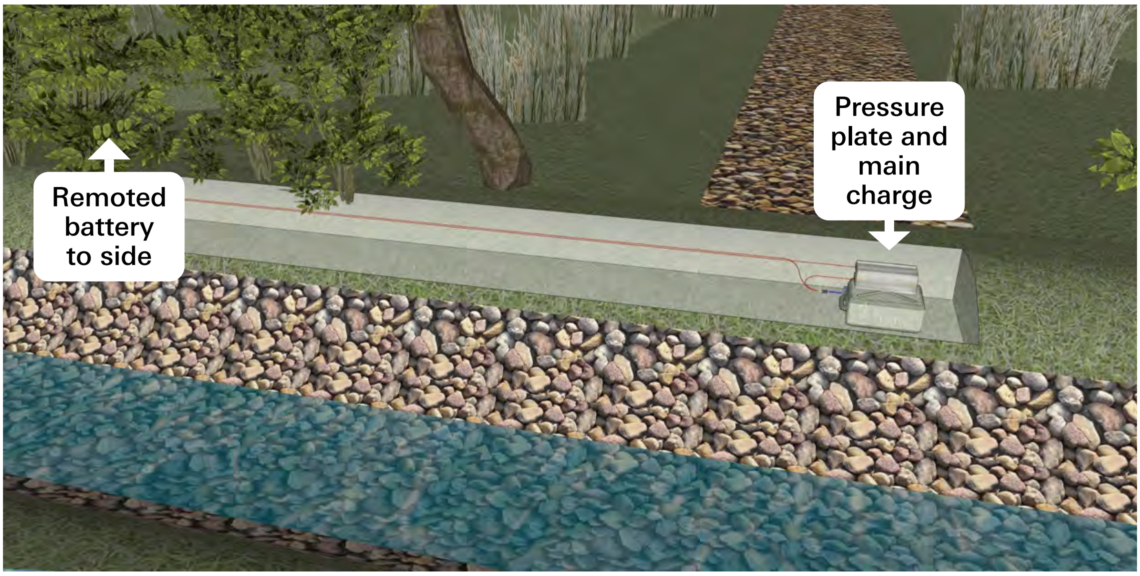

Image 72. The VOIED with the low metal content pressure plate and plastic main charge in the opening, with the remoted battery to one side

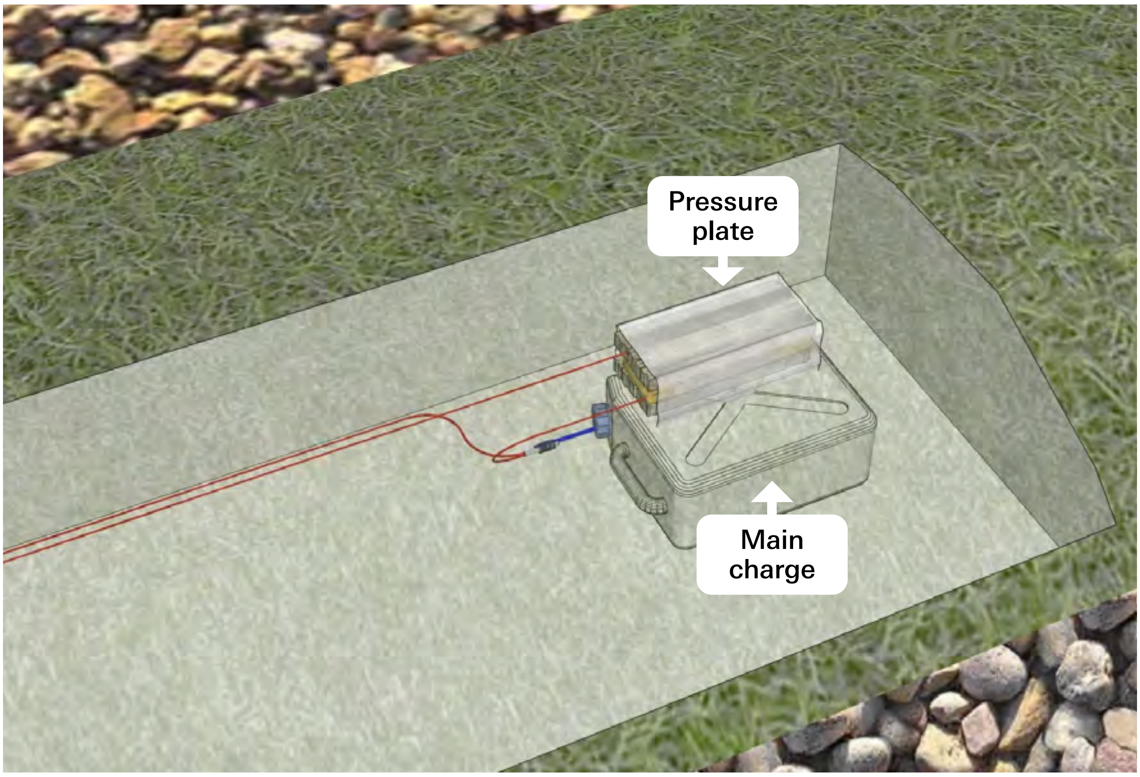

Image 73. The main charge and pressure plate stacked on top of each other in the centre of the opening in the tree line

3.6.4. SCENARIO 4 – COMMAND-WIRE IED (DAISY CHAIN) TARGETING A ROUTE

Image 74. Showing the contact point (track junction) and firing point (tree on high ground)

SURVEY INFORMATION

A rural community identified a suspect object near the primary junction at the entrance to their village. Having previously received risk education they believed it may be an IED.

A survey team visited the community and a 3 m section of wire was reported running along a ditch perpendicular to the main track junction. The junction had been continually used by the community over the last 12 months with no accidents.

It was reported that during the conflict a state armed group would patrol the village once a week. They would travel to the village in three lightly armed vehicles, which would halt at the main crossroads to allow troops to dismount and then progress into the village on foot. The community reported that the track had 'sunk' in three locations where vehicles from a state armed group would normally have stopped. These areas were now collecting water and this had not happened previously.

Prior to the cessation of hostilities, the community believe that the NSAG had been planning a spectacular attack. However, the community reported that an air strike was conducted by the government on the main NSAG operating base in the area, killing the vast majority of their fighters.

INTENT

The intent of the NSAG was to target the state armed group as they patrolled the village. They did not want to cause inadvertent casualties, either of their own forces or of the local community.

CAPABILITY

The NSAG had access to high metal content pressure plates with HME-filled metal cased main charges or HE abandoned explosive ordnance (AXO) / unexploded ordnance (UXO) that they had sourced. They also had command wires up to 200 m long utilising the same types of main charges. As the state armed group had effective electronic counter-measures (ECM) the NSAG rarely used RCIEDs.

OPPORTUNITY

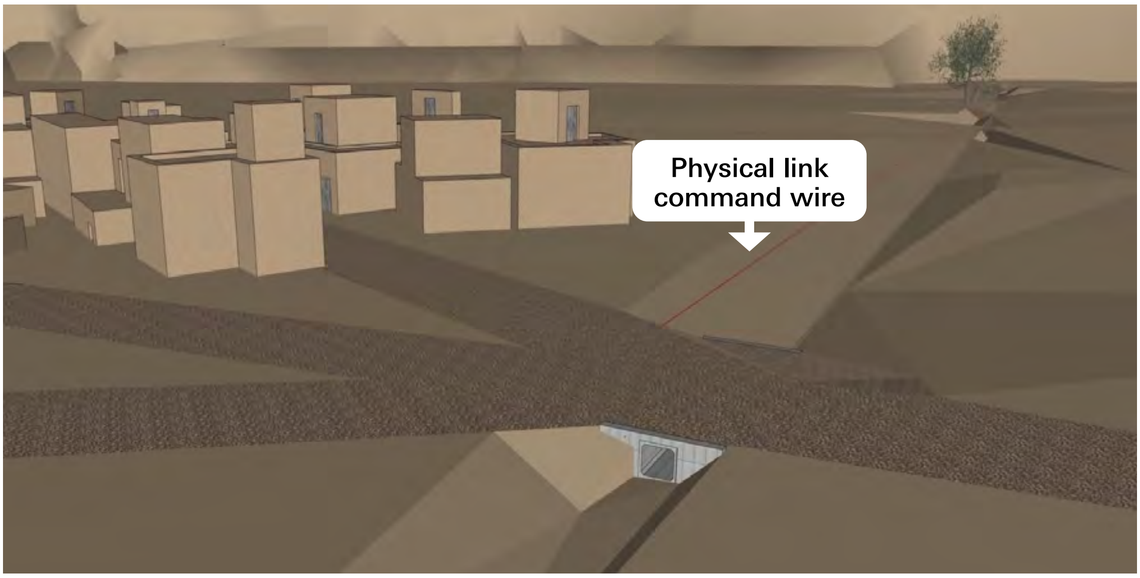

Image 75. Physical link command wire shown as a red line

The state armed group had become confident in the use of their jammers and if a route had been trafficked by civilians then they would believe it to be safe. They did not conduct checks before, or even after they stopped their vehicles, or pay particular attention to VPs such as main track junctions.

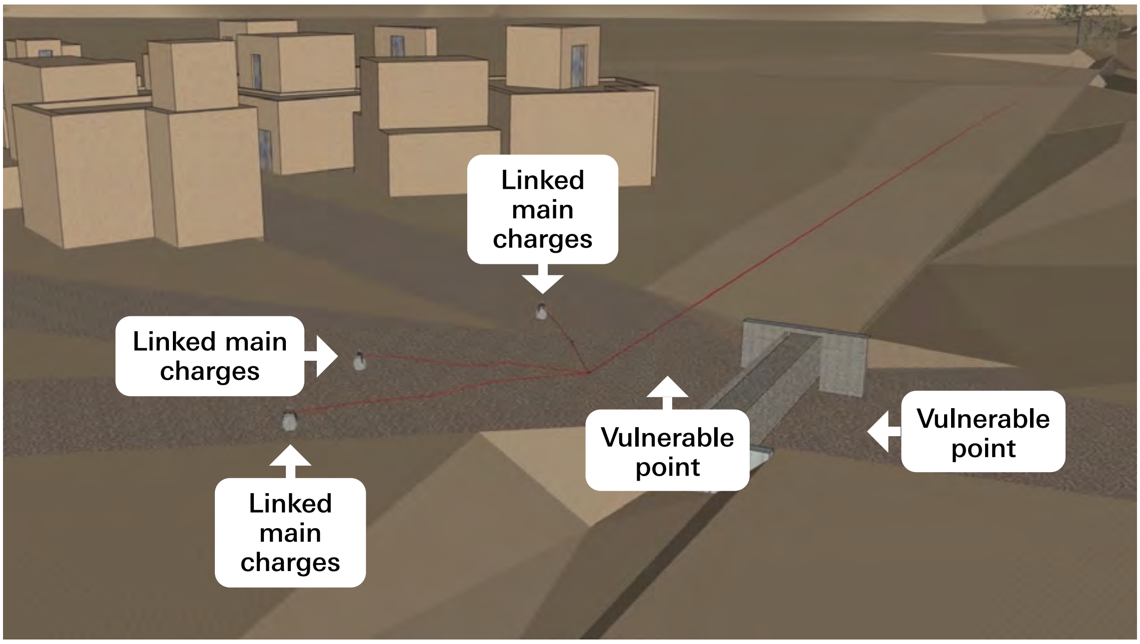

Image 76. Linked main charges in the assessed location
where vehicles would stop (or vulnerable point)

THREAT SUMMARY

A command-wire IED is probably located at the vulnerable point formed by the main track junction. This may have up to three main charges, probably AXO / UXO HE or HME packed into expended EO carrier munitions. The possibility of VOIEDs is assessed as very low.

3.6.5. SCENARIO 5 – RC-ARMED PASSIVE INFRARED IED

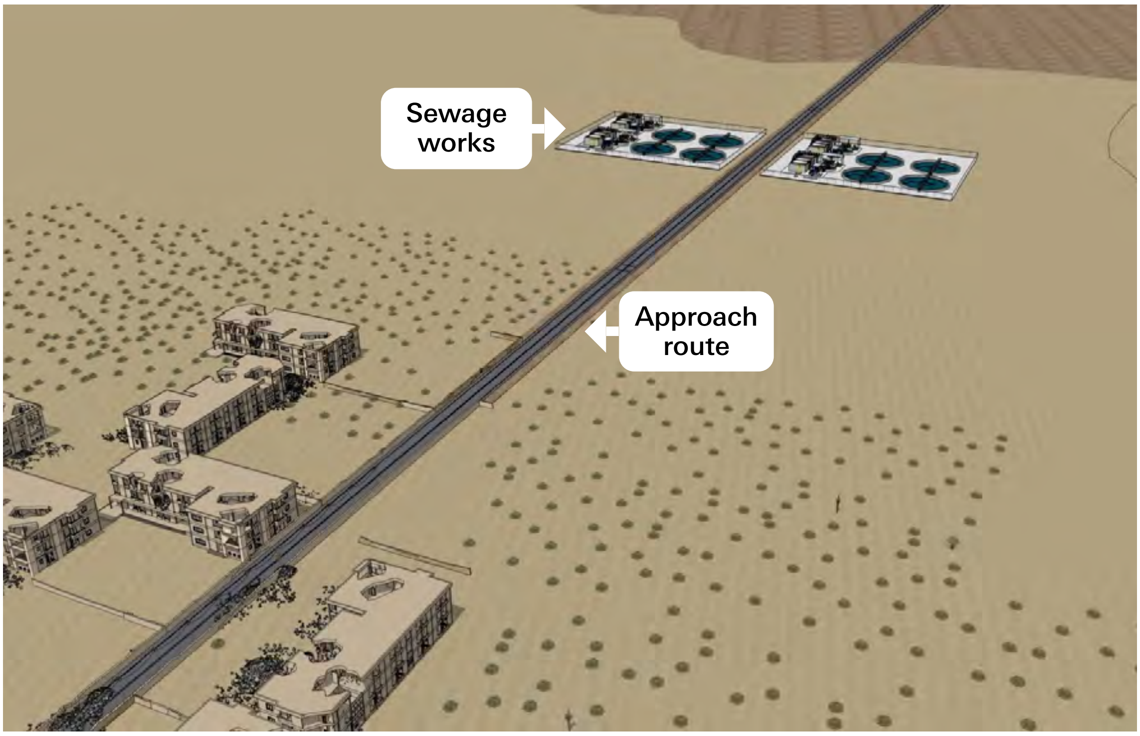

Image 77. Main approach route in relation to a sewage works

SURVEY INFORMATION

The local community reported an explosion affecting a council vehicle trying to access the sewage works. The explosion resulted in significant localised damage to the council's vehicle, killing both individuals in the front of the cab.

An NTS team visits the community and conducts several key informant interviews. The council vehicle had been recovered by the local police, who reported that there was no large seat of explosion under or adjacent to the vehicle. Instead, they reported that there was a crater (0.5 m diameter and 0.25 m deep) on the verge of the route. This would have been approximately 3 m from the vehicle when the explosion occurred. The vehicle itself was viewed by the NTS team and an entry hole approximately 200 mm in diameter was observed in the passenger door.

A UAV is used to survey the route which is confirmed as being surfaced in tarmac, and approximately 6 m wide. The reported crater on the verge can be observed and is located just before a speed bump. There is another speed bump prior to the entry to the sewage works and there is also another tarmac road entering the sewage works from the other side. No one has entered the sewage works since the NSAG withdrew from the area.

INTENT

The intent of the NSAG was to defend the sewage works as an area of operational importance. As part of this defensive plan they needed to maintain their own freedom of movement along the two main routes in and out of the site.

CAPABILITY

The NSAG had access to the full spectrum of IEDs, from armoured VBIEDs to time, command and VO devices. They had been known to use a combination of switches, either as safe-to-arm, or as multiple firing switches for the same IED. They would carefully match the main charge to the target in order to achieve the best effect.

OPPORTUNITY

The NSAG needed to maintain ease of access into and out of the site but at the same time needed an effective explosive obstacle both day and night. The state armed group made use of ECM to mitigate RCIEDs and there are no aiming markers or suitable firing points to aid an effective command wire attack.

There are, however, lines of sight down the route from the sewage works that would have enabled VOIEDs to be armed by RC prior to any ECM being effective at jamming signals.

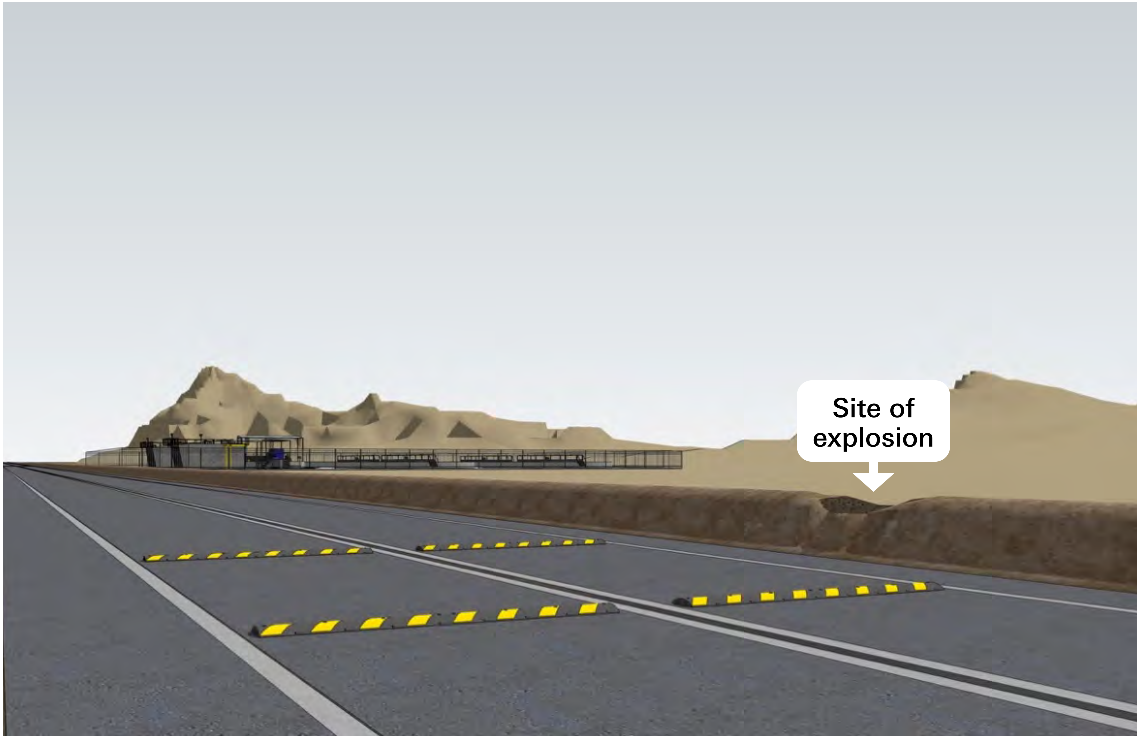

Image 78. Site of the explosion between the speed bumps

THREAT SUMMARY

It is likely that the IED that caused the explosion was an RC-armed VOIED (sensor). It is probable that the main charge was an EFP located off route in an elevated position on the bund adjacent to the route. It is probable that the sensor was offset from the main charge. The sensor is probably a passive infrared, although other sensors cannot be discounted.

It is probable that additional RC-armed VOIEDs (sensors) are located on the other approach route and it is possible that further devices are located on the same route where the explosion occurred.

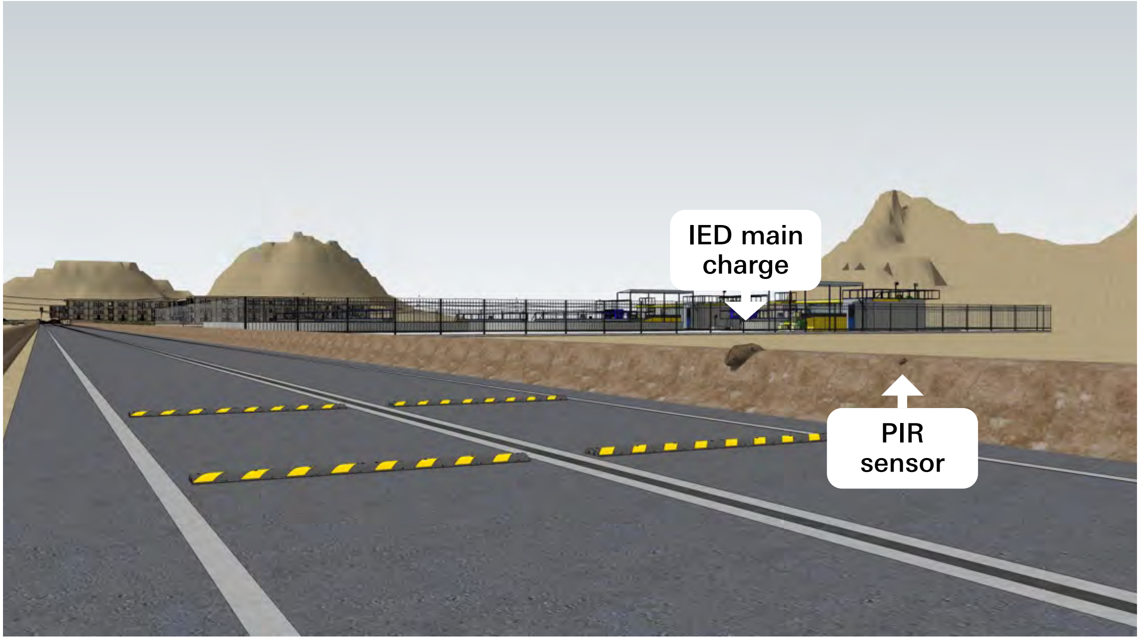

Image 79. The location of the VOIED (sensor) armed by RC

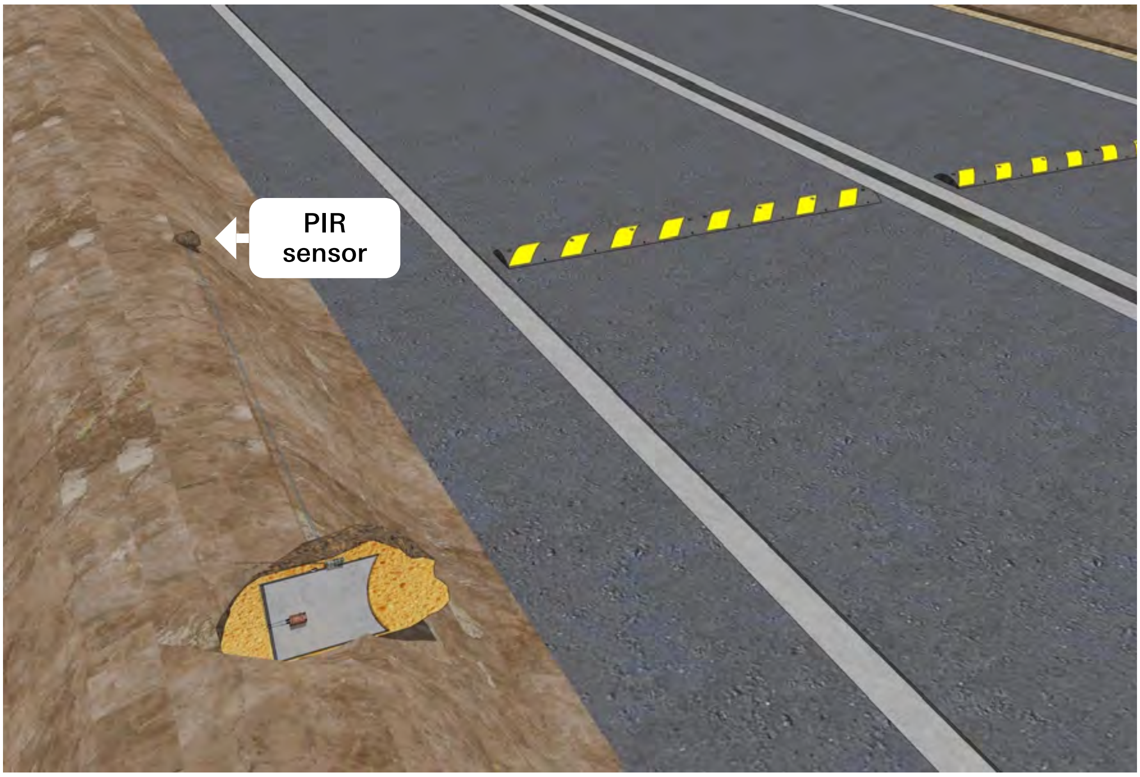

Image 80. Image in detail showing the VOIED (sensor) consisting of an EFP main charge co-located with an RC-arming receiver contained in expanding foam. The PIR sensor is offset by approximately 3 m so that the EFP hits the cab of the vehicle

4. LEXICON OF ACRONYMS

ADS	Animal detection system
AN	Ammonium nitrate
ANAL	Ammonium nitrate & aluminium
AP	Anti-personnel
APMBC	Anti-Personnel Mine Ban Convention
CHA	Confirmed hazardous area
CP	Control point
CW	Command wire (improvised explosive device)
ECM	Electronic counter-measure
EFP	Explosively formed projectile
EO	Explosive ordnance
EOD	Explosive ordnance disposal
EOR	Explosive ordnance reconnaissance
EORE	Explosive ordnance risk education
ERW	Explosive remnants of war
GIS	Geographic information system
H&L	Hook and line
HE	High explosive(s)
HMC	High metal content
HME	Home-made explosive
IED	Improvised explosive device
IEDD	Improvised explosive device disposal
IM	Information management
IMAS	International Mine Action Standards
IMSMA	Information Management System for Mine Action
JFC	Jet forming cone
KSA	Knowledge, skills and attitude
LMC	Low metal content
MA	Mine action
MLCA	Main load carrying area

NEQ	Net explosive quantity
NMAA	National Mine Action Authority
NMAS	National Mine Action Standards
NSAG	Non-state armed group
NTS	Non-technical survey
OJT	On the job training
PAT	Plastic adhesive tape
PIR	Passive infrared
PPE	Personal protective equipment
PPIED	Pressure plate improvised explosive device
QA	Quality assurance
QC	Quality control
QMS	Quality management system
RC	Radio controlled
RCIED	Radio controlled improvised explosive device
RF	Radio frequency
RHF	Rolled homogenous steel
ROV	Remotely operated vehicle
RSP	Render safe procedure
RX	Receiver
SHA	Suspected hazardous area
SOP	Standard operating procedure
TNMA	Technical Note for Mine Action
TS	Technical survey
TX	Transmission
UAV	Unmanned aerial vehicle
UNMAS	United Nations Mine Action Service
VBIED	Vehicle-borne improvised explosive device
VO	Victim operated
VOIED	Victim operated improvised explosive device
VP	Vulnerable point

5. GLOSSARY OF TERMS

Abandoned Explosive Ordnance (AXO). Explosive ordnance that has not been used during an armed conflict, that has been left behind or dumped by a party to an armed conflict, and which is no longer under control of the party that left it behind or dumped it. Abandoned explosive ordnance may or may not have been primed, fuzed, armed or otherwise prepared for use. [CCW protocol V]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Accreditation. The procedure by which a mine action organization is formally recognised as competent and able to plan, manage and operationally conduct mine action activities safely, effectively and efficiently. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Accreditation body. An organisation, normally an element of the NMAA, responsible for the management and implementation of the national accreditation system. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

All reasonable effort. Describes what is considered a minimum acceptable level of effort to identify and document contaminated areas or to remove the presence or suspicion of explosive ordnance. All reasonable effort has been applied when the commitment of additional resources is considered to be unreasonable in relation to the results expected. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Anti-handling device. A device intended to protect a mine and which is part of, linked to, attached or placed under the mine and which activates when an attempt is made to tamper with or otherwise intentionally disturb the mine. [This definition equally applies to improvised mines and IEDs]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Battle Area Clearance (BAC). The systematic and controlled clearance of hazardous areas where the hazards are known not to include mines. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Cancelled area. Cancelled land (m^2). A defined area concluded not to contain evidence of explosive ordnance contamination following the non-technical survey of a SHA/CHA. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Clearance. *In the context of mine action, the term* refers to tasks or actions to ensure the removal and/or the destruction of all Explosive Ordnance from a specified area to a specified depth or other agreed parameters as stipulated by the NMAA/Tasking Authority. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Cleared area. Cleared land (m^2). A defined area cleared through the removal and/or destruction of all specified Explosive Ordnance hazards to a specified depth. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Cleared lane. Safety lane. The generic term for any lane, other than a boundary lane, cleared by a survey or clearance team to the international standard for cleared land. This may include access lanes outside the hazardous area or cross/verification lanes inside a hazardous area. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Confirmed Hazardous Area (CHA). Refers to an area where the presence of explosive ordnance contamination has been confirmed on the basis of direct evidence of the presence of Explosive Ordnance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Control area or point. All points or areas used to control the movements of visitors and staff on a demining worksite. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Counter IED. C-IED is a government process specifically designed to reduce or eliminate the threat posed by improvised explosive devices. It is generally framed around three pillars of activity: attacking the network; defeating the device; preparing the force. Whilst prepare the force and defeat the device may relate to humanitarian mine action, attack the network does not as this would compromise the neutrality of the Humanitarian Mine Action community. As such, C-IED cannot be considered Mine Action. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Deflagration. A technical term describing subsonic combustion that usually propagates through thermal conductivity [hot burning material heats the next layer of cold material and ignites it (AOP 38)]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Demining. Humanitarian demining activities which lead to the removal of Explosive Ordnance hazards, including technical survey, mapping, clearance, marking, post-clearance documentation, community mine action liaison and the handover of cleared land. Demining may be carried out by different types of organisations, such as NGOs, commercial companies, national mine action teams or military units. Demining may be emergency-based or developmental.

> Note: In IMAS standards and guides, explosive ordnance clearance is considered to be just one part of the demining process.
>
> Note: In IMAS standards and guides, demining is considered to be one component of mine action.
>
> Note: In IMAS standards and guides, the terms demining and humanitarian demining are interchangeable. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Demining machine. *In the context of mine action*, the term refers to … a unit of mechanical equipment used in demining operations. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Demining worksite. Any workplace where demining activities are being undertaken.

> Note: Demining worksites include workplaces where survey, clearance and EOD activities are undertaken including centralised disposal sites used for the destruction of explosive ordnance identified and removed during clearance operations.
>
> Note: Survey, in relation to a demining worksite includes general survey undertaken to identify mine, and or ERW hazards and hazardous areas. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Destroy (destruction) in situ. Blow in situ. The destruction of any item of ordnance by explosives without moving the item from where it was found, normally by detonating an explosive charge alongside. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Detection. *In the context of humanitarian demining, the term refers to* ... the discovery by any means of the presence of Explosive Ordnance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Effectiveness. *In the context of mine action evaluation, the term refers to ...* the extent to which the intervention's objectives were achieved, or are expected to be achieved, taking into account their relative importance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Efficiency. *In the context of mine action evaluation, the term refers to ...* a measure of how economically resources/inputs (funds, expertise, time, etc.) are converted to results (outputs and outcomes). **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Electronic Counter-Measures (ECM). The equipment, techniques and specialists available within IEDD to temporarily inhibit or mitigate the threat posed by RCIEDs. **(Source: UN IEDD Standards)**

Excavation. Procedures employed in the process of demining whereby ground is removed to detect or confirm the presence of sub-surface Explosive Ordnance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Explosively Formed Projectile (EFP). Specially designed main charge configuration incorporating an explosive charge with a concave metal liner, which by the force of the charge reshapes the plate into a high velocity metal slug capable of penetrating armor. **(Source: UNMAS IED Lexicon)**

Note: In some literature an EFP can sometimes be called an explosively formed penetrator, or a self-forging fragment (SFF).

Explosive Ordnance (EO). Interpreted as encompassing mine action's response to the following munitions:

- Mines
- Cluster Munitions
- Unexploded Ordnance
- Abandoned Ordnance
- Booby traps
- Other devices (as defined by CCW APII)
- Improvised Explosive Devices (IEDs)

Note: Improvised Explosive Devices (IEDs) meeting the definition of mines, booby-traps or other devices fall under the scope of mine action, when their clearance is undertaken for humanitarian purposes and in areas where active hostilities have ceased. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Explosive Ordnance Disposal (EOD). The detection, identification, evaluation, render safe, recovery and disposal of EO. EOD may be undertaken:

- As a routine part of mine clearance operations, upon discovery of EO;
- To dispose of ERW discovered outside hazardous areas, (this may be a single item of ERW, or a larger number inside a specific area); or
- To dispose of EO which has become hazardous by deterioration, damage or attempted destruction. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Explosive Remnants of War (ERW). Unexploded Ordnance (UXO) and Abandoned Explosive Ordnance (AXO). [CCW Protocol V]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

High risk area. An identifiable area that is typically mined in a Confirmed Hazardous Area, or an area that is described by a non-technical survey as being more likely to be mined, or contain ERW than others. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Home Made Explosive (HME). A combination of commercially available ingredients combined to create an explosive substance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Humanitarian principles. A set of principles that guides humanitarian action, which include the principles of humanity, neutrality, impartiality and independence.

Note: See IMAS 01.10 (6.2) for more on humanitarian principles in mine action. These principles are endorsed in UN resolutions 46/182 and 58/114 and considered the foundation for humanitarian action [UNOCHA]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Improvised Explosive Device (IED). A device placed or fabricated in an improvised manner incorporating explosive material, destructive, lethal, noxious, incendiary, pyrotechnic materials or chemicals designed to destroy, disfigure, distract or harass. They may incorporate military stores, but are normally devised from non-military components [IATG 01.40:2011].

Note: An IED may meet the definition of a mine, booby trap, and/or other type of explosive ordnance depending on its construction. These devices may also be referred to as improvised, artisanal, or locally manufactured mines, booby traps, or other types of explosive ordnance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

IED Disposal (IEDD). The location, identification, rendering safe and final disposal of IEDs. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Initiator. Any component that may be used to start a detonation or deflagration. An initiator will be categorized as either a detonator or an igniter. **(Source: UNMAS IED Lexicon)**

Inspection. The observation, measurement, examination, testing, evaluation or gauging of one or more components of a product or service and comparing these with specified requirements to determine conformity. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Key informants. All men, women and children who have relatively good knowledge on the hazardous areas in and around their community.

> Note: Key informants may include, but are not limited to, community leaders, mine-affected individuals, schoolteachers, religious leaders etc. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Land release. In the context of mine action, the term describes the process of applying "all reasonable effort" to identify, define, and remove all presence and suspicion of Explosive Ordnance through non-technical survey, technical survey and/or clearance. The criteria for "all reasonable effort" shall be defined by the NMAA. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Main Charge. The explosive charge which is provided to accomplish the end result in a munition. Examples for end results are: bursting a casing to provide blast and fragmentation; splitting a canister to dispense sub-munitions, or producing other effects for which it may be designed. **(Source: UNMAS IED Lexicon)**

Main Charge Configuration. The arrangement or design of the main charge and other materials (usually metal) to create an effective weapon to attack personnel, vehicles, or structures. **(Source: UNMAS IED lexicon)**

Marking. Emplacement of a measure or combination of measures to identify the position of a hazard or the boundary of a hazardous area. This may include the use of signs, paint marks etc, or the erection of physical barriers. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Marking system. An agreed convention for the marking of hazards or hazardous areas. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Mechanical demining operations. Refers to the use of machines in demining operations and may involve a single machine employing one mechanical tool, a single machine employing a variety of tools or a number of machines employing a variety of tools. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Mechanical tools. The working component(s) attached to a machine, such as flails, tillers, sifters, rollers, excavators, ploughs, magnets etc. A single machine may utilise a number of different tools, which may be fixed or interchangeable. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Mine action (MA). Activities which aim to reduce the social, economic and environmental impact of mines, and ERW including unexploded sub-munitions.

> Note: Mine action is not just about demining; it is also about people and societies, and how they are affected by landmines and ERW contamination. The objective of mine action is to reduce the risk from landmines and ERW to a level where people can live safely; in which economic, social and health development can occur free from the constraints imposed by landmine and ERW contamination, and in which the victims' different needs can be addressed. Mine action comprises five complementary groups of activities:

a. Mine Risk Education (MRE);

b. Humanitarian demining, i.e. mine and ERW survey, mapping, marking and clearance;

c. Victim assistance, including rehabilitation and reintegration;

d. Stockpile destruction; and

e. Advocacy against the use of anti-personnel mines.

> Note: A number of other enabling activities are required to support these five components of mine action, including: assessment and planning, the mobilisation and prioritisation of resources, information management, human skills development and management training, QM and the application of effective, appropriate and safe equipment. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Mine action organisation. Refers to any organisation (government, military, commercial or NGO/civil society) responsible for implementing mine action projects or tasks. The mine action organisation may be a prime contractor, subcontractor, consultant or agent. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Monitoring. Refers to a continuing function that uses systematic collection of data on specified indicators to provide management and the main stakeholders of an on-going project, programme or policy with indications of the extent of progress and achievement of objectives, and progress in the use of allocated funds. [OECD/DAC]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Munroe Effect. A focusing of blast energy caused by a hollow or void cut into the surface of an explosive. **(Source: UNMAS IED Lexicon)**

National Mine Action Authority (NMAA). The government entity, often an inter-ministerial committee, in a mine-affected country charged with the responsibility for the regulation, management and coordination of mine action.

> Note: In the absence of a NMAA, it may be necessary and appropriate for the UN, or some other recognised international body, to assume some or all of the responsibilities, and fulfil some or all the functions, of a MAC or, less frequently, an NMAA. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Non-permissive environment. In the context of humanitarian mine action: an operational area during a specified time period where there is a humanitarian need, where access is not possible, or where consent is not provided by relevant stakeholders, preventing mine action activities to take place according to the humanitarian principles and within the framework of International Humanitarian Law. (opp. Permissive environment). **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Non-Technical Survey (NTS). Refers to the collection and analysis of data, without the use of technical interventions, about the presence, type, distribution and surrounding environment of explosive ordnance contamination, in order to define better where explosive ordnance contamination is present, and where it is not, and to support land release prioritisation and decision-making processes through the provision of evidence. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Omni-directional Effect. An aspect of main charge configuration where the explosion expands in all directions. **(Source: UNMAS IED Lexicon)**

Outcome. *In the context of mine action evaluation, the term refers to* ... the likely or achieved short-term and medium-term effects of an intervention's outputs. Outcomes are related to the 'effectiveness' of an intervention. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Output. *In the context of mine action evaluation, the term refers to* ... the products, capital goods and services which result from a mine action intervention. Outputs may also include changes resulting from the intervention which are relevant to the achievement of outcomes (such as the development of local capacities). **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Passive Infrared (PIR). A switch that detects movement of a heat source. When the change in ambient temperature is detected, the sensor acts as a trigger to function the IED. **(Source: UNMAS IED Lexicon)**

Permissive environment. In the context of humanitarian mine action: an operational area during a specified time period where there is a humanitarian need, where access remains possible, and where consent is provided by relevant stakeholders, allowing mine action activities to take place according to the humanitarian principles and within the framework of international humanitarian law. (opp. Non-permissive environment)

> Note: Reference can be made to IMAS 01.10: 6.2 Humanitarian Principles: In its response to explosive ordnance, mine action is first and foremost a humanitarian concern. Framing of the standards and their application as part of any humanitarian response shall reflect the fundamental humanitarian principles of humanity, impartiality, neutrality and independence. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Person Borne IED (PBIED). An IED worn, carried, or housed by a person, either willingly or unwillingly. **(Source: UNMAS IED Lexicon)**

Personal Protective Equipment (PPE). All equipment and clothing designed to provide protection, which is intended to be worn or held by an employee at work and which protects him/her against one or more risks to his/her safety or health. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Platter charge. The use of an explosive to propel a metal plate toward a target in a manner where the plate remains intact. **(Source: UNMAS IED Lexicon)**

Plunger. A switch utilizing a shaft, like that found in a syringe, where application of pressure on the head of the device will force the shaft downward, functioning the IED. **(Source: UNMAS IED Lexicon)**

Power source. A device that either stores or releases electrical or mechanical energy. The key elements of information about a power source are its type and source, number of batteries and their configuration (series or parallel), its voltage (if electrical) and how it is connected to close an IED switch. **(Source: UNMAS IED Lexicon)**

Pressure. A switch designed to function when pressure is applied in a predetermined direction (plate, tube, plunger, crush wire). **(Source: UNMAS IED Lexicon)**

Pressure Release. A switch for activating the device that occurs as a result of reductions in pressure. **(Source: UNMAS IED Lexicon)**

Pull. A switch that functions when a person applies tension to a firing mechanism – such as pulling a spring. The tension causes an action that releases a firing pin or activates an electrical or electronic switch. **(Source: UNMAS IED Lexicon)**

Quality Assurance (QA). Part of QM focused on providing confidence that quality requirements will be fulfilled. [ISO 9000:2000]

> Note: The purpose of QA in humanitarian demining is to confirm that management practices and operational procedures for demining are appropriate, are being applied, and will achieve the stated requirement in a safe, effective and efficient manner. Internal QA will be conducted by demining organisations themselves, but external inspections by an external monitoring body should also be conducted. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Quality Control (QC). Part of QM focused on fulfilling quality requirements. [ISO 9000:2000]

> Note: QC relates to the *inspection* of a finished product. In the case of humanitarian demining, the 'product' is safe cleared land. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Quality Management (QM). Coordinated activities to direct and control an organisation with regard to quality. [ISO 9000:2000]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Radio Controlled IED (RCIED). A switch initiated electronically by wireless means consisting of a transmitter/receiver. **(Source: UNMAS IED Lexicon)**

> Note: The term 'remote' controlled IED is sometimes used. In either case the definition refers to the use of the electromagnetic spectrum to initiate an IED.

Reduced land (m^2). A defined area concluded not to contain evidence of explosive ordnance contamination following the technical survey of a SHA/CHA. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Relevance. *In the context of mine action evaluation, the term refers to* ... the extent to which the objectives of a project, programme or policy are consistent with beneficiary requirements, country needs, global priorities, and donor policies. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Remote action. Positive actions that can be carried out without the need for an EOD operator to leave the EOD Control Point (CP) and approach suspected EO. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Render Safe Procedure (RSP). The application of EOD methods and tools on EO to interrupt functions or separate components to prevent an unacceptable detonation.

> Note: The term permanent neutralisation is sometimes used interchangeably here.
>
> Note: EO is said to be "neutralised" when it has been rendered, by external means, incapable of firing on passage of a target, although it may remain dangerous to handle. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Risk assessment. Overall process comprising a risk analysis and a risk evaluation. [ISO Guide 51:1999(E)]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Safe waiting period. Waiting times which an operator must allow to elapse prior to making a manual approach, including approaches after conducting remote or semi-remote positive actions.

> Note: The term "soak time" is sometimes used interchangeably here. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Search. An activity used to find EO to specified parameters through the application of appropriate methods and procedures.

> Note: This is not an IMAS 04.10 referenced term but developed to provide consistency in the use of the term 'search' in this guide.

Secondary fragmentation. In an explosive event, fragmentation which was not originally part of the explosive ordnance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Semi-remote action. Positive actions that require the EOD operator to leave the EOD Control Point (CP) and approach the immediate vicinity of the EO in order to place an EOD tool which is then operated/ activated remotely once the EOD operator has returned to the CP. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Sensor. A switch used to detect change in heat, light, movement, vibration, electromagnetic frequency, sound or magnetic field. **(Source: UNMAS IED Lexicon)**

Shaped Charge. A main charge configuration incorporating explosives shaped so as to concentrate explosive force utilizing the Munroe Effect in a particular direction in order to cut or penetrate. **(Source: UNMAS IED Lexicon)**

Specified area. *In the context of humanitarian demining, the term refers to* ... that area for which mine or ERW clearance activity has been contracted or agreed, as determined by the NMAA or an organisation acting on its behalf. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Specified depth. *In the context of humanitarian demining, the term refers to …* the depth to which a specified area is contracted or agreed to be cleared of mine and ERW hazards, as determined by the NMAA or an organisation acting on its behalf. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Standard Operating Procedures (SOPs). Instructions which define the preferred or currently established method of conducting an operational task or activity.

> Note: Their purpose is to promote recognisable and measurable degrees of discipline, uniformity, consistency and commonality within an organisation, with the aim of improving operational effectiveness and safety. SOPs should reflect local requirements and circumstances. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Suspected Hazardous Area (SHA). An area where there is reasonable suspicion of explosive ordnance contamination on the basis of indirect evidence of the presence of mines/ERW. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Switch. A device for making, breaking, or changing a connection in an IED. A single switch can have multiple functions (i.e. arming and firing). **(Source: UNMAS IED Lexicon)**

Tension. A switch that functions when tension is applied to a firing mechanism – such as pulling a trip wire. The tension causes an action that releasing a firing pin or activates an electrical or electronic switch. **(Source: UNMAS IED Lexicon)**

Time. A type of switch that functions after a period of time. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Unexploded Ordnance (UXO). Explosive ordnance that has been primed, fuzed, armed or otherwise prepared for use or used. It may have been fired, dropped, launched or projected yet remains unexploded either through malfunction or design or for any other reason. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Victim Operated. A type of switch designed to be initiated by a victim's presence, proximity, contact or activity causing a device to function that may injure or kill one or more persons. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

CHAPTER 2
SEARCH

1. INTRODUCTION

This chapter provides International Mine Action Standards (IMAS) compliant guidance for mine action (MA) organisations planning and conducting improvised explosive device (IED) search operations. It describes good practice related to search principles, staff safety, threat assessment, operational planning, search techniques and procedures, staff training, reporting and information management. This guidance can be applied to rural, peri-urban or urban environments that are contaminated with IEDs and other explosive ordnance (EO). There is a deliberate focus on urban areas and buildings in order to assist the MA sector with this specific challenge.

In this guide the term 'search' refers to:

An activity used to confirm or discount the presence of EO to specified parameters through the application of appropriate methods and procedures.[1]

This chapter describes search as one activity which is part of a broader process that is applied to achieve "all reasonable effort". Search can be conducted in any type of space (e.g. open areas, roads, buildings, etc.) in order to provide the required level of confidence that it is safe from IEDs.

This chapter has been developed based on the norms that are in practice during MA operations in IED-contaminated environments and where traditional demining methods and procedures have been adapted to account for this specific threat. Although it focuses on abandoned or failed IEDs in a post-conflict context, much of it can be applied to the finding of other types of EO using manual search techniques and procedures.

1.1. SCOPE

This chapter focuses on finding IEDs through the application of manual search techniques and procedures. It explains common challenges and problems faced during IED search activities and outlines potential options for these to be mitigated and overcome. It is intended to be applicable to a variety of contexts. This is achieved through a principles-based approach to assist National Mine Action Authorities (NMAAs) developing National Mine Action Standards (NMAS) and conducting monitoring of operations in the field. It will also assist MA operators developing global and programme-specific standard operating procedures (SOPs) and staff training that are pertinent to their operations.

Mine action organisations are increasingly working in areas that are only recently post conflict with little to no community return. They may also be tasked directly to a specific building or area, especially if it is critical in providing support to the local population and enabling sustainable rehabilitation / reoccupation. These challenges, combined with potentially concealed IEDs, mean that it is often safer and more efficient to deploy a technical team that will carry out the initial survey and may move straight to technical survey or clearance if feasible. The processes and documents are focused on this way of operating, as non-technical survey (NTS), technical survey (TS) and clearance are already well established as separate defined phases in current guidance, but the contents of this guide can be easily adapted to support any IED clearance operations.

This chapter does not provide detailed guidance on the use of mechanical demining machines or animal detection systems (ADS) in IED threat environments.

1 This is not an IMAS 04.10 referenced term but developed to provide consistency in the use of the term 'search' in this guide and its use in other IMAS.

1.2. GENERAL SEARCH PRINCIPLES

The following eight principles are specified in IMAS 09.13 Building Clearance but can be applied to other types of space being searched for IEDs. The principles are explained in relation to IED contamination in an operational context.

PRINCIPLE 1
An EO threat assessment based on all available evidence gained from survey and technical interventions should be developed and continually reviewed.

Threat assessment is the primary means by which to make evidence-informed decisions during MA operations involving IEDs. All available information sources should be investigated throughout the entire course of an operation; from the initial survey to the final handover. If this does not happen, safety may be compromised and opportunities to enhance efficiency may be lost.

HINT. The trigger for reviewing a threat assessment is a change in the information that was used to make the previous threat summary.

For example, at the commencement of operations it may not be possible to discount the threat of tripwires. As operations progress, new information may emerge that can be analysed and used as evidence to discount this threat, enabling the search procedures to be modified and efficiency increased. This modification could change the search procedure by removing the use of a tripwire feeler as a tool, to enhance visual detection of a tripwire.

Image 1. Conducting 'tripwire feeling' in a complex environment to enhance visible detection. This procedure should be specified in the clearance plan

PRINCIPLE 2

Building clearance should be executed in accordance with an approved clearance plan. This plan should include control measures to account for the threat assessment being updated as more evidence on the EO contamination is obtained.

This principle is applicable to searching for IEDs in any environment. A clearance plan that outlines how different activities (e.g. non-technical survey, search, improvised explosive device disposal (IEDD) and information management) will be used together, can help achieve "all reasonable effort". It also enables controls to be specified in how to deal with changes, such as alterations in search procedures based on new evidence. The clearance plan will likely combine set procedures, detailed in an MA operator's operational SOPs, with different combinations selected based on the threat assessment.

Image 2. Hazard marking may be important evidence used in the development of a threat assessment-informed clearance plan

PRINCIPLE 3

If the threat assessment cannot confidently discount victim operated EO then appropriate procedures should be used as mitigation.

Appropriate procedures should be matched to both the threat and the environment. This is built on MA's significant experience of clearing anti-personnel mines and means that there must be confidence that the procedures and tools are suitable to find any EO that has been assessed as being present.

For example, there is no point specifying that a metal detector must be used inside a concrete building, or that a tripwire feeler must be used if there is no threat of tripwires.

Image 3. In this example the threat of tripwires has been discounted and the searcher is only using a metal detector to search for subsurface IEDs

PRINCIPLE 4
Safe separation between individual searchers and search teams should be applied to minimise casualties in the event of an unintended detonation.

This is appropriate to all environments. It can be particularly challenging in large multi- floored buildings where it is not practical to be cleared by just one person.

Consideration should also be given to structural failure occurring in the event of an un-planned explosion and how to minimise the severity of such an event on individuals and teams.

Image 4. A cutaway image of a task involving a multistorey building

PRINCIPLE 5
Appropriate personal protective equipment (PPE) commensurate with the threat assessment should be worn.

PPE reduces the consequences (or impacts) of an accident when one occurs and therefore should be seen as a final form of mitigation and is not a replacement for good procedures. IMAS 10.20 Demining worksite safety and IMAS 10.30 Personal Protective Equipment - PPE should be followed and both explosive and non-explosive hazards considered. How PPE integrates with equipment, human factors and the environment are all issues that should be taken into account.

Image 5. Note that the searcher conducting visual search here is not protected at the side or rear from the rebounding of fragmentation in an enclosed environment. His head is also exposed to falling debris and fragmentation should there be an unintended detonation somewhere else in the building

Image 6. Note the improvement in the PPE for the body and head. The visor has been lifted temporarily to aid visual detection; before conducting any further action, including tripwire feeling, the visor will be closed

PRINCIPLE 6
Assessment of structural integrity of the building should be carried out prior to entry.

MA organisations should have mechanisms in place to assess buildings prior to staff entering them. These should be specified in NMAS and SOPs that are guided by IMAS 07.14 Risk Management in Mine Action having assessed the nature of the damage and the construction type of the building. The question of whether the building is salvageable and requires manual search, or is too unstable and will be demolished, should be established prior to survey or clearance by MA organisations.

Image 7. This image shows indicators such as the damage to the upper floor and supporting structure – questionable structural integrity?

PRINCIPLE 7
If there is a suspicion that non-explosive hazards are present, personnel should be appropriately trained and equipped for these hazards.

Different environments will present different non-explosive hazards that can pose a risk to MA staff. These should be identified and mitigated, even if the only action taken is that they are avoided completely until suitable resources and trained staff become available; this may require the assistance of a subject matter specialist in the planning stages, such as an electrical engineer for large electrical infrastructures. Examples include toxic industrial chemicals, biological hazards, confined spaces, unstable structures (see Image 7) and working at height (see Image 8).

Image 8. A member of MA staff identifying a working at height hazard

PRINCIPLE 8
Building clearance should only be conducted in appropriate light levels. If these do not exist naturally, then artificial light sources should be used.

Visual detection is one of the primary techniques to identify IEDs in any environment and is of particular use inside buildings. Low light levels will significantly hinder a searcher's ability to visually identify IEDs. Both general and focused sources of lighting should be used to enhance natural light levels when required.

Image 9. A searcher using a handheld torch to aid visual observation of a room with lower light levels

1.3. IED CLEARANCE PARAMETERS

Historically, MA clearance was defined in IMAS 04.10 as:

"… in the context of mine action, the term refers to tasks or actions to ensure the removal and/or the destruction of all mine and ERW hazards from a specified area to a specified depth".

Although specifying depth for certain spaces contaminated by IEDs remains extremely pertinent, additional clearance parameters need to be set in order for there to be confidence that the space is safe.

In 2018 this was revised and clearance is now defined in IMAS 04.10 as:

"… in the context of mine action, the term refers to tasks or actions to ensure the removal and/or the destruction of all Explosive Ordnance from a specified area to a specified depth or other agreed parameters as stipulated by the NMAA/Tasking Authority".

This new 2018 definition of clearance can be more effectively applied to urban areas that frequently incorporate different types of 'area' in one MA task site. It means that specific parameters for clearance other than depth can be set, with suitable quality management checks and inspections put in place to ensure they are met during clearance and subsequent reporting.

Having this ability to specify parameters other than just depth is used in IMAS 09.13 Building Clearance with the statement that: "A building shall be accepted as "cleared" when the MA organisation has ensured that all structural surfaces, loose items and household fittings are free from EO." Image 10 illustrates why this is important:

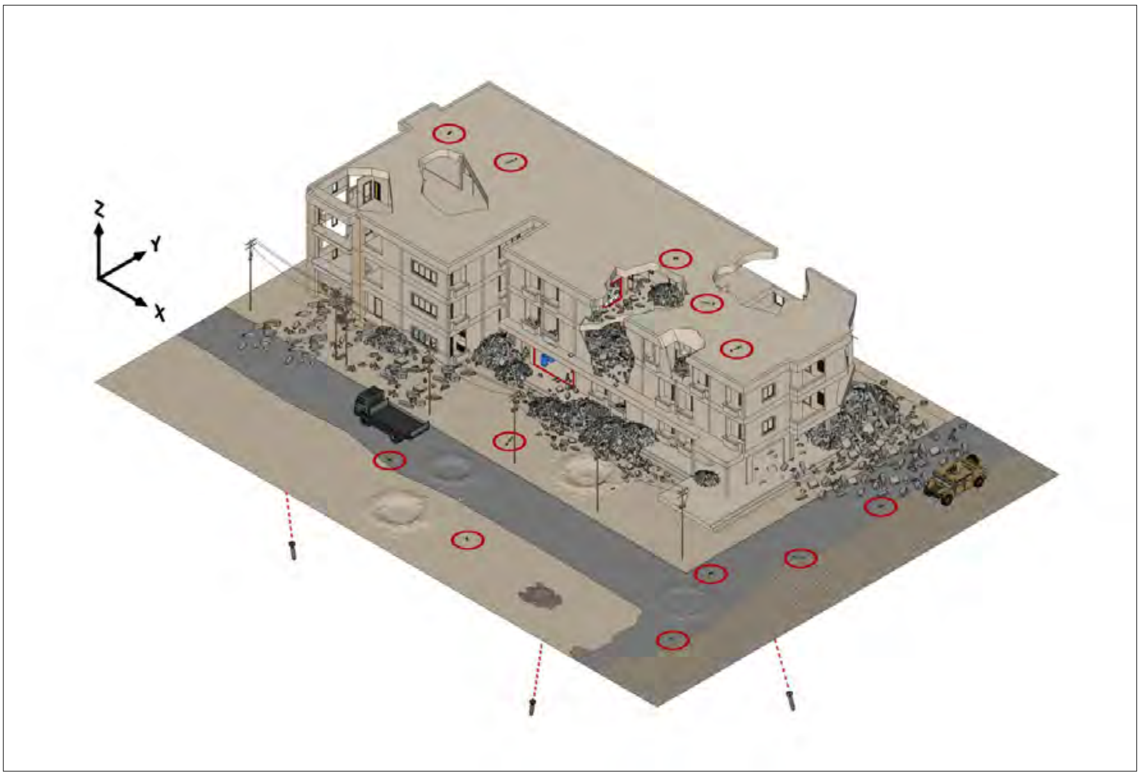

Image 10. Image showing a three-dimensional urban space contaminated with explosive ordnance

Image 10 shows an urban environment that contains multiple types of 'space'. In addition to open ground, which is soft enough to easily dig in and conceal an IED, there are access routes and buildings. A building's structural surfaces can be constructed using a multitude of methods and materials (e.g. tiles, wood, concrete, and brick), contain many loose items (furniture, appliances, debris) and can contain different types of household fixings (e.g. suspended ceilings, electrical wiring). Access routes may also be surfaced with different materials such as compacted soil / gravel, tarmac or concrete. All these factors will influence the opportunity that an armed group has to conceal / emplace IEDs in these urban spaces and in turn affect the equipment and procedures required to search for them.

1.4. WORKSITE SAFETY

MA has always encountered hazards that may present risks to safety other than those associated directly with EO. The scale of these hazards in urban environments can be severe with the associated risks frequently including the following:

- Large-scale bulk fuel storage, hazardous industrial chemicals, biological hazards and electricity supplies;
- Hazardous worksite activities such as working at height when a fall would result in injury, or difficult access and egress for emergency and non-emergency personnel in the event of an accident;
- Factors causing lack of oxygen or an increase in toxic substances, commonly found in confined spaces;
- Significant amounts of debris caused by building collapse, construction works, refuse or waste;
- Unavoidably high personnel numbers resulting in worksite control challenges and potential security concerns;
- Suitable access and exit points for general work and casualty evacuation in the event of a detonation within a building.

Image 11. Image highlighting non-explosive hazards

1.4.1. GENERAL SAFETY MANAGEMENT DURING IED SEARCH OPERATIONS

Searching for IEDs, especially in urban environments, is a challenging task due to three specific factors: the nature of the explosive contamination, the frequency of encounters with non-explosive hazards, and the injurious nature of these non-explosive hazards. The NMAA should use IMAS 10.10 Safety & occupational health - General requirements as guidance in the development of associated NMAS. If these NMAS do not exist, then MA organisations should use this IMAS to inform SOPs. Failing to properly manage these risks in the execution of IED search activities will likely adversely affect the safety, effectiveness and efficiency of operations.

A key challenge for MA organisations operating in urban areas contaminated by IEDs will be the assessment of structural integrity. A risk management approach in accordance with IMAS 07.14 Risk Management in Mine Action is key, with the approaches outlined in this IMAS also commonly applied in other industries. Consideration should be given to:

- Use of tools to ensure hazards that pose a risk are identified;
- Controlling identified risks;
- Allocating responsibilities on worksite safety;
- Ensuring that "all reasonable effort" is made so that personnel working in a safe environment have appropriate equipment, such as PPE, including that required for non-explosive hazards;
- Ensuring all personnel have the relevant safety information required for their role and position;
- Ensuring all personnel are correctly trained and qualified for their role and assessed hazards;
- Ensuring that substances hazardous to health are stored and used correctly;
- Providing an uninhibited forum to discuss safety issues;
- Providing a means of recording accidents and incidents;
- Developing applicable emergency procedures;
- Conducting regular quality assurance (QA) checks to ensure that working conditions are as safe as possible.

Identifying and controlling risks in a worksite with hazardous conditions is critical to underpin the safety of operations. Using a risk assessment process is the recommended course of action since such assessment has a proven track record in many hazardous and high-pressure industries. The process normally consists of:

IDENTIFYING RISKS	Not to be confused with threat assessment, this is a survey of the worksite noting any potential worksite conditions that may be hazardous.
IDENTIFYING WHO IS AT RISK	This step identifies whether the hazard is applicable to the workforce and / or third parties such as the local community.
ANALYSING AND MITIGATING THE RISK	Analysing the probability and the consequences (impact) of the risk against a specified tolerance level. If the risk level is outside of tolerance, then mitigating actions to reduce it to a tolerable level should be applied. This will involve a hierarchy of actions, from avoiding or removing the risk, to reducing the risk with active control measures.
RECORDING AND BRIEFING	The findings and corresponding control measures.
REVIEWING ON A TIMELY BASIS	It is recommended that risk assessments are regularly reviewed, and personnel briefed on changes.

The MA sector has always faced a challenge in surveying and clearing EO from buildings in rural areas and populated urban centres, including those in Afghanistan, Palestine and the Balkan states. However, the increasing use of explosive weapons in population centres since the beginning of the 21st century has driven a change, especially when combined with the scale and speed in the movement of vulnerable people to and from heavily contaminated urban areas. This has reinforced an already established need for MA to ensure activities are conducted safely, efficiently and effectively to facilitate rehabilitation, and ultimately the safe return of communities.

MA organisations face several key problems when attempting to conduct clearance and survey in urban areas.

1.4.2. PROBLEM: CALCULATING WORKING / SEPARATION DISTANCES

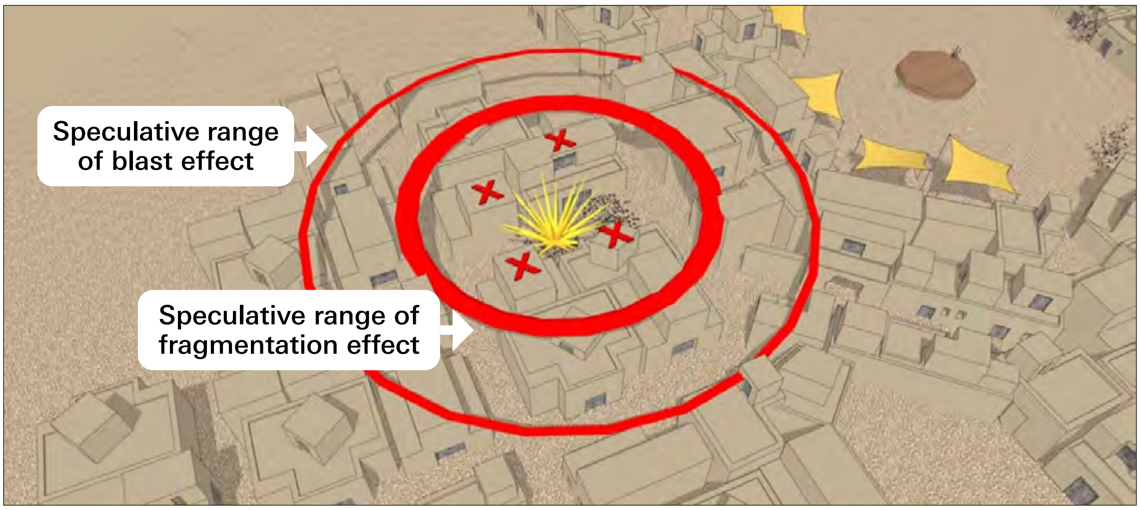

Image 12. Explosion occurring in a built-up area. The red crosses indicate the buildings directly affected by primary and secondary fragmentation and blast effects of the explosion. The concentric circles represent the predicted distance of blast and fragmentation effects if unhindered by buildings

Safe working and separation distances between active search operations, the task site contact point (CP) and the local population need to take into account the net explosive quantity of IEDs that are assessed as likely to be present. This separation provides mitigation in the event that an unplanned explosion occurs and is normally calculated with the use of IMAS Technical Note 10.20/01 Estimation of Explosion Danger areas.

In an urban area additional factors can increase or decrease the risk to personnel in the event of an unplanned explosion. These include:

INCREASED RISK FACTORS	Channelling of an explosive blast pressure wave between structures, walls and through windows and doors could **focus** its energy in specific directions. Secondary hazards such as fuel, gas, electricity supply and toxic chemicals that are abundant in an urban area may **enhance** the effects of an explosive blast, or affect the safety distance itself. Secondary fragmentation from buildings and structural failure.
DECREASED RISK FACTORS	Channelling of an explosive blast pressure wave between structures, walls and through windows and doors could **divert** its energy. Safety distances of explosives have been assessed against the power of TNT. Home-made explosives (HME) may have a **reduced** relative effectiveness factor compared with most military and commercial grade explosives and this should be considered when assessing IED safety distances. Consideration should be given to the level of confidence related to the HME type that is present and the worst-case scenario. Walls and pre-existing structures (including specifically constructed blast mitigation protective works) occur regularly in urban environments and can significantly **reduce** the risk of high velocity primary fragmentation being projected from an explosive blast in the same way protective works do.

IMAS 09.13 Building Clearance provides the following guidance on how this risk to personnel can be mitigated:

MITIGATION	The task must be planned and executed to reduce the potential number of casualties to a minimum should an unplanned explosion or structural failure occur. When conducting search within the confines of a building, the three-dimensional environment, along with the building's construction type, should be considered. If there is a threat of victim operated IEDs (VOIEDs) there should never be more than one searcher per room, and it is further recommended that a separation of two interior walls / floors between searchers is maintained. This is detailed in IMAS 09.13 Building Clearance. There should never be a searcher in a room directly above or below another. At their basic level, safety distances are spherical. Current IMAS provide guidance that enables MA organisations to reduce working and separation distances based on mitigation. This could include both pre-existing structures and specifically constructed protective works. Consideration should be given to how the energy of a pressure wave will alter inside buildings and urban environments. Channelling between structures, walls and through windows and doors will mean it may be possible to reduce a safety distance in one direction but increase it in another direction where it is channelled. Expert advice should be obtained when secondary hazards are identified (fuel, gas, electrical supply and toxic chemicals) that may enhance the effects of an explosion. This may involve liaison with the NMAA, other implementing partners, as well as local services such as fire and emergency rescue.

1.4.3. PROBLEM: LOCAL COMMUNITY SAFETY IN URBAN ENVIRONMENTS

In urban environments, MA organisations may be required to operate in close proximity to the affected community. These communities will likely be in a state of flux, with people returning to their homes and starting to rebuild their lives. Such is the motivation to return home that these communities are often prepared to take considerable risks in the process. This needs to be taken into account when urban MA survey and clearance operations are planned. For example, local communities have been known to remove explosive contamination from their properties to areas that have already been cleared by MA organisations.

Community engagement is one of the primary means to mitigate this risk and should be started at the earliest opportunity. This engagement should use effective communication channels with the affected community at risk and go some way towards developing risk-reduction strategies. On a task site level, good communication with local inhabitants and multi-agency liaison with local authorities has benefitted the information collection process as well as streamlining the task site cordon and control aspects. This can be supported by other activities such as EO risk education for the affected communities.

Key to community engagement is the use of community liaison officers, however all staff should be aware and trained in its importance.

HINT. As with all MA operations, community engagement should be conducted using approaches that build confidence and ensure that no gender, ethnic, religious or tribal group is marginalised. MA organisations should be aware that densely populated urban environments can be comprised of a multitude of diverse communities that all identify by different ethnicities and / or religions. Key qualities that an organisation should look for in staff are an interest and concern for the local community and an appropriate level of empathy. Specific training to enhance knowledge, skills and attitudes should then be provided by the MA organisation.

1.4.4. PROBLEM: SUITABLE LIGHT FOR IED BUILDING SEARCH

The majority of IED search techniques requires the ability to conduct detailed visual observations. This includes both manual search techniques, and search techniques using optics and cameras. By studying the environment and taking into account the IED threat assessment, vital information can be gained on potential indicators and signs of IED emplacement, as well as other EO and non-explosive hazards.

WARNING. IED search inside buildings can only be conducted accurately and safely when light levels are appropriate.

SOLUTION

A minimum of two light sources should be provided if the natural light levels hinder visual observation of IED signs and indicators. This will allow light from at least two angles to assist in the visual identification of EO and indicators, and provide safe exiting of the building should one light source fail. At least one light source should be handheld enabling it to be focused in a precise direction. It is recommended that the other light source be mounted on the ground or on a tripod, usually allowing for a more powerful light source to be used. This will enable the light source to be used when the searcher needs both hands to conduct other techniques and procedures.

WARNING. Light sensitive sensors have been used as switches in IEDs but this is uncommon. An MA threat assessment should consider an armed group's capability and opportunity to use light sensitive devices.

Image 13. Conducting visual search in an open space containing industrial machines. Note that the visor has been lifted temporarily to increase the effectiveness of visual observation prior to conducting any interaction such as using a tripwire feeler

1.4.5. PROBLEM: COMMUNICATIONS

Good communications on a large urban MA worksite are essential for safe operations. It is not normally possible for a searcher to have a communications device on their person. This is due to interoperability issues with search equipment and applying a suitable separation distance between the transmitter and any electrical initiators (detonators) that may be present in IEDs. Nonetheless, control is paramount and there is only so much value that a thorough brief can provide prior to beginning operations.

Image 14. Observing a deminer / searcher in a complex environment. Note that a safe separation distance is still maintained

SOLUTION

The use of a suitably protected and equipped second person, positioned at a vantage point from where he / she may observe the searcher's actions. This second person's position must take into account the effect of an unintended detonation on buildings or structures. This person should be sited at the minimum safe distance stated in NMAS / SOPs and should maintain verbal communications with the searcher. These communications can be relayed from the searcher to the section or team leader in order to control progress and seek guidance.

Linked to communications, marking systems should be appropriate to the environment and provide clear visual communication of where is safe or unsafe. Markers may initially be painted wooden blocks or stones to temporarily mark progression, which are then periodically enhanced with coloured flags, larger painted blocks or upright sandbags.

WARNING. An unplanned detonation will probably remove or displace some markings in this environment, potentially hindering casualty extraction and incident management.

To counter this scenario, it is recommended that search teams remain aware of progression at the site, not just their working area but where all staff members are located across the task site. This should be conducted formally at the start and end of the works, including site familiarisation walks to physically show staff where teams are working.

1.4.6. PROBLEM: SUPERVISION

Management of risks on a demining worksite include effective supervision and control of tasks being conducted, and this can be easier to implement in open areas or where the required working distance can be applied, while keeping staff in view. In buildings, team leaders and other supervisory staff may often have to place themselves within the danger area to observe personnel. This is not only to comply with quality management requirements for conduct of the task but also includes the health and safety of site personnel.

SOLUTION

Supervisors should still carry out these checks but keep time to a minimum and leave the danger area once the following have been established:

- Has there been a change to the environment affecting the searcher's health or ability to work e.g. low light levels, excessive dust from the search activity?
- Is the correct PPE available and being worn correctly?
- Are the procedures and equipment being employed correctly?
- Is the area marked correctly?
- Is the searcher in good health and able to continue working?

There is an element of confidence required that staff continue to conduct their tasks correctly while unobserved. This confidence could also be gained through greater time allocated to initial training or only allowing personnel to work for periods unobserved after their competence has been proven and recorded on observed tasks.

1.5. MANAGEMENT OF NON-EXPLOSIVE HAZARDS

Image 15. Hazards in this image include bulk fuel, high voltage power and an enclosed water tank. Note that the operator's visor has been temporary lifted to aid in visual observation

The frequency and complexity of non-explosive hazards in an urban environment pose significant challenges to an MA organisation. Considering the situation shown in Image 15, if the threat assessment specifies a need to search the electrical boxes, then the clearance plan would need to specify which procedures in the organisation's SOPs would be applied. Other hazards that need to be considered are the following:

- Questionable structural integrity of buildings;
- Chemicals and substances, domestic or industrial, that are hazardous to health may be present and not in a controlled state;
- Spaces in the worksite that are hazardous environments and pose additional risks due to their construction. These are generally referred to as 'confined spaces';
- Areas of the worksite at height, where risks can arise from lack of fall protection, and fragile surfaces. These areas are generally referred to as 'working at height';
- Infrastructure and bulk substances that may enhance the effect of planned or un-planned explosions or cause additional hazardous environments if damaged by explosions. These are generally referred to as 'secondary hazards' and may consist of bulk fuel, gas and chemical storage or electricity supply.

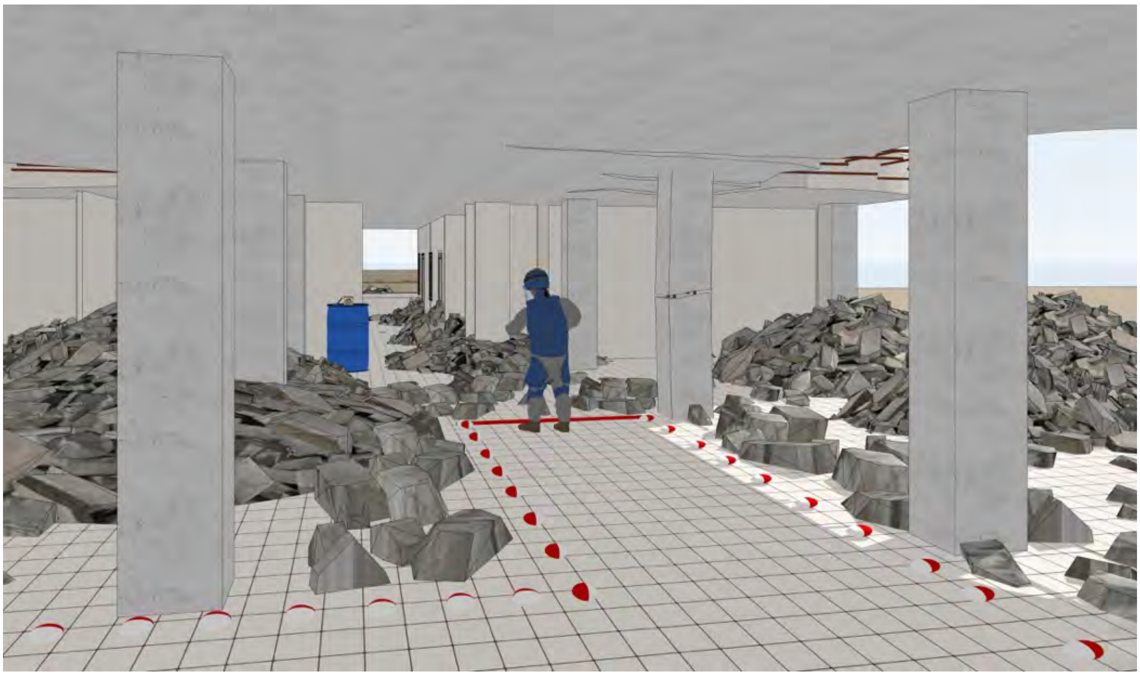

Image 16. Showing the manual clearance of rubble in a multi-hazard (explosive and non-explosive) environment

WHAT HAPPENS IF HAZARDS ARE NOT MANAGED?

- Misidentification of additional hazards can lead to MA organisations taking unknown or unnecessary risks. It can also mean that they grade the hazard with a severity that is not proportional to the risk, hindering operations from being conducted.
- An inappropriate approach to managing additional hazards can lead to fundamental breaches of an MA organisation's duty of care to their staff, with potential reputational and legal consequences in the event of an accident.

Desktop and non-technical survey should be used to gain information on task sites prior to intrusive search operations being conducted.

Four additional hazards frequently faced by MA organisations are reviewed below.

1.5.1. STRUCTURAL INTEGRITY

An urban area that has been subjected to high-intensity conflict will have extensively damaged buildings and structures due to the use of explosive weapons such as artillery barrages, large air-dropped bombs and IEDs.

Cognitive bias, as explained in IMAS 07.14 Risk Management in Mine Action, can hamper decision-making when assessing structural integrity. It is recommended that construction and engineering specialists from the development sector such as United Nations Development Programme (UNDP) are involved in the management of structural risks. This does not mean they need to visit every site but potentially approved guidance can be developed that enables informed decisions to be made at the right level and for escalation when required.

Experience has shown that damage to buildings, including partly collapsed structures, can easily be misinterpreted. Sometimes structural integrity has clearly been compromised, meaning that manual clearance of the structure will exceed the risk threshold. At other times it will be much less obvious and require detailed consideration. It is important to assess building integrity at the earliest opportunity to aid the organisation in the follow-on decision on the feasibility and the need for any specialist resources.

Factors to consider during structural assessment are:

- Building type, size and height;
- Number, location and condition of supporting walls and structures remaining;
- Extent of fire damage that may have weakened any reinforcement or exposed toxic materials;
- Length of time the building has been damaged and has remained standing;
- Weather conditions and seasons that the damaged structure has endured;
- The anticipated effect that planned or unplanned explosions would have. What is the assessed size and type of EO expected?

1.5.2. TOXIC CHEMICALS AND SUBSTANCES HAZARDOUS TO HEALTH

Toxic chemicals and substances hazardous to health may be encountered frequently in critical infrastructure, industrial facilities and through a general exposure to a dense concentration of people. They may also be present where certain commercial chemicals and materials have been used in the manufacture of IEDs and are not readily identifiable as hazardous, especially if not in their original container. While MA is not involved in the disposal of chemical munitions, stakeholders should have effective risk management processes, training and equipment to care for a casualty resulting from unintended contact with improvised chemical weapons.

In order to gain an understanding of what hazards may be encountered, a desktop analysis can be used to establish what common substances are likely to be encountered and to gain information on the community's diligence in labelling, storing and use of chemical and hazardous substances. Correct and clear labelling and safety data sheets outlining pertinent precautions and procedures is an internationally regulated practice of controlling hazardous substances through the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). An awareness of the type of labelling used on hazardous substances would be beneficial in the identification process.

Labelling will normally consist of bold and contrasting colours with a pictogram identifying the nature of the risk posed by the product, like in the examples below:

Conflict-affected urban areas present the challenge of hazardous substances stored without clear labelling either due to damage and deterioration, or non-adherence to regulations.

The presence of these substances may be indicated by:

- Purpose-built storage facilities, more secure or ventilated, which could be separate from general areas;
- Symptoms of nausea and sickness in their presence;
- Strong odour;
- Large robust containers;
- Discarded PPE in the immediate area, such as goggles and rubberised gloves.

Image 17. Potentially hazardous chemicals

Home-made explosives (HME) are commonly encountered in IEDs and pose an additional hazard on a task site. Manufactured from commercially available precursor chemicals, they can pose a toxic hazard in their own right. HME precursor chemicals may be acquired legally or illegally and are usually used / stored in bulk. The presence or evidence of HME precursor chemicals proves critical in threat assessment (specifically on the supply chain of the armed group).

HINT. IED precursors include common chemicals that are used as both fuels and oxidisers in the production of HME. These include peroxides, potassium sulphate, potassium nitrate, magnesium sulphate, ammonium perchlorate, potassium chlorate and acetone, as well as fuels such as diesel.

Image 18. Evidence of precursors for the manufacture of HME

1.5.3. CONFINED SPACES

A confined space is any place where there is a risk from lack of oxygen, presence of poisonous gases, fumes or vapours, movement of liquids or solids, fire and explosion, dust or heat. Additionally, confined or enclosed spaces may restrict entry and exit, and in turn reduce the ability to conduct effective clearance and casualty evacuation. Consider Image 19 and the access to a silo. If a detonation occurred, or a low oxygen environment was encountered, how would the staff member be evacuated? Factors to consider here would be the possible damage to the structure and the availability of specialist equipment and stretchers. Response plans would need to be briefed and rehearsed by the team.

Image 19. Image showing a potential confined space

Indicators for identifying whether a confined space is hazardous include:

- Previously sealed area with little or no ventilation;
- Low-lying space, inside or out (excavations);
- Lack of passage or use of the space;
- Presence of rotting or degrading materials such as metal (rust), faeces, waste matter or litter;
- Commercially available gas sensors warning of the presence of toxic gases or lack of oxygen.

Hazardous confined spaces include, but are not limited to:

- Fuel tanks
- Silos
- Storage bins
- Hoppers
- Vaults
- Pits
- Manholes
- Equipment housings
- Ductwork
- Pipelines
- Tunnels

WARNING. Confined spaces can also enhance an explosion if fine particles such as flour, soot, wood shavings or aluminium are present. Fine powders can act as further fuel for an explosion when mixed appropriately with the air. This leads to a phenomenon known as 'fuel-air' explosions where the blast effects of the explosion are enhanced over a much wider area.

CONFINED SPACE VIGNETTE

April 2000, Northern Ireland, UK. A specialised military search team planned a search of a large deep-sea vessel 'Diamond Bulker' loaded with 23,000 tonnes of coal. Coal may be subject to oxidisation, leading to depletion of oxygen and an increase in carbon dioxide in the cargo space.

Although hazardous confined spaces were expected on board, the plan for dealing with these spaces was unclear, PPE and emergency equipment commensurate with the dangers was not readily available, and not all the team was trained to a sufficient level.

Two team members entered a cargo hold without testing the environment, allowing for sufficient venting or equipping themselves with escape breathing apparatus. Both team members succumbed to the lack of oxygen and fell from the access ladder further into the hold. A third team member entered the hold in an attempt to render first aid and also succumbed.

Breathing apparatus and lifelines were located and employed, the main hatch was opened by the ship's crew for increased ventilation and a belated rescue attempt was made to recover all three members. However, unfortunately two people died, and the third person was seriously injured due to lack of oxygen. This event led to a review and changes to training and SOPs.

A report of this accident can be found on the UK Government website, Accident Investigation Report 9/2001.

1.5.4. WORKING AT HEIGHT

WARNING. When a person is working at height a fall could cause injury.

Armed groups will often place weapons systems at the highest point on structures to provide a vantage point for when they are used. IEDs can be used to protect these positions from attack or to make clearance of the area difficult. By nature of their location, these positions are often targeted by an array of military ordnance which further adds to the contamination. As such, contamination from EO on roofs and the upper levels of buildings is common in urban areas.

Image 20. Image showing MA staff working at height conducting battlefield area clearance (BAC). Just looking at the damage to this structure, is it safe?

Three simple ways to identify if staff are working at height:

- Working above ground or floor level using a ladder or other means to gain height;
- A fall could occur over an edge;
- A fall could occur through an opening in a floor, a hole in the ground or through a weak surface.

Image 21. Another example of working at height

Consider Image 21. Is this safe practice? The assessment of the ladder suggests that it is structurally sound, has an enclosed back and suitably spaced steps to allow use without specialist equipment. However, should the visor be replaced by a helmet or a combined helmet / visor? This will depend on what the individual is searching for, as well as other non-explosive hazards.

1.6. MITIGATING ADDITIONAL HAZARDS

Image 22. Image of a water feature that represents a non-explosive hazard

Once an additional hazard(s) or risk(s) has been identified, an assessment can be conducted, and mitigation measures implemented. Fundamentally, the approach should consider:

- Viable alternatives to identify if the clearance requirement can be met using the safest option;
- Avoiding the additional hazards;
- A safe system of work being put in place with adequate emergency procedures, including for rescue, before work starts;
- Hazardous confined spaces require a considerable amount of specialist equipment and qualifications if they are to be operated in safely;
- A tightly controlled safety procedure to ensure that hazardous energy sources and dangerous machinery are properly shut down and isolated during operations that may be affected by such infrastructure (commonly referred to as a lockout or tagout procedure);
- Providing appropriate training and additional equipment and PPE for risk mitigation;
- Minimising the risk by favouring the use of the least amount of personnel over efficiency, to safely succeed in the task;
- Engineering solutions to decrease the probability or reduce the consequences of the risk(s) (a common mitigation tactic in unstable structures).

2. SEARCH PLANNING AND EXECUTION

Image 1. An MA IED clearance task site incorporating buildings, routes and open areas

2.1. INTRODUCTION

MA operations are complex and require detailed and thoughtful plans. The IED threat, especially in urban environments, may add further complexities that hinder operations and prevent the real needs of affected communities from being addressed. MA organisations must make concerted efforts in planning throughout the lifespan of operational tasks. This section of the GICHD IED Clearance Good Practice Guide provides tools and examples to aid in the planning and execution of MA IED search tasks. These tools are found in the following annexes:

- **Annex C1 - Non-technical survey form example**
- **Annex C2 - Threat assessment form example**
- **Annex C3 - Risk assessment form example**
- **Annex C4 - Clearance plan form example**

2.2. STAGES OF IED SEARCH

The following five-stage process can be applied to IED search tasks whether they are in an urban or rural environment. Survey and clearance have been combined for the purposes of this guide, as it is focused on a post-conflict environment with little-to-no population return. This type of situation would mean that it is more likely that a more technical team would conduct the initial survey with the ability to move to TS or clearance if required.

- **Stage 1 - Tasking and desktop study**
- **Stage 2 - Survey and clearance plan**
- **Stage 3 - Establishing the worksite (CP, marking, cordon and evacuation)**
- **Stage 4 - Systematic search**
- **Stage 5 - Reporting, completion and handover**

REMEMBER. The threat summary produced at the end of Stage 1 should be reviewed any time there is a change in the available information. If this results in a change in the threat assessment, it should be recorded and reflected in an amended clearance plan.

2.2.1. STAGE 1 – TASKING AND DESKTOP STUDY

TASKING

It is the responsibility of the NMAA to ensure a tasking order is given to an MA operator that falls within their capability. If no NMAA exists then an international agency may act in its stead, or in extremis the MA organisation may need to self-task based on engagement with the affected community and in line with its own mandate and capabilities.

MA operators may have different capabilities, and this may affect which organisations are best suited to different types of tasks and the specific challenges that they represent. For example, a critical infrastructure site such as a water purification facility, with obvious hazardous chemicals or materials, will require different equipment and staff competencies to that of clearance of open agricultural land. The MA operator, NMAA and other stakeholders should make sure that the tasking process takes this into account.

Image 2. Challenges such as working at height should be considered at the tasking stage

DESKTOP STUDY

The desktop study is terminology for information gathering and analysis from a range of sources and is closely linked to site survey. It is an extremely valuable part of all MA operations and should begin at the earliest opportunity. The level of detail required will depend on the type of task and the information sources available. Further detail for threat assessment and sources of information can be found in IMAS 07.14 Risk Management in Mine Action, Annex C.

Information sources will include previous MA reports which should be analysed by suitable staff and the findings recorded. Previous report types include:

- Impact assessments
- Incident reports
- Community liaison
- Explosive ordnance risk education (EORE)
- Non-technical survey (NTS)
- Clearance plans
- Spot tasks
- Completion
- EO technical reports

Key informant interviews are an extremely useful source of information, and although normally associated with NTS, can be conducted at the desktop level. These interviews may be conducted by telephone, through social media or in face-to-face meetings away from the IED-contained areas. Potential interviewees include:

- **Affected community.** Community members will have direct and indirect information relating to IED contamination. This includes community members who left their homes during the conflict and are waiting to return, as well as those who have remained and are now living in close proximity to IED contamination.
- **Security forces.** As part of the government, the NMAA should have links with the government security forces, who may be willing to share information on the IED contamination that they have encountered.
- **Explosive ordnance disposal (EOD) units.** Building on general engagement with security forces, these specialist units may have important technical information, including reports.
- **Key infrastructure and governmental workers.** These workers may be some of the first individuals entering a post-conflict area in order to start the process of rehabilitating the infrastructure needed to help the large-scale return of the community.
- **Hospitals and healthcare units.** Casualty data aids in threat analysis. The types of injuries and where they happened are important to note.

Openly available sources of information should also be investigated and incorporated into the desktop study. These may include:

- Action on Armed Violence
- The Armed Conflict Location & Event Data Project
- Small Arms Survey
- Insecurity Insight
- IED Awareness
- Conflict Armament Research
- Geneva Declaration on Armed Violence and Development
- Governmental foreign travel advice websites

It may also be possible to access reports from other humanitarian and stabilisation actors in country. These could include:

- National and international medical organisations
- National and international development organisations
- National and international security forces

Open source mapping applications, including aerial imagery, may have an accessible date range over many years. This enables comparisons of an area pre and post conflict which can then be compared and analysed by staff with fairly basic levels of training. This mapping can also be used to identify battle damage, confrontation lines, critical infrastructure and transportation networks.

Image 3. Social media posts from the affected community can provide useful information for the desktop study. This may include geotagged images that can be cross referenced (see Image 4)

Image 4. Cross-referenced aerial imagery of the location in Image 3. Source: GoogleEarth ©

OUTPUTS OF THE DESKTOP STUDY

Initial threat assessment. This will indicate the general levels and nature of the IED contamination and the resources (trained staff and equipment) that are likely to be required.

Terrain and infrastructure analysis. The key transportation network, hospitals, power, sanitation, municipality, industrial and education infrastructure can all be identified through open source information during the desktop study. There are a number of readily available information management (IM) tools that are useful in communicating this analysis through accurate geospatial visual layers.

Identification of safe routes. Prior to MA staff accessing new areas, it is important that routes are assessed for both damage and potential contamination. Establishing the 'pattern of life' of the community, including localised behaviours, is a key enabler to ensure that safe access can be achieved. This may include assessing levels of vehicle or pedestrian traffic through interviews. It should be noted that this will not discount explosive hazards, especially conventional ordnance such as mortars and projectiles, and suitable precautions should be taken by the teams travelling to a new area of interest to visit an MA organisation.

Potential CP locations. At the task site level potential control point (CP) locations can be identified using aerial imagery or mapping. A study of the area will determine the scale of a potential task and hence the placement of main CPs and intermediate CPs for a larger site. Considerations for locating a control point in a large urban task site include:

- A location secure from third party interference. This may mean the CP is situated inside the boundary fence or wall of the task site, potentially requiring clearance to be conducted;
- A location in the vicinity of adequate and safe parking, administration areas and equipment preparation and maintenance areas.

2.2.2. STAGE 2 – SURVEY AND CLEARANCE PLAN

SELECTION OF SUITABLE PERSONNEL AND ASSETS TO CONDUCT A SURVEY

Survey tasks should be carried out by competent staff, using suitable equipment (accredited where appropriate), in compliance with safety and operational standards. NMAS should outline appropriate IED survey methodologies that can then be developed by MA operators and specified in SOPs that can be accredited. MA operators should be aware that there may be cases in the urban environment contaminated by IEDs, where national standards do not cross over easily. This may be due to the complexity of the IED threat, as well as other non-explosive hazards.

Survey teams should have the resources, skills, knowledge and attitudes to carry out safe, effective and efficient survey in the locations to which they are tasked. In particular, in urban environments, they should be supported by IM systems that are appropriate to the level of engagement that they will have with the local community and enable this to be recorded accurately, and disaggregated between the needs of women, girls, boys and men.

Survey teams need to have a thorough understanding of the use of IEDs during the conflict, including how armed group tactics varied between different types of spaces (i.e. open areas vs buildings). MA survey staff should have the knowledge to identify benign items that could be misidentified by the community as IED components, explain this to the community and then not record them as evidence of IED contamination. These items could include discarded batteries and wires that have no relation to IED contamination.

Image 5. Industrial areas offer complex task scenarios

COMMUNITY ENGAGEMENT

This is a wide-ranging topic and requires MA staff to have specific knowledge, skills and attitudes to be able to carry out community engagement effectively. Often, risk-taking groups are difficult to engage with, and MA staff need to actively seek their participation to gain the best evidence relating to IED contamination. An urban community will also take different risks from those of rural communities and this should be understood by MA staff. There may also be highly hierarchically structured societies which MA staff will need to be sensitive to in order to gain access to certain community members.

NON-TECHNICAL SURVEY (NTS)

As with all MA survey and clearance activities, good NTS is the first activity that provides tangible evidence, helping to ensure that IED contaminated spaces are released back to the community not just effectively but also efficiently.

The purpose of NTS is to:

- Confirm whether or not there is evidence of a hazard;
- Identify the type and extent of any hazard within the area;
- Define, as far as possible, the perimeter of the actual hazardous areas, without physical intervention or use of clearance assets.

In an urban area contaminated by IEDs, NTS should also gather evidence on:

- Secondary or non-explosive hazards such as issues in structural integrity;
- Obstacles to clearance requiring specific resources;
- Potential CP locations and access routes;
- Physical features in the urban terrain to be used to delineate large sites and form smaller zones.

PRODUCTION OF AN OPERATIONAL THREAT ASSESSMENT

Chapter 1 provides detailed guidance on the completion of IMAS 07.14 Risk Management in Mine Action, Annex C threat assessments.

In the context of IED search, an operational threat assessment consists of information gathered on an armed group(s): intent, capability of and opportunities in the use of IEDs and other explosive weapons inside a defined area. Annexes C2 and C3 provide examples of an operational threat assessment in the context of search operations.

CLEARANCE PLAN

The following guidance highlights sections of the clearance plan form that may require more description on what and how information should be recorded. Not all sections are covered as many require only basic information. It is useful to have the Clearance Plan annex (C4) in view when reading this section.

A clearance plan should always be developed and recorded for an IED search operation. It will provide transparency and auditability in decision-making and enable post release evaluation. The level of detail and authorisation processes required will depend on NMAS and the MA organisation's SOPs. Where possible the content of a clearance plan should be kept to the minimum acceptable level of detail to reduce any unnecessary burden. This can be facilitated by using templates, referencing SOPs, NMAS or other suitable documents rather than writing information out in full.

The following section covers many of the considerations and information requirements for a clearance plan document, following the model in Annex C4 - Clearance Plan Form.

SECTION 2A – LOCATION DETAILS

It should be the NMAA's decision on spatial location systems that must be followed but, where possible, official gazette information should be used when entering information into this section.

When stating the total m², it may be the case that there are buildings with multiple floors which are not easily represented with a two-dimensional image. Multiple floors or significant elevation affecting the total m² should be stated either in this section or in 2b, where the identification of these may be easier to convey visually.

SECTION 2B – MAPPING

Mapping may consist of multiple images, especially where pertinent information may be better presented through aerial imagery. When a task consists of a large area that incorporates multiple different sub-areas such as hard / soft open areas, buildings, vegetation and water features, consideration should be made for treating these as separate annexes in the plan. If there are restrictions that will prevent or hinder the full clearance of the site, these should also be recorded visually on any mapping for the task and the GPS coordinates recorded. Potential CP locations should also be recorded on any mapping.

SECTION 3 – REFERENCES AND ANNEXES

References are the key documents and sources used to support the previous sections. This may include the tasking document or extra diagrams / images / mapping to support the previous sections.

SECTION 4 – THREAT SUMMARY

Once an operational threat assessment, following the guidance in IMAS 07.14 Risk Management in Mine Action, Annex C, has been completed, it should be inserted into the clearance plan as a threat summary. This threat summary should detail the most likely cases for the category and subcategories of IEDs that could be present in specifically assessed areas. This should specify the composition of component parts, their configuration, and location including depth or elevation. It is useful to express this in terms of most likely and worst case, especially if anti-disturbance, multiple or secondary devices are a threat.

The threat summary should clearly state:

WHO?	Who placed, dropped or threw the IED(s)?
WHO?	Who was the target?
WHAT?	What are the components and layout of the IED?
WHEN?	When was the IED(s) placed, dropped or thrown?
WHERE?	Where is the IED(s) located?
WHY?	Why is the IED there? What was it intended to achieve or target?

HINT. If there is a lack of information for a detailed threat summary, stating what is most likely NOT to be present or most likely locations to NOT have contamination will also aid search.

REMEMBER. Annex C2 provides a useful form to assist in operational threat assessment.

SECTION 5 – SECURITY RISK ASSESSMENT

This should include the current situation and its likelihood for change on, to and from the MA task site. It should also include the potential for unauthorised access, whether this includes malicious intent towards the MA organisation or not.

SECTION 6 – OUTCOMES AND BENEFICIARIES

The indicators for outcomes and beneficiaries vary between countries and possibly tasks. Suitable indicators should be established in consultation with the NMAA and donors. A benefit outcome could be expressed as a value of power output, for example '15 megawatts' or even better, watts per number of community residences.

Where a task is a site of critical infrastructure such as a hospital, its value could be expressed as providing for the specific town or district. Care should be taken to prevent exaggerating the direct and indirect beneficiaries of a task site. Sites that provide employment such as a factory should be expressed in the number of employees and as these may number in the thousands it would be difficult and costly to ascertain how many dependents they have. There is a significant number of other potential indirect beneficiaries such as suppliers, transport companies and customers who will also be affected, but again this is likely to be difficult to measure. A process to monitor land use following the end of the clearance task should be properly planned and agreed between the different parties.

SECTION 7 – CLEARANCE METHOD

This is a key section and is closely linked to Section 4 – Threat summary. The clearance method should be clearly written without the need for excessive text. A good example is referencing specific procedures from the organisation's SOPs. If there are several different methods being used due to varied IED and other EO contamination, deviations from SOPs or other non-explosive hazards, then this should be highlighted in Section 7b – Works plan.

The time and schedule should be realistic and where possible attributed to reliable benchmarks. Tasking authorities should be aware that these may change if there is new information obtained in relation to the threat assessment. Reporting thresholds may be time, sub-area or based on another measurement that should be established by the tasking authority.

The clearance method statement should outline a systematic plan for the site. Areas where the definable edges are difficult to search systematically (examples include rubble and rubbish dumps, and sprawling infrastructure fixtures) will need identifying at an early stage and plans made accordingly. Awareness of these areas and marking out will give deminers a clear boundary and ensure areas are not missed or searched multiple times.

Clearance priorities may be established for several different reasons and if required these should be stated in the tasking document, for example:

- Access for assessment by development organisations;
- Establishment of a CP and access for work to begin;
- Areas presenting a high threat to local communities or clearance teams.

SECTION 7D – QUALITY MANAGEMENT

The main components for this section are quality assurance (QA) and quality control (QC): requirements that will be used to build confidence that clearance parameters will be met (QA) and that they have been met (QC).

QUALITY PLANNING – ESTABLISHMENT OF CLEARANCE PARAMETERS

Specifying clearance parameters (or requirements) is an essential element in creating a clearance plan for a specific task. It may be appropriate to define a specific depth in some types of IED-contaminated spaces when subsurface IEDs are considered to be a threat. It may also be appropriate to set other parameters that are relevant to buildings, and other structures, when solely specifying depth would be inappropriate.

The parameters should be developed based on evidence related to post clearance use and be appropriate to both the type of urban space(s) to be cleared (open area, route, building) and also the assessed explosive hazard threat.

An example of a clearance parameter (from IMAS 09.13 Building Clearance): "A building shall be accepted as "cleared" when the MA organisation has ensured that all structural surfaces, loose items and household fittings are free from EO."

QUALITY ASSURANCE

Image 6. Assessment of MA search staff. Would this individual be competent to undertake building clearance?

In terms of clearance planning, QA starts with the task being deemed to fall inside the scope of activities for which the MA organisation has been accredited.

> **REMEMBER. It is important that the SOPs, staff and equipment under which this accreditation was granted, remain extant.**

On-site visits to conduct QA can be carried out internally by the MA operator, and externally by the NMAA or a third party. These visits should be specified in a quality management system (QMS) which should provide direction on how different tasks should be broken down into constituent elements such as management, manual clearance, building clearance, BAC, mechanical demining, ADS, medical and information management. The QMS should specify the frequency of these QA checks, and the associated reporting, including observations and nonconformities, to enable continual improvement through the application of appropriate actions.

For example, there is no point specifying that a mechanical QA be carried out every month of a task where only manual clearance is being conducted. At this worksite it might be that only management, manual clearance, medical and information management QAs are required, although the precise details will be determined by the QMS. For example, it may be that manual QA is conducted every week. This might include checking and reporting that the correct PPE is being worn.

Image 7. Standard mine action PPE

Image 8. Additional protection is provided with this PPE, including protection from the rear and above

QUALITY CONTROL

Quality control is usually carried out at the end of the clearance by a separate organisation via inspection and sampling of the area. The norm in mine action is to use the same procedures and equipment that was used to carry out the clearance, since this is a fair and reliable way for an inspection to be carried out for IEDs. This again can be difficult in buildings where there are multiple varied environments in which a variety of procedures have been used.

Internal QC conducted by MA organisations on-site will need to check that parameters have been met in new and novel ways. Essentially, they need to prove that there can be no EO in the sampled area whether that be an open area, the confines of a building or areas affected by gross industrial contamination.

IMAS 07.40 Monitoring of mine action organisations, Annex C, 6.3 – equipment and methods states that any method used for inspection must be capable of indicating any potential target and therefore other methods apart from those used for clearance may be considered for QC. Ultimately the NMAA must decide on what will give them the confidence that the clearance has achieved the clearance parameters.

SECTION 8A – INCIDENT MANAGEMENT

Incident management should be detailed in the plan, briefed to MA staff and either held directly in this section or as an annex to the clearance plan. Incident management should include immediate actions for uncontrolled explosions, non-explosive incidents, security incidents and specific details on the casualty evacuation plan.

Incident planning should consider:

- Worst case casualty types and numbers.
- Medical support requirements.
- Casualty transportation and routes.
- Care provision in the immediate local area.
- Suitability and length of route to actual and recommended medical facilities.

Image 9. Casualty evacuation drills being conducted in accordance with SOPs

SECTION 8B – MEDICAL FACILITY DETAILS

This section should be used to clearly specify medical care, taking into account the medical facilities that are available to deal with different levels and types of injury. Maps with routes to and from these medical facilities should also be included with the casualty evacuation plan.

SECTION 9 – ACCIDENT AND INJURY PREVENTION

Application of IMAS 10.20 Demining worksite safety defines general requirements for worksite layouts which may need additional thought when planning for MA operations in urban areas. The IMAS requirements are designed to:

- Provide a clearly visible separation of hazardous areas (including demolition danger areas), cleared areas and useable areas;
- Ensure that approved working distances are maintained between individual deminers, machines or ADS and other staff on the MA worksites;
- Control the movement of demining worksite staff and visitors (including members of the public) at the worksite;
- Control the movement of demining machines and other vehicles;
- Limit the number of demining worksite staff and visitors allowed into danger areas;
- Take all reasonable precautions to exclude demining worksite staff, visitors and members of the local population from demolition danger areas during the controlled destruction of mines and explosive remnants of war (ERW), or provide suitable protection inside buildings, bunkers or mobile structures; and
- Include measures to prevent structural and environmental damage.

A large urban task site may provide ample opportunities to deliver these requirements but will almost certainly need extra supervision by staff confident in a robust clearance plan.

- Risk assessments may already exist for common hazards such as use of ladders or working at height; therefore, they should only be referenced here.
- For any other hazards that are found to exist, a risk assessment must be conducted, and suitable mitigation methods planned, ideally using the Annex C3 Risk Assessment Form or similar, and listed in this section in 9c – Site-specific risk assessment reference.

An organisational culture that encourages safe practices should be promoted by the MA organisation by scheduling regular safety meetings for all to attend, on either general or specific site safety, to provide a forum to air concerns if needed. At the very least, an organised meeting with respective MA staff should be held to brief a site-specific risk assessment along with mitigation factors. This should be scheduled before work starts on-site and re-briefed if the work conditions change, or if there is an incident to warrant amendments or additions.

SECTION 9D – ROLES AND RESPONSIBILITIES

This section is used to list MA staff that have roles and responsibilities pertinent to maintaining an efficient and safe site. On a large complex site, it may be appropriate to divide the responsibilities between areas and list specific management roles for the worksite such as overall site management, medical, IEDD, search, mechanical and ADS team leaders.

2.2.3. STAGE 3 – ESTABLISHING THE WORKSITE (CP, MARKING, CORDON AND EVACUATION)

Image 10. Main CP, administration, parking and marked approach lanes

MARKING / RECORDING OF TASK / HAZARDOUS AREAS

If areas are to be effectively recorded there must be total confidence in the quality and accuracy of the data. In most urban areas, a handheld GPS set to a worldwide geometric projection will not deliver accurate enough positional information to identify specific boundaries of safe and unsafe areas. Being 30 cm out due to inherent inaccuracies in GPS reception could mean the difference between a person being on the same side of a wall as an IED, rather than the opposite side. Common geometric projections should be agreed so that all operators are working with the same data and tolerances. Abundant linear features in the urban area, such as paving stones and edges of hardstanding, coupled with up-to-date aerial imagery from an unmanned aerial vehicle (UAV), will aid the MA organisation considerably when recording boundaries of site and internal zones or areas.

TECHNICAL SURVEY

Technical survey is the natural stepping stone from NTS to full clearance or release and should be planned accordingly. Allowing the previous survey activities to delineate the site into smaller zones could aid in the adoption of technical survey principles as in IMAS 08.20 Technical Survey. Of these principles, the following are key to operations in an urban area with an IED threat:

- Targeted technical survey should be preferred over systematic technical survey;
- The technical survey methodology should reflect any need to preserve information about the nature and distribution of contamination; and
- Details of what was found and where, and what was done and where, should be recorded and reported with sufficient accuracy to satisfy applicable standards and allow meaningful analysis of the type, nature and distribution of contamination within its surrounding environment.

OCCUPYING SUITABLE CONTROL POINTS

Safe access for MA teams is paramount. Any area affected by conflict will have the potential for IED and other EO contamination on routes to and from survey and clearance sites. Consideration should be given to other undefined areas in the immediate vicinity of planned CP locations. It may not be immediately evident which routes are safe or what level of residual risk may exist. Duty of care to staff is paramount and corners should not be cut in the rush to get access.

Referring to the national threat analysis conducted during the desktop study should be a key element in determining the EO threat on potential routes to and from CPs. It should provide confidence in making decisions on which routes may be contaminated and which should be safe. It will also enable the identification of other sources of information for more detailed assessment.

CP CONFIRMATORY CHECK

Prior to establishing a CP, all team members should be aware of the intended location and boundaries of the CP (ideally briefs should include imagery). Linear features on the ground, such as kerb edges and road surfaces, should be used to specify these boundaries.

Time should be spent while establishing the CP to conduct a check of the surroundings from known safe areas to ensure that there are no suspicious items present. This should be repeated each time a CP is occupied.

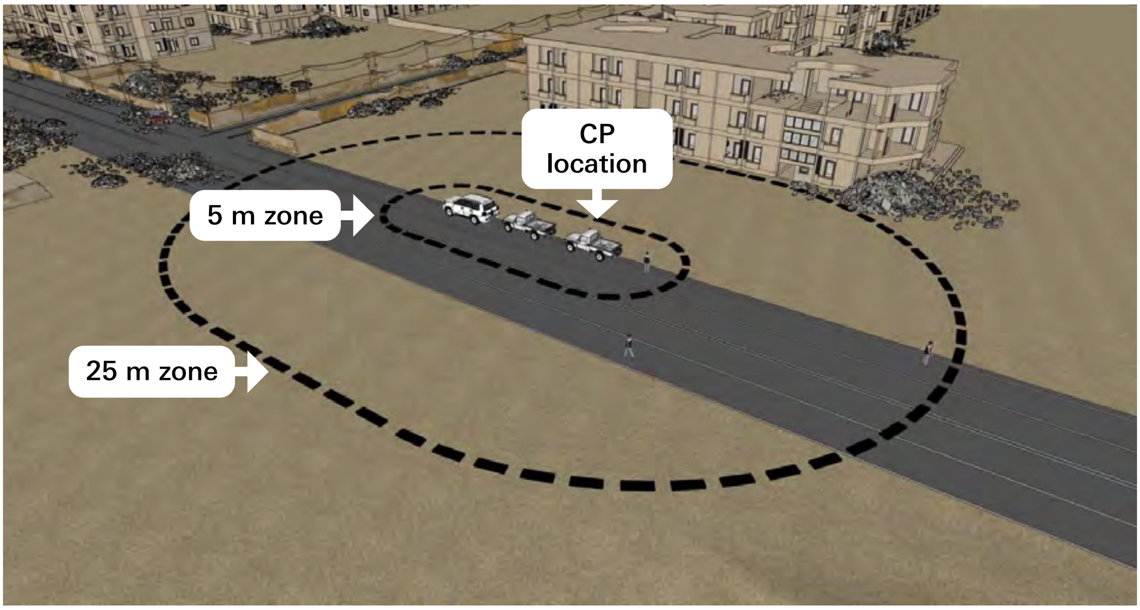

Image 11. Conducting visual confirmation that a temporary CP is safe

WARNING. Even after EORE has been provided, community members may bring EO from surrounding areas to CP locations knowing that MA organisations will remove them.

HINT. A 5 m and 25 m check (or sometimes a 5 m and 20 m check) is a procedure used for a visual and physical check of a location such as a CP. It means that all areas are physically checked to within 5 m, with this extended out to 25 m as required, with a visual check only.

2.2.4. STAGE 4 – SYSTEMATIC SEARCH

Image 12. A task involving technical survey and clearance of an IED belt, as well as building clearance

CONTROL OF MA TASK SITES

There should be specified procedures for controlling the entry of unauthorised persons into MA task sites. This should be achieved by:

- Informing the local community, MA staff and visitors of the extent of the worksite, hazardous areas and danger areas;
- Physically controlling entry into danger areas during the EO destruction processes by the use of warning signs and positioning sentries;
- Marking of hazardous and danger areas (see IMAS 08.40 Marking mine and ERW hazards).

Warning systems should include the following:

- Warning signs on approach routes (roads, tracks or paths) informing persons that they are entering a hazardous or danger area. Signs should include information on the nature of the hazard or danger and the extent of the area. Signs should also remind demining staff of any need to be wearing personal protective equipment whilst inside any danger area;
- Risk reduction education through briefings or signs or information sheets to persons living or working near a demining worksite, and to the local authorities in the area. The briefings and / or information sheets should include information on the audible warning methods used to advise workers and the local public of the demolition of EO;

- Risk reduction education, including site dangers, and the implications of ignoring the directions of demining workers appointed to control access into danger areas; and
- Documented standards and SOPs should include the use of sentries to control entry into danger areas, warning signs and audible signals to be used during any disruptive, disposal or destruction process.

360-DEGREE OBSERVATION

Achieving 360-degree observation of the task site significantly enhances the understanding of staff prior to commencing operations. It can be achieved from vantage points in known safe areas and also through the use of UAVs. Every opportunity should be taken to update the threat assessment from the information that is gained.

Considerations include:

- Observation into buildings **to identify** explosive and non-explosive hazards;
- Observation through windows may provide information on explosive hazards located in vulnerable points such as behind closed doors; and
- A manual check for physical link command IEDs should be conducted, depending on the threat assessment.

CONDUCTING SEARCH

Image 13. Detector calibration being checked prior to use

> **NOTE. Clearance of open areas is commonplace across the MA sector and therefore the following guidance focuses on the search for IEDs inside buildings.**

ENTRY TO BUILDINGS

When conducting IED building search, there should be specific consideration given to building search. If possible, points such as main entrances, doorways and approach routes should be avoided as these points are often the most likely locations for firing switches of IEDs to be located. These points are commonly referred to as vulnerable points (VPs).

The casualty evacuation plan should account for the entry phase, as there may be specific considerations to mitigate until standard entry points can be effectively searched. The immediate priority should then be searching from inside to the main entrance point and linking this with a clearly marked safe approach lane(s).

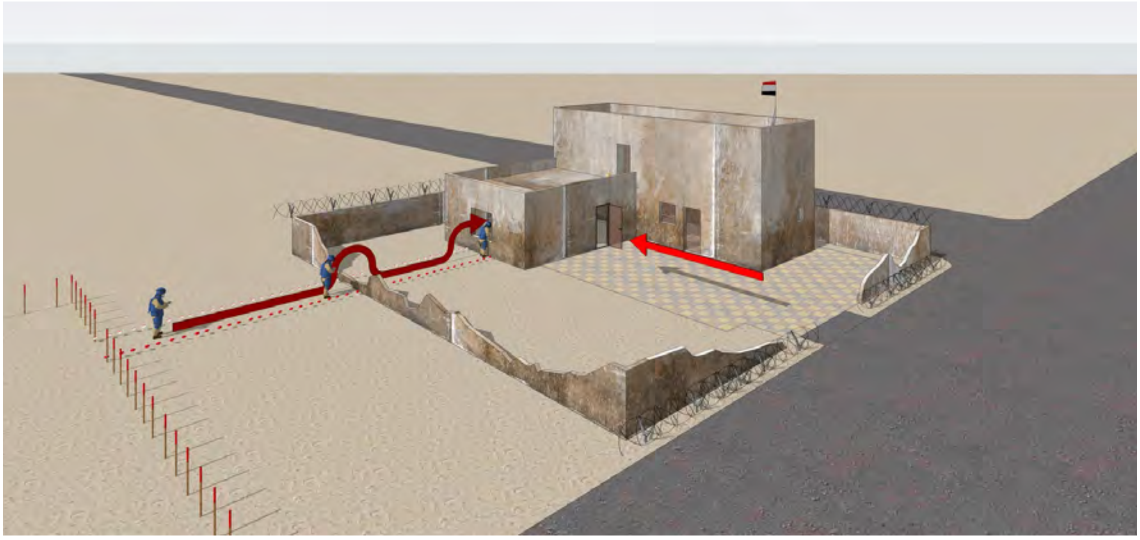

Image 14. An initial access route has been selected into a building suspected of having VOIEDs present. The route has avoided the main entrance way

If access through a VP is the only available option, then this should be carefully planned and managed with appropriate search procedures applied (see Section 3 – Search Core Skills and Procedures). This could include assessing the device layout and whether firing switches have been offset from the main charges.

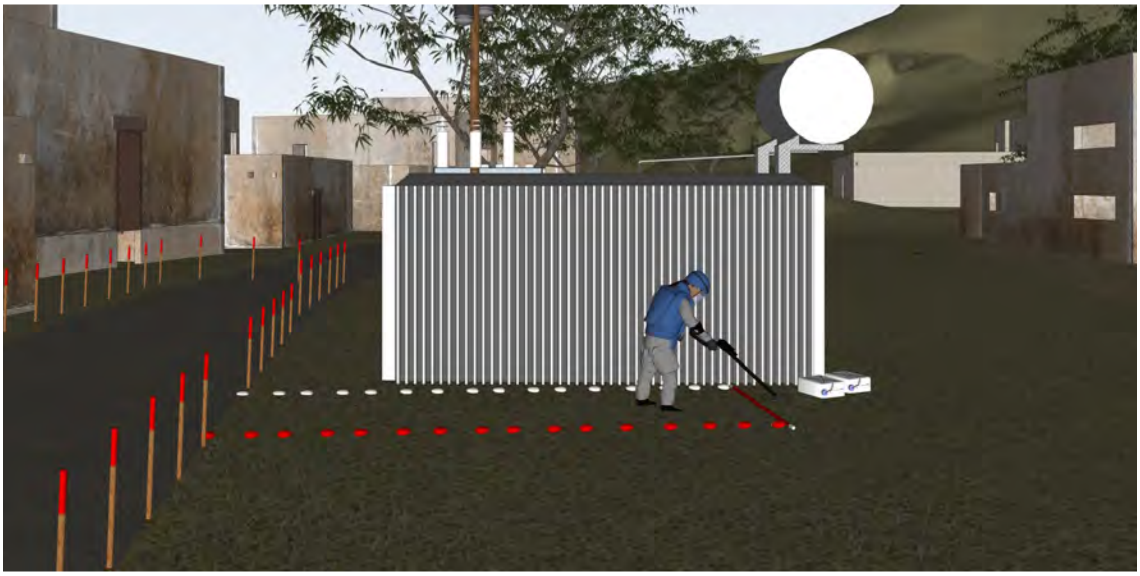

Image 15. Gaining safe access to abandoned IED main charges. Note the markings are clear and appropriate for their purpose

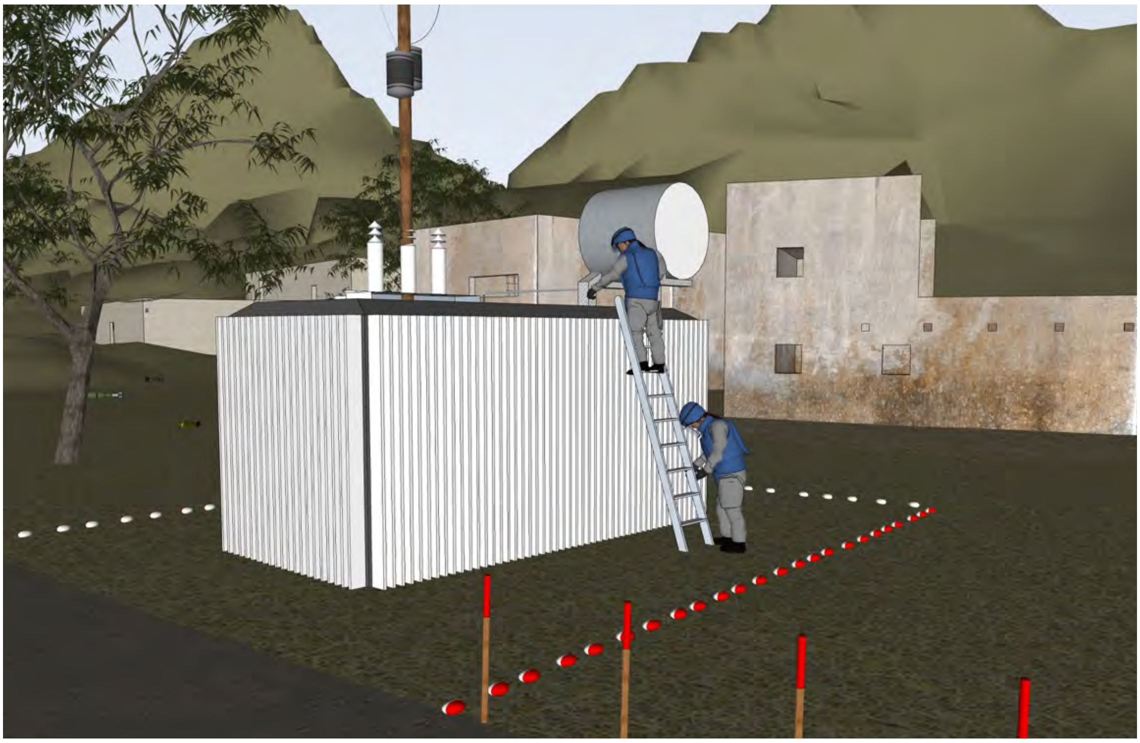

Image 16. Once the known explosive hazards are removed, a second searcher is brought forward to assist in safe working at height. The balance of risk between explosive and non-explosive hazards is being managed by the site supervisor and MA operations manager

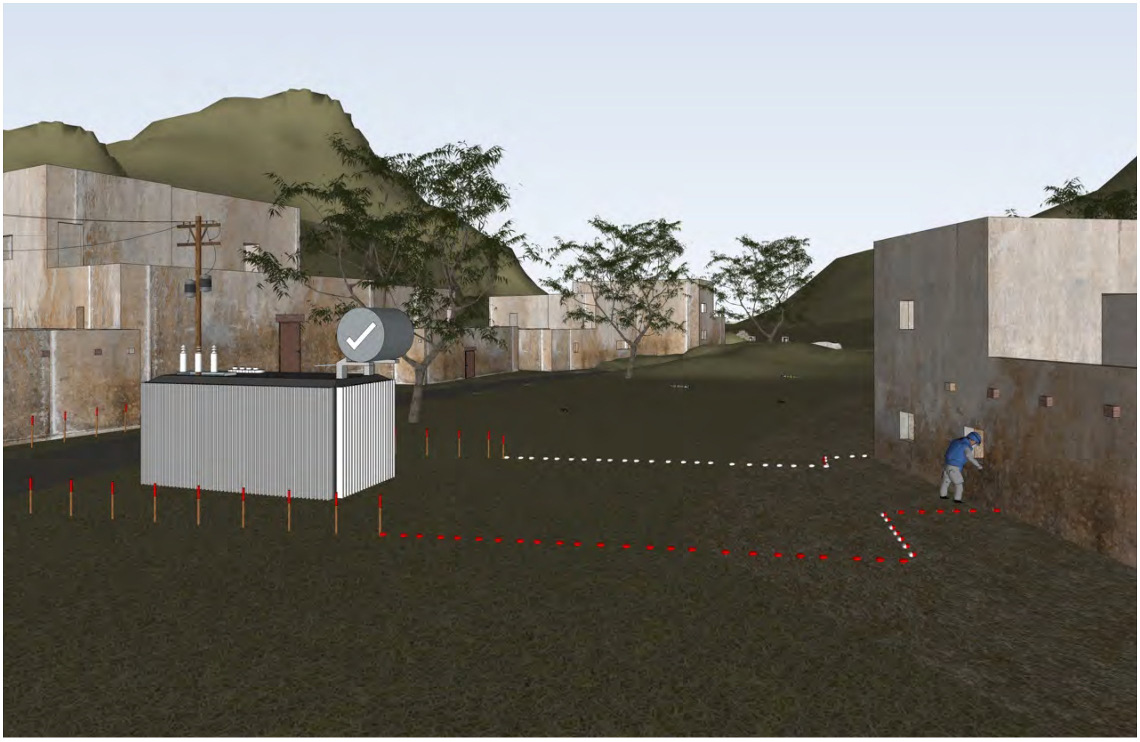

Image 17. The power transformer has been marked as clear with a white tick. Access has now been achieved to a window to enable observation into the building

Gaining access to alternative observation points such as adjacent windows, or approaching and searching each side of the entrance point can enable components such as main charges and power sources to be identified. This should be conducted prior to searching the entrance point itself, as this is where the firing switch is most likely to be located.

Image 18. A searcher has begun to access a building via a window, avoiding the main entrance. The searcher can clearly see hitherto hidden IED components at the main entrance

SYSTEMATIC SEARCH OF BUILDINGS AND URBAN AREAS

There is an abundance of clear boundaries inside buildings and these should be used to the advantage of MA operators conducting building search tasks. Large parts of buildings can be divided easily in order to effectively control the search, allocate resources or specify threats. Image 19 and Image 20 are examples of controlling a systematic search and recording valuable progression data.

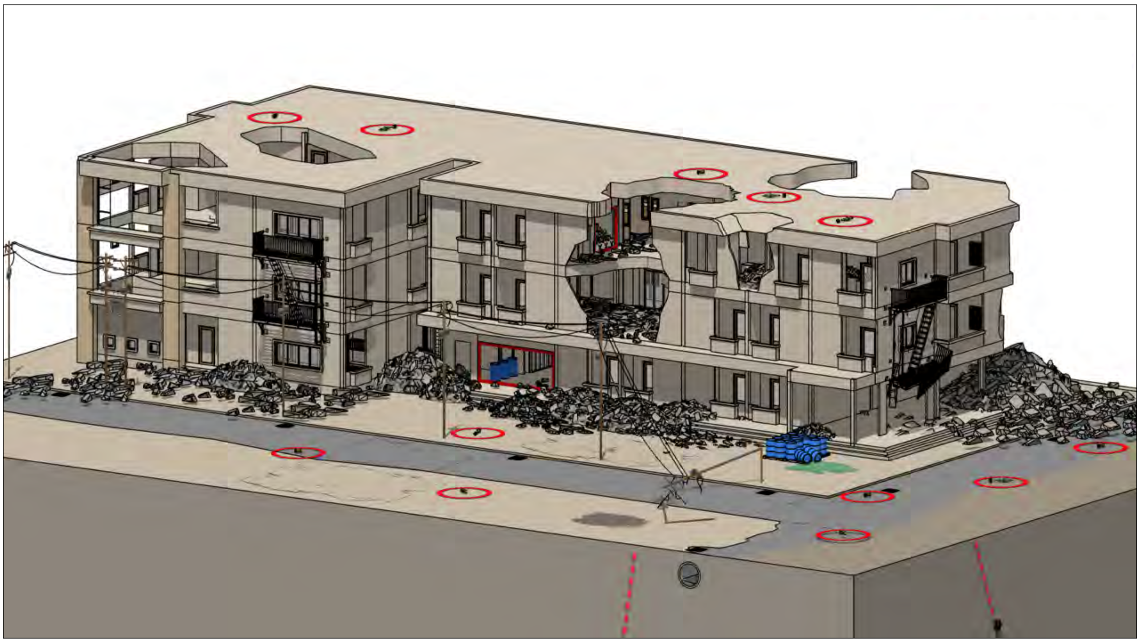

Image 19. An example of a complex sub-task in an urban area representing non-explosive hazards, limitations to search, a combination of threats and a complicated arrangement of areas to manage

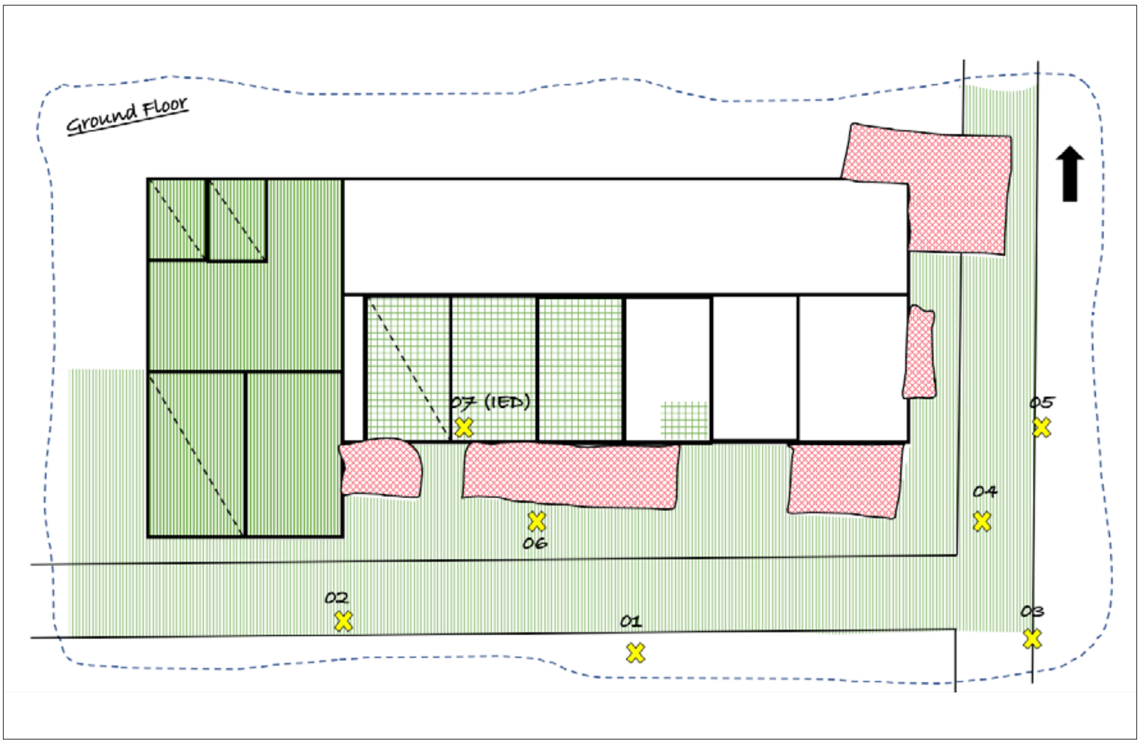

Image 20. A sketch map of Image 19 (ground floor and external)

Developing a sketch map such as the one in Image 20 helps to record progress by colour coding what has been completed and the category of search (1, 2 or 3) conducted as per IMAS 09.13 Building Clearance: category 1 (blue vertical hatching), category 2 (square hatching) or category 3 (green vertical hatching). Internal QC can then be annotated in specific rooms with diagonal dashed lines. The locations of finds are annotated with yellow crosses. Search limitations are annotated with red hatching. Additional sketches of floors 2 and 3 and the roof would also record progression and be a useful tool for efficiency and effectiveness.

2.2.5. STAGE 5 – REPORTING, COMPLETION AND HANDOVER

The reporting, completion and handover of MA sites that have been cleared of IED contamination is a vital part of the process of providing confidence to the community that they are now safe to make use of the released spaces. An information management system should be developed and specified from the outset of an MA response. This should integrate with the Information Management System for Mine Action (IMSMA) and be compliant with IMAS 08.30 Post-clearance documentation. There are also decision support tools that can bring significant benefit to how information can be evaluated and used as evidence, as MA response to IEDs continually seeks to improve.

Key reporting considerations include:

- Geographical extent of search including reference points, turning points and benchmarks. Consideration may be given to communicating these figures in both m2 and m3 to reflect both the footprint of the building and the interior volume;
- Details of finds including location, intention, state of degradation, quantity, proficiency of construction, camouflage if applicable or any notable information that may affect future clearance;
- Geotagged digital photographs can be a valuable source of such information that do not require translation; and
- Areas that may not have been searched due to restrictions such as rubble, water and confined spaces, and any associated permanent markings as applicable.

2.3. SUPPORT TO IEDD SPOT TASKS

Image 21. Taught and briefed handover drills are vital in the crossover from search to IED disposal. Here you see temporary markings clearly indicating a previously located suspicious object

On occasion, it may be appropriate for an MA organisation to conduct an IEDD spot task. The first question that must be answered is "does the task fall inside the NMAA remit for a spot task?" If it meets the requirements, then potentially an IED search team can assist in establishing CPs and other enabling tasks. Also, the search team should be involved in the planning conducted with the MA IEDD operator.

Below are some considerations and activities that the search team may be asked to assist with:

- Occupation of a CP
- Assisting with set-up of equipment
- 360-degree observation
- Manual search to provide access for the IED team / operator
- Secondary and non-explosive hazard management
- Actions on incidents – casualty evacuation
- Packaging, storage and transportation of recovered materials and explosives

ANNEXES C1-C4.
SEARCH PLANNING AND EXECUTION FORMS

Blank forms can be downloaded here :
https://www.gichd.org/en/our-response/mine-action-standards/improvised-explosive-device-clearance-good-practice-guide/

Non-Technical Survey Report	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

1. Report preface				
Report ID:	GS006	Area / Point of interest:	Al Obady Wheat Store	
Report status:	Initial	1st	2nd	
Report date:	11 March 2019			
Report supervisor:	A. Jones	Report prepared by:	S. Smith	
Report supervisor job title / qualification:	EOD Team Leader	Preparer job title / qualification:	EOD Team Leader	
Organisation:	Global Solutions Ltd	Organisation:	Global Solutions Ltd	
2. Report framework				
Area / Point details	*Include imagery of area / point with access routes and points of interest*			

Map 1: Wheat store general area showing proven access route from Highway 1 in the north

1

Non-Technical Survey Report	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

Map 2: Wheat store showing key locations and the site split into CHA 01 and 02 for initial reference

Access details	*List details of access routes and arrangements required and discovered during the survey*
Highway 1 to CP Green (MGRS GU0531913317) (check access through interpreters daily). Unpaved well-trafficked track from highway to main entrance of wheat store, the route has good observation from CP Green and an additional CP at MGRS 05310133106 (see map).	
Security risk assessment	*Record the results of or reference to risk assessments examining the security risks and vigilance levels pertinent to the area:* *N/A* ☐
Supporting document reference: *Global Security Risk Assessment AO001* Summary: There still exists a threat from insurgents and / or criminality. Global security alert states remain at High and corresponding security measures will be upheld. In the event of a security incident the Global security personnel are to take charge of the situation and withdraw to the designated safe location.	
References and annexes:	*Insert details of all previous reports, reference documents and annexes to be used in conjunction with this report*
Desk Top Assessment AO002	
Useful contact details	*List details for survey points of contact, ground support and emergency services / police*

Name / Job Title / Role	Contact details
A. Habbaniya, wheat store manager	(telephone no.)
A. Ash Shamah, Major, security forces, responsible for security of the wheat store	(telephone no.)

2

Non-Technical Survey Report	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

Report methodology	*List methods used during the survey*
Supporting document reference: Global Solutions Manual Search SOP After initial desktop assessment, one EOD team and one local national team deployed to the wheat store currently occupied by a skeleton security staff to interview persons, take images (with UAV) and inspect the interior of the wheat store on foot where deemed safe to do so.	
Hazardous area criteria	*Define organisational criteria for defining NEF, CHA, SHA, reduced, cancelled, etc.*
Supporting document reference: Global Solutions Manual Search SOP CHA: Direct evidence witnessed by EOD team members of explosive ordnance threat contained in the area and the area is on the Global Solutions task register. SHA: Indirect evidence received by EOD team members from a reliable source and the area is on the Global Solutions task register.	
Report summary	*Summarise survey activities and results*
The teams spent 2 hours on-site interviewing and inspecting the areas. VOIED contamination is visible in areas and suspected in others. There is direct evidence of UXO contamination. Access around the site was reasonably safe with well-known and worn access routes to most areas.	

3

Non-Technical Survey Report	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

3. Survey location details	
Survey location:	Al Obady Wheat Store, Al Banar province.
Survey location address:	Southern outskirts of Al Obady, 2 km south of CP 'Green' (MGRS GU0531913317).
Survey location situation & history:	It's widely known that a non-state armed group occupied this area for some time and were eventually pushed north along the river and the main supply routes into the west. They occupied the area for approximately 12 months and prepared large areas for defence generally from the south. Locally, areas were also prepared for defence from all directions. This area and site received indirect and direct fire from both sides including air-dropped weapons, artillery, mortars and rockets (conventional and improvised), projected grenades (40 mm) and small arms.
Survey location potential outcomes and beneficiaries:	The wheat store was a new facility before the recent fighting and purpose built to hold and distribute large volumes of wheat and grain across Banar province by road and rail. Wheat supply for Northern Banar is currently being held across the border because there isn't a safe and secure facility to store large amounts of wheat in the area. Wheat and grain distributors are reluctant to transport supplies over the border in large quantities until there is a suitable facility to store and distribute, which will greatly enhance the food supply network to hundreds of thousands of Banar citizens. With clearance of specific areas of the wheat store, the wheat and grain will be able to be stored and distributed and the perimeter wall will be repaired for security.
Survey location size (m2):	Total site: 638,277 m2. CHA 02: 273,960 m2.
Survey location hazardous areas:	

Mapping:
Map 3: Wheat store CHA 02 split into sub CHAs

4

Non-Technical Survey Report	Title: Al Obady Wheat Store	Organisation Ref: GS006

Survey location hazardous area details	*Each area and sub-area is to be associated with an EO threat (mine, IED, cluster munition, booby trap, UXO, combination) and where possible geographical boundary points to be recorded*						
Hazardous area	Threat association	Point (BM, SP, TP)	From	To	Bearing (°)	Dist. (m)	Geographical ref.
WS SHA 01 + WS CHA 02	Combination (IED / UXO)	RP	N/A	N/A	N/A	N/A	Lat. 34.424190° Long. 41.232618° (track Junction)
		BM	RP	BM	183	83	Lat. 34.422817° Long. 41.231183°
		SP	BM	SP	270	30	Lat. 34.422772° Long. 41.230940°
		TPs	TBC				
WS CHA 02 A	Combination (IED / UXO)	TBC					
WS CHA 02 B	Combination (IED / UXO)	TBC					
WS CHA 02 C	Combination (IED / UXO)	TBC					
WS CHA 02 D	UXO	TBC					
WS CHA 02 E	Combination (IED / UXO)	TBC					
WS CHA 02 F	Combination (IED / UXO)	TBC					
WS CHA 02 G	UXO	TBC					
Positional data methodology and accuracy:	Handheld GPS' serial nos: GS089/GS087						

Associated evidence		
Information sources *(interview, observation, photo, open source data, assumption, comparison, etc.)*	Attachment reference	*Details (indirect, direct, first-hand, second-hand, etc.)*
Photos and observations of UXO and IED components in place	Att. 1-8	Direct evidence recorded by EOD Team Leader in WS CHA 02

5

Non-Technical Survey Report	Title: Al Obady Wheat Store	Organisation Ref: GS006

Interview with wheat store staff and manager	N/A	Reliable indirect evidence received by EOD Team Leader on WS CHA 02 and the surrounding area concerning the location of visible VOIEDs on the perimeter and 'no-go' areas within the site, recent history and armed group occupation, and post occupation military clearance limits.
Interview with military EOD @ CP Green	N/A	Reliable indirect evidence received by EOD Team Leader of info regarding recent finds during military clearance and casualties received during clearance.

Environmental observations	
Weather factors (present and historic):	The water feature in the north of the site in CHA 2A was once much bigger, as can be seen from the ground sign, during armed group occupation.
Vegetation factors:	*The water feature has high vegetation which will inhibit search.*
Search limiting contamination:	There is a large amount of discarded waste on the SE perimeter potentially inhibiting search.
Marking (existing and arranged):	Some spray paint markings exist marking cleared and uncleared (by military EOD) buildings in the main entrance area. Blind 40 mm hand grenade marked as per SOPs.

Accident and injury prevention (health and safety) observations:	
Additional hazards specific to this area	*List potential hazards that may cause major injuries, mass casualties or severely hamper production (if applicable)*

Hazard	Attachment reference
Structural integrity of buildings in WS CHA 2G	Att. 10 & 11

Recommendations (additional survey, technical assessment, reduction, cancellation, clearance, etc.)
Begin clearance operations in WS CHA 02 with multiple teams. Technical assessment of SHA 01 with UAV.

4. Further area / Point recommendations (additional survey, technical assessment, reduction, cancellation, clearance, etc.)
Determine the border between SHA 01 and CHA 02 and confirm tasking of just CHA 02.

5. Translation	*N/A* ☐		
Translated by:	A. Razazza	Translation reference:	GS006

6. Authorisation	*All signatories agree to the contents of this report*		
Name / Job Title / Organisation	Signature	Date	Remarks
Prepared by			
S. Smith / EOD Team Leader / Global Solutions	S. Smith	11 Mar 2019	

6

Non-Technical Survey Report	Title: Al Obady Wheat Store	Organisation Ref: GS006

Checked by			
A. Jones / EOD Team Leader / Global Solutions	A Jones	11 Mar 2019	
Organisational authorisation			
B. Brown / Operations manager / Global Solutions	B Brown	11 Mar 2019	
Additional authorisation *N/A* ☐			

7. Organisational handover	*All signatories agree to the contents of this report before handover to another organisation*		
Name / Job Title / Organisation	Signature	Date	Remarks
Handed over by			
Received by			

7

Non-Technical Survey Report	Title: Al Obady Wheat Store	Organisation Ref: GS006

8. Attachments	Imagery, documents and information used in the analysis process	
Type	Description	Reference ID
Photo	DFC within building in CHA 2A	Attachment 01
Photo	20 kg plastic main charge inside building in CHA 2A	Attachment 02
Photo	Abandoned crush wire switch CHA 2B	Attachment 03
Photo	Abandoned anti-lift switch CHA 2B	Attachment 04
Photo	Abandoned pressure plate switch CHA 2B	Attachment 05
Photo	Blind 40 mm projected grenade CHA 2D (Lat. 34.422429° Long. 41.231674°)	Attachment 06
Photo	Blind hand grenade CHA 2D (Lat. 34.422297° Long. 41.231566°)	Attachment 07
Photo	20 kg plastic main charge on perimeter wall CHA 2F	Attachment 08
Photo	20 kg plastic main charge on perimeter wall CHA 2F	Attachment 09
Photo	Damaged building in CHA 2G	Attachment 10
Photo	Inside damaged building CHA 2G	Attachment 11


Attachment 1


Attachment 2

8

Attachment 3

Attachment 4

Attachment 5

Attachment 6

Non-Technical Survey Report	Title: Al Obady Wheat Store	Organisation Ref: GS006

Attachment 7

Attachment 8

Non-Technical Survey Report	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

Attachment 9

Attachment 10

Non-Technical Survey Report	Title: Al Obady Wheat Store	Organisation Ref: GS006

Attachment 11

13

ANNEX C2. THREAT ASSESSMENT FORM – EXAMPLE

Threat Assessment & Summary	*Title:* *Officers' Quarters Neighbourhood Threat Assessment*	*Organisation Ref:* GS 107 TA (2)

1. **Assessment preface**			
Task / Assessment ID:	GS 107	Task / Assessment name:	***Officers' quarters***
Assessment date:	28 Feb 2019	Assessment status:	Initial / 2nd / 3rd
Assessor:	J. Smith	References:	A. *GS 107 TA (1)* B. *GS 107 NTS Report* C.
Assessor job title:	EOD Team Leader		
Organisation:	Global Solutions Ltd		

2. **Location details**	
Area / Region:	Officers' Quarters neighbourhood
Address: N/A ☐	Central Armardi, Al Banar province
Geographical reference 1: Include description	Lat. 33.097334° Long. 40.037593° Traffic island on main route south of the area
Geographical reference 2: Include description	MGRS: 3754488578 As above
3. **Threat summary**	*Based on the findings of Section 4 (below) state the most likely type(s) of explosive threats and where they are most likely to be located to define requirements and procedures in a clearance plan. If a worst-case threat is applicable that should also be stated*

It is most likely that the respective non-state armed groups placed VOIEDS with low metal content switches, anti-lift switches and plastic main charge containers (20 kg) in the majority of the uninhabited houses within the area known as the *'Officers' Quarters*' 12–18 months ago, in order to deny the buildings' use by opponents, and inflict casualties on EOD troops during subsequent fighting. These devices will most likely be found on the soft ground on the access routes to the house entrances and in the house entrances themselves.

Additionally, UXO cannot be discounted, in the form of projected grenades, mortars, rockets and projectiles from the indirect fire support from both sides during the conflict; some of these items may be improvised.

1

Threat Assessment & Summary	*Title:* *Officers' Quarters Neighbourhood Threat Assessment*	*Organisation Ref:* GS 107 TA (2)

4. Evidence *(Only evidence in which there is suitable confidence to be used for analysis)*		
4a. Threat intent	Consider who are the armed group(s) and their direct/indirect target(s). What were / are the armed group's desired effects, objectives and results? Consider the time frame since the threat(s) developed	
Information source *(interview, observation, photo, open source data, assumption, comparison, etc.)*	**Attachment Ref.**	***Assessment***
1. *Open source (various)*	N/A	It's widely known that this non-state armed group occupied this area for some time and then withdrew north after prolonged fighting with state armed groups, 12 months ago (Feb 2018). Their intention in this area was to defend from infantry assault generally from the south and east and locally 360°, leaving no warning signs, with a disregard for the safety of returning civilians.
2. *Conversation with mayor's staff, Feb 2019*	N/A	
3. *GS 107 NTS Report*	A1	
4. Conversation with locals Feb 2019 Attachment 3 (sketch map)	A3	

4b. **Threat capability**	Consider what resources and freedom of movement was available to the armed group(s). What was the armed group's ability and how were/are they influenced and motivated?
Capability analysis	List capabilities that may be in the armed group(s) ability and ~~score out~~ if not specifically applicable after analysis

- *Large improvised mortar + projectile (120 mm+)*
- *Smaller improvised mortar + projectile*
- ~~*Command devices*~~
- *VO devices*
- *Crush wire switch*
- ~~*High metal content pressure plate*~~
- ~~*Trip wire*~~
- ~~*Directional frag main charge*~~
- *Plastic jug main charge*
- ~~*Chemical weapons*~~
- *Anti-lift switches*

Information source *(interview, observation, photo, open source data, assumption, comparison, etc.)*	**Attachment Ref.**	***Assessment***
1. GS 107 NTS Report	A1	*During recent clearance operations in this area the almost exclusive main charge construction is the '20 kg' plastic jug, and consequently the clearance conducted by the military EOD on this site reveals the same. The same unit has recovered abandoned anti-lift switches of the 'fridge light' variety and other components.* *There are photographs in the GS 107 NTS Report of local stockpiles of plastic jug main charges, 9V power sources, a mixture of civilian and improvised detonators and low metal content switches.*

2

Threat Assessment & Summary	*Title:* *Officers' Quarters Neighbourhood Threat Assessment*	*Organisation Ref:* GS 107 TA (2)

2. *Previous Global Solutions Clearance Reports (Dec 18–Feb 19)*	N/A	
3. *Conversation with EOD Major Feb 2019 Attachment 2 (business card)*	A2	

4c. **Threat opportunity**	Consider the target(s) vulnerability and how the environment would dictate the threat(s)

Information source *(interview, observation, photo, open source data, assumption, comparison, etc.)*	**Attachment Ref.**	***Assessment***
1. *GS 107 NTS Report*	**A1**	This area offers defensive value to the occupier, both local and general defence, and was favoured as an area to occupy. The houses in question were under construction, presenting soft ground suitable to hide main charges inside and outside of each house. Parts of the estate, mainly to the east, are assessed as uncontaminated; this area was used for living quarters by the occupiers and has since had some reoccupation by returning civilians. It's well known that military EOD troops leave themselves open to anti-lift attack during their clearance operations due to their unsafe procedures; this was observed and taken advantage of by the occupier, and there has been a prolific use of anti-lift switches as a result. Cont. on Attachment 4.
2. *Conversation with EOD Major Feb 2019 Attachment 2 (business card)*	**A2**	
3. *Conversation with locals Feb 2019 Attachment 3 (sketch map)*	**A3**	
4. *Text continues on Attachment 4 ('opportunity' enclosure)*	**A4**	

5. **Additional information**	*Any additional information from direct & indirect evidence, inferences and assumptions*
Initial Threat Assessment GS 107 TA (1) was conducted without the benefit of NTS Report GS 107, which divulged much useful information from the site and from speaking to the local military EOD detachment, notably the presence of anti-lift switches.	

6. **Attachments**	Imagery, documents and information used in the analysis process (if extra space is required for text, record it here as an enclosure)	
Ser.	Description	Attachment Reference
1	GS 107 NTS Report	GS 107 NTS Report
2	EOD Major business card	A2
3	Sketch map	A3
4	Continued opportunity enclosure	A4

7. **Acknowledgement**			
Name / Job Title / Organisation	Signature	Date	Remarks
Prepared by			
J. Smith EOD Team Leader Global Solutions Ltd	J. Smith	28 Feb 2019	

3

Threat Assessment & Summary	*Title:* *Officers' Quarters Neighbourhood Threat Assessment*	*Organisation Ref:* GS 107 TA (2)

Checked by			
A. Jones EOD Team Leader Global Solutions Ltd	A Jones	28 Feb 2019	
Organisational approval			
B. Brown Operations Manager Global Solutions Ltd	B Brown	28 Feb 2019	Let's review this after start of task

4

ANNEX C3. RISK ASSESSMENT FORM – EXAMPLE

Risk Assessment	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

1. **Assessment preface**			
Task / Activity / Assessment ID:	GS006	Task / Activity / Assessment name:	Al Obady Wheat Store
Assessment date:	12 Mar 2019	Task / Activity start date:	TBC
Assessor:	S. Smith	References:	A. Global Solutions Anbar site health and safety plan B. Al Obady Wheat Store clearance plan GS006 C. Al Obady Wheat Store Level 2 Survey (NTS)
Assessor job title:	EOD Team Leader		
Organisation:	Global Solutions Ltd		
2. Task / Activity location details			
Area / Region:	Al Banar province		
Address:	Southern outskirts of Al Obady, 2 km south of CP 'Green' (MGRS GU0531913317)		
Geographical reference 1: Include description	Lat. 34.421932° Long. 41.231321° Entrance to wheat store		
Geographical reference 2: Include description	MGRS GU 05052 11198 Entrance to wheat store		

1

Risk Assessment	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

3. Risk rating (RR) matrix ***(plot the hazard on the matrix to produce the RR code before and after control measures if applicable)***						
Severity *(outcome/degree if an incident, accident or near miss has occurred)*	Probability *(likelihood to cause an incident, accident or near miss)*					
	Improbable (Imp)	Occasional (Occ)	Probable (Pro)	Frequent (Fre)		
Catastrophic (Cat)	3	4	4	4	*Catastrophic: Multiple fatalities and / or casualties with disabling injuries*	
Severe (Sev)	3	4	4	4	*Severe: Single fatality and / or a casualty with disabling injuries*	
Minor (Min)	1	2	3	4	*Minor: Minor injuries*	
Negligible (Neg)	1	1	1	1	*Negligible: No injurious circumstances*	
	Improbable: Has never occurred but is possible	*Occasional: Has been known to occur but unexpected*	*Probable: It will occur in some circumstances*	*Frequent: It is expected to occur*	***Risk rating code (RRC) explained***	
					1	*No control measures required*
					2	*Implement and review control measures*
					3	*Implement and review control measures with managerial oversight*
					4	*Review task and needs, with managerial oversight*

2

Risk Assessment	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

4. Hazard and risk register *(identifying and analysing risk)*

Serial	*Description of hazard and / or risk*	*Risk rating (RR)*			*Evaluation and treatment required?*		*Supporting documentation (SOP, instructions, manual, etc.)*
		Probability	*Severity*	*RR*	Yes	No	
1	Explosive ordnance clearance and unintended detonation	Imp	Sev	3		X	Global Solutions Manual Clearance SOP
2	Working at height and falling from the roofs of buildings WS CHA 2A, B and G whilst searching	Imp	Sev	3	X		N/A (to be included in site health and safety plan)
3	Risk of burial whilst searching large mounds of grain	Imp	Min	1		X	N/A
4	Lack of structural integrity in buildings in sub sector WS CHA 2G causing collapse of buildings whilst searchers are inside	Occ	Cat	4	X		Risk Assessment GS 006A
5	Live electricity cable routed underneath soil mounds designated for mechanical clearance in sub sector WS CHA 2C	Pro	Sev	4	X		N/A
6	Noxious fumes whilst operating on the wheat piles causing light headedness and lack of concentration	Pro	Min	3	X		N/A

The following list includes areas for potential hazards that may be encountered on the worksite. It is not exhaustive, and assessors and supervisors must stay alert to other hazards that may present or develop.

- *Explosive ordnance and remnants of war*
- *Excessive noise and vibration*
- *Lifting operations*
- *Exposure to electricity*
- *Exposed machinery*
- *Excessive environmental and physical stress*
- *Exposure to blood-borne viruses*
- *Lighting levels*
- *Exposure to hazardous materials and substances*
- *Working at height*
- *Confined spaces and explosive atmospheres*
- *Transport*
- *Construction activities*
- *Pressure systems*
- *Fire*
- *Structural integrity*

3

Risk Assessment	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

5. Risk evaluation and treatment *(implement control measures and referral if applicable to reduce risk to a tolerable level)*

Serial (Ref Sec. 4).	*Description of hazard and / or risk*	*Control / mitigation measures*	*Residual risk rating (RRR)*		
			Probability	*Severity*	*RRR*
2	Working at height and falling from height	• UAV to be used to search rooftops for suspicious items where possible. • Ladders of sufficient length to extend above the roof level and at a suitable angle to be used and always 'footed' by a team member. • Minimum staff (1 person) on the roof and the team member keeping at least 1 m from the roof edge while searching. Any tools required are hoisted up on a line and not carried up the ladder. • Only persons with experience of exposure to height should gain access to height. • Any items of ERW that are safe to move must be lowered down to the floor with a line in a sandbag and not carried. • Any items found on the roof requiring an RSP need referral. • A line is to be available and tied in a bowline knot over the rear of a casualty's body armour, under the arms and through the centre of the front straps to A: aid a casualty from above during self-extraction; B: lower an unconscious / immobile casualty, strapped to a stretcher if required (with the arms secured to the side).	Imp	Sev	3
4	Lack of structural integrity in buildings in WS CHA 2G causing collapse of buildings whilst searchers are inside	• A structural integrity assessment is to be made including input from the whole team as to which buildings are not safe to be inside. • Any large buildings deemed not safe are recorded and marked up as not searched and recorded as search restrictions. • Potentially, smaller buildings deemed not safe can be demolished by mechanical assets and the rubble processed for ERW.	Imp	Neg	1
5	Live electricity cable routed underneath soil mounds designated for mechanical clearance in sub sector WS CHA 2C	• Each morning the mechanical support team leader is to ensure the cable supply is switched off at the manager's office. • A banksman is to be at a safe distance watching for the digging up of cable by the mechanical asset and be prepared to stop the asset, using VHF radio.	Imp	Neg	1
6	Noxious fumes whilst operating on the wheat piles causing light headedness and lack of concentration	• Wear face masks. • Limit exposure to 30 minutes at a time with a 10-minute break. • Regular checks of personnel by supervisors, every 10 mins minimum.	Imp	Min	1

4

Risk Assessment	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

6. Translation	*N/A* ☐		
Translated by:	A. Razazza	Translated reference:	GS006

7. Initial review and authorisation	***For assessment control, all signatories must sign document before any works commence, to show their agreement***		
Prepared / Authorised by: Name / Job Title / Organisation	Signature	Date	Remarks
Prepared by			
J. Smith / EOD Team Leader / Global Solutions	J. Smith	12 Mar 2019	
Checked by			
A. Jones / EOD Team Leader / Global Solutions	A. Jones	12 Mar 2019	See Risk Assessment GS006A for a specific risk assessment of the damaged buildings in CHA 2G
Organisational approval			
B. Brown / Operations Manager / Global Solutions	B. Brown	12 Mar 2019	A generic risk assessment for working at height and with dubious structural integrity will be written and kept in the site health and safety plan

8. Record of amendments / reviews	***Any reviews necessary after a change in circumstance, such as an incident, situation, time lapse or threat assessment are to be recorded here***			
Reviewed by: Name / Job Title / Organisation	Review date	Reason for review	Actions to be taken	Signature
*** BLANK***				

9. Acknowledgement	**All groups and / or individuals using the risk assessment are to acknowledge communication of the hazards and control measures here**				
Acknowledged by: Name / Job Title / Organisation	Signature	Date	Acknowledged by: Name / Job Title / Organisation	Signature	Date
A. Najaf / Mechanical Team Leader / Global Solutions	A. Najaf	12 Mar 2019	H. Amarah / Search Team Leader / Global Solutions	H. Amarah	12 Mar 2019

5

Risk Assessment	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

C. Wasit / Search Team Leader / Global Solutions	C. Wasit	12 Mar 2019		A. Jones / EOD team Leader / Global Solutions	A. Jones	12 Mar 2019
M. Diyalah / Search Team Leader / Global Solutions	M. Diyalah	12 Mar 2019				

ANNEX C4. CLEARANCE PLAN FORM – EXAMPLE

Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

1. Task preface			
Task ID:	GS006	Task name:	Al Obady Wheat Store
Task start date:	12 Mar 2019	Estimated end date:	20 Aug 2019
Supervisor:	A. Jones	Plan prepared by;	S. Smith
Supervisor job title:	EOD Team Leader	Job title:	EOD Team Leader
Organisation:	Global Solutions Ltd	Organisation:	Global Solutions Ltd

2a. Location details	
Area / Region:	Al Anbar province, Iraq
Address:	Southern outskirts of Al Obady, 2 km south of CP 'Green' (MGRS GU0531913317)
Geographical reference 1: Include description	Lat. 34.421932° Long. 41.231321° Entrance to wheat store
Geographical reference 2: Include description	MGRS GU 05052 11198 Entrance to wheat store
Site size (m2):	Total site: 638,277m2 CHA 02: 273,960 m2

1

Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

2b. Mapping	*Task site details (including access) showing all areas and sub-areas pertinent to the clearance plan*

Map 1: Wheat store general area showing assessed access route from Highway 1 in the north

Map 2: Wheat store showing key locations and the site split into CHA 01 and 02 (the border between areas is TBC after technical assessment)

Map 3: Wheat store CHA 02 split into sub CHAs for the works plan

2

Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

3

Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

2c. Details of hazardous area	*Each area and sub-area is to be associated with a threat (mine, cluster munition, IED, booby trap, UXO, combination) and where possible geographical boundary points are recorded*						
Hazardous area	Threat association	Point	From	To	Bearing (°)	Dist. (m)	Geo Ref.
WS SHA 01 + WS CHA 02	Combination (IED/UXO)	RP	N/A	N/A	N/A	N/A	Lat. 34.424190° Long. 41.232618° (track junction)
		BM	RP	BM	183	83	Lat. 34.422817° Long. 41.231183°
		SP	BM	SP	270	30	Lat. 34.422772° Long. 41.230940°
		TP's	TBC				
WS CHA 02 A	Combination (IED / UXO)	TBC					
WS CHA 02 B	Combination (IED / UXO)	TBC					
WS CHA 02 C	Combination (IED / UXO)	TBC					
WS CHA 02 D	UXO	TBC					
WS CHA 02 E	Combination (IED / UXO)	TBC					
WS CHA 02 F	Combination (IED / UXO)	TBC					
WS CHA 02 G	UXO	TBC					

3. References and annexes:	*Insert details of all reference documents and annexes to be used in conjunction with this clearance plan*

Global Solutions Manual Search SOP
Global Solutions Mechanical Search SOP
Global Solutions Hazard and Operational Marking SOP
Global Solutions Quality Management SOP
Desk Top Assessment AO002
Wheat Store NTS report

4

Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

4. Threat summary	*Consider the most likely type(s) of explosive threat and where it is most likely to be located to define requirements and procedures in a clearance plan*
Supporting document reference: *Threat Assessment GS006 (11 mar 2019)* An armed group has probably placed VOIEDs along part of the inside of the perimeter wall as part of a defensive plan. The VOIEDs are likely to have crush wires or pressure plate switches in two lines parallel to the wall at approximately 5 m and 10 m. The main charges are probably plastic and contain 8–10 kg of HME. It is also possible that VOIEDs have been placed in vulnerable points inside buildings to hinder the rehabilitation of the site. It is possible that pressure release switches have been incorporated into some of the IEDs. UXO ranging from 40 mm projected grenades to large air-dropped weapons may be found (some with improvised fusing) throughout the site and cannot be discounted.	
5. Security risk assessment	*Record the results of, or reference to risk assessments examining the security risks and vigilance levels pertinent to the site:* *N/A* ☐
Supporting document reference: *Global Security Risk Assessment AO001* There still exists a threat of criminality in this area. Global security alert states remain at High and corresponding security measures will be upheld. In the event of a security incident the Global security personnel are to take charge of the situation and all staff will move to a designated safe location.	

6a. Outcomes and beneficiaries	*Record the impact this task may have on the wider community*		
Supporting document reference: *Desk Top Assessment AO002* The wheat store was a new and modern facility before the conflict, purpose built to hold and distribute large volumes of wheat and grain across the province by road and rail. Wheat is currently being held in makeshift storage that is insufficient to meet demand. Once this wheat store is rehabilitated it will provide a key part of a food supply network for hundreds of thousands of people from the conflict-affected community.			
6b. Stakeholder details	*Record the key stakeholders' and / or beneficiaries' titles and contact details*		
Title / Position	*Name*	*Contact details*	*Remarks*
Wheat store manager	A. Habbaniya	(telephone no.)	
Al Obady Mayor's Office	H. Tharthar	(telephone no.)	POC in the Mayor's Office
Community representative	J. Islamiyah	(telephone no.)	POC for job recruitment
Major, security forces	A. Ash Shamah	(telephone no.)	Responsible for security of the wheat store

7. Clearance method	*Practical details of the clearance plan*
7a. Scope of works	
Clearance priorities	1. Main CP and access within the site for mechanical clearance and category 2 / 3 search areas. 2. Mechanical clearance WS CHA 2C then G. 3. Technical assessment and clearance of unoccupied buildings in WS CHA 2A. 4. Clearance of known IEDs on the southern perimeter in WS CHA 2F. 5. Technical assessment of the perimeter wall in all areas of WS CHA 02.
Summary *of the clearance method*	Once the main CP is established and assessment confirmed, the teams will confirm areas for category 1, 2 and 3 search and areas for technical assessment and mechanical clearance. All search categories will run concurrently, safety distance and resources allowing. On completion, all remaining CHAs / SHAs will be marked and WS SHA 01 will be permanently fenced (not required for full store productivity at this time).

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Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

Time frame / Schedule	Estimated priority 1: 3 days Priority 2: 2 weeks Priority 3: 1–2 weeks Priority 4: 5 weeks Priority 5: 6 weeks Completion: 7 weeks
Reporting thresholds	Daily: Operations manager Weekly: Country manager (via Ops manager) Specific: On completion of technical assessment of unoccupied buildings in WS CHA 2A on completion of mechanical clearance

7b. Works plan	*Task specifics broken down into areas and sub-areas, to include specific procedures, limitations, locations and hazards based on the threat summary and hazard survey / risk assessment*

Threat summary reference: *Threat Assessment GS006 (11 Mar 2019)*

Risk assessment reference: *Risk assessment GS006 (12 Mar 2019)*

(Note: for clarity only one area has been included here as an example, this may be templated for similar hazardous areas if suitable)

WS CHA 2A:

- The buildings on the eastern side of the main access route are unoccupied and require category 2 search on the approach to each entrance and category 3 search for technical assessment within each building; category 2 search will be external on the soft ground for technical assessment until the required level of assurance has been achieved to continue with cat. 1 search.
- The roof of the buildings in WS CHA 2A will only be searched if cat. 1 search is adopted in the buildings; see risk assessment GS 006.
- The perimeter wall and minimum of 10 m out to the west of the buildings requires technical assessment using cat. 2 search until the required level of assurance has been achieved to continue with cat. 1 search.
- It's anticipated cat. 1 search in the open ground west of the buildings will be suitable after technical assessment.
- Suitable points on the western edge of WS CHA 2A are to be marked as the border between WS CHA 02 and WS SHA 01 and permanently fenced.

7c. Marking	*To include details of specific marking or changes to SOPs / standards*

All marking will follow SOPs apart from the following deviations:

- Due to the threat of criminality on site there will be a reduced use of marking equipment that includes materials that may hold value such as wood, metal and plastic.
- Where possible, locally available materials such as stones / bricks will be spray-painted to replace standard marking. Permanent surfaces such as walls, floors and tarmacked road surfaces may be directly spray-painted on, this has been agreed with the NMAA.
- Any deviations must be stated in the site brief to visitors.

7d. Quality management	*To include details of quality control requirements and parameters*

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Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

Supporting document reference: Global Solutions Manual Clearance and Global Solutions Quality Management SOPs Team leaders and supervisors will carry out QA checks on searched areas in accordance with Manual Clearance and Quality Management SOPs. Due to the importance of the site the NMAA will be carrying out QA checks every 2 weeks; dates and times to be confirmed.

8a. Incident management	*To include details of immediate actions for an uncontrolled explosion, non-explosive incident, security incident, casualty evacuation (CASEVAC) route, cordon and evacuation, etc.*

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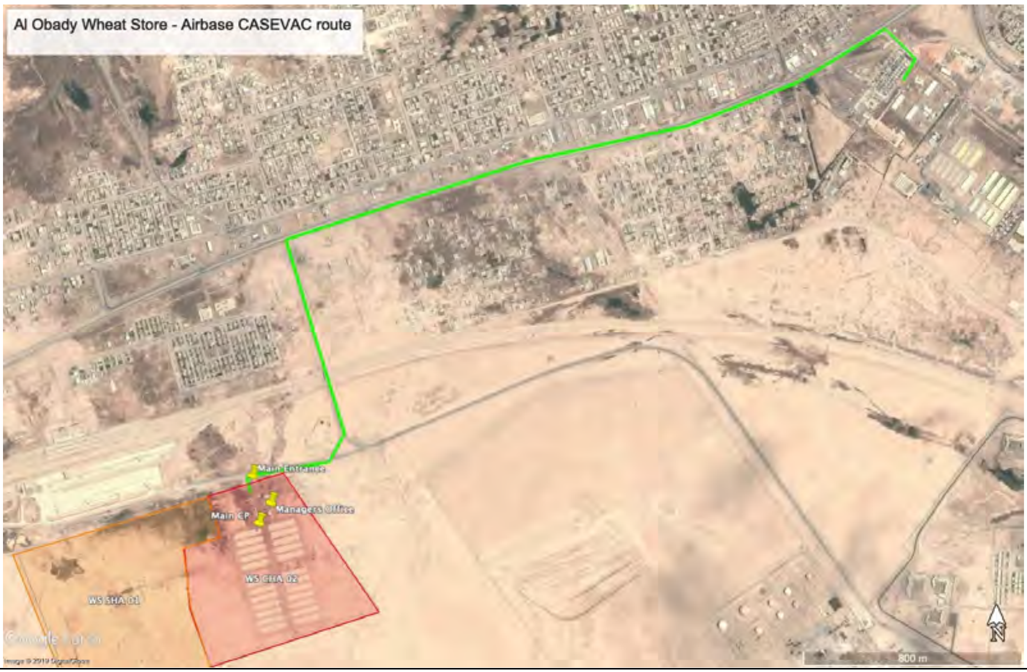
Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

Supporting document reference: Global Solutions Medical Support SOPs

In accordance with GS Medical Support SOPs, each team is to have a dedicated 2-person unit on standby as a CASEVAC team, equipped with stretcher, first aid kit and explosive ordnance detecting equipment for the worst-case scenario, and tested communications with the team leader. Each team will have an ambulance in close proximity; the ambulance may support more than one team, but it is to be in tested communications with the team leaders and to be no more than 2 minutes' travel away from the team leaders' location.

Immediate actions:

- If an uncontrolled explosion occurs or other incident or there is receipt of emergency communications – all personnel are to stop work and look to their team leader.
- Team leaders are to communicate to all (teams and medical support) which area / team is affected; all other teams are to return / remain in their rest areas. No work is to continue.
- Medical support is to be mobilised via an already designated safe route to the team managing the incident.
- If appropriate, the CASEVAC team is to mobilise to the hazard area under command of the team leader / deputy ensuring the route is cleared and marked. Be prepared to administer first aid in the hazardous area, guide a medic into the hazardous area and extract a casualty from the hazardous area.
- Medical support: Be prepared to enter a hazardous area only after it has been cleared and marked appropriately by the CASEVAC team.
  - The lead for all medical support is the Global security medic who will coordinate medical support and decide the best option for CASEVAC.
- Team leaders:
  - You will ensure the CASEVAC team makes all reasonable effort to not create further casualties through their actions.
  - You are to manage the team and the medical support, delegating personnel to man the HLS (if appropriate) and vehicles to promote a speedy CASEVAC.
- Supervisor:
  - You are to ensure that the above is carried out correctly and communicate back to the operations staff in a timely manner with the following information, at a minimum:
    - Location of incident
    - Brief description
    - Any additional support required
    - Number and names of casualties
    - Extent of injuries
    - Location you intend to take casualties to and how
  - The supervisor is to continue to keep the operations staff informed of further developments.



Clearance Plan	Title: Al Obady Wheat Store	Organisation Ref: GS006

8b. Medical facility details	*To include local medical services, helicopter landing sites (if applicable) and on-site medical assets*					
Description	Medical support level	Location	Geographical reference	Point of contact		Additional information
				Name / Title	Communication	
Al Obady Airbase	Two	Check Point Green 2	Lat. 34.396970° Long. 41.293439°	• Lt Campbell • Reception	(telephone no.) (telephone no.)	Heli support: 9 liner required 15 mins NTM
Wheat store helicopter landing site	N/A	Main CP	Lat. 34.422335° Long. 41.231078°	Global security team leader	(telephone no.) VHF channel 1	
Baghdad Military Hospital	Three	Capital Green Zone	Lat. 33.322543° Long. 44.432213°	Via Al Obady Airbase	N/A	Via heli support from Al Obady Airbase
Global security medic	One	On-site	With EOD team leader	Global security medic	(telephone no.) VHF channel 1	

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Clearance Plan	*Title:* Al Obady Wheat Store	*Organisation Ref:* GS006

On-site ambulances	One	On-site	Main CP and intermediate CPs	Global security medic	(telephone no.) VHF channel 1	

Clearance Plan	Title: Al Obady Wheat Store	Organisational Ref: GS006

9. Accident and injury prevention	*Health and safety*	
9a. Significant hazards specific to this site	*List hazards that may cause major injuries, mass casualties or severely hamper production (if applicable)*	
Hazard	Control measure / documentation	Supporting document reference
Working at height in WS CHA 2A, B and G Structural integrity for sub sector WS CHA 2G Live electricity cable in sub sector WS CHA 2C	UAV / See risk assessment See risk assessment See risk assessment	Risk Assessment (RA) GS006
9b. Organisational safety plan reference	Global Solutions site health and safety plan Sept 2018	
9c. Site-specific risk assessment reference	Risk Assessment (RA) GS006	
9d. Roles and responsibilities	*List persons pertinent to maintaining an efficient and safe site*	

Name / Job Title	Role	Contact details
A. Jones / EOD Team Leader	Site lead and areas WS CHA 2A-D	(telephone no.) VHF Channel 1
S. Smith / EOD Team Leader	Areas WS CHA E-G and SHA 02	(telephone no.) VHF Channel 1
C. Taylor / Team leader	Security team leader	(telephone no.) VHF Channel 1
M. Sadr	Local supervisor: search teams and mechanical	(telephone no.)

10. Logistical requirements	*List key logistical requirements not covered by organisation's standard operating procedures (if applicable)*
Transport:	Light truck on standby for demolition site run weekly
Medical:	Two ambulances
Equipment:	2 hook and line kits. UAV
Welfare:	Portable shade cover
Other:	Face masks for use whilst working on the grain itself

11.Communications	*List communication options and details*
11a. Primary means of site communication	11b. Secondary means of site communication
VHF radios During EOD action: assistant observing During clearance procedures: team leader's whistle	Mobile telephone Voice
11c. Emergency communication	Continuous vehicle horn blasts Continuous whistle blasts Continuous verbal shouting
11d. Useful contact details	*List contact details for management, support and emergency services / persons*
Name / Job Title / Role	Contact details
M. Abu Nuwas / Wheat store manager	(telephone no.)

11e. Translation	*N/A* ☐		
Translated by:	A. Razazza	Translated reference:	GS006

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Clearance Plan	*Title:* Al Obady Wheat Store	*Organisational Ref:* GS006

12. Authorisation	*All signatories have to agree to and sign the document before the task commences*		
Name /Job Title / Organisation	Signature	Date	Remarks
Prepared by			
S. Smith / EOD Team Leader / Global Solutions	S. Smith	12 Mar 2019	
Checked by			
A. Jones / EOD Team Leader / Global Solutions	A. Jones	12 Mar 2019	
Organisational approval			
B. Brown / Operations Manager / Global Solutions	B. Brown	12 Mar 2019	I want types and status of IEDs and components from CHA02-F ASAP
Additional approval *N/A* ☐			
H. Hosseinia / DMA	H. Hosseinia	12 Mar 2019	

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3. SEARCH CORE SKILLS AND PROCEDURES

3.1. INTRODUCTION

This section describes the core skills and procedures related to IED search. It focuses on the threat of VOIEDs in an urban environment, whether the contaminated space is a building or open area. It is not intended to be globally prescriptive, but rather to help in the development of NMAS and SOPs that are specific to the situations faced in different countries and MA programmes in relation to IED contamination.

Search core skills are described in terms of building blocks that can be combined together as procedures to provide confidence that different types of spaces are safe. This approach means that various operational contexts and threats can be accounted for and enables adaption in order to increase efficiency when opportunities for improvement are identified.

Image 1. Use of visual search using a torch as an aid

MA operators should employ search procedures that use a number of linked principle-based core skills to form a toolkit of options to find IEDs. In this sub-section the following core skills are described:

1. **Core skill 1 – Visual search from a safe area**
2. **Core skill 2 – Visual search using an aid such as a tripwire 'feeler', mirror or laser**
3. **Core skill 3 – Handheld detector sweep**
4. **Core skill 4 – Fingertip search**
5. **Core skill 5 – Progressive marking of safe areas**
6. **Core skill 6 – Excavation and confirmation**
7. **Core skill 7 – Semi-remote search (hook and line)**
8. **Core skill 8 – Dealing with vegetation**
9. **Core skill 9 – Handovers during manual search**

OPEN AREA SEARCH

Survey and clearance of urban areas is not confined to buildings and structures. Open areas, transport routes, gardens, parks, sports fields, and undeveloped or waste ground may be contaminated with IEDs; if this is suspected or confirmed they will need to be released.

BUILDING SEARCH

The challenges of land release in buildings and structures are not confined to the characteristics of the devices likely to be found. The environment will require unique methods and approaches in addition to the fundamentals recommended here. Each procedure and technique will have a postscript concerning buildings and structures.

SEARCH PROCEDURE EXAMPLES

These are examples of how the core skills can be incorporated into procedures to provide a capability to meet a specific hazard in an environment. The application of core skills and procedures will depend heavily on the EO type, the environment it is in and how it came to be there. Below are some examples of combinations of core skills used to meet specific hazards, including considerations where the search coordinator may have to adapt them because of restrictions, while still meeting the clearance parameters.

SEARCH FOR COMMAND WIRES (CWS)

When could it be employed? / what is the threat?

- Isolation of a CP location
- Isolation of a task area
- Isolation of a suspected IED

This procedure is employed when the threat assessment has identified the reasonable possibility of a CW device that will present a hazard to the search team. While it is highly unlikely that the person who emplaced it and who was going to fire the device is still in the area, a CW device presents an explosive hazard where the control of its detonation may be outside of the task area. For this reason, a mine action operator should try to discount its presence, or identify and take control of the device at the earliest opportunity.

Visual

The wire of a command wire IED, while a thin component, can create a large, potentially identifiable footprint. If surface laid it may be identified as a straight line that is out of place in the environment; a small excavation may be made where it is then camouflaged but this may also present a visible ground sign. Wires often follow linear features such as ditches or fence lines in an attempt to reduce the chance of being detected visually.

Detector

There are types of commercially available detector that can be used to detect concealed command wires. A minimum length of wire often needs to be present for it to be discovered by the detector.

NOTE. A hook can be used as a rake in areas where CWs may be buried or camouflaged, especially when crossing linear features such as fences or ditches where they, historically, are more likely to be secreted. This is a very physically intrusive method and should only be used where the chance of VOIEDs is low enough to allow for its use.

MANUAL SEARCH IN BUILDINGS WITH A VOIED THREAT

WHEN COULD IT BE EMPLOYED? / WHAT IS THE THREAT?

Manual search of a building is very similar to manual search of an open area where mines or VOIEDs are a hazard. There are other considerations that may restrict the use of some of the skills selected, such as buildings with high metal content or debris, and which may place a higher emphasis on the use of other skills or enhancing those skills with equipment.

WHY THIS COMBINATION?

Visual

The skill of visual search and its enhancement through the use of visual aids such as binoculars, mirrors or lasers is of great importance due to the potential restrictions in the use of detectors. The searcher is looking for visual clues that could identify the presence of an IED, including component parts and disturbances that might indicate emplacement or concealment. These include signs of interference with loose items such as furniture or other such everyday objects.

Additional equipment used

As the use of detectors may be restricted, the following equipment can be used to enhance visual search and improve the searcher's chance of locating any potential signs of IED presence.

- **Optics** such as binoculars when used at a low magnification can allow the searcher to more closely assess suspect items and the environment in general.
- **Trip wire feeler** if required, depending on the threat assessment; it may also have value in ensuring that the searcher's visual search is more deliberate, especially when a detector cannot be used.
- **Mirrors** that can be used by the searcher to visually inspect an area prior to moving forward, or in a recess or void before placing their head in a position to look inside.

Detector

Most mine detectors are metal detectors that are generally unsuitable for use in buildings that have any metal content in their construction, in household items or debris. There is a very small number of handheld detectors that can discount this type of background metal contamination. It should not be assumed however that detectors will not work and their use should be tested until proven that they provide no value to the task, without placing the searcher in any danger.

3.2. CORE SKILL 1 – VISUAL SEARCH

Image 1. Visual detection to locate an IED inside a building. Note that the visor has been deliberately raised and will be lowered prior to carrying out any further actions

The MA sector's experience has shown that IEDs, and other EO, can be detected at the earliest opportunity through good visual search techniques. The probability of early identification is greatly increased when staff conducting searches have been provided with detailed technical information on the IED components (colour, material, markings) that are likely to be present, how devices have been constructed and how they have likely been emplaced. This early method of detection means that follow-on intrusive procedures can be minimised and / or conducted in the safest way possible.

Visual search techniques are therefore one of the single most important skills for MA staff carrying out manual searches for IEDs and should never be underestimated. They are not a haphazard 'look', but detailed systematic observations in the near, mid and long distances; to the peripheries; at high and low levels; and into cavities or recesses, from a safe area.

HINT. It can be useful for a searcher to visualise a grid formation of near left and right and far left and right, with the visual search commencing with near left to right, then far right to left.

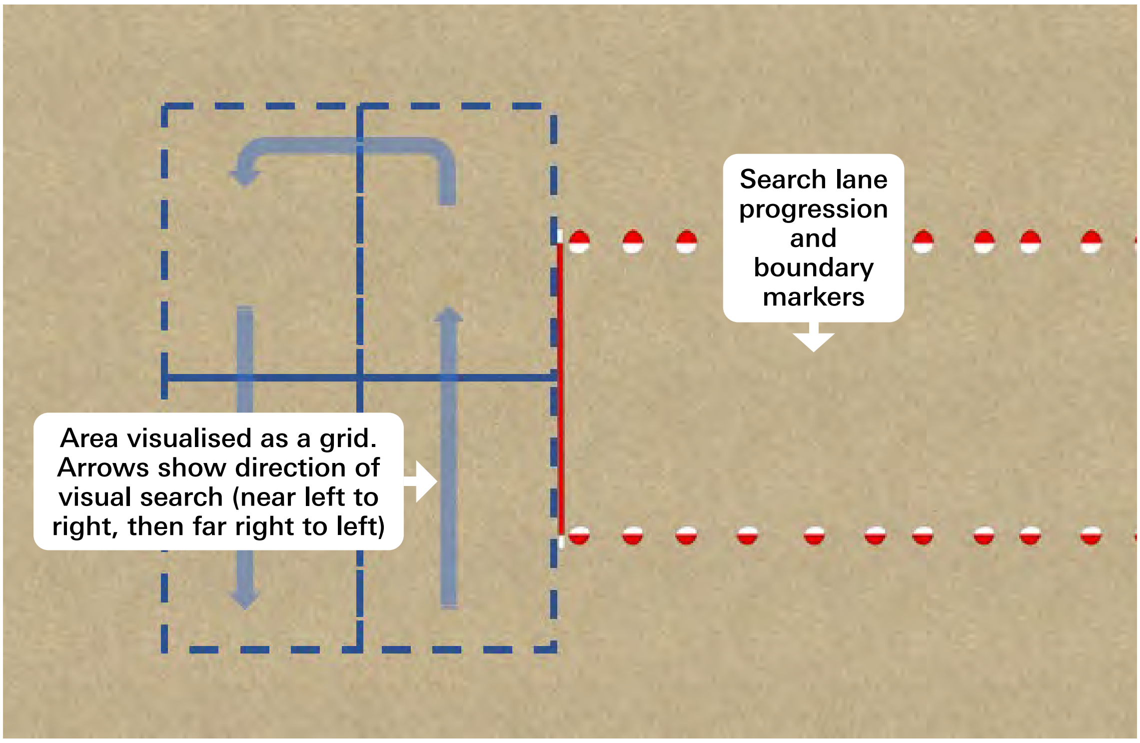


Image 2. Diagram showing the area to be visually searched visualised as a grid to search systematically

Visual search should be conducted prior to any intrusive technique or forward movement into a hazardous area. Based on the operational threat assessment, searchers should be made aware of the likely IED signs and indicators that may be detected, as well as an assessment of the following key factors:

- What category and sub-category of IEDs may be present;
- The length of time the IEDs have been in place and how this could have changed the appearance of component parts;
- The high-risk areas where IEDs are most likely to be located;
- What IEDs are most likely to be encountered, what the worst-case assessment is, and also what IEDs are not likely to be present.

WARNING. Eye protection may be removed to perform the visual search as long as the searcher remains in the safe area. This MUST be replaced prior to intrusive techniques commencing, such as detector sweeps or forward movement into the suspect area.

The visual search techniques for IEDs look for the presence of the abnormal. This is also referred to as the absence of the normal. This can be a ground sign or top sign and is commonly referred to through the following characteristics:

1. **Regularity.** Regularity is a straight line, arch or other geometrical shape that would not normally be encountered in nature.
2. **Flattening.** Flattening is caused through human actions that apply pressure to an area. These can be identified through comparison with the immediate surroundings.
3. **Transfer.** Transfer or transference is a deposit (e.g. dust, sand, soil, mud) carried unintentionally from one area to another.
4. **Discardables.** Discardables are items associated with IEDs (or other EO) that have been left behind either intentionally or otherwise. Discardables can include IED components, electrical tape, packaging or ancillaries.
5. **Colour change.** Colour change is the difference in colour from a specific area to its surroundings. Colour change may be produced by soil excavation to place devices or where vegetation has been cut and used to camouflage devices; the cut vegetation changes colour as it ages.
6. **Disturbance.** Disturbance is a change or rearrangement of the normal state of an area caused by the emplacement of a suspicious object.

3.2.1. LONG-DISTANCE VISUAL SEARCH

Image 3. Conducting visual search with binoculars

Opportunities should be sought to conduct a visual search as a preliminary measure over a broader area before moving into specific search lane(s). The use of optics such as binoculars should be considered to visually search the ground and surroundings, including upper levels if present, and the mid to longer distances, with vantage points used if available. As the search progresses this process should be repeated.

HINT. Long-distance visual search using optics may identify indicators that are not apparent to the naked eye or if concentrating only on the near to mid distance. This may include regularities in lines of emplaced IEDs that have been laid as defensive belts.

An example of an opportunity for long-distance visual search is discussed in Chapter 2, Section 2 of this guide: Search task planning and execution – '360-degree observation'.

3.2.2. BASICS OF VISUAL SEARCH

Image 4. Kneeling visual search with eye protection removed, concentrating on the immediate area in front

Image 5. Standing visual search from a safe area with eye protection removed

WARNING. Visual search in buildings and structures can only be conducted accurately and safely with appropriate light levels. If the light levels mean that a person cannot see as well as they can outside in normal daylight, then additional light sources should be used.

3.3. CORE SKILL 2 – VISUAL SEARCH USING AN AID

3.3.1. TRIPWIRE ‘FEELER’

The most common aid to visual search is a tripwire ‘feeler’. This tool is used in a systematic manner to focus the eye of a searcher on a precise point and can be used from ground level to above head height. The feeler is normally a length of moderately stiff wire that may be painted to enhance its effectiveness as an identification tool. It works by focusing the eyesight of the searcher, and the movement that is used should be slow and cautious, enough that the risk of the feeler inadvertently touching a tripwire is minimised.

HINT. The tripwire ‘feeling’ procedure takes time and should only be conducted when tripwires or other surface-laid switches, such as crush wires, have been assessed as being present.

3.3.2. FUNDAMENTALS OF USING A TRIPWIRE FEELER

The whole width of the lane to be cleared should be examined for tripwires and other component parts. There are two methods that are commonly used:

The box method. The searcher pushes the tripwire feeler into the lane parallel to its sides on the left, centre and right systematically, before raising it to the desired height whilst visually searching. This method is shown in Image 1.

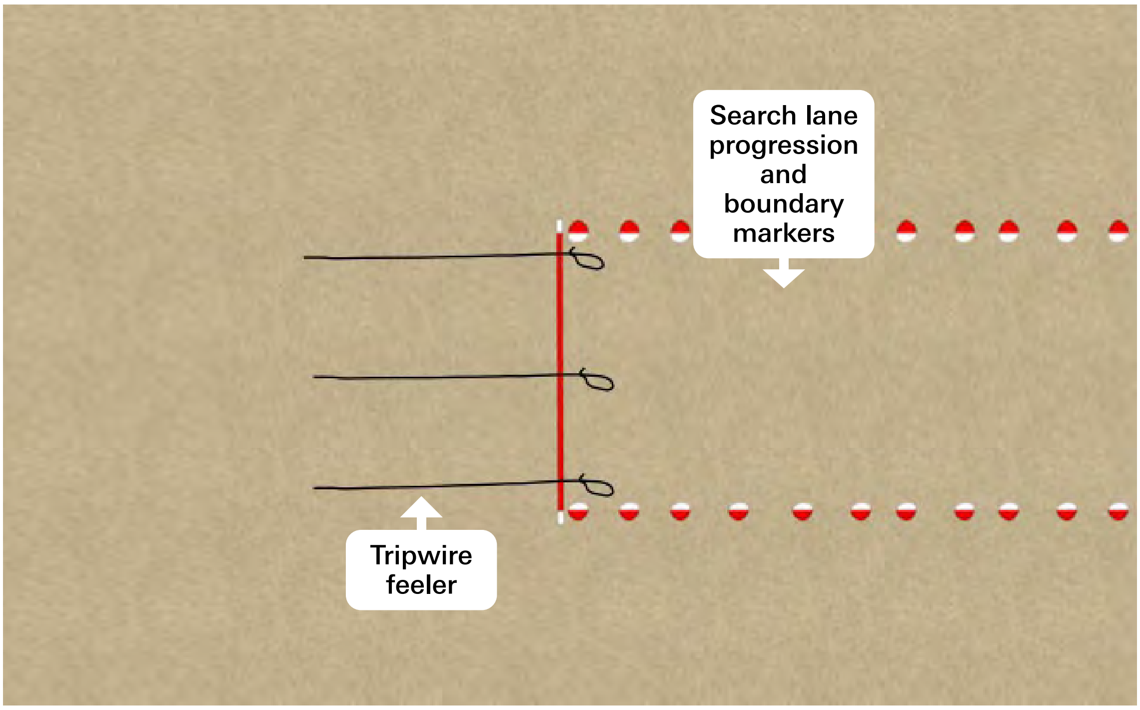


Image 1. Box method – tripwire feeling

The crow’s foot method. The searcher pushes the tripwire feeler into the lane on the left, centre and right systematically from the centre of the lane before raising it to the desired height whilst visually searching, as in the image below:

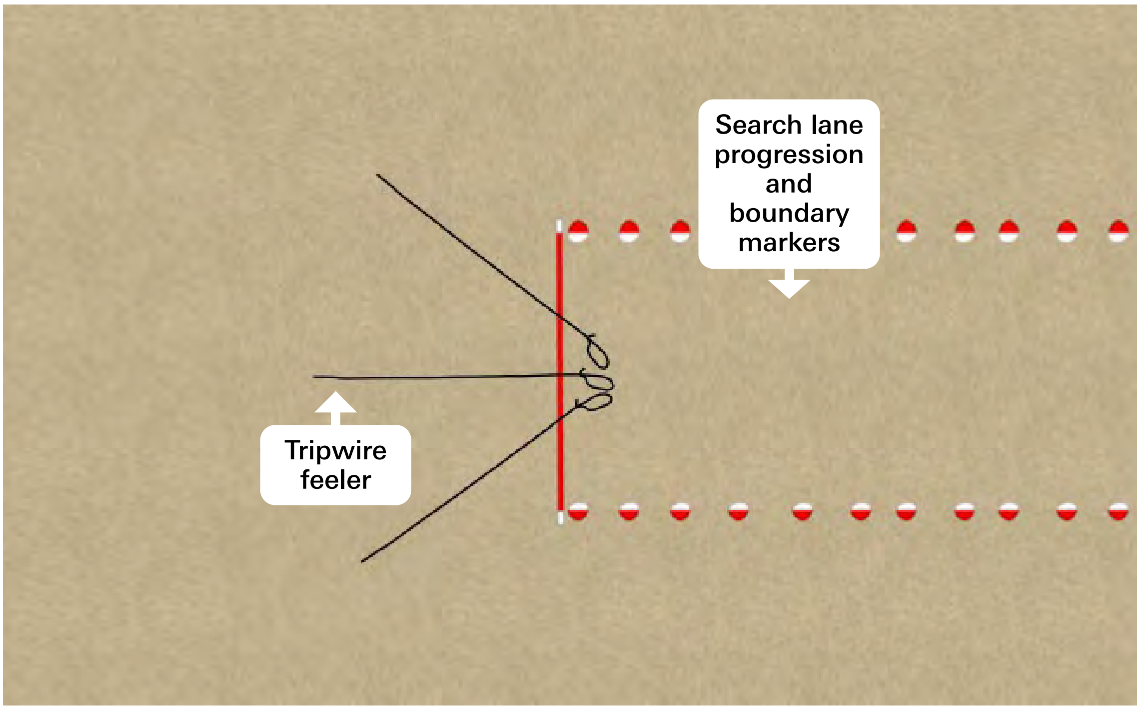


Image 2. Crow's foot method – tripwire feeling

The following series of six images illustrates the basics of an open area tripwire feeling procedure. They show the systematic use of a tripwire feeler, starting from ground level, to waist height, then on to head height from the standing position.

> HINT. The degree to which tripwire feeling is conducted should be driven by the operational threat assessment. This should be documented in the clearance plan.

Image 3. Low level starting at the side (this would be conducted at each side of the lane)

Image 4. Low level in the centre of the lane

Image 5. Starting to progressively increase the height

Image 6. Only go as high as is comfortable

Image 7. Once the lower search has been completed, the searcher stands up to continue the search higher

Image 8. Increase the height of the tripwire feeler as high as the operational threat assessment dictates

3.3.3. BUILDINGS AND STRUCTURES

Tripwires can be used very effectively by armed groups inside buildings, where constrictions in passageways offer good emplacement opportunities and lower levels of natural light hamper visual detection.

Image 9. Using a tripwire feeler in a passageway where there is less natural light

Image 10. Tripwire feeler pushed through the top layers of sand to locate a slack tripwire. Note that in this picture the feeler is not touching the wire

Image 11. Using a tripwire feeler to increase the effectiveness of visually searching a doorway. Care is being taken not to put the head outside the safe area

Image 12. Searcher ensuring that the whole of the doorway is fully searched

3.3.4. DETECTING OTHER COMPONENTS WITH A TRIPWIRE FEELER AS A VISUAL SEARCH AID

The detection of other surface-laid switches can also be enhanced by the use of a tripwire feeler or other aids such as laser pens. This is especially true for the crush wire pressure IED switches that have been commonly encountered since 2015 in Iraq and Syria.

WARNING. The principle is not to interact with the switch, rather to use the feeler to help focus the searcher's vision.

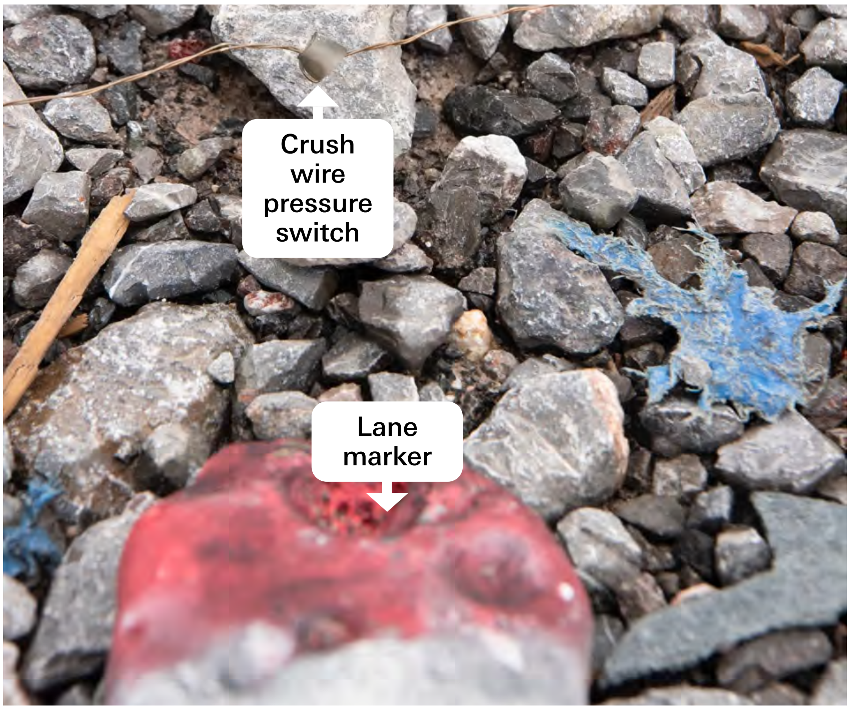


Image 13. Surface-laid crush wire switch located with the help of a tripwire feeler

3.3.5. DETECTING TRIPWIRE USING A LASER AS A VISUAL SEARCH AID

Searchers can use additional aids such as commercially available laser pens in these environments. The concept is that a tripwire will visibly break or interrupt the laser's line or interrupt the dot depending on the type of laser being used.

WARNING. It is important that training and familiarisation of this technique is conducted and that it is used alongside a visual search, just like tripwire feeling, and not used in isolation.

WARNING. Approval and accreditation are required by the NMAA or equivalent with regards a suitable procedure and the procurement of a laser pen that is safe to use.

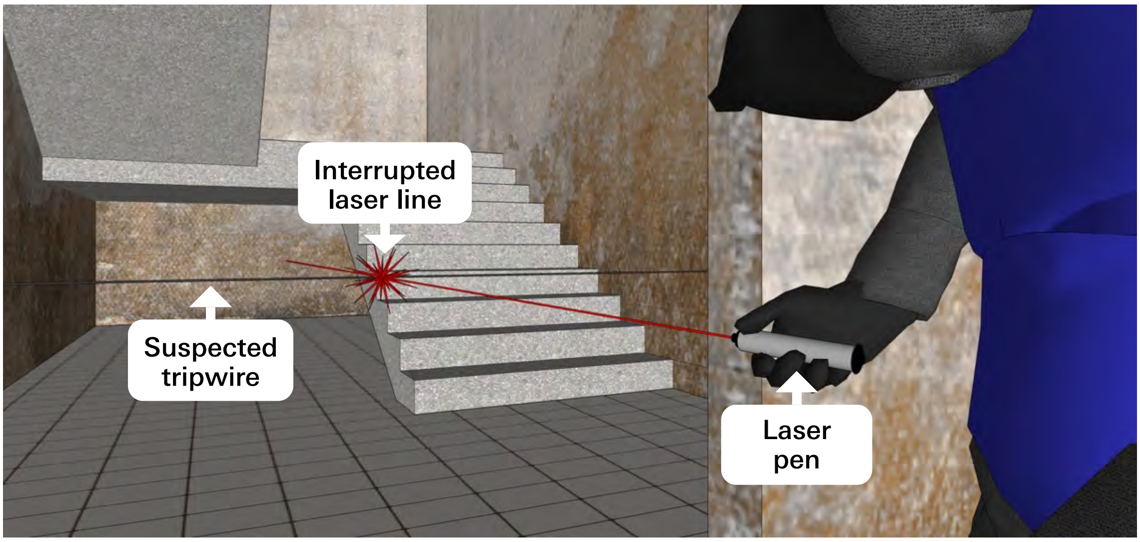


Image 14. Image showing the use of a laser pen as an aid to visual search locating what could be a tripwire

3.3.6. USING MIRRORS AS A VISUAL SEARCH AID

Buildings and structures present an environment where IEDs and their components, including large components such as main charges, can be easily hidden by placing objects such as furniture in front of them, placing them around corners or edges such as doorways or around bends in corridors, or in overhead loft spaces. Once an initial visual search has been conducted, another aid to visual search of these obscured positions is a mirror held in a position to provide a vantage point to search the area. This mirror can be mounted on a small telescopic pole such as the example shown in Image 15.

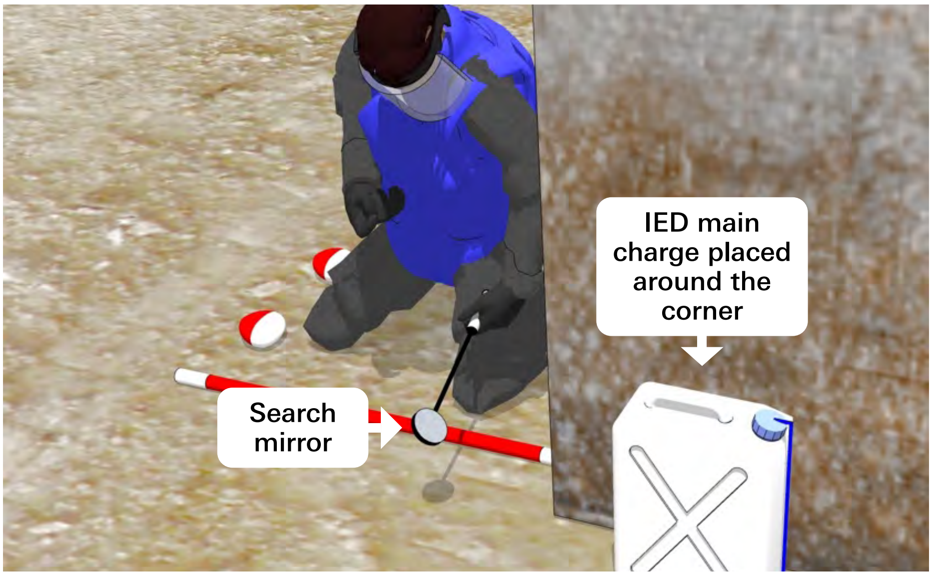


Image 15. A purpose-made search mirror identifying a previously unsighted IED component

WARNING. Placing a mirror to observe an unsearched area may require the aid to be placed into an unsearched area. Before this, ensure a visual search and possibly tripwire feeler search have been conducted.

This is an adaptation of a technique used by static security personnel to rapidly search the underside of vehicles for suspicious objects before they enter an establishment.

3.3.7. VISUAL SEARCH WITH AN AID – INTRUSIVE SEARCH

Experience has shown that objects such as furniture and household appliances or cavities in construction within buildings and structures can easily hide emplaced EO or explosive components and often limit a manual search visually and physically.

If a threat analysis recognises the potential for this situation and for a more efficient search to minimise damage to property, then simple hand tools that facilitate access to the inside of these objects or cavities, and widely available optical aids (see Image 16), should be used to efficiently search inside these objects.

Image 16. An optical aid used with a smartphone to search inside furniture

3.4. CORE SKILL 3 – USE OF DETECTORS IN IED SEARCH

Initially, mine detectors in mine action focused on the requirement for the sensor to be capable of reliably detecting anti-personnel mines with a specific metal content to a set depth. Now, a multitude of sensors exist that can detect the presence of other materials and anomalies that may indicate the presence of an item of EO. These sensors include ground penetrating radar (GPR), which detects subsurface cavities or differences in material between an item and the ground around it. Other sensors include those for the detection of long and short wires and even carbon rods.

Selecting the detector type for IED search should be initially based on the national threat analysis and clearance criteria set by the NMAA or an equivalent body. This will help ensure that detectors purchased and imported to facilitate a programme will provide the capability needed by the programme. The selection process should include conducting a cost benefit analysis, as spending more money on enhanced detectors could be offset by a reduction in labour costs, while achieving a greater level of output. This should be confirmed during site specific operational threat assessments, to ensure that the situation has not changed.

3.4.1. FUNDAMENTALS FOR USING DETECTORS FOR IED SEARCH

Image 3. Using the detector from inside the safe area using a stable kneeling position

There are five key fundamental points to remember when using a detector during IED search:

1. The searcher should be suitably trained on user maintenance, preparation, operating procedures and functions of the respective detector.
2. The detector should be prepared reasonably close to, but prior to being used in, a hazardous area and calibrated to the assessed IED components at the assessed depth.
3. The sensor head should be kept as close as possible to the surface, without touching, throughout the sweep.
4. There should be overlap between the sweeps; the size of these overlaps will be dependent on the detector and the IED component that is being searched for.
5. Progression should be clearly marked following an approved system and the searcher should remain inside the marked safe area.

WARNING. Detector sweeps should be conducted from a stable position inside the safe area. The detector should be set to the correct length for the searcher to reduce the chance of their becoming unbalanced.

Image 4. Using the detector incorrectly. A supervisor / team leader should monitor searchers for basic errors such as stretching forward and stepping outside of the cleared area. This is common to conventional mine clearance operations

Image 5. Detector moving to the right-hand side. This is progressed with consistent overlap between sweeps within a comfortable forward limit for the searcher

Image 6. Detector completing the final sweep prior to moving the progression marker

WARNING. The construction and layout of IEDs often means that a searcher may only detect one component or one material inside a larger component. An example of this is a carbon rod in a low metal content pressure plate. This must be factored into how detectors and follow-on excavation drills are conducted.

Image 7. Some buildings only contain limited metal in the structure yet metal detectors may still provide benefit to search operations

3.4.2. FALSE POSITIVES

False positives in detector search has been an issue in wider MA operations since their conception in the late 1980s. An example of this is data gathered by the Cambodian Mine Action Centre, from March 1992 to October 1998, that shows that for every item detected there was a 99.7 percent chance that it was scrap metal and not EO. This figure would certainly hold true in urban areas, where metal contamination exists in large quantities alongside EO contamination.

Detector search procedures should consider in detail the degree to which false positives will reduce efficiency and these should be mitigated as far as possible. Procedures should consider gross contamination to the point where detectors are not able to provide any value to the searcher. This should be linked with the MA organisation's accredited SOPs to state under which conditions rapid excavations could be conducted or certain signals not investigated at all. The type of detector being used in relation to the IED threat will significantly influence these SOPs.

3.4.3. DETECTING COMMAND WIRES (CWs)

There are two primary procedures used in MA to detect and locate physical link command wires. This IED tactic is described in Chapter 1 and although MA operations should be conducted outside of conflict, after devices have been abandoned, it is still considered good practice to locate command wires and 'take control' of them prior to staff being inside the explosive danger of the contact point. Specifically, the two procedures are:

Use of wire detectors. Most handheld mine detectors are not designed to detect long CWs. Purpose-built wire detectors for long wire detection are commercially available and can be used to help search for CWs.

Use of tools. Other tools to locate CWs are improvised hooks or rakes that have been used by security forces in the location of CW for decades. Normally, hooking procedures are used on the edges of linear features or borders such as road or path verges, irrigation or drainage ditches, fence lines or hedgerows, where irregularity from digging in CWs is easily hidden.

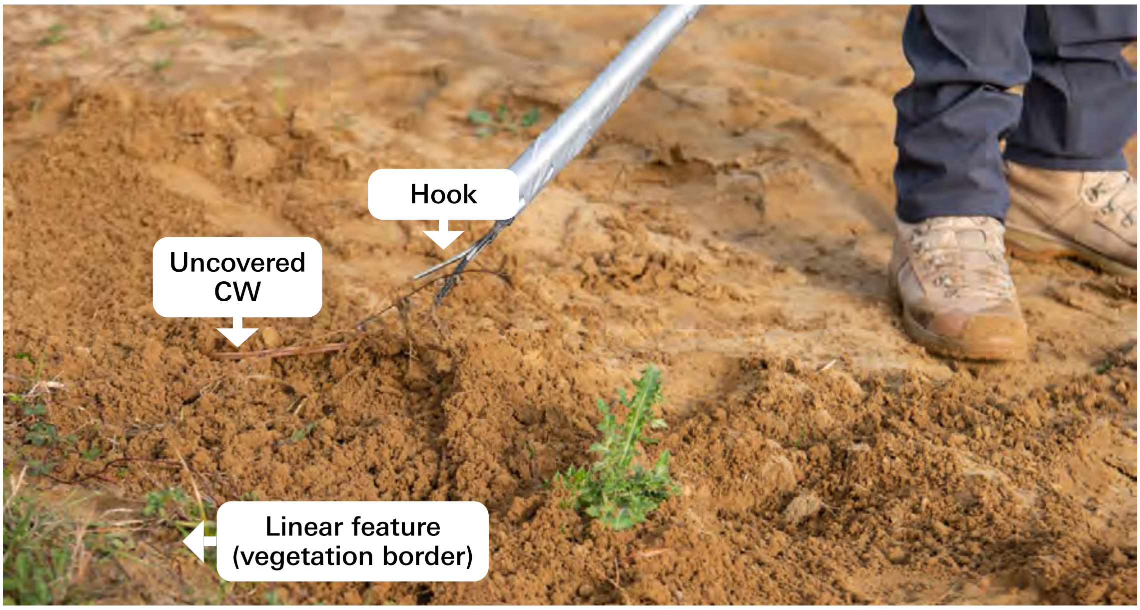


Image 8. Improvised hook uncovering a suspected CW

When hooking, the searcher must take into account the fundamental principle of detector use that 'there should be overlap between sweeps'. This can be achieved by raking in a pattern often called a 'crow's foot', where the raking or hooking should cross at some point to ensure coverage.

Buried CWs. CWs may have been intentionally buried to a substantial depth (20 to 30 cm) or abandoned for some time and become covered over by soil movement over a long period of time. This might leave the CW still detectable by wire detector but not by the hook / rake alone. If the operational threat assessment dictates, it may be prudent for the group that is attempting to locate CWs to utilise a spade or other similar digging tool to excavate and confirm a detection by the wire detector if the hook / rake proves negative.

Mitigation against VOIED switches attached to CW to target CW searchers. There have been occasions when VOIEDs have been attached to CWs to target personnel attempting to take control of the CW, or to target poor practices such as the act of pulling on the wire to bring it into a CP. The procedures used to locate CWs should therefore avoid disrupting the CW and actions such as hooking or raking should be conducted in a controlled manner (and only after the detector has confirmed that the immediate area is free from other IED components). If a CW is uncovered, then search procedures should stop and the task be handed over to a qualified IEDD operator.

3.5. CORE SKILL 4 – FINGERTIP SEARCH

3.5.1. IED SEARCH AND GROSS METAL CONTAMINATION

In an urban area there is likely to be an abundance of metal contamination disguising IED components from handheld detector signals. Sometimes this may even be a deliberate part of the armed group's tactics. Within buildings and structures there will be instances when handheld detectors will not have the ability to discriminate between individual objects and other ferrous detritus.

Fingertip search is a fundamental procedure that may help to overcome this issue when there is not a threat of IED components being buried or concealed by more than a couple of centimetres. When conducting fingertip search the following points should be observed:

- Whenever possible the search should be undertaken in the prone position, wearing appropriate PPE, with only one hand extended and the other arm tucked under the torso to protect from blast.
- The extended hand is pushed carefully forward in the direction of the search progression through the top surface layer, at a depth determined by conditions and threat, feeling for changes in the micro-environment that indicate an object or abnormal ground variations.
- The search should be systematic and there should be overlap.
- The head and torso should remain in the safe area and the searcher should not reach out at an uncomfortable distance.

Image 1. Fingertip search over a sand-covered hard surface

Image 2. Here you can see the tracks of the fingertip search. Whether or not gloves should be worn is a key consideration

The searcher is using a systematic pattern in Image 2 working from right to left. They are keeping their head and torso in a cleared area at all times. The searcher is wearing protective gloves due to the risk of sharp objects such as broken glass. This means that they should practice the technique under the conditions in which it will be conducted and be confident that the gloves will not hinder the effectiveness of the search due to a lack of dexterity. The operational threat assessment will be key to determining whether gloves can or cannot be worn.

3.6. CORE SKILL 5 – MARKING

Marking of confirmed EO and hazardous areas in MA task sites are covered in detail in IMAS 08.40 Marking mine and ERW hazards, however, it is worth mentioning that the scope of IMAS 08.40 states that "*It does not specify marking systems used by organisations during demining operations.*" NMAS and MA organisational SOPs should be developed further to specify clear warning markings for communities, especially in densely populated areas, and (if possible) physical barriers that should be used to reduce the risk of unintentional entry into hazardous areas.

Conducting manual search techniques requires robust procedures and a thoughtful plan for marking and recording the progression of a searcher in a hazardous area, building or structure to promote efficiency, manage safety and ensure the entire area has been searched.

Image 1. A searcher / deminer being trained in marking safe lanes

3.6.1. FUNDAMENTALS FOR MARKING PROGRESSION OF MANUALLY SEARCHED AREAS

Image 2. Searcher progressing into a structure

The progression marking system should:

- Be thoroughly briefed, alongside general task site markings, to all team members and associated people such as visitors and members of the local community.
- Be easily recognisable against the backdrop of the environment.
- Alternatives should be available for problematic areas such as inside buildings, where there is low light or uneven ground, or areas of ascent (such as staircases) or access (raised platforms or tunnels).

The progression markers:

- Can be temporary in nature and should be reinforced at regular intervals.
- Should be easily moveable by the searcher.
- Should not be unduly influenced by weather conditions. For example, 'mine tape' can be disturbed easily during windy conditions.

Image 3. Progression marking used for fingertip search

Marking systems, however well planned and intended, can be difficult to recognise in urban areas when there is an abundance of debris and 'street furniture' such as lamps, refuse bins, and traffic signs.

HINT. Breaking down large urban areas into smaller, sub-areas is a useful method when using temporary progression markers. This can be achieved using linear features, which are abundant in urban areas, and recording the progression on diagrams of plan views using simple colour coding (areas completed, in progress or not yet started).

Image 4. Image showing a cutaway of a building portraying systematic recording: completed areas are annotated in green, areas to be searched remain in red

Search teams should have designated responsibility for sub-areas. For example, if Building A is attributed to Team 1 for the length of the task, Team 1's supervisor annotates the team's progress of searching Building A on a sketch map. This will facilitate efficient briefing and continuation of search following a stand-down period and a well organised handover between teams if necessary.

3.7. CORE SKILL 6 – EXCAVATION AND CONFIRMATION

The deminer / searcher tasked with identifying EO using the techniques and procedures in previous sections should confirm to a degree if objects are benign or are suspected to be an IED component or other EO. Objects detected with visual search are unlikely to require any further 'confirmation'. Subsurface objects that are detected by a sensor (metal, GPR, carbon rod, wire, etc.) will require location through excavation by the deminer / searcher to enable confirmation if they are a suspect item.

Image 1. A training lane for practising excavation

3.7.1. FUNDAMENTALS OF EXCAVATION FOR CONFIRMATION OF IEDs AND EO

MA organisations should have SOPs that stipulate the techniques and procedures used to confirm if suspect signals represent an IED or one of its components. For subsurface indications these procedures are referred to as excavation. The following fundamentals should be remembered:

EXCAVATION FUNDAMENTAL 1 – ESTABLISHING A START POINT

- The signal's centre mass should be pinpointed and delineated using the detector. The centre mass is then recorded to calculate distances to a start point, this can be achieved by using obvious visual reference points or physical markers that are placed on the ground.

WARNING. If delineation and distance markers are used, they should not penetrate the surface or impart any force that could activate a switch, especially if indicating the suspect signal's centre mass.

- A temporary marker is placed back towards the cleared area at a distance to be confirmed through the operational threat assessment and specified in the clearance plan using the calculations in Table 1.

This temporary marker is where the excavation will begin and therefore should be at a safe distance from the signal's centre mass to prevent a worst-case scenario occurring if an IED component is disturbed. Having confidence in this distance enables the searcher to use hand tools to break the ground in order to achieve the required depth, prior to starting an excavation channel towards the suspect signal.

WARNING. The area where excavation will begin should be in the direction of search and should have already been searched visually and with a detector.

Images 2 to 6 show the delineation of a low metal content bare wire pressure plate. Due to its design only the centre mass of the plate provides a detector signal.

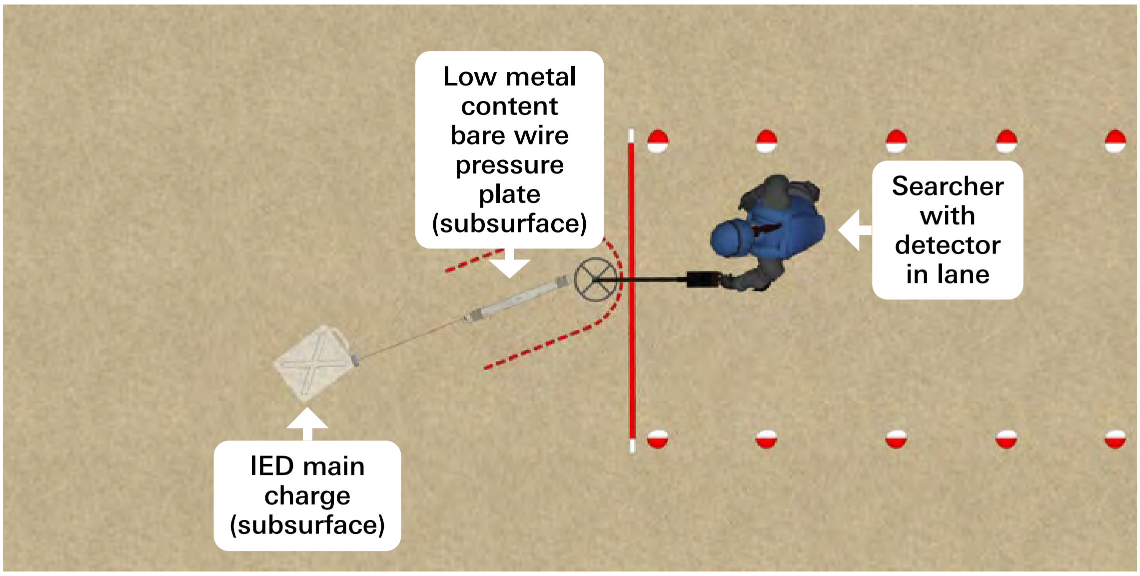


Image 2. The searcher receives a signal that a subsurface object is present

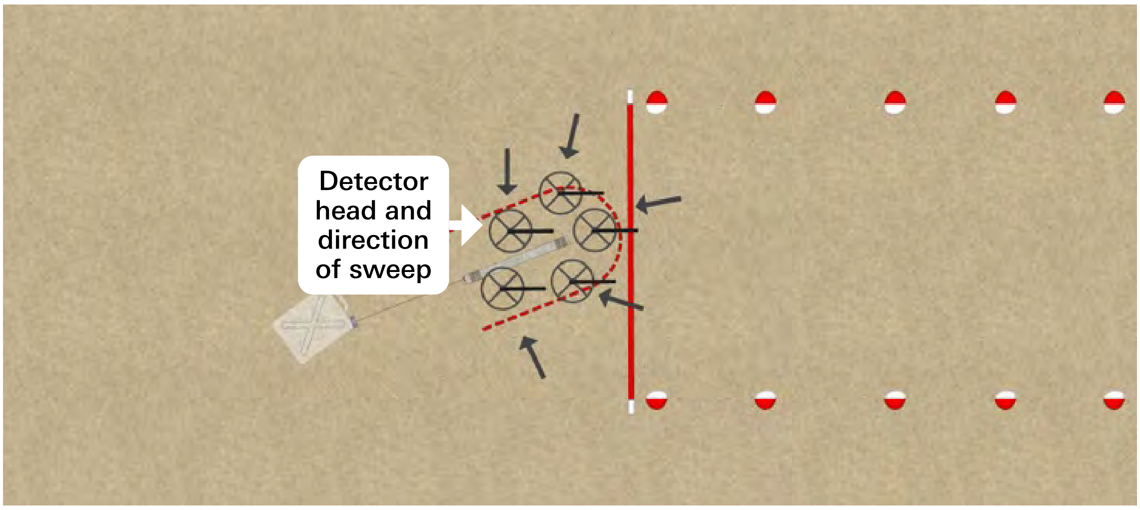


Image 3. The searcher uses detector delineation techniques to try to gain as much information as possible about the size and orientation of the suspect item

WARNING. In Image 3 the searcher does not extend their reach.

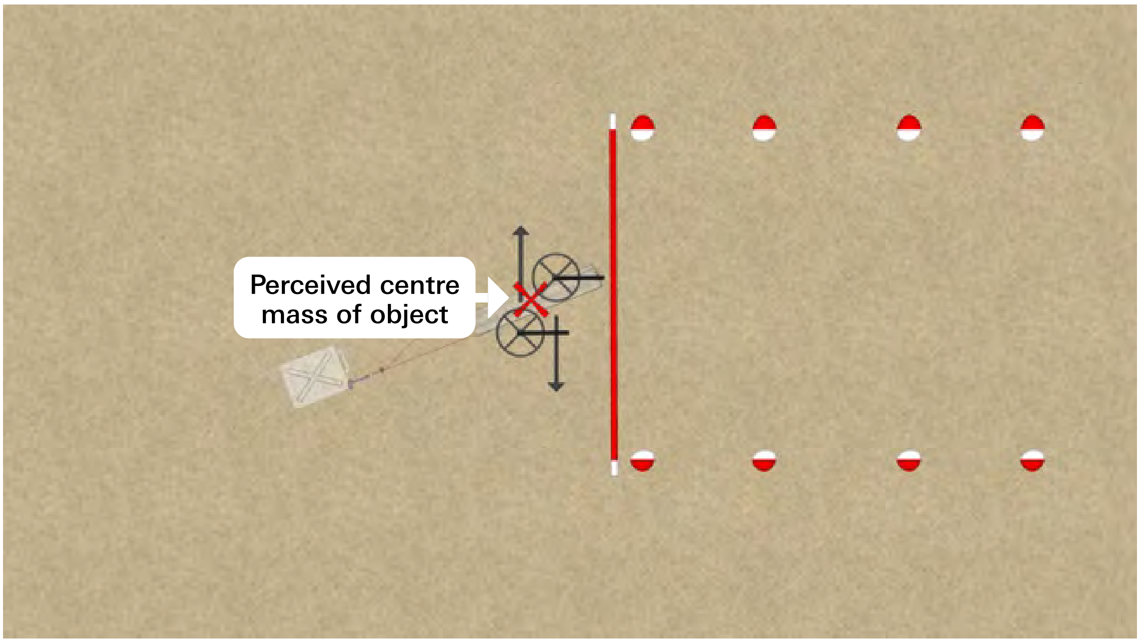


Image 4. The searcher is only able to establish the signal at the centre of this pressure plate

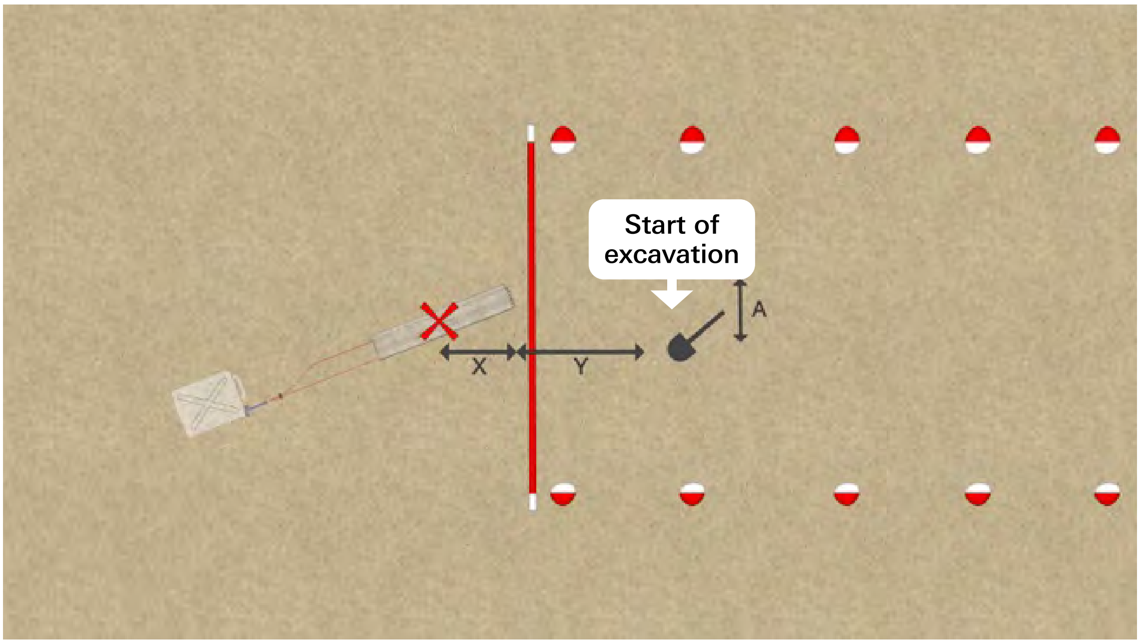


Image 5. This image shows that by having a set minimum distance (x + y) the excavation will start from a safe position

	EXCAVATION DISTANCES REFERENCE FOR IMAGE 5 AND IMAGE 6
X	Assessed worst-case distance from suspect signal to the end of a component
Y	Additional distance to ensure excavation in a safe area
X+Y	Distance from pinpoint to start of excavation
A	The depth of excavation

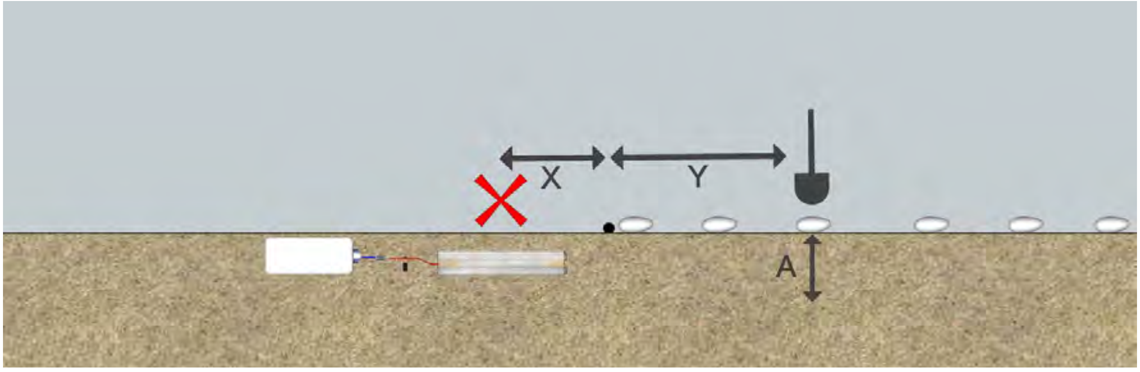


Image 6. This image shows excavation depth in relation to Image 5

EXCAVATION FUNDAMENTAL 2 – EXCAVATION TO CONFIRM THE NATURE OF THE SUSPECT SIGNAL

The excavation should initially be to a required depth determined by the MA operator and approved by the NMAA based on the operational threat assessment. Once this depth is achieved excavation can start towards the suspect signal.

- The excavation should be conducted in a manner that decreases the risk of inadvertently interacting with IED components. If tools are required, then they must be tested and approved for the task.
- The depth of the excavation should allow the searcher to uncover any components without any undue pressure being exerted onto possible pressure-activated switches.
- The excavation channel should allow the hand to progress towards the signal without exerting force on either side. It is recommended that the channel should be at least a hand's width, or 10 cm, wide.

WARNING. It is often the case that as the excavation of the channel progresses, it inadvertently becomes narrower. This should be mitigated through good staff training and monitoring.

- The searcher should make every attempt to reduce their exposure to the suspected item. It is recommended that the excavation is conducted in a prone position, with one arm tucked under the torso, the torso and head remaining in a cleared area and without the searcher extending their reach to an uncomfortable distance.

Image 7. Here a temporary marker is placed to indicate the centre mass of the suspect signal

Image 8. The start point is established, and downward excavation is conducted

Image 9. The correct depth of excavation can be checked with a dedicated depth gauge

Image 10. Tools can be used for harder ground

Image 11. A channel is excavated towards the suspect signal. Depth and width must be maintained

WARNING. During the excavation it is common for the searcher to be focused on the task and neglect his / her body positioning, in particular by splaying their legs and placing equipment outside the cleared area. This cleared area could be narrow and have sensitive IED and EO components close by, especially in a confined environment such as buildings or walled areas.

Image 12. A suspicious object has been located by excavation below it. At this point the searcher should make the assessment (dependent on accredited SOPs) on whether it has the potential to be part of an IED

3.7.2. EXCAVATION AND CONFIRMATION – PRESSURE RELEASE SWITCHES

Confirmation brings with it the threat of activating EO and procedures should be put in place to mitigate this threat, taking into account device construction. This awareness and training will prepare the searcher for effective confirmation.

Image 13. Pressure release switch located under rock

Image 13 shows a multi-switch VOIED with both pressure and pressure release switches. This presents a scenario where if a searcher hasn't attributed the rock to an IED and not located the other components he / she may lift it up manually, detonating the device. Mitigation for this scenario is threat assessment and the use of thorough visual techniques prior to any positive action during the fingertip search.

3.8. CORE SKILL 7 – SEMI-REMOTE SEARCH (HOOK AND LINE)

Impediments and obstructions to the progression of manual search will occur in all types of space (buildings, open areas and routes), with buildings potentially presenting the greatest challenge. Obstructions can vary in size, material and complexity, making the search difficult. In such circumstances it may not be possible to discount the presence of an IED using visual search, tripwire detection, fingertip search or handheld detectors.

Specific semi-remote equipment and stand-alone procedures commonly referred to as hook and line (H&L) or disruptive search, have been used satisfactorily to discount or confirm EO in these types of circumstance, allowing manual search to progress unhindered.

3.8.1. FUNDAMENTALS FOR SEMI-REMOTE SEARCH

- Semi-remote search is achieved by searchers connecting the object(s) to a cable and then returning to a CP which is in a safe location. The line is then pulled under tension to move the object.
- A safe waiting period is then applied before returning to the item, confirming what has been achieved and then continuing a manual search. The **minimum** safe waiting period applied should be 10 minutes.
- When safe to do so, multiple items should be pulled simultaneously to reduce the number of safe waiting periods that need to be applied.
- Semi-remote searches should be planned and controlled by the team leader and conducted as a 'one-person risk', with the whole team briefed before anyone leaves the CP.
- For an item to be considered 'successfully moved' by semi-remote procedures, it must be pulled or toppled through at least two planes and removed fully from its initial position. In the case of windows and doors they should be opened fully.

WARNING. Care must be taken to avoid inadvertently causing the object to move during attachment or by pulling of the cable prior to all staff returning to the CP. This is normally achieved by 'snake coils' in the line at the attachment end (see Image 1).

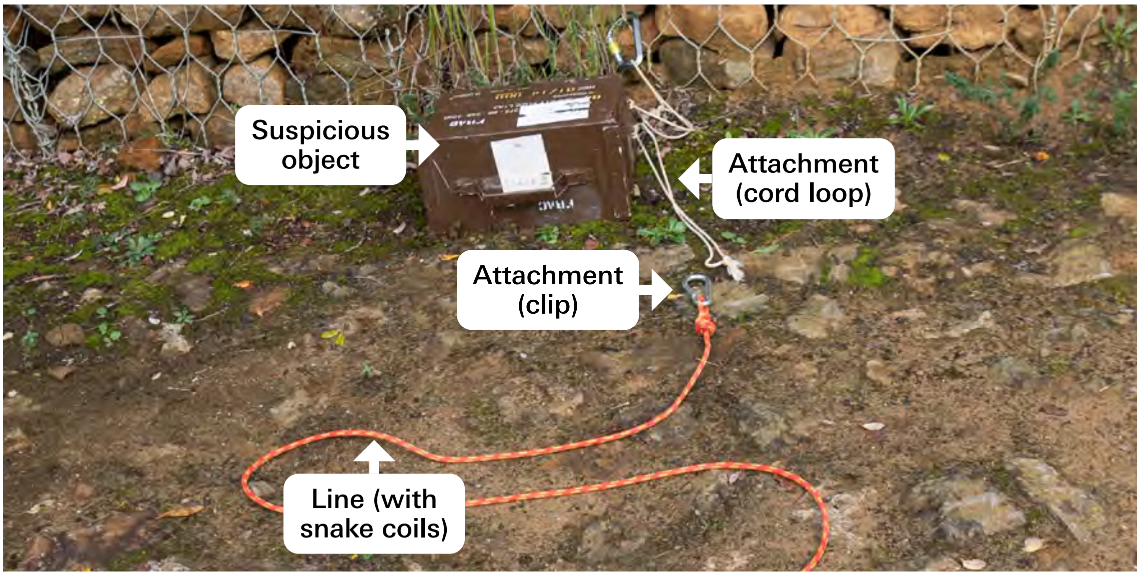


Image 1. Example of a snake coil in a line

3.8.2. EQUIPMENT NECESSARY FOR SAFE AND EFFECTIVE SEMI-REMOTE SEARCH

To achieve semi-remote actions an H&L kit is required. Some items that this kit is likely to contain include:

- Object attachments
- Line or cable on a reel
- Changes of direction for the line with clips, karabiners and pulleys
- Anchoring
- Miscellaneous items such as straps, prusik or paracord loops, door wedges and hand tools

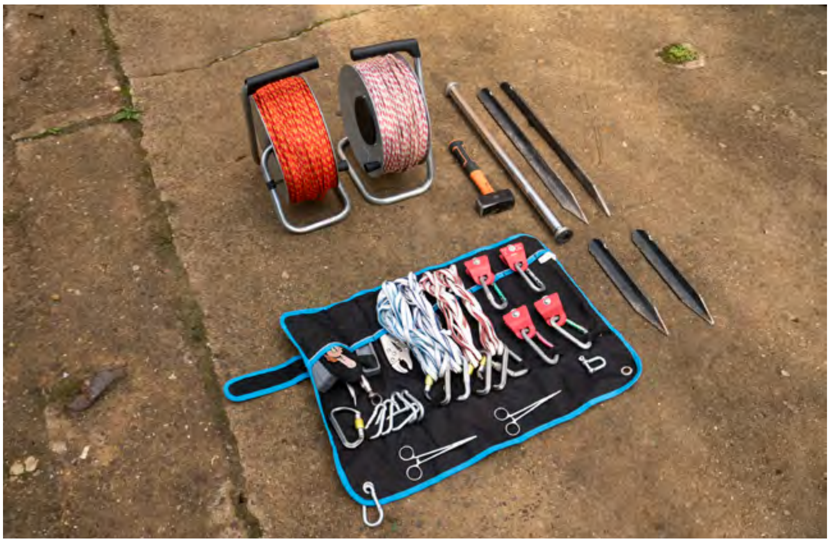


Image 2. Typical improvised semi-remote search equipment

An MA organisation can acquire or improvise these items locally, with some key considerations being:

- **Object attachments.** Tools and items that attach the line to the object by hooking, gripping or being tied to the object.

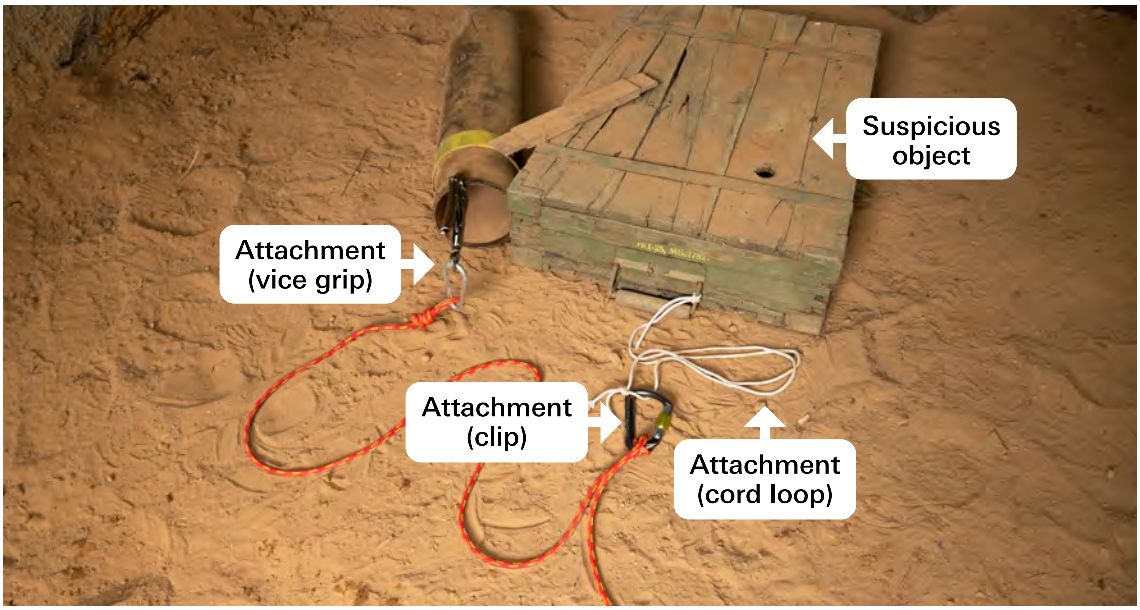


Image 3. An example of typical object attachment equipment (note snake coils in pulling cables) and attachment

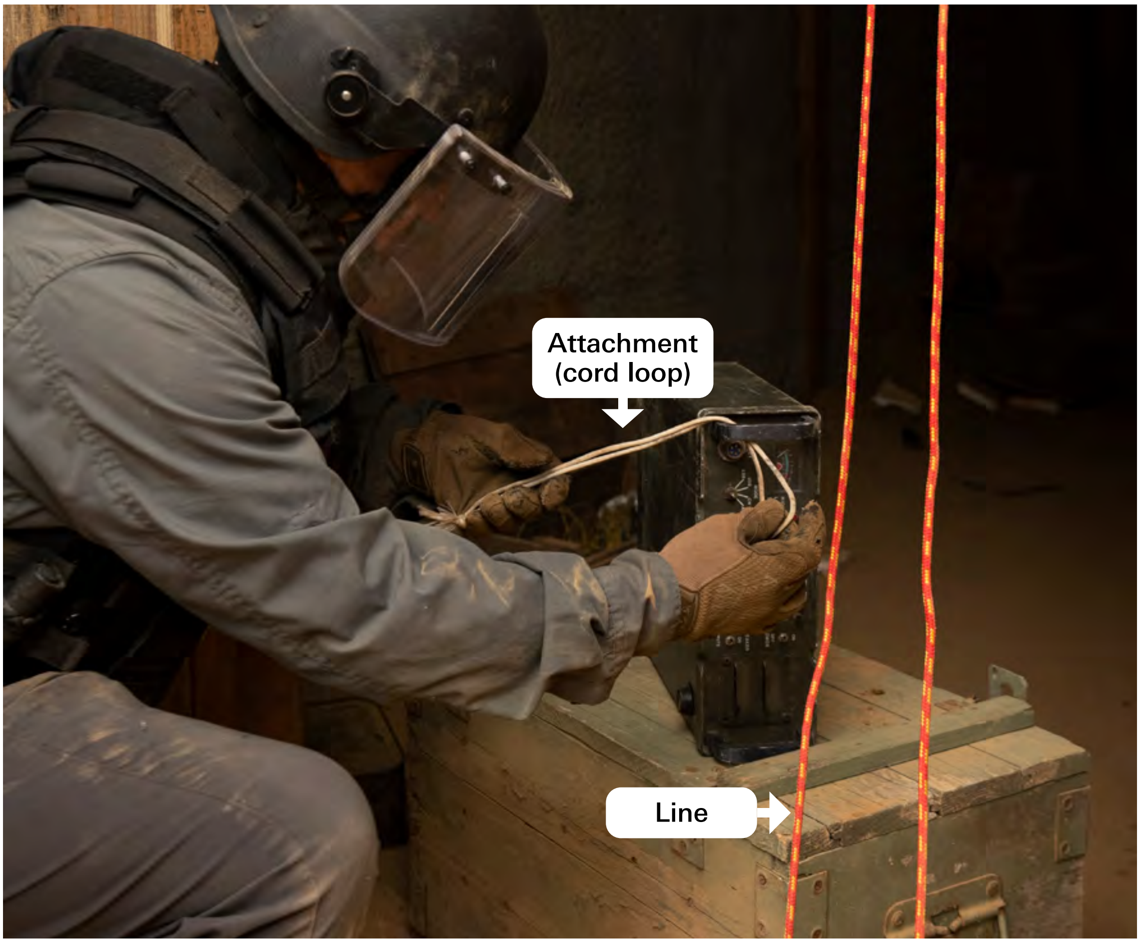


Image 4. An example of typical object attachment equipment

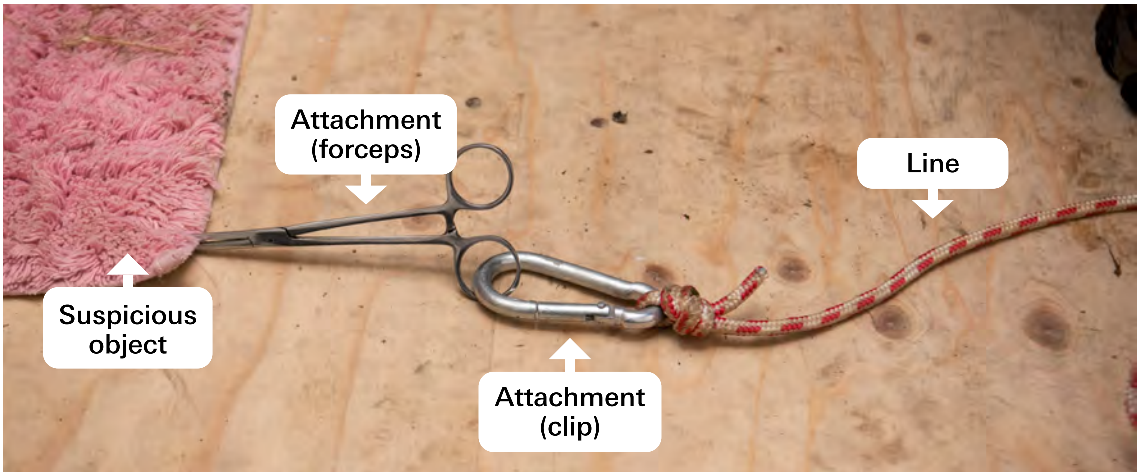


Image 5. An example of typical object attachment equipment

- **Line or cable.** A cable of sufficient length to reach from the object to a safe area (the CP). The cable must be of sufficient strength to move objects that are routinely encountered, with stronger vehicle cables also useful for very large or heavy items. Ideally these cables will be low stretch. Two separate ropes are advantageous for pulling objects in different directions during the same action, or for moving multiple items simultaneously. Cables may often run over rough surfaces and should preferably be made of a durable material and checked before and after use.
- **Changes of direction for the line.** For the line to effectively disrupt the object from a safe area it needs to follow a clear unobstructed path, preferably avoiding touching or running over any surface or edge. To achieve this the line should pass through pulleys and karabiners to enable it to run freely from the object to the CP.

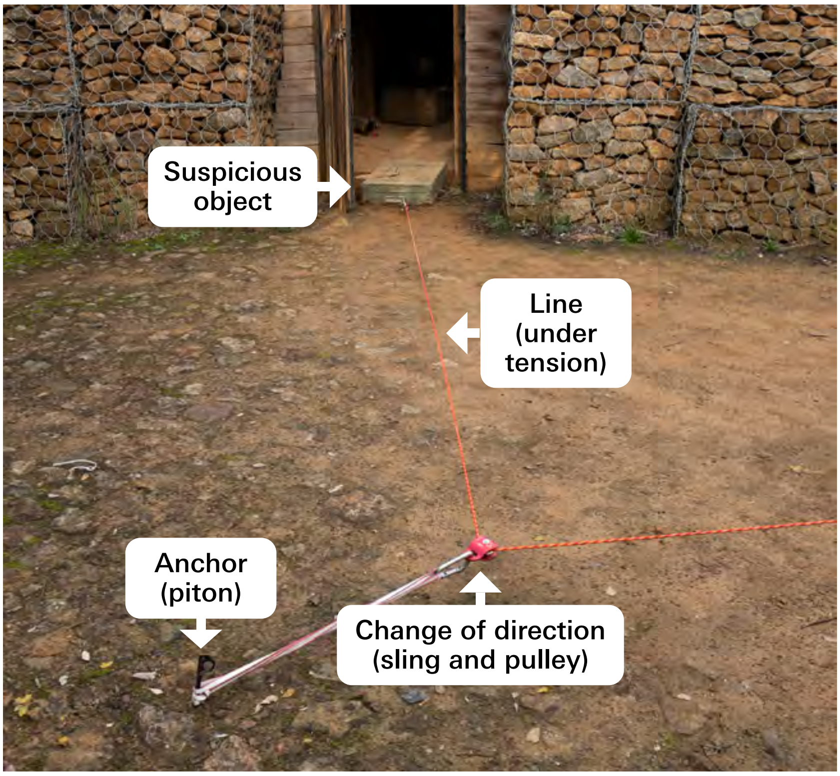


Image 6. Example of typical changes of direction equipment

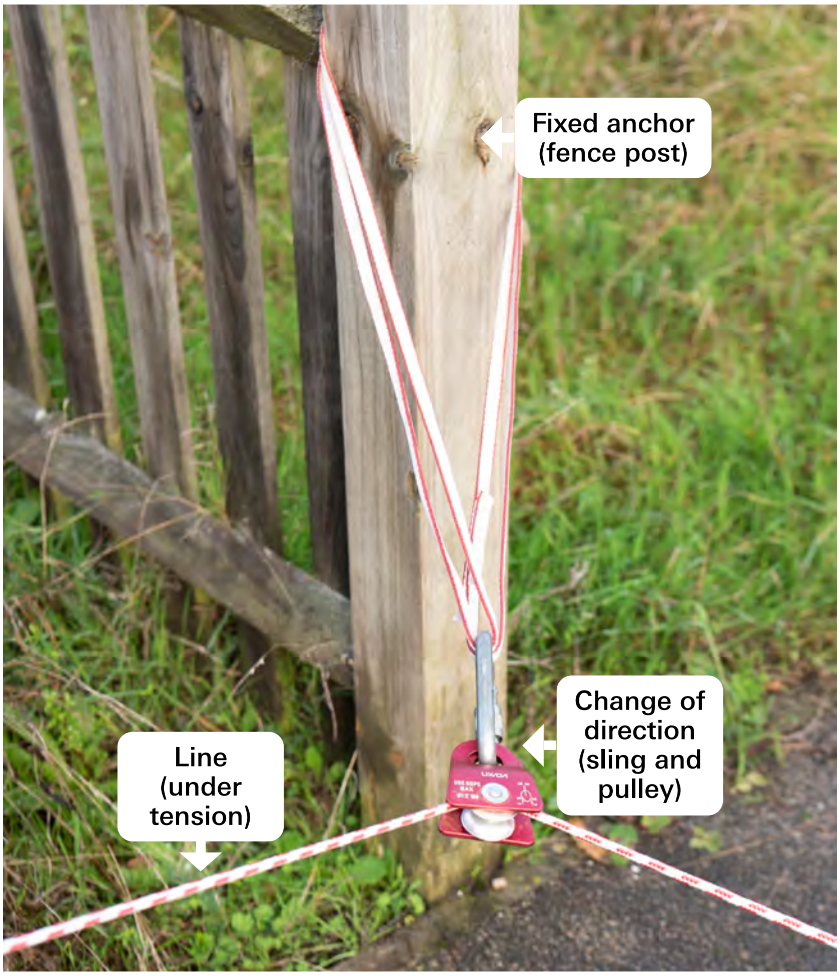


Image 7. Example of a fixed anchor point used as a change of direction with a sewn sling, karabiner and pulley

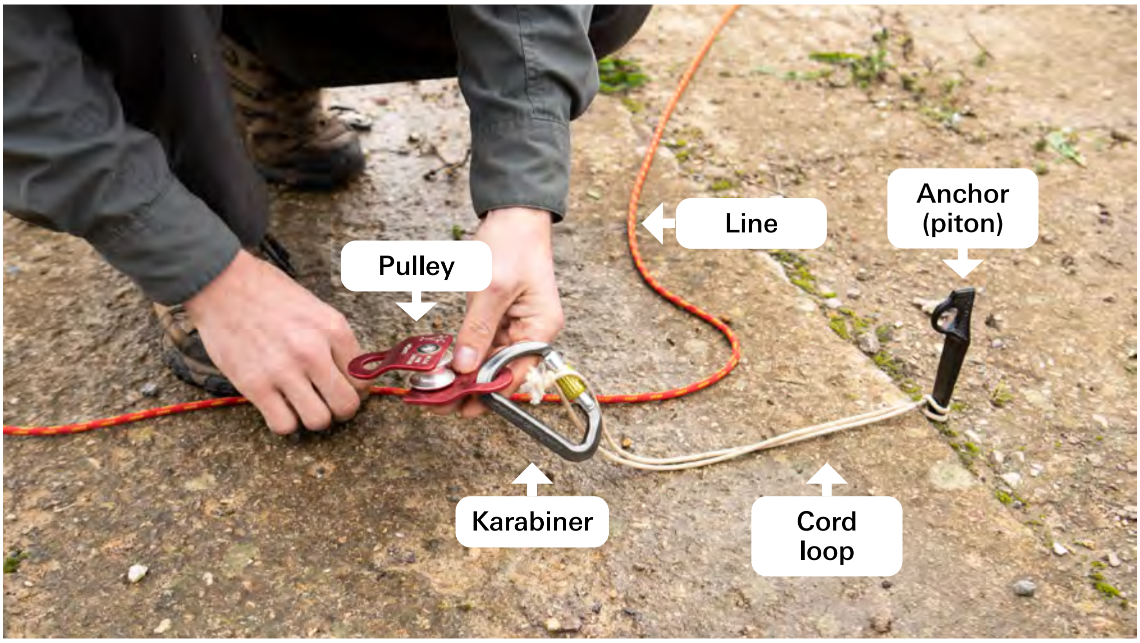


Image 8. Example of typical changes of direction and anchoring equipment with piton, white prusik cord loop, karabiner and pulley

- **Anchoring.** Changes of direction require a firm anchor either in the ground or affixed to solid stable objects.

Image 9. An off-the-shelf clamp used as an anchor for changes of direction with white prusik cord loop, karabiner and pulley

Image 10. Karabiners or clips are used in abundance in semi-remote searches

Image 11. A cable or line reel requires close supervision

3.8.3. SEMI-REMOTE SEARCH – BUILDINGS AND STRUCTURES

A semi-remote search within the confines of a building or structure is a common occurrence in IED clearance of urban areas. It is far more complex than operating in an open area and may require the need for multiple pulls, anchors and changes of direction. As such, frequent training on the set-up and conduct of semi-remote searches in buildings and structures is necessary.

Image 12. A typical semi-remote search set-up in buildings and structures

Image 13. A typical semi-remote search set-up in buildings and structures arranged for pulling multiple items on one pull

3.8.4. WEIGHT DROPPERS

During the search of buildings, a team may come across a door that opens inwards. This would be extremely difficult to open semi-remotely using H&L.

An improvised solution, often referred to as a 'weight dropper', consists of a heavily weighted hinged frame held by a pin that can be removed remotely with cable or line. Removing the pin allows the weighted frame to fall on to the closed door to force it open. Weight droppers can be fabricated locally or improvised from objects such as stepladders and sandbags. As with all semi-remote search techniques, fundamental care must be taken during preparation to make sure that safety is maintained.

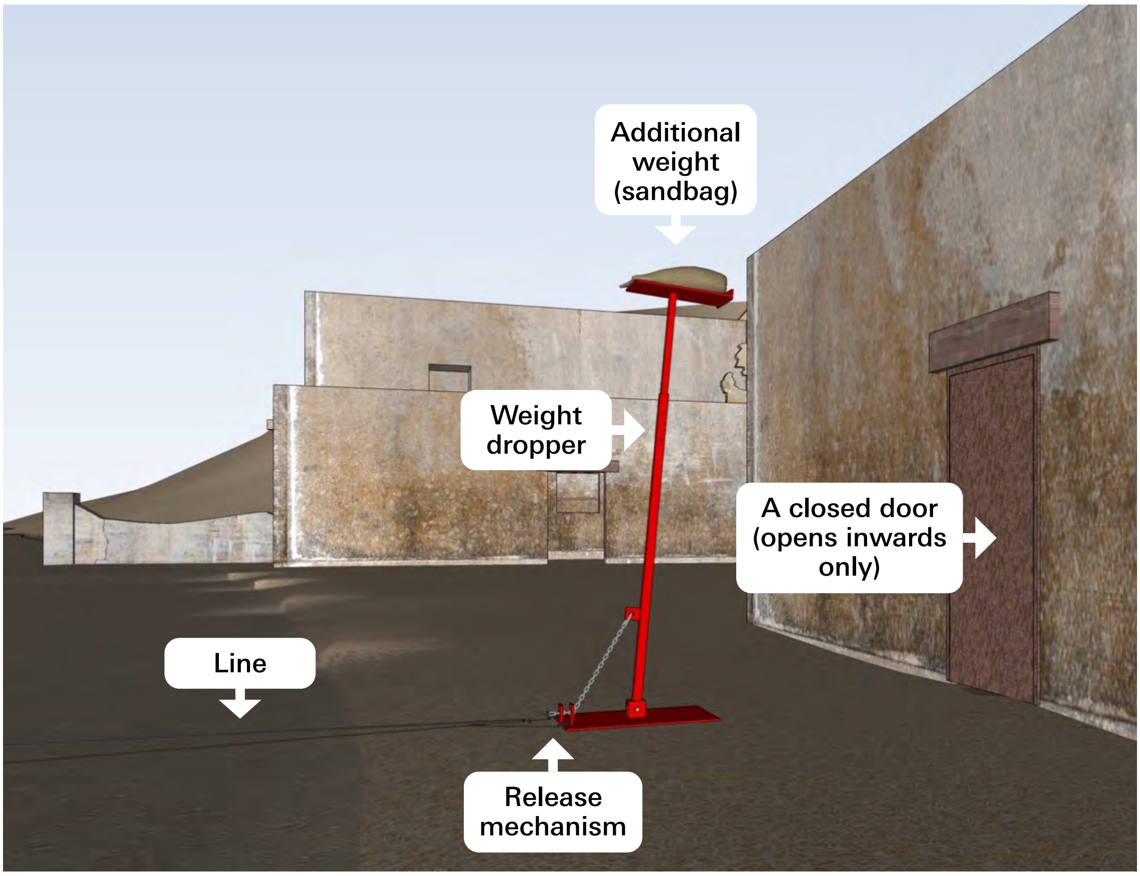


Image 14. Image of a weight dropper in position. Note that the system at the base allows the mechanism to be released and dropped via a line from a safe distance

3.9. CORE SKILL 8 – DEALING WITH VEGETATION

Vegetation will be an obstacle confronting searchers in open areas and may be an issue that increases over time as lack of maintenance allows it to flourish, further obscuring IEDs.

Image 1. Visual search prior to any interaction with the vegetation

Manual search of vegetated areas should begin with visual search (see Image 1). This should be conducted from a range of heights and positions from inside the safe area. A visual search aid such as a tripwire feeler may be used in line with the operational threat assessment (see Image 2).

Image 2. Use of a tripwire feeler as an aid to visual search in the top layer of vegetation

Vegetation removal should be conducted in stages starting from the top. This facilitates visual search into the next layer of vegetation. The visual search aid should be reused as required.

Image 3. Searcher using secateurs to remove the vegetation. In this example no more than 30 cm is removed at any time

Once the vegetation has reached a suitable level, a handheld detector sweep can be included in the procedure (see Image 4).

Image 4. Initial detector sweep with some vegetation still needing to be removed

Image 5. Vegetation has been fully removed and the searcher is now able to effectively use the detector at ground level

WARNING. Any vegetation that has been removed should be placed behind the searcher in a safe area. It should not become a hinderance to safe passage and should be regularly removed.

NOTE. If the threat assessment and worksite conditions allow, consideration could be given to removing vegetation with commercially available motorised strimmers or hedge cutters. A thorough appreciation of the threat likely to be expected and a risk assessment for the process should be conducted.

3.10. CORE SKILL 9 – HANDOVERS DURING MANUAL SEARCH

Image 1.

To reduce fatigue and prevent accidents due to lack of concentration, regular rests and changeovers are recommended and should be planned. A face to face brief between searcher and / or supervisors should take place, ideally in sight of temporary progression markings. The briefing should include:

- Direction of search
- Communications
- Temporary progression markings
- Any previous finds
- Any suspicious areas not yet reached

The temporary progression markings should be used to assist in the handover process and the new searcher should begin searching behind the previous searcher's last marked progression to provide an overlap in the search areas.

3.10.1. SUSPECT ITEM IS LOCATED

An effective search will find evidence of IED contamination, which is commonly referred to as 'confirmation'. When an IEDD team is separate to a search team it is essential that a detailed handover takes place to underpin a safe and efficient render safe procedure. Ideally, the handover should take place in a safe area (such as the CP) but in sight of the progression markers. If it is not possible to conduct it in sight of the progression markers, then photographs or diagrams should be used.

The handover on a find should include the same points that are included in a handover between searchers during a manual search. The searcher must also be prepared to answer analytical questions on the suspect object from the IEDD operator.

For protracted task sites, or sites without a dedicated IEDD element on standby, a sketch or photo of the suspect object, with its details and surroundings is also helpful.

A useful tool to indicate where confirmed components are situated is a coloured marker laid on the searched ground which points to the object. A minimum distance should be specified in SOPs to ensure this is conducted in a safe manner. Another option is to use markers to form a 'T' as shown in Image 3 and Image 4.

Image 2. Tripwire feeler being laid on searched ground pointing to the object for handing over to an IEDD operator

Image 3. An example of a clear marking system used to denote the location of a suspect object

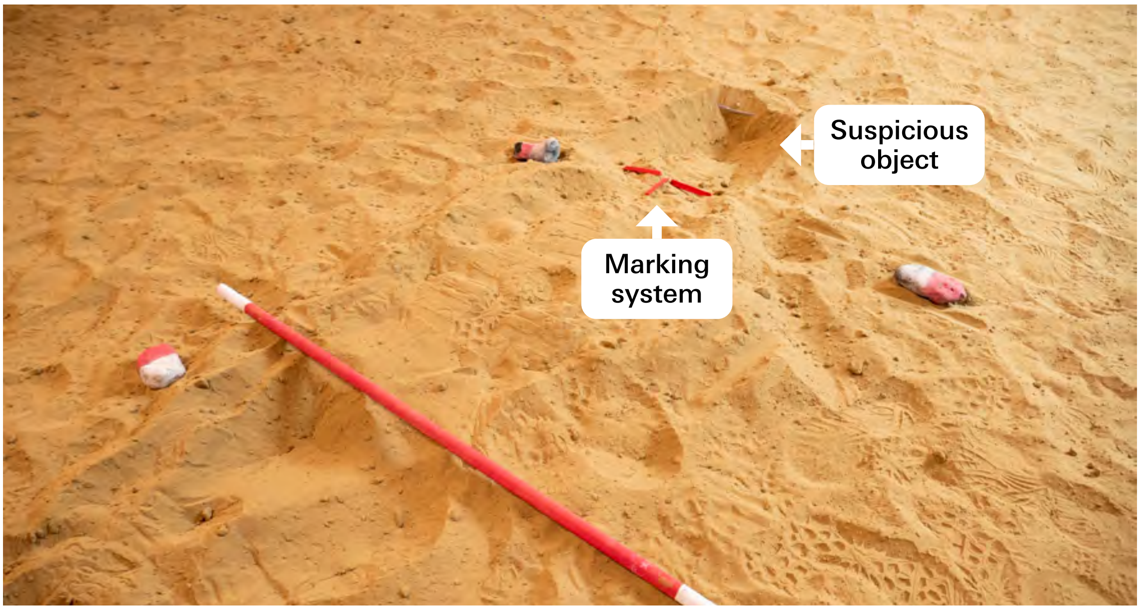


Image 4. A good procedure is to move the base-stick back a specified distance prior to handing over to the IEDD operator

4. CLEARANCE REPORTING

4.1. POST CLEARANCE ACTIVITIES

4.1.1. REPORTING, HANDOVER AND LIAISON WITH THE NATIONAL MINE ACTION AUTHORITY (NMAA)

As with any MA response, there should be continual liaison between the MA operator conducting IED clearance operations and the NMAA, or if they are not present then the recognised body that is assuming their role (the Authority). This starts with the registration and accreditation of the MA operator by the NMAA to ensure there is suitable confidence in them conducting the activities that are required. QA should then be continued once operations commence, in order to build confidence that the end product, a released building or open area, will meet the requirements that were set, and that it is safe for future use by the community. QC is the final inspection that ensures that these requirements have indeed been met through the application of "all reasonable effort" by the MA operator.

Prior to any external QC inspection, the Authority should already be fully aware of the effort that has been applied by the MA operator. This is achieved through site visits throughout operations to conduct QA, and in the submission of reports by the MA operator. The Authority should therefore already be aware of any parts of a confirmed hazardous area (CHA) that cannot be completed. These are often referred to as restrictions and may be due to lack of suitable mechanical demining machines to work in areas of dense vegetation, debris, rubble or unstable structures that are not suitable for manual operations. A detailed clearance plan will help to reduce the need to report hazardous areas as being suspended, as it should be possible to define them as separate suspected hazardous areas (SHAs) / CHAs, which can in turn be reported for release independently.

Restrictions of released areas, as well as areas adjacent to SHAs / CHAs, require appropriate marking in accordance with IMAS 08.40 Marking mine and ERW hazards. The community as a whole, and specific users, should be provided with EORE briefs in relation to adjacent or remaining hazardous areas and what the marking means.

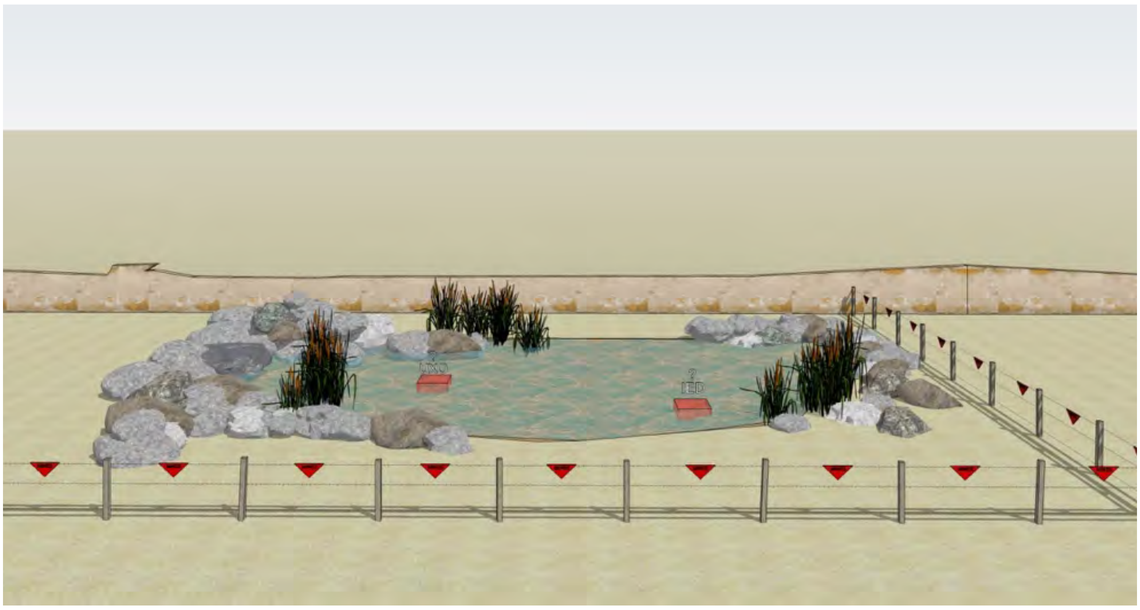


Image 1. Water feature marked off as a search restriction

4.1.2. HANDOVER OF SITE

In IED contaminated environments it is recommended that strong emphasis is placed on accreditation, quality planning and quality assurance (QA); rather than on post-clearance quality control (QC). This is due to difficulties in setting and identifying a critical nonconformity in QC other than the location of IEDs inside the specified clearance requirements. These difficulties may be associated with the prevalence of IED contamination in buildings and with the use of sensors to detect IEDs other than just metal. These detectors have a reliance on user skill and experience to correctly interpret signals. It is therefore essential that the Authority has confidence in the MA staff, equipment and procedures through accreditation and that these have been appropriately applied through QA of operations. This does not mean that QC is not important, it remains so and should be carried out. Normally, QC will be conducted by reapplying the approved procedures in a sample of the space (building, open area or route) that has been presented as complete. If IEDs are identified inside the specified parameters then a critical nonconformity must be recorded, the product failed, and appropriate remedial actions taken.

4.1.3. RECORDING AND REPORTING OF RESTRICTIONS

The NMAA should develop guidance on how restrictions should be recorded and reported. This needs to be particularly robust in urban environments where debris and rubble will be frequently encountered. These should be reported by MA operators at the earliest possible opportunity, enabling a suitable plan to be established and the necessary resources to be allocated.

At a minimum the MA operator should record and report the following:

- Perimeter reference points;
- Size in m2;
- Nature of the restriction: water features or extensive rubble, etc;
- Threat assessment;
- Dangerous working environments, such as confined spaces requiring specialist resources;
- Estimation of resources required to complete the task.

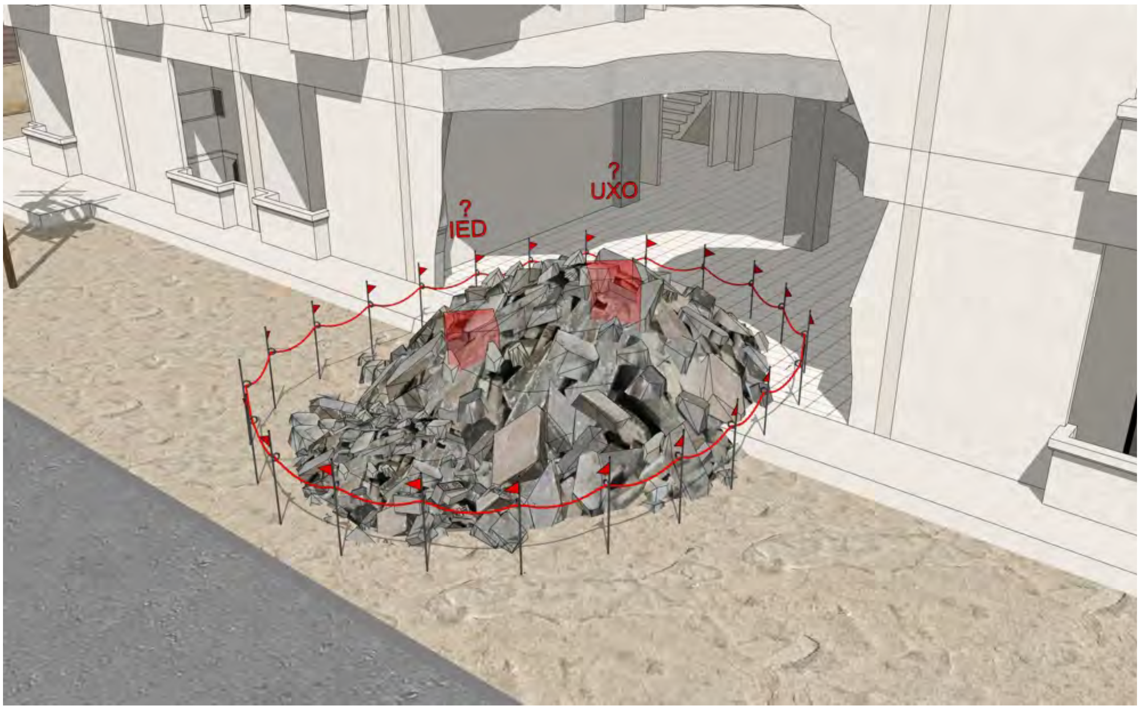


Image 2. Marking of a search restriction (rubble)

In a post-conflict urban area there will be an urgent need to make spaces available for productive use. Communities will often accept significant risk levels when the alternative is to remain in displaced persons' camps. However, there are some important issues that must be addressed and tasks that must be completed before any SHA / CHA can be considered formally released and available for use; these are covered in IMAS 08.30 Post-clearance documentation.

MA organisations must consider the points below in detail when handing over an urban area:

- Post-clearance inspections taking into account differences in threat, ground conditions and quality tolerances;
- Designing, placing and recording permanent markings in relation to adjacent SHAs / CHAs;
- Designing, placing and recording permanent hazard markings and markings of areas not cleared.

4.2. INFORMATION MANAGEMENT AND REPORTING

Image 3. Detectors can still be of use inside some buildings. How would this be reported?

Information management (IM) in MA refers to the process of defining and continually improving information requirements from all relevant stakeholders and to the subsequent collection, validation, storage, analysis and dissemination of timely, accurate and easy to access information that meets these requirements. The ultimate goal is to deliver information products to stakeholders.

MA organisations conducting survey and clearance of IEDs will be required to implement an IM policy along the guidelines found in IMAS 05.10 Information Management for Mine Action. There are some specific challenges associated with IED contamination for which this sub-section aims to provide guidance.

Due to the varied nature of IED contamination, the concentration and sheer number of sources of data and information, especially in an urban area, require a high degree of management checks and controls. MA organisations, whether operators or NMAAs, should organise an IM unit with dedicated systems and tools. An MA organisation's IM system should encompass:

- Information governance framework. This should ensure the information is protected and secure;
- Configurable taxonomy, or classification system. Allowing flexibility as operations change in scale and manner;
- Unified visibility with full text search and advanced search functions. Accessing a unified and fully visible user interface to retrieve information allowing users to find information easily;
- Organisation alerts and dashboard. This visually displays schedules, progress and disposition alerts;
- Compatibility across all potential platforms and technologies. Use of web applications (apps) has increased data gathering efficiency. Compatibility must be a key attribute when choosing the applications. Apps must, at a minimum, compliment IMSMA.

4.2.1. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

MA is inherently geographic, and with the challenges of buildings and structures grossly contaminated with EO in the urban area, the geography is three dimensional. Many project types are using GIS for gathering, managing and analysing data. It analyses spatial location and organises layers of information into easily understandable visual language using mapping, which allows users to see multiple perspectives at once. GIS reveals deeper insights into data, such as patterns, relationships and situations, helping organisations make better-informed decisions and share information effectively.

WHAT IS IMSMA?

First released in 1998, the Information Management System for Mine Action (IMSMA) is software designed to support the needs of the mine action community for decision support, monitoring and reporting. Core elements of IMSMA include a 'PostgreSQL' database engine and a GIS for displaying information on maps. Its client / server architecture enables stand-alone installations for small mine action programmes as well as client / server installations for large programmes with many users distributed across multiple sites and organisations.

Image 4. IMSMA example (Source: GICHD)

IMSMA is provided for free at http://mwiki.gichd.org/IMSMA and is the primary software in mine action, and is installed in over 47 countries. IMSMA includes built-in flexibility to support a variety of information management needs, ranging from the largest humanitarian programmes in the world to the smallest.

Its features include:

- A decision-support system with embedded GIS;
- Designed for the Windows operating system and requires 3GB of free disk space;
- Currently available in multiple languages including English, French and Spanish.

A typical IED is constructed from a number of separate components. These components, by chance or intention, are often compatible with multiple device types. For example, main charges could be used with various types of switches and vice versa. An MA organisation should make attempts to collect accurate and relevant data concerning IEDs, their construction and components, and components as singular items if identified.

This data should be recognisable across the MA sector using one point of reference. It is recommended that MA organisations use the UN Mine Action Service (UNMAS) IED Lexicon. This lexicon provides the user with an operational vocabulary for IED employment scenarios, a variety of IEDs and their critical components. The lexicon will assist in standardising terminology across IED reporting.

There can be different interpretations when recording IED data. The 'initiator' is a prime example of this. Globally there are many different types of initiator with variations in size, colour and material composition. This is further increased by improvised variants that may even be made from plastic. It is important to record as much detail as reasonably practical, using the UNMAS IED Lexicon, to try and help avoid any misperceptions.

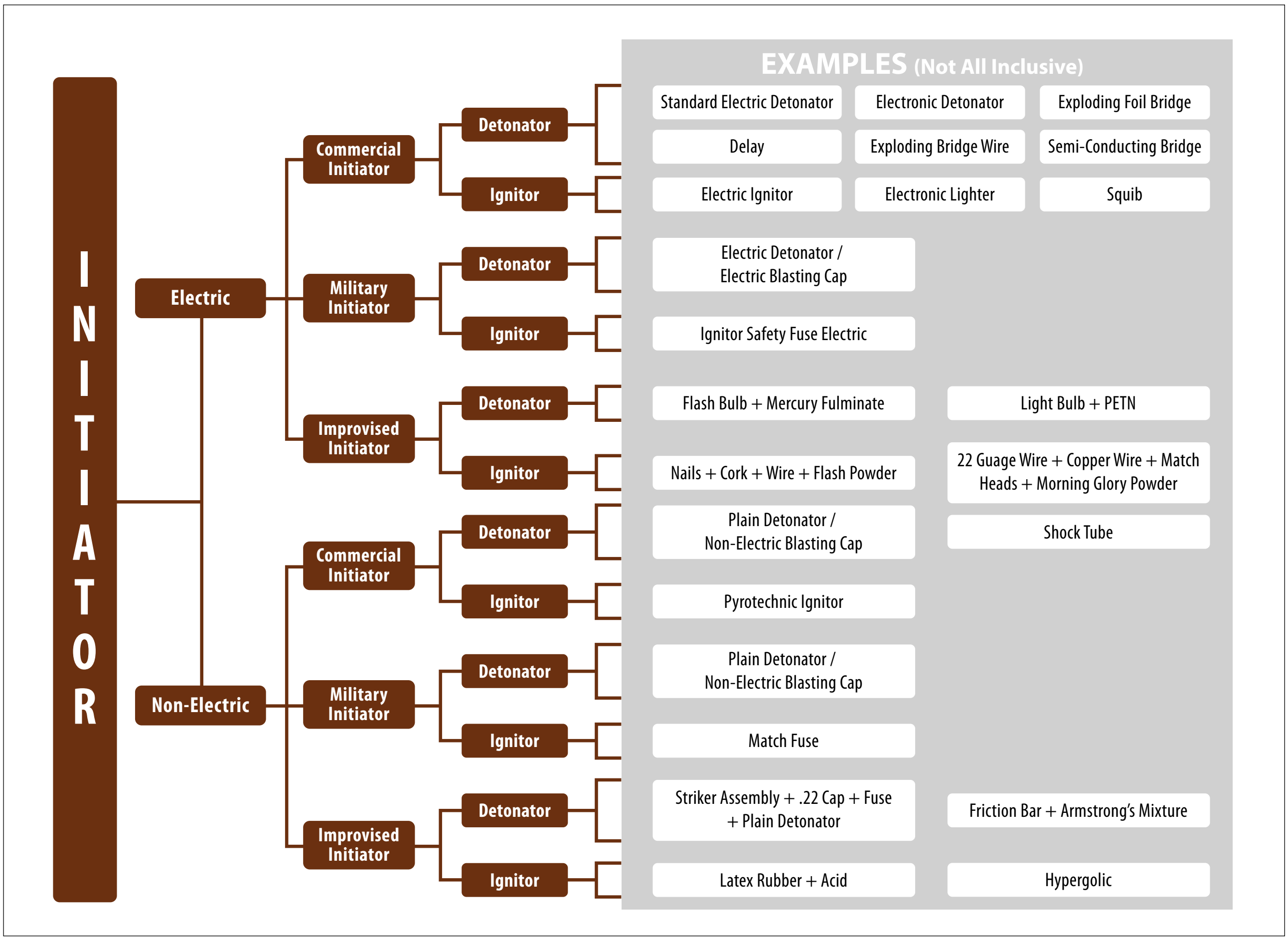


Image 5. Excerpt from the UNMAS IED Lexicon (Initiator). Source: UN ©

During visual search procedures, ground signs may lead to the suspicion of EO (see Chapter 4 – IED indicators and ground sign awareness). The identification and assessment of these signs is a defined skill and should be a competency, trained and tested for MA staff involved in identifying IED contamination. The recording and reporting of IED detection using ground signs can aid significantly in sharing good practice and increases efficiency, effectiveness and safety across the MA sector.

HINT. If reports include photographs and consistent terminology, they will assist in the accessibility and common understanding of how ground signs can aid in IED detection.

4.2.2. LEGAL REQUIREMENTS FOR IM AND REPORTING FOR CONVENTIONS

NMAAs will be required by international humanitarian law to gather information on EO for the purpose of reporting to the various international conventions to which they are a party. In particular, this includes the Anti-Personnel Mine Ban Convention (APMBC), the Convention on Cluster Munitions (CCM) and the Convention on Certain Conventional Weapons (CCW). As a result, the national framework for reporting – and related reporting formats – will need to be considered by organisations when establishing their own reporting formats and requirements for operators. For example, some IEDs can and do meet the definition of an anti-personnel mine that is found in the APMBC:

"A munition designed to be placed under, on or near the ground or other surface area and to be exploded by the presence, proximity or contact of a person or vehicle."

Due to the fact that IED is a very broad term, referring only to the way in which the device has been constructed (using artisanal methods instead of being manufactured in a formal sector factory), the term describes a range of weapons spanning from improvised rockets and mortars to improvised anti-personnel mines and remotely-controlled devices.

5. MANAGEMENT OF TRAINING

Image 1. Instructor assessing visual search technique

In almost all MA programmes there is a requirement for the training of staff for operational tasks. This training must be relevant to the knowledge, skills and attitudes (KSA) required by the role and tasks that will be conducted by the staff member.

5.1. RECOMMENDED MINIMUM COMPETENCIES FOR IED SEARCH

In response to needs identified by MA organisations, the IMAS Test and Evaluation Protocols (T&EP) IMAS 09.31 IEDD provides guidance on competencies related to the detection, location and recognition of IEDs under Level 1. Level 2 competencies listed in this T&EP relate to both assisting an MA IEDD operator in the preparation of IEDD equipment and also the management of teams of personnel conducting the Level 1 'find' function. This T&EP for IMAS 09.31 should be used in conjunction with IMAS 06.10 Management of training in the development of a training needs analysis and training management package. Depending on the EO threat, staff may also need relevant conventional EO competency lists found in T&EP for IMAS 09.30 EOD Competency Standards. If the organisation's structure means that staff will have dual role responsibilities to conduct both disposal and search, they should have the relevant competencies from IMAS 09.31 T&EP at Levels 3 and 3+.

WARNING. To be compliant with IMAS only MA staff with IMAS 09.31 IEDD Level 3 or Level 3+ competency standards are to conduct the disposal of IEDs.

All IED search team members and leaders / supervisors must be fully trained in accordance with NMAS, which should comply with the IMAS guidance. This should be verified by the NMAA during accreditation. MA operations should conduct refresher and task specific training to fully prepare for likely operations.

Image 2. A good example of a VOIED training aid showing the switch and main charge in place

5.2. KEY CONSIDERATIONS

IED characteristics and tactics should be included in IED search training at the appropriate level.

IED characteristics:

- Components and sub-components.
- Packaging, wrapping and weatherproofing of components and sub-components.
- Explosive and electrical links between components (detonating cord and electrical leads).
- Individual component's depth in the ground, or their positioning.
- Likely effects on components from the weather and annual seasons.
- Blast or fragmentation effects of main charges.
- Arrangement or spacing of IEDs.
- IED construction equipment.

IED tactics:

- Component positioning for best effect, including depth.
- Known modus operandi of armed groups.
- Locations of importance for opposing armed groups.
- Anticipated skill level of armed groups.
- Local IEDD techniques used (military or other) prior to or during MA operations.

Image 3. Instructor assessing detector use after visual search. The decision on when to give feedback will depend on many considerations such as significant safety issues and the stage of training

5.3. URBAN IED SEARCH TRAINING

Hazardous environments awareness. In order to identify hazardous environments so they can be properly managed as a risk, awareness training focusing on identification is recommended for all staff on the following:

- Factors that reduce the structural integrity of buildings.
- Indicators for identifying whether a confined space is hazardous.
- Identifying toxic chemicals and substances hazardous to health.
- Situations where they may be 'working at height'.

Specialist equipment. The following equipment is normally considered for use in urban environments contaminated with IEDs. Whatever equipment is used, suitable training should be provided.

- UAVs.
- Access equipment for working at height.
- Rescue and access equipment for confined spaces.
- Gas alarm and warning systems for confined spaces.
- Additional casualty evacuation equipment for difficult worksite conditions.
- Equipment to augment structural integrity.
- Specialist detection equipment and innovative handheld detector types (ground penetrating radar, line / cable detectors).

HINT. Different programmes will have different requirements and not all staff may need training on everything.

5.4. MANAGEMENT OF TRAINING

Image 4. An example of a good learning environment with training aids and literature on display, providing passive learning

In accordance with IMAS 06.10 Management of training the primary purpose of conducting training for MA staff is to enable them to acquire, or enhance, existing KSAs through formal, on the job training (OJT) or continuation training. This in turn provides confidence that they can fulfil the duties and responsibilities assigned to them.

Formal training normally requires the allocation of the most resources and consists of a concentrated course conducted in accordance with a training management plan (TMP) that has been informed by the results of the training needs analysis.

The frequency of OJT and continuation training will depend on the nature of the programme, factors such as rotation through operational cycles, new equipment and procedures being adopted, and professional development of staff as they progress to the next level. It is also essential to monitor specific areas that are of high importance but are not practiced by staff regularly. For example, staff may have been trained to work at height but have not used these KSAs operationally for some time. Continuation training may be essential for these staff to be viewed as current, and therefore capable, to complete the task. This may be a short half-day refresher or, depending on various factors, may be extended to repeating the formal training course in its entirety.

The following factors should be considered when determining the frequency and nature of OJT or continuation training:

- **Team composition and currency**. Leave periods may affect a search team's (or individual's) currency in relation to specific tasks.
- **Routine monitoring of KSA levels**. Routine monitoring of techniques and procedures being conducted can reveal the need for a period of continuation training.
- **Incident investigation.** An investigation after an incident (or near miss) may reveal the need for continuation training.
- **Lessons learnt.** Continuation training in order to implement new lessons learnt from any source.

REMEMBER. Unbiased continuation training is a standard industry response to serious incidents and is recommended.

5.5. TRAINING ASSESSMENTS

Image 5. Providing constructive feedback to the student, always try to finish on a positive point

Training assessments are an important part of any TMP and provide assurance that the KSA competencies have been successfully adopted by the MA staff. Written and practical formal assessments are an important indicator for an NMAA monitoring an MA organisation that are awarding staff with qualifications. It can also be used as part of the accreditation process by the NMAA to confirm that MA organisations have staff that are competent to safely, effectively and efficiently perform IED search tasks.

Since staff are required to perform IED search as part of a team, it is important to assess KSA at both individual and team levels. Assessment should be continuous during a training activity to ensure smooth progression and resolve any learning issues that may arise at the earliest opportunity. It may also be necessary for an MA organisation to assess personnel to confirm that they have the prerequisite KSA before they are hired or are about to undertake a specific task.

5.5.1. CONDUCTING ASSESSMENTS

Assessing KSAs can be achieved through oral, written and practical tests, exercises and simulations. Training should allow enough time and practice for students to assimilate KSAs before being formally assessed. Practical exercises should require students to apply their knowledge, use a range of search equipment, tools and training aids and display their overall attitude. Training assessments should only be conducted by qualified instructors from an accredited MA organisation.

HINT. To ensure impartiality and quality assurance, best practice is for assessments NOT to be performed by the same instructors who deliver the training, where possible.

The assessment method should drive students to apply KSA in realistic simulated operational scenarios. All competencies required at the applicable level of search expertise should be evaluated for each student, although several can be integrated together in one exercise or simulation. All formal assessments should be documented in the course report and maintained by the MA organisation and potentially the NMAA. Assessed students should receive the results of their assessments as part of a course report, in a timely manner, and be debriefed on areas for improvement.

5.5.2. ASSESSMENT STANDARDS

Assessments must be conducted against a defined standard, which must be achieved by students in order to receive their qualification. It is important that search courses are assessed as a pass-fail course. If students are unable to meet the course criteria, then they should not be considered IED search qualified, nor be employed within a search team in the MA organisation. In cases where the individual fails to attain the standard, remedial training with reassessment may be considered.

MA organisations and NMAAs should strive to record pertinent standards of IED search training based on IMAS, and NMAS where available. The key considerations mentioned in this guide should be used for specific search training requirements of urban areas with an IED threat.

5.6. IED RISK EDUCATION

This sub-section looks at IED awareness training in the context of explosive ordnance risk education (EORE) and is intended to comply with IMAS 12.10 Mine/ERW Risk Education and TNMA 12.10/01 Risk Education for IEDs.

REMEMBER. The term 'mine risk education' (MRE) refers to activities that seek to reduce the risk of death and injury from all EO by raising awareness and promoting safe behaviour.

IED contamination in an urban area will present additional factors to be considered when planning and conducting EORE and it should be based on careful assessment of the different needs of the affected communities. Specifically, the assessment should consider:

Target groups. An urban environment affected by conflict will likely experience sharp influxes of people returning, even when it is generally assumed not safe to do so. The sheer numbers may mean risks will be taken by some of those returning, with certain groups likely to take more risks than others.

Nature of the IED contamination. A national threat analysis and operational threat assessment should be used to make evidence-based decisions on the nature of the IED contamination that the community will encounter. This should in turn directly influence the nature of the EORE that is given. This may potentially include mitigation measures that can be followed so that people can re-enter their homes as safely as possible.

EORE staff and facilitators. MA organisations should ensure that persons providing IED EORE are suitably trained so that the educational approach is efficient, and the technical content is pertinent to the needs of the community, therefore helping to ensure the efficacy of the teaching.

There are three common elements to EORE messaging:

1. **Don't go into contaminated areas.**
2. **Don't touch items of ERW.**
3. **Report any items of ERW found.**

Don't go into contaminated areas. IED contamination may not be obvious, and patterns often used (historically in EORE) for minefield indicators will vary, especially when IEDs have been used in urban areas. EORE should therefore provide information based on the assessment of most likely IED placements (in accordance with IMAS 07.14 Risk Management in Mine Action, Annex C).

Don't touch items of ERW. IEDs may purposely be intended to stimulate curiosity in order to encourage a normally safe act to be conducted. Due to the improvised nature of the threat a principle-based approach is likely to be effective. This could provide education on the five components of an IED (see Chapter 1), as well as IED ground signs and indicators (see Chapter 4).

Report any items of ERW found. This should be realistic, understanding that official reporting channels may be strained or not present. It should also be pertinent to the threat, with IEDs sometimes being reported as an everyday object such as a 'suspect wire'.

6. LEXICON OF ACRONYMS

ADS	Animal detection system
AN	Ammonium nitrate
ANAL	Ammonium nitrate & aluminium
AP	Anti-personnel
APMBC	Anti-Personnel Mine Ban Convention
CHA	Confirmed hazardous area
CP	Control point
CW	Command wire (improvised explosive device)
ECM	Electronic counter-measure
EFP	Explosively formed projectile
EO	Explosive ordnance
EOD	Explosive ordnance disposal
EOR	Explosive ordnance reconnaissance
EORE	Explosive ordnance risk education
ERW	Explosive remnants of war
GIS	Geographic information system
H&L	Hook and line
HE	High explosive(s)
HMC	High metal content
HME	Home-made explosive
IED	Improvised explosive device
IEDD	Improvised explosive device disposal
IM	Information management
IMAS	International Mine Action Standards
IMSMA	Information Management System for Mine Action
JFC	Jet forming cone
KSA	Knowledge, skills and attitude
LMC	Low metal content
MA	Mine action
MLCA	Main load carrying area

NEQ	Net explosive quantity
NMAA	National Mine Action Authority
NMAS	National Mine Action Standards
NSAG	Non-state armed group
NTS	Non-technical survey
OJT	On the job training
PAT	Plastic adhesive tape
PIR	Passive infrared
PPE	Personal protective equipment
PPIED	Pressure plate improvised explosive device
QA	Quality assurance
QC	Quality control
QMS	Quality management system
RC	Radio controlled
RCIED	Radio controlled improvised explosive device
RF	Radio frequency
RHF	Rolled homogenous steel
ROV	Remotely operated vehicle
RSP	Render safe procedure
RX	Receiver
SHA	Suspected hazardous area
SOP	Standard operating procedure
TNMA	Technical Note for Mine Action
TS	Technical survey
TX	Transmission
UAV	Unmanned aerial vehicle
UNMAS	United Nations Mine Action Service
VBIED	Vehicle-borne improvised explosive device
VO	Victim operated
VOIED	Victim operated improvised explosive device
VP	Vulnerable point

CHAPTER 3

IMPROVISED EXPLOSIVE DEVICE DISPOSAL

1. IEDD IN MINE ACTION – OVERVIEW

1.1. INTRODUCTION

Although improvised explosive devices (IEDs) are among the world's oldest types of explosive weapons, recent years have demonstrated a global trend in their increased use, especially in conflicts involving non-state armed groups. IED contamination in affected states severely impacts upon humanitarian operations, impedes stabilisation, reconstruction and longer-term development. The mine action (MA) sector is now being routinely called upon to survey and clear IEDs at an unprecedented scale, with 'disposal' being a key activity in the clearance process.

This chapter intends to provide suitable reference literature for the MA sector on IED disposal (IEDD) by sharing knowledge and skills related to IEDD task conduct, threat assessment, and disposal techniques and procedures which constitute good practice. It has been developed in order to comply with the existing guidance in International Mine Action Standard (IMAS) 09.31 for Improvised Explosive Device Disposal. This defines IEDD as:

"IED Disposal (IEDD) in a mine action context is the location, identification, render safe and final disposal of IEDs."

This chapter takes IEDD as an activity conducted as part of a broader MA clearance process which achieves all reasonable effort to locate, identify, render safe and dispose of IEDs within specified parameters. Therefore, IEDD is not a means in and of itself but viewed as a critical component of a much broader MA survey and clearance operation which enables follow-on actions to achieve humanitarian outcomes.

There is, by definition, no manufacturing standard for an IED. Design and purpose are based upon supply chain availability, the intent of the armed group and their technical capability. Qualitative and quantitative analysis over many years has identified that armed groups continually alter components, methods of functioning, and emplacement. Section 2 of this chapter 'IED tactics' describes in detail the fundamentals of the global deployment of IEDs, with a deliberate focus on those types of device commonly encountered by the MA sector. This section should not be considered as an encyclopaedia on IED threats; rather it is a guidance on some of the technical characteristics that MA organisations should be recording, reporting and sharing through their information management systems.

1.2. SCOPE

Image 1. Demonstrating the use of a shaped charge explosive tool to deliberately detonate an IED main charge containing home-made explosive (HME)

This document details requirements to plan and execute IEDD activities and is intended for use by appropriately qualified MA staff. It expands on the high-level policy guidance provided through IMAS 09.31 to enable the practical development of effective National Mine Action Standards (NMAS), standard operating procedures (SOPs), technical notes and training material. It provides detailed descriptions and scenarios to explain the core components of IEDD philosophy, principles, mandatory actions, conventions and management oversight.

WARNING. As with the rest of the guide, this chapter is not intended to replace IMAS-compliant training. It is not intended to 'convert' or 'expand' the remit of other qualifications.

Image 2. MA IEDD operators often need to locally develop tools based on a sound understanding of explosive principles. Here an improvised disruptor has been constructed to cause general disruption of a vehicle-borne IED (VBIED)

1.3. MINE ACTION IEDD GUIDING PHILOSOPHY

The following statements, as per IMAS 09.31 and listed in order of importance, make up the guiding philosophy used when undertaking MA IEDD operations:

1. Preservation of life;
2. Preservation of infrastructure and property;
3. Restoration of the situation to normality as quickly as possible commensurate with safety or the quality requirements for the task;
4. Gathering technical information to inform the national threat analysis and task level threat assessment.

How can this guiding philosophy be applied to IEDD operations during an MA intervention?

SCENARIO EXPLANATION

A hospital contains a large IED with two completely independent means of initiation: a failed mechanical timer that is 'stuck fast', and a secondary anti-lift switch under the main charge. Each of these has its own power source, detonator and explosive chain.

The hospital is being cleared in accordance with IMAS 09.13 for Building Clearance when this IED is identified. The MA IEDD operator conducts questioning of the deminer / searcher who discovered the IED to gather information, enabling them to establish a task-specific threat assessment. Information, however, is limited.

The IEDD operator conducts the first approach, however the initial threat assessment did not account for the IED having two independent means of initiation. The IEDD operator therefore only took over a single disruptor.

When the two independent means of initiation are identified, the assessment is as follows: **"If the battery for the timer is targeted then the anti-lift switch will function; if the anti-lift switch is targeted then the timer may restart."** What should they do?

Options that the IEDD operator considers:

- **Option 1.** Conduct a manual action on the detonator lead from the anti-lift switch and then place the disruptor to target the battery connected to the timer.
- **Option 2.** Place a semi-remote cutting option on the electrical lead from the anti-lift switch and then place the disruptor on the battery connected to the timer.
- **Option 3.** Return to the control point (CP), replan and conduct a second approach with two disruptors instead of one.

This is a difficult scenario to consider, especially as the specific risks of both the failed timer and the anti-lift switch must be considered.

Option 1 discussion. If the IEDD operator conducts a manual action and the device functions, then fatalities will occur, and the hospital will be destroyed. This should **never** be considered as a viable option and runs contrary to the first and second guiding philosophies for MA IEDD. There is no recognised quality control in the construction of IEDs and the possibility of an error in judgement could result in a fatal accident.

Option 2 discussion. This option lowers the risk to life as all positive actions can be conducted from the safety of the CP. However, these positive actions cannot be conducted simultaneously, increasing the possibility of an accidental detonation which would destroy the hospital. This would be contrary to the second guiding philosophy for IEDD.

Option 3 discussion. Having the IEDD operator return to the CP will mean they need to make a second manual approach. Whilst the second manual approach will increase the total time in the danger area for the IEDD operator, which is not ideal, overall it is safer. It will mean the IEDD operator can replan, return with two disruptors, and then conduct the render safe procedure (RSP) with disruption as the preferred means of neutralisation (see below). Both disruptors can be fired in series using the same electrical circuit, meaning that they will function simultaneously. **This is the option that should be selected to comply with the IEDD philosophy for MA.**

WARNING. This is an abandoned failed time IED. If the threat of an active time IED is identified MA operations should stop immediately. All MA staff and the community should be informed that there is probably going to be an uncontrolled explosion. MA IEDD operators are unlikely to be equipped or trained to deal with this highly dangerous scenario as actively used IEDs fall under the responsibility of security elements.

1.4. GENERAL PRINCIPLES

During the development of NMAS, SOPs, training packages, clearance plans, and render safe plans, the following eight IEDD principles should be observed to ensure compliance with IMAS 09.31 for Improvised Explosive Device Disposal.

IMAS 09.31 – PRINCIPLE 1. MANUAL NEUTRALISATION TECHNIQUES

Manual neutralisation techniques should not be conducted. Remote (if available) and semi-remote actions should be conducted to neutralise and / or dispose of IEDs.

Any interactions conducted during an IEDD task which physically change the state of a device, provide an opportunity for it to function. If the IEDD operator does this when they are in close proximity to the device, then this is viewed as a manual action.

REMEMBER. A manual action should not be confused with a manual approach which simply means the IEDD operator has moved from the CP towards a confirmed or suspected IED.

Examples of manual actions that should not be conducted:

- Moving by hand any IED component from the original location in which it was found.
- Cutting wires or detonating cord by hand.

Examples of actions that are not viewed as manual actions but should be conducted with extreme care:

- Manually slicing or peeling back adhesive tape.
- Conducting a fingertip search in the immediate vicinity of a device.

WARNING. If possible, always introduce at least one element of safety before slicing or peeling back adhesive tape to enable the removal of a detonator from the explosive chain or separating detonating cord links to reduce the potential net explosive quantity (NEQ).

IMAS 09.31 – PRINCIPLE 2. DESTRUCTION IN SITU

When feasible, destruction in situ, using an explosive donor charge targeting the main charge(s) of the IED, is the preferred method of disposal.

Image 3. Placing a suitable charge of serviceable explosives to destroy a pressure plate IED (PPIED)

Placing (remotely or semi-remotely) a suitable charge of serviceable explosives, which can be functioned from the CP, is the preferred method of disposal.

This option significantly reduces the time and number of actions the IEDD operator needs to perform inside the explosive danger area. It also has reliable results, which cannot be guaranteed with low order techniques, and negates the requirement to transport, store and subsequently dispose of the recovered explosive components.

However, this option may not always be feasible if serviceable explosives are not available, prohibitions are in place by the relevant national authority, there would be unacceptable damage to the surrounding area, or there is unsuitable access to the main charge.

HINT. If there is unsuitable access to the main charge this can sometimes be mitigated by the use of shaped charges.

IMAS 09.31 – PRINCIPLE 3. NEUTRALISATION

Water-based energetic disruption of the power source(s) is the preferred means of neutralisation.

The preferred method of neutralisation in MA is to use a water load to target the location of identifiable components (specifically the power source) in electrically initiated IEDs. The intention is to separate the IED's electrical circuit far more quickly than the energy from a battery can heat the bridge wire in a detonator (initiator) to cause the primary explosives to function.

This option allows for a degree of stand-off, thereby avoiding interaction with the IED, and can be used when the exact location of the power source is not known (e.g. if all items are located within a box). The disruptor can be placed quickly, therefore reducing the time the IEDD operator spends inside the danger area whilst the threat from an IED remains.

The two main types of disruptor are barrel and bottle; they are described in detail in Section 4 of this chapter.

Image 4. Image of a barrel disruptor being used to neutralise an IED

IMAS 09.31 – PRINCIPLE 4. ONE-PERSON RISK

Manual approaches should be conducted as a one-person risk.

This is to ensure that if an accident occurs, the minimum number of staff are exposed.

There may be occasions when being accompanied by an assistant can be justified. For example, to help carry and set up a large piece of hook and line (H&L) equipment that cannot be done by one person alone. As soon as this is achieved the second person should return to the CP before any further actions are conducted.

Reasons such as having a second operator closely monitoring or coaching a new operator, with both operators exposed to the explosive danger, cannot be justified. There should be sufficient confidence in an IEDD operator's abilities, through assessment in safe representative conditions, to enable tasks to be coached and monitored from the CP.

HINT. Appropriate on-site coaching and mentoring of newly qualified IEDD operators is strongly encouraged. It is an extremely good way to build experience, staff confidence and to conduct quality assurance (QA). If the mentor needs to be exposed, then the IEDD operator is not ready for live operations.

Time spent inside the explosive danger area should be minimised and a robust plan should be developed and briefed before leaving the CP.

There can be a temptation in MA, especially at sites that have been subject to clearance operations for some time, for planning to be conducted close to IEDs and for staff to become complacent.

Fundamentally, even when dealing with belts of hundreds of similar IEDs, thorough planning and exposing the fewest people for the shortest amount of time possible are all key and proven factors to reduce the danger to everyone involved.

WARNING. 'Least amount of time feasible' does not mean cutting corners that could result in a safety error. Instead it should encourage a mindset of efficiency, and effective IEDD planning and task conduct.

IMAS 09.31 – PRINCIPLE 5. SAFE WAITING (SOAK) TIMES

Appropriate safe waiting times should be applied after a positive action is conducted.

Safe waiting times are used to mitigate a number of risks during an RSP.

As with any demolition, there is a risk of a misfire occurring that could subsequently cause the IED to detonate. For IEDs that do not incorporate timers, a safe waiting period of 10 minutes for electrical IEDs or 30 minutes for non-electrical IEDs should be applied after positive actions that could cause a misfire to occur. For example, if an action such as severing an electrical link were to cause a misfire in an electrical IED, then applying a safe waiting period before the next manual approach would mitigate this risk to the IEDD operator.

Safe waiting periods can also be used for IEDs that incorporate timers as firing switches or as safe-to-arm switches. This is especially pertinent for mechanical timers that may have become 'stuck-fast' by dust or dirt after the device has been emplaced by the armed group. Movement caused by remote or semi-remote action could then cause the mechanical clockwork mechanism to restart.

WARNING. MA organisations should not be faced with a time IED that is still actively 'counting down'. However, in some circumstances, it will be essential to consider longer safe waiting times than these 10-min. or 30-min. periods.

If there is any possibility of a mechanical timer restarting during an RSP, the safe waiting time should be the maximum period which the timer can be set to, plus a reasonable safety factor. For example, if the known or assessed mechanical timer is 60 minutes, then it would be appropriate to apply a safe waiting period of 80 minutes.

WARNING. At times it is essential to consider applying safe waiting times longer than 10-minute or 30-minute periods. The application of these longer safe waiting times is applicable whether the timer is being used as a firing switch or a safe-to-arm switch.

IMAS 09.31 – PRINCIPLE 6. PERSONAL PROTECTIVE EQUIPMENT (PPE) ON ALL APPROACHES

Appropriate PPE should be worn on all manual approaches to a suspected IED.

Image 5. MA IEDD operator using a full explosive ordnance disposal (EOD) suit during the RSP of a VBIED

PPE should be used as mitigation in the event of an accident (as referred to in IMAS 10.30 Safety & occupational health - PPE).

The primary mitigation should be factors reducing the likelihood of an accident occurring in the first place. A risk assessment should therefore be conducted to ensure that the PPE is suitable and does not in itself increase the probability of an accident occurring.

It is important to remember that IEDD bomb suits were originally designed to protect an IEDD operator on the approach to and from an IED. This was not only to mitigate the threat of an active time or command initiated IED, but to take account of an IED's improvised and unpredictable nature. IEDD operators in an MA context are frequently dealing with buried or concealed victim operated IEDs (VOIEDs), and in such circumstances avoiding degradation, and maintaining dexterity and situational awareness are paramount.

HINT. Situations may arise where wearing the full PPE specified in SOPs could increase the risk to the IEDD operator. There should be appropriate provisions and referrals to control the removal of PPE.

IMAS 09.31 – PRINCIPLE 7. CORDON AND EVACUATION

Appropriate cordon and evacuation should be in place before conducting any positive action.

Cordon and evacuation during an explosive incident save lives. Appropriate distances can be assessed using TNMA 10.20/01 Estimation of Explosion Danger Areas. The danger area should be cordoned off and evacuated prior to any positive EOD action taking place.

This underpins IMAS IEDD Principle 4 (one-person risk) and ensures that in the case that an IED functions prematurely, or as a direct result of positive EOD action, then the community remains safe from the effects of blast and / or fragmentation.

Cooperation from other agencies such as the security forces may be required to achieve these cordons and evacuations, as MA staff are unlikely to have any legal remit. It is extremely unlikely that a safe and robust cordon and evacuation plan can be put in place without liaison with these agencies.

IMAS 09.31 – PRINCIPLE 8. COMPONENT HANDLING

All IED components should be moved remotely or semi-remotely prior to any manual handling.

Image 6. Preparing H&L equipment to semi-remotely remove a main charge. The spade handle will act as a fulcrum to lift and pull the main charge

The level of movement should be sufficient to provide confidence that the item(s) is safe to handle manually. At a minimum an item should be moved through all its planes and entirely out from its original location. Often it is not feasible to completely search around an item, such as a buried main charge, or inside an item where there could be a secondary device.

If the threat assessment identifies a likely secondary device or switch / initiation system, then further remote and semi-remote actions should be considered prior to manual handling.

1.5. MANDATORY ACTIONS

Image 7. Commercial shaped charges and bottle disruptors prepared along with target HME for demonstrations conducted to support this guide

As described in IMAS 09.31, mandatory IEDD actions provide specific direction to support IEDD philosophies and principles.

The following two mandatory actions are listed in IMAS 09.31 as being generally applicable to MA IEDD activities and provide examples on which further mandatory actions can be based.

IMAS 09.31 – MANDATORY ACTION 1

In the event that an IED is identified which is suspected to have been emplaced since survey was conducted or clearance commenced, all operations shall be suspended immediately. Work shall only resume once it has been ascertained that the MA organisation is not being deliberately targeted, or that sufficient security is in place.

In MA, IEDD operators do not have the mandate, training or equipment to conduct disposal operations when IEDs are being actively used in a conflict. This is the responsibility of the security forces.

IMAS 09.31 – MANDATORY ACTION 2

Prior to the disposal of specific device types, a pre-disposal plan shall be produced in writing and be subject to the appropriate level of approval.

Depending on programme specific conditions, more restrictions are likely to be placed on certain IEDs than others. For example, a radio controlled IED (RCIED) requires a specific disposal plan whilst a PPIED may be a 'standard' case not requiring as much management oversight. It is up to National Mine Action Authorities (NMAAs) and MA organisations through respective NMAS and SOPs to clearly communicate to MA staff when pre-disposal plans need to be produced and the process to be followed for their approval.

In accordance with IMAS, the NMAA and MA organisations should develop and enforce mandatory actions that are appropriate to specific operational contexts.

OTHER MANDATORY ACTIONS THAT MAY BE CONSIDERED

- An IMAS 3+ operator must be responsible for management oversight of IMAS 3 IEDD operators.
- A written pre-prepared disposal plan must be submitted if the threat assessment indicates IEDs of a complex nature. This could include IEDs incorporating sensors, multiple switches, VBIEDs, those initiated by radio-control, linked main charges, and those thought to contain chemicals.
- All mechanically initiated IEDs must be destroyed in situ.

1.6. WORKING PRACTICES

As described in IMAS 09.31, working practices are a series of general control measures that can be applied to IEDD task conduct. They also provide supporting detail to help guide IEDD operators and facilitate quality assurance and monitoring of IEDD operations.

IMAS 09.31 – WORKING PRACTICE DESTRUCTION IN SITU

Destruction in situ using a suitable explosive donor charge, either bulk or shaped charge, should be considered as the preferred means of disposal. The IED's main charge(s) should be the only component(s) that is attacked using this method.

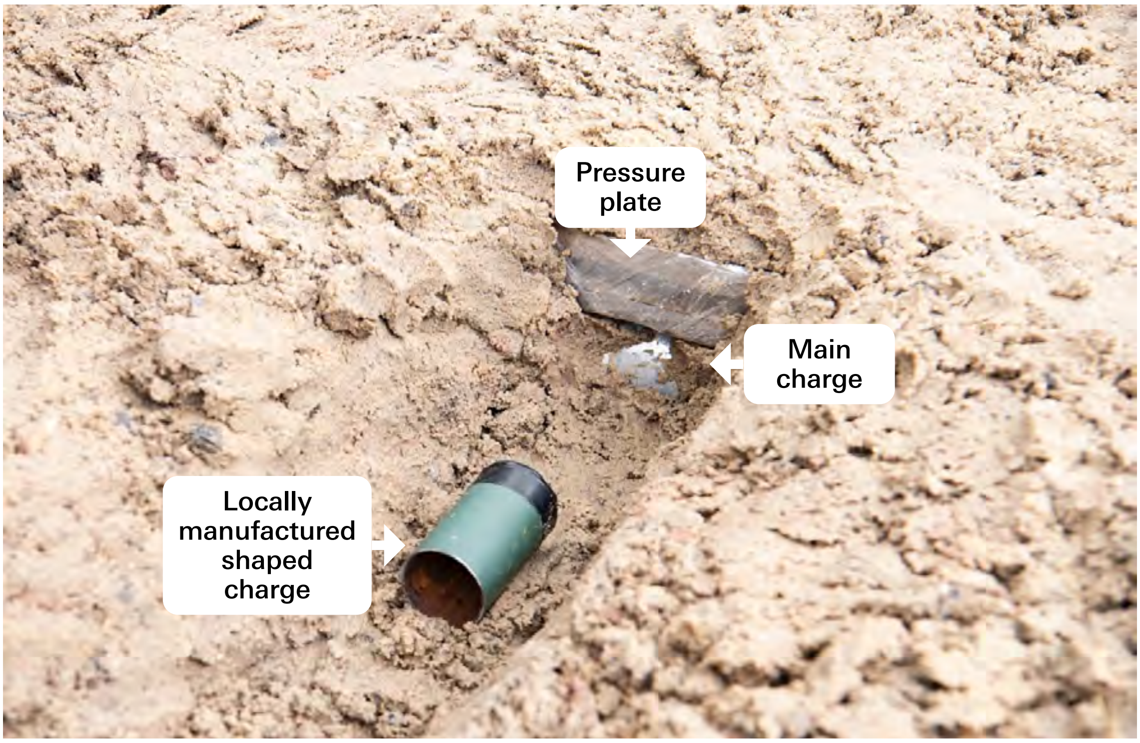


Image 8. Image of a locally manufactured shaped charge targeting an HME main charge located directly under a pressure plate

Reference to disposal rather than neutralisation is an important distinction. After the application of an in situ disposal procedure, the intention should be that no hazardous components will remain.

Normally a bulk explosive charge is applied. This should be placed as close as possible to the main charge without touching it. If separation has to be increased, so does the quantity of donor explosive, however after a point it will be more effective to revert to a shaped charge. The type of main charge container (for example a heavy cased artillery shell) will also determine the quantity of donor explosive that is required.

In conventional munition disposal, shaped charges are normally associated with the aim of causing low order deflagration. For an HME filled main charge this option may also result in a low order event, however the outcome is less reliable than for conventional munitions. This is due to variations in the explosive properties and loading density of HME, even if visually their consistency appears similar across a number of main charges.

The construction of HME filled main charges is also notably different to conventional munitions, which normally have a fuze and booster located in well-defined geometries. An HME main charge may present less-defined geometries and will normally incorporate detonating cord as the booster. This may run through a large portion of the main charge. If this detonating cord is impacted by a shaped charge, then it is very likely that a high order event will occur.

WARNING. While HME may not have the same explosive properties as its military or commercial variant, it can still cause significant damage to infrastructure and property.

IMAS 09.31 – WORKING PRACTICE SINGLE WIRE ATTACK

When dealing with electrically initiated IEDs, especially when buried, an IEDD operator should consider introducing an element of safety into the circuit by remotely or semi-remotely cutting a single electrical wire when one is presented during fingertip search / execution. Care should be taken at this stage to avoid creating an additional open switch (short), which could have safety implications.

Image 9. Image showing an MA IEDD operator conducting a semi-remote positive action on a second detonator lead after already applying this procedure to the first lead

Any RSP on a buried VOIED exposes an IEDD operator to considerable risk by having to manipulate the ground close to components that are not fully visible. Therefore, if an IEDD operator identifies a single wire during fingertip search, they should consider cutting it using a suitable remote or semi-remote technique and then insulating it with tape on their next approach.

HINT. The IEDD operator should consider the location of the IED's power source. If this can be easily accessed it may be more prudent to continue the fingertip search for a few more minutes in order to place an appropriate disruptor.

WARNING. DO NOT cut more than one wire at a time unless the entire circuit and geometry of the IED is clearly understood. Cutting more than one wire provides the opportunity of a short-circuit, which could give power to the detonator. IEDD operators have been killed cutting more than one wire due to their actions on subsequent confirmatory approaches causing the short to close.

IMAS 09.31 – WORKING PRACTICE AVOIDANCE OF FIRING SWITCHES

Interaction with firing switches significantly increases the possibility of an unintentional detonation. When planning an RSP, an assessment should be made of the probable means of initiation and the location of the associated firing switches. This will enable the IEDD operator to avoid switches whenever possible.

Image 10. Marking and avoiding an identified firing switch and using a commercial semi-remote cutting tool to induce an element of safety whilst continuing a fingertip search to identify a battery

A VOIED is designed to function due to the proximity or contact of a victim. The firing switch should be avoided as much as possible, especially until at least some element of safety has been introduced.

IMAS 09.31 – WORKING PRACTICE OPERATOR SEARCH

Where the presence of a victim operated IED cannot be discounted an appropriate combination of detector assisted search and / or visual inspection (including tripwire feeler and optical aids), should be adopted.

Image 11. IEDD operator conducting an assessment during accreditation by an NMAA

During an RSP of a buried VOIED there may well be a requirement for an IEDD operator to search in close proximity of the IED. It is not appropriate to place a searcher / deminer at additional risk due to a shortfall in an IEDD operator's competency.

Therefore, there must be the same **minimum** level of confidence in the ability of an IEDD operator to find IEDs as there should be for a deminer / searcher. If the IEDD operator cannot achieve this then they are not competent for the task and should not be conducting operations.

IMAS 09.31 – WORKING PRACTICE MULTIPLE COMPONENTS

The potential presence of additional power sources, main charges, and switches / firing devices should be considered when planning an RSP.

Image 12. Appropriate levels of operator search in response to a threat of possible linked components. Note that the IEDD operator has not worked over the switch to achieve this

The IEDD operator should conduct actions that are commensurate with the threat assessment. This will significantly influence the degree to which confirmation through fingertip search drills is conducted in the immediate vicinity of a buried IED.

Often the safest course of action, when linked components are not assessed to be a threat, is to conduct the minimum actions necessary to complete the RSP. However, when there is a threat of linked components, appropriate EOD actions must take place.

IMAS 09.31 – WORKING PRACTICE DETONATOR SAFETY

Detonator safety should be conducted as early as possible during an RSP.

Image 13. An IEDD operator has conducted detector safety at the earliest safe opportunity

If, during an RSP, there is the opportunity to safely remove a detonator then this should be done as early as possible.

A detonator contains the primary explosives that provide the initial energy to start an explosive chain. If there is no detonator then the rest of the explosive chain is in a much safer state.

WARNING. A detonator must only be removed when it is safe to do so. Refer to Section 4 of this chapter for further guidance.

IMAS 09.31 – WORKING PRACTICE LACK OF ENERGETICS / EXPLOSIVES

If energetic material for disruption is not available or permitted, then semi-remote component separation techniques should be used. Instructional guides and Technical Notes for Mine Action (TNMA) provide further direction.

Image 14. Placing a J Knife cutter to semi-remotely sever an electrical wire. This technique may become the primary option when access to energetics is restricted

Some MA programmes are faced with significant restrictions on the use of energetics. This could apply to the use of donor charges, low explosives for barrel disruptors, pyrotechnic torches and thermite.

When these restrictions are in place, MA IEDD operators will have limited options available to them. H&L will often become the primary option available and staff should be suitably trained in its use, with robust SOPs developed and accredited by the NMAA. These SOPs should describe specific control measures in the form of mandatory actions and management oversight referrals.

IMAS 09.31 – WORKING PRACTICE
SAFE WORKING AREA

The area around a confirmed IED should be searched / cleared. This area should be clearly marked and large enough to facilitate the RSP.

Image 15. An IEDD operator working from a well-defined safe area that they have created during an accreditation assessment

There is likely to be a need to access an IED from various directions and / or locate dispersed components. To achieve this successfully the IEDD operator must use suitable search procedures in accordance with the threat, environment, and NMAS / SOPs. Safe working areas should be progressively marked in accordance with the colour coding system specified in the NMAS / SOPs.

> HINT. When dealing with a subsurface IED, a fingertip search is often required to identify hidden components. When these are exposed, they should be clearly marked as the RSP progresses.

IMAS 09.31 – WORKING PRACTICE
DEVICE MAKE-UP

In situations where an IED is buried it may be appropriate to expose additional parts of the device as part of an RSP.

A challenge of dealing with a VOIED is gaining safe access to components so that appropriate positive EOD action can be conducted. The IEDD operator should always start these actions back from where components have been confirmed or are suspected to be located. They should excavate a vertical 'hole' to the required depth before proceeding to form a trench of a suitable width towards the target.

> WARNING. If the IEDD operator cuts corners and tries to excavate and confirm components directly on target signals, or without being completely certain that the starting point is 'safe', then there is a significant risk that they come vertically down on components, exerting a force that could cause the IED to function.

IMAS 09.31 – WORKING PRACTICE
360-DEGREE COMPONENT CONFIRMATION

Extensive component confirmation can increase the risk of initiating a device through unintended interaction with a secondary switch. This should be a consideration when determining whether, and to what level, excavation of buried components is conducted.

Image 16. Image showing an IEDD operator conducting actions to mitigate against further linked components

An IEDD operator's actions must be consistent with the threat assessment. There should not be any template applied as the 'gold standard'. Templating will likely result in actions being conducted through a perception that they are mandatory, rather than based on need. For example, the degree to which an IEDD operator searches around a main charge before attaching H&L or placing a donor charge should be the absolute minimum to ensure safety. This means that on occasion the threat assessment will dictate that the main charge should be excavated 360 degrees around the sides and on other occasions there should only be the minimum amount exposed to conduct the actions required.

IMAS 09.31 – WORKING PRACTICE APPROPRIATE IEDD TOOLS

During each approach, an IEDD operator should carry suitable tools to deal with a range of scenarios.

Image 17. Image showing an IEDD operator prepared to conduct detonator safety. They have removed their gloves, prepared tape and placed a sharp scalpel-type folding knife at the ready. A sealable metal container will also be available and ready

This does not mean an IEDD operator should simply take over all the kit from the CP. Instead they should bring the tools that are appropriate for the plan that they have developed. This should be based on the 'likely-case' and 'worse-case' scenarios that they have assessed and planned against.

Appropriate tools do not necessarily always mean energetic tools. IEDD tools should have been assessed through trials and testing as being suitable to meet the requirements for the task. For example, a commercially available H&L costing maybe $1000 will not necessarily be any better quality than an H&L kit procured locally, which can be much more easily maintained when parts need replacing.

HINT. Prior to leaving the CP, the IEDD operator should carefully plan what tools are required and how they will be used to execute the required procedure(s).

1.7. MANAGEMENT OVERSIGHT AND REFERRALS

In accordance with IMAS 09.31, MA organisations should include a specific list of referrals that IEDD operators must make when they are faced with certain situations. IMAS lists the following referral examples.

REFERRAL	EXPLANATION
IF AN IED IS IDENTIFIED WHICH EXCEEDS THE TECHNICAL COMPETENCY OF THE IEDD OPERATOR.	This is one of the most important referrals to save the life on an IEDD operator. There are two levels that MA staff are assessed against in order to be deemed capable of disposing of an IED: IMAS IEDD Level 3 and IMAS IEDD Level 3+. **WARNING. IEDD Level 2 is an IEDD assistant that can help prepare equipment and IEDD Level 1 staff are searchers / deminers.** Even an IEDD Level 3+ operator might not have all the competencies required for every eventuality. If this is the case, they must stop operations, refer to their MA operations manager and request relevant support.
A DEVICE INCORPORATING MULTIPLE FIRING SWITCHES IS IDENTIFIED.	It is recommended that a written plan is developed for such devices, which is reviewed and formally approved by an IMAS IEDD Level 3+ operator with specific training for this type of device. If the task is being conducted by an IMAS IEDD Level 3+ operator, they should refer to the MA operations manager, who MUST be qualified to IMAS IEDD Level 3+. From there an appropriate RSP can be determined. **WARNING. If it is not possible for an MA organisation to execute a safe RSP then the IED should be marked and reported to the NMAA.**
PRIOR TO POSITIVE IEDD ACTION ON A DEVICE DEEMED SIGNIFICANT BASED ON A PROGRAMME'S SOPS.	Significant devices could include: • IEDs with multiple firing switches. • VBIEDs. • Projected IEDs with a means of initiation still attached and which could be launched. • VOIEDs incorporating sensors such as passive infrareds (PIRs) that operate on the proximity of a victim. • IEDs where the main charge could be chemical, biological or radiological.

AN UNPLANNED EXPLOSION OCCURS DURING THE CONDUCT OF A POSITIVE IEDD ACTION.	If an explosion occurs when a remote or semi-remote positive action is conducted, then the MA operations manager should be informed immediately. A safe waiting period should be applied and, if available, a UAV / remotely operated vehicle (ROV) used to observe the site of the explosion from a safe distance. A suitable plan should be developed and then briefed to all parties, including the local community. It may be sensible to pause operations until this plan is written down and reviewed. **WARNING. If an unplanned explosion, such as a partial detonation, occurs when the IEDD operator is forward of the CP, then they should immediately cease operations, make safe the work site, and return to a known safe location where a full assessment of the situation can be made in controlled conditions.**
IDENTIFICATION OF A NEW OR NOVEL DEVICE, WHETHER FOR TECHNICAL GUIDANCE OR TO ENSURE IMMEDIATE PASSAGE OF CRITICAL INFORMATION TO OTHER IEDD OPERATORS AND CLEARANCE TEAMS.	**Example 1:** The IEDD operator is working in an area understood to incorporate pressure plate IEDs and comes across a PIR sensor or a radio-controlled device. **Example 2:** The IEDD operator is working in an area understood to contain pressure plates with a high metal content and discovers one with very low metal content. Both examples demonstrate a shift in the anticipated threat, which poses danger to all those operating in the area.
PRIOR TO CONDUCTING OPERATIONS OUTSIDE AN APPROVED TASK SITE, INCLUDING IED SPOT TASKS.	When MA clearance operations commence it is common for members of the local community to approach staff with information on further contamination. Some information may lend itself to 'spot tasks', such as the recovery of main charges and other IED components that have been removed by security force personnel after the conflict but not taken away and destroyed. At a bare minimum this information should be recorded, and appropriate advice provided to the community. Under no circumstances should MA staff conduct any ad hoc tasks without prior approval of the MA operations manager. It is often better to adopt a more deliberate approach and pre-plan a series of spot tasks that can be conducted with suitable management checks.
IF IT IS BELIEVED THAT DEVIATION FROM ANY PRINCIPLE OR MANDATORY ACTION IS REQUIRED TO COMPLETE A TASK SAFELY.	For example, it may be mandated that an IEDD operator wear a ballistic helmet with visor on all approaches. However, if access during an RSP is an issue it may be appropriate to remove the helmet briefly. **WARNING. This deviation should be conducted for the minimum amount of time possible. As soon as the helmet is not restricting access then it should be put back on.**

IF IT IS BELIEVED THAT THERE IS A LACK OF TRAINING, EQUIPMENT OR CAPABILITIES TO SUCCESSFULLY COMPLETE THE TASK.	MA staff should be confident that they have the appropriate level of training, tools and equipment necessary to complete the task with an acceptable level of safety. If this is not the case, then operations should cease until the minimum necessary level is achieved / procured.
ANY OTHER ORGANISATIONAL ISSUES SPECIFIED FOR IMMEDIATE ESCALATION.	The above list is not exhaustive and MA organisations should conduct an assessment of the conditions under which they are operating and ensure that their SOPs specify suitable referrals. This should be checked by NMAAs during accreditation and follow-on QA checks.

As specified in IMAS 09.31, there will be occasions when MA organisations must inform an NMAA that a situation has arisen, or an event has occurred. The NMAA should specify these in relevant NMAS and in turn ensure that organisations include them in their programme-specific SOPs. The following examples from IMAS 09.31 are only intended as a guide:

EVENT	EXPLANATION
A DEVICE IS IDENTIFIED THAT FALLS OUTSIDE THE CAPABILITIES OF THE MA ORGANISATION.	Not all MA organisations will have the same range of capabilities to hand. If an MA organisation cannot safely conduct an IEDD task then they should inform the NMAA and seek their support. In countries where energetics are restricted this could mean requesting assistance from the security forces.
AN UNPLANNED EXPLOSION OCCURS DURING AN IEDD TASK THAT RESULTS IN INJURY OR DEATH.	There may well be legal requirements associated with these events. MA organisations should have contingency plans specified in their SOPs to clearly outline the procedure for their staff.
A NEW OR NOVEL DEVICE IS ENCOUNTERED.	If an MA organisation identifies a new or novel IED its technical details should be recorded and passed to the NMAA and other MA organisations, as soon as possible. This is extremely important to help common understanding of the IED threat and facilitate safe operations.
A TRAINING GAP IS IDENTIFIED FOR THE CONDUCT OF SAFE, EFFECTIVE AND RELIABLE IEDD OPERATIONS.	This may mean that an MA organisation pauses operations to conduct continuation training or enforces specific limitations on what IEDD operators can and cannot do.
A NEW PROCEDURE OR IEDD TECHNIQUE IS DEVELOPED TO IMPROVE SAFETY, EFFECTIVENESS, AND EFFICIENCY.	If one MA organisation develops a new system, procedure or technique it is good practice to share this widely with the rest of the humanitarian MA sector to facilitate continual improvement.

2. IED TACTICS

2.1. TIME IEDs

Time IEDs may be encountered by MA organisations having failed to function as intended or having been constructed but not deployed. There are numerous subcategories of time IEDs but the three that are encountered most frequently are:

- Mechanical
- Electronic
- Igniferous

Time IEDs provide a delay between the device being armed and it functioning. This gives the armed group time to vacate the area once the device is placed in order to prevent injury to themselves and help them to evade capture. When an armed group wants to prevent casualties, time IEDs can also be utilised in conjunction with a warning to provide time for evacuation, ensuring only property is damaged. Other types of time IED incorporate a short delay to provide the opportunity to put a safe distance between an IED that has been thrown or projected and members of an armed group.

These key characteristics provide a number of advantages, such as enabling IEDs to be thrown, projected and placed, and for them to then function with no further interaction from the armed group. The principle disadvantage is that unless additional switches are incorporated, once activated, the armed group no longer has control. This increases the possibility of unintended casualties, as well as making it extremely difficult to accurately target something which moves, unless a precise time pattern can be exploited.

2.1.1. MECHANICAL

Mechanical time IEDs are normally constructed by adapting mechanical clockwork timers with electrical contacts which close at a predetermined time. The following example is a failed mechanical time IED located in a hospital. The device has become 'stuck fast' after sand has clogged the clockwork mechanism.

WARNING. If disturbed, the clockwork mechanism could become unstuck and start working again, meaning the IED would then function as originally intended.

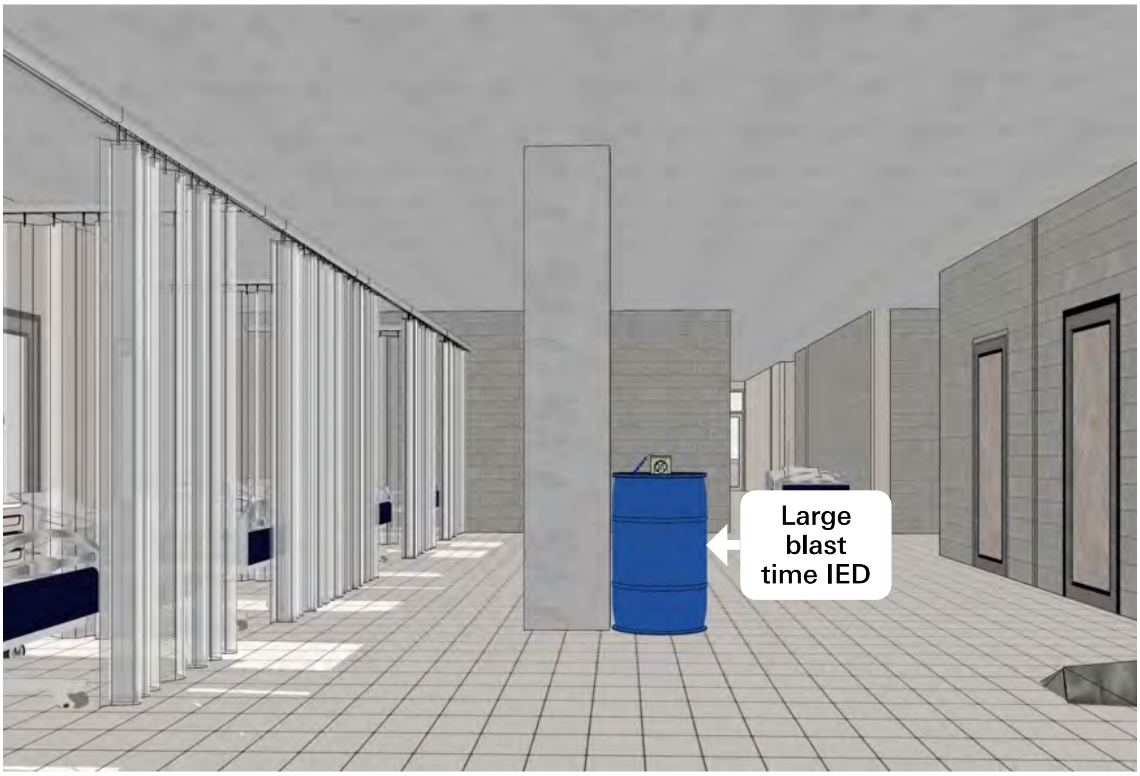


Image 1. Image showing a large blast time IED located in a hospital

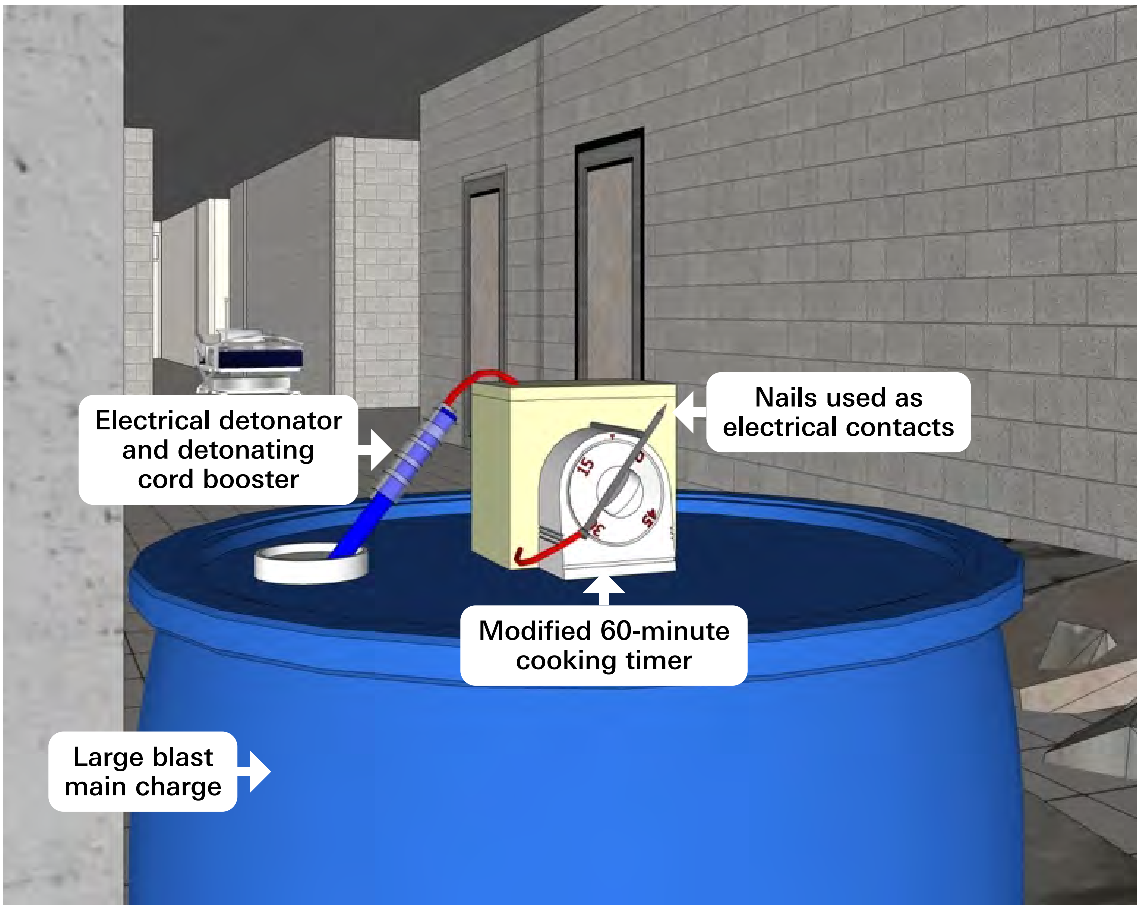


Image 2. Image showing a mechanical time switch created by modifying a 60-minute clockwork cooking timer by attaching two nails as electrical contacts

2.1.2. ELECTRONIC

An electronic time IED uses a digital timer, either from adapted commercially available components or from a bespoke circuit, which provides a specified output at a predetermined moment in time. This output is often not large enough to directly function an initiator (detonator) so frequently an additional step-up circuit is incorporated to increase the power.

Image 3. Image showing critical infrastructure providing a suitable target for a time IED

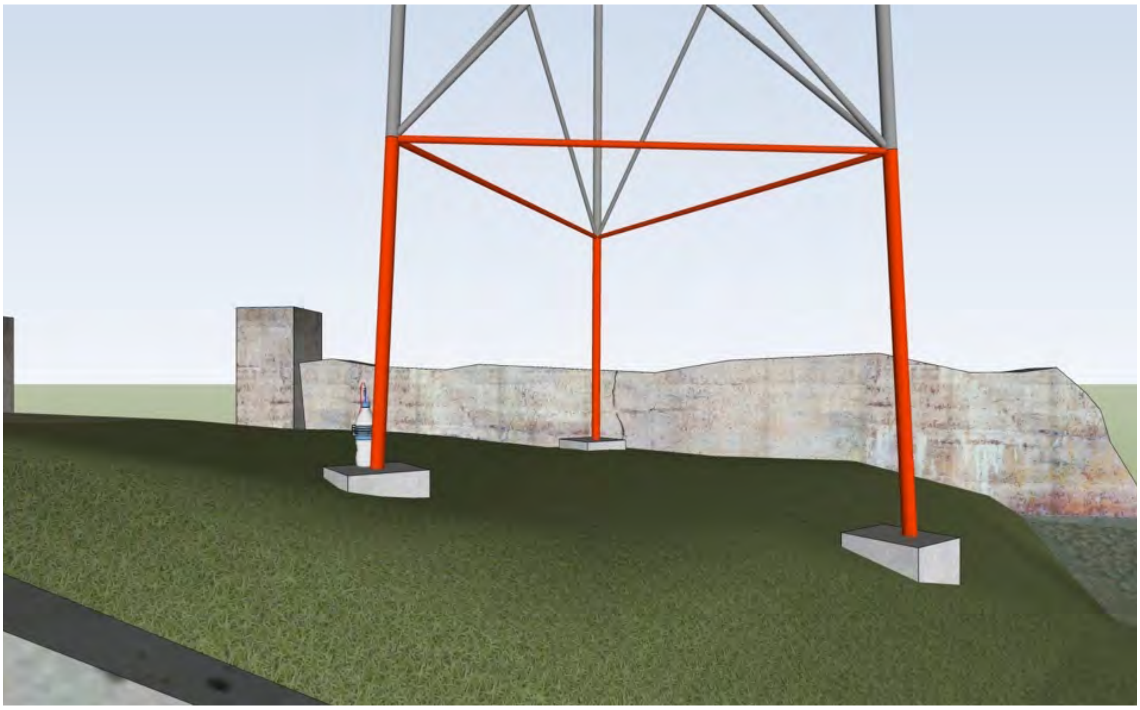


Image 4. Image showing a time IED placed against a supporting leg. The aim is that when the IED functions, the support leg of the tower will break and the rest of the tower will collapse under its own weight

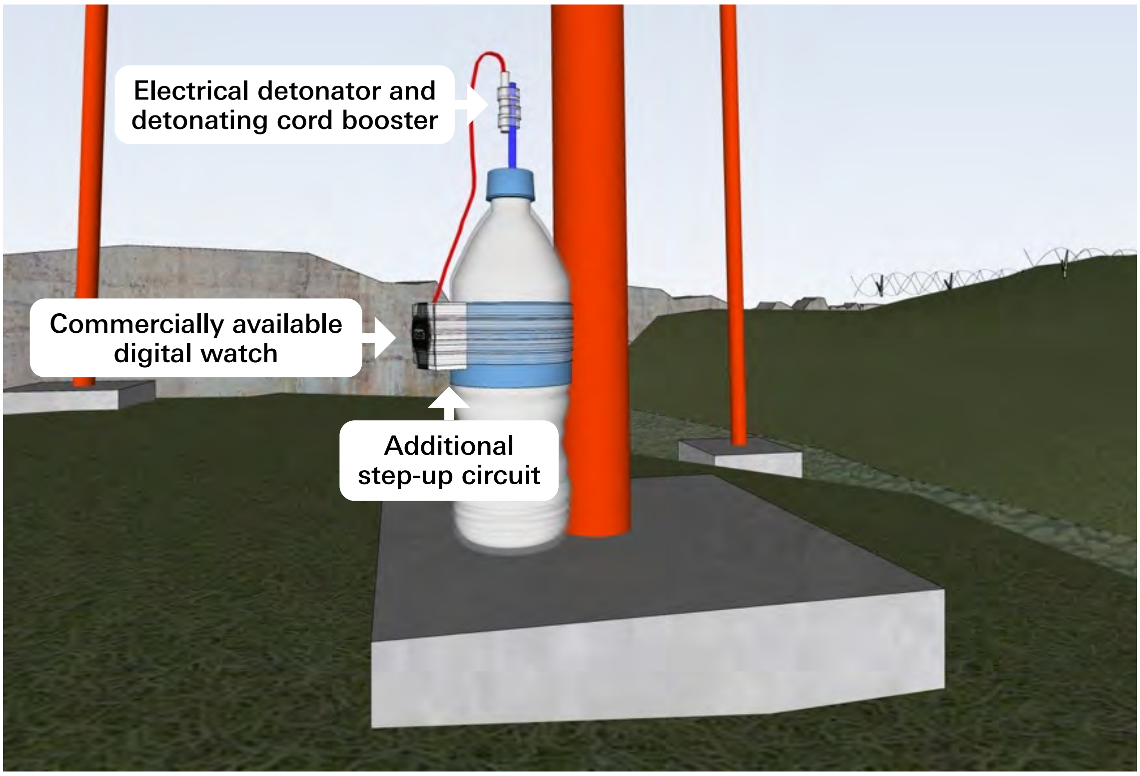


Image 5. Image showing an electronic time IED utilising a commercially available digital watch and an additional step-up circuit

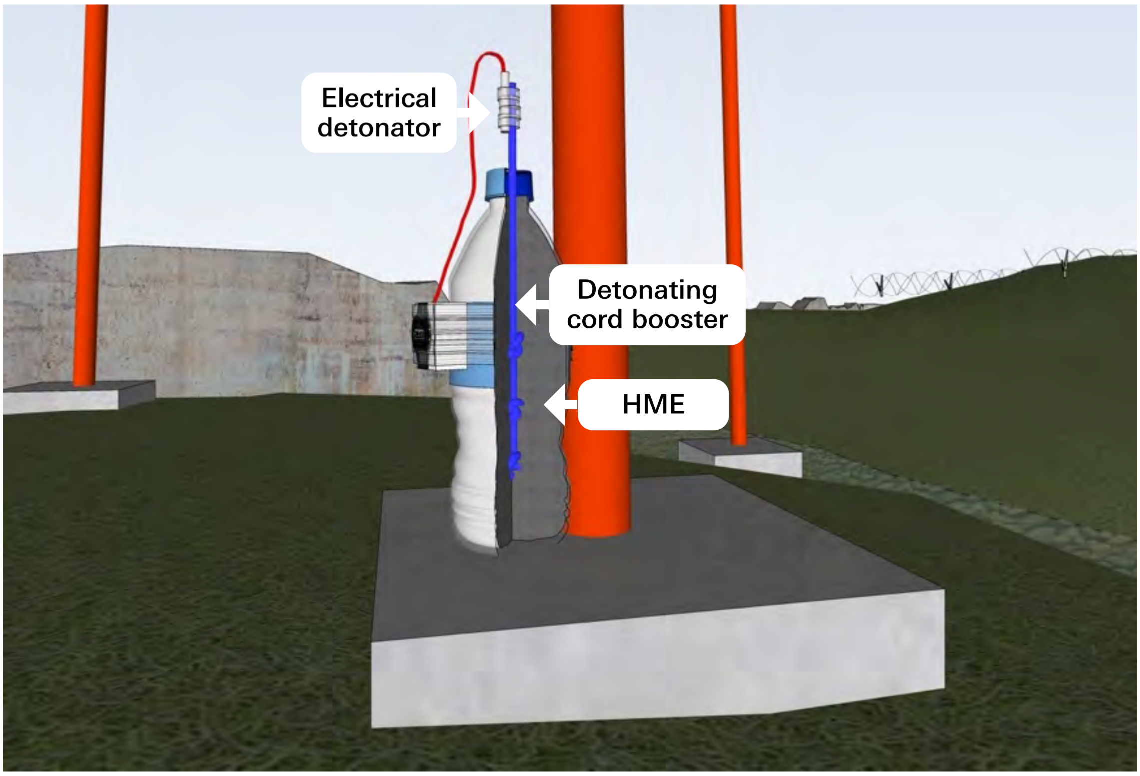


Image 6. Image showing a cross-section of the electronic time IED in detail

2.1.3. IGNIFEROUS

Armed groups can use IEDs to overcome shortages in a wide range of different weapon systems. Igniferous IEDs are relatively simple devices that involve no electrical circuitry and instead use a burning fuze that initiates a plain (flash) detonator or initiator. This means of initiation is frequently associated with hand-thrown 'improvised grenade' type devices but has also been used in a wide number of device types, including large anti-infrastructure IEDs and VBIEDs.

Image 7. Image of an igniferous hand-thrown IED that has been abandoned after close quarter fighting in an urban environment

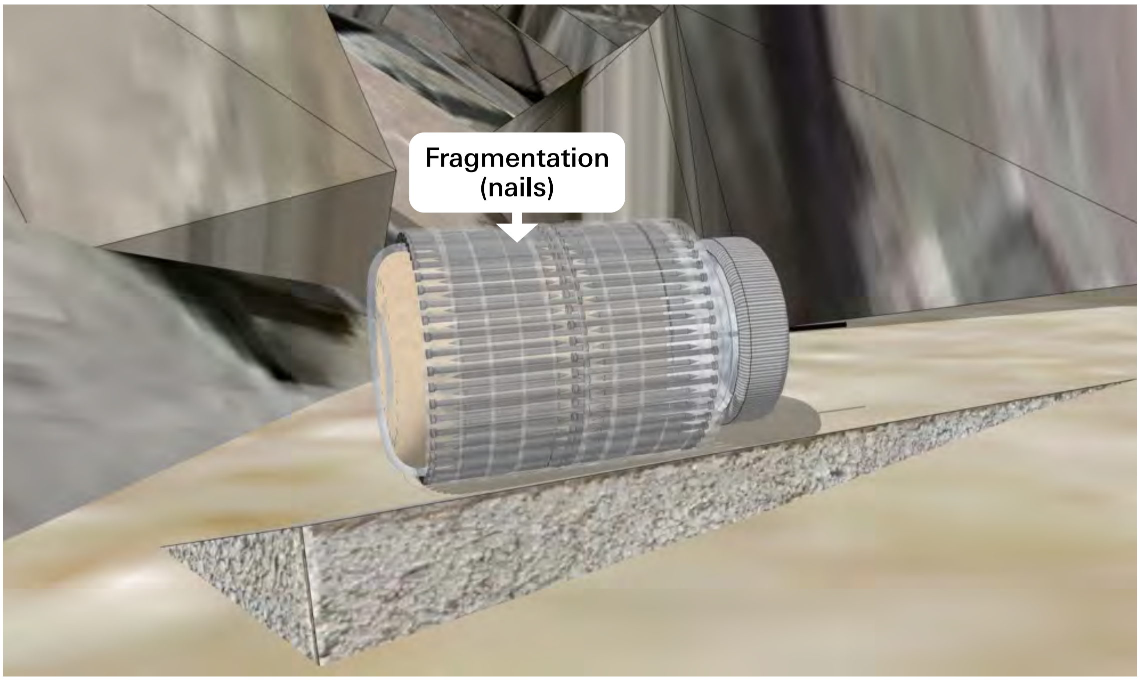


Image 8. Image of an igniferous hand-thrown IED which has failed or been dropped and abandoned

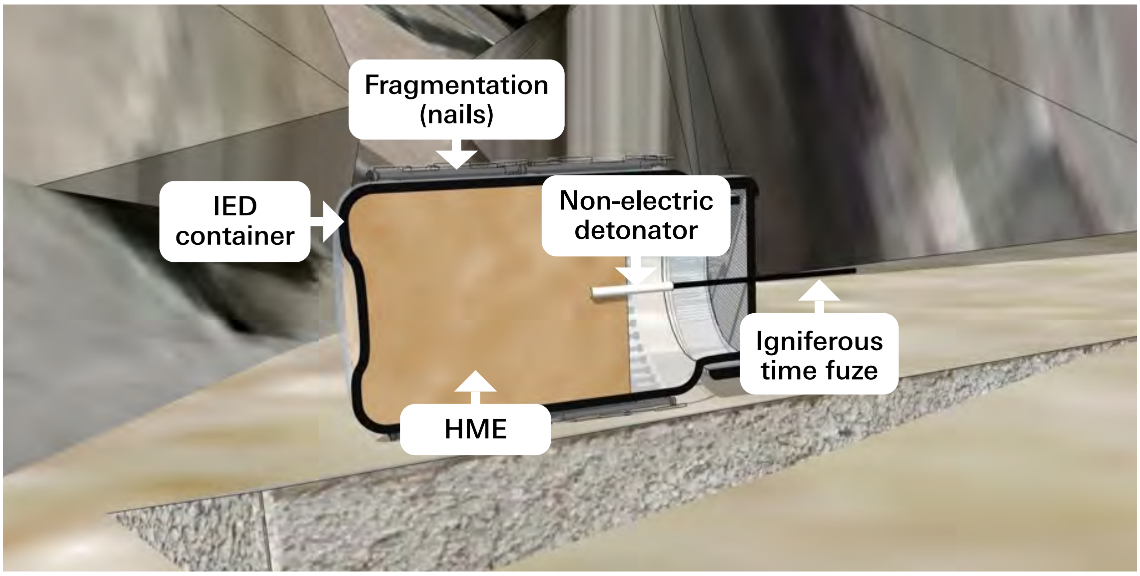


Image 9. Image showing a cross-section of an igniferous hand-thrown IED

An even simpler variation of an igniferous hand-thrown IED that has been frequently encountered by MA organisations is a simple piece of metal pipe or small arms cartridge case, usually .50 calibre, that has been filled with HME.

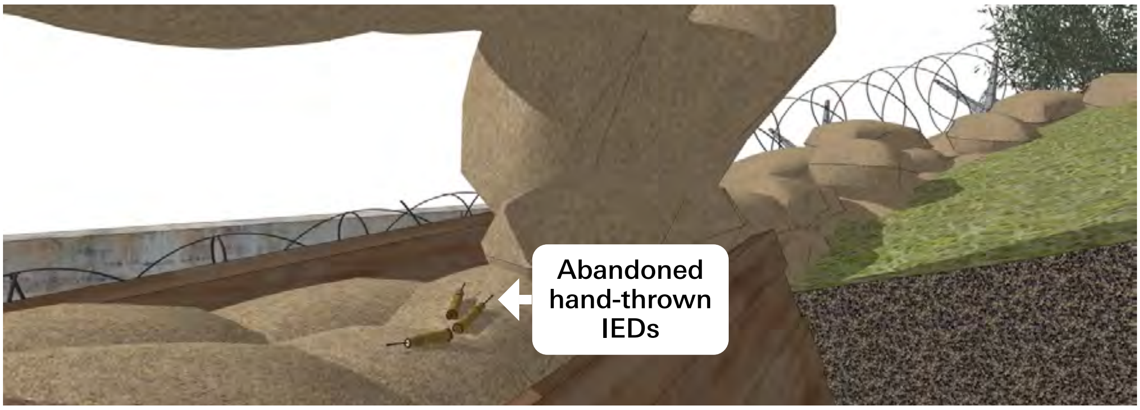


Image 10. Image of igniferous hand-thrown IEDs located in an abandoned fighting position

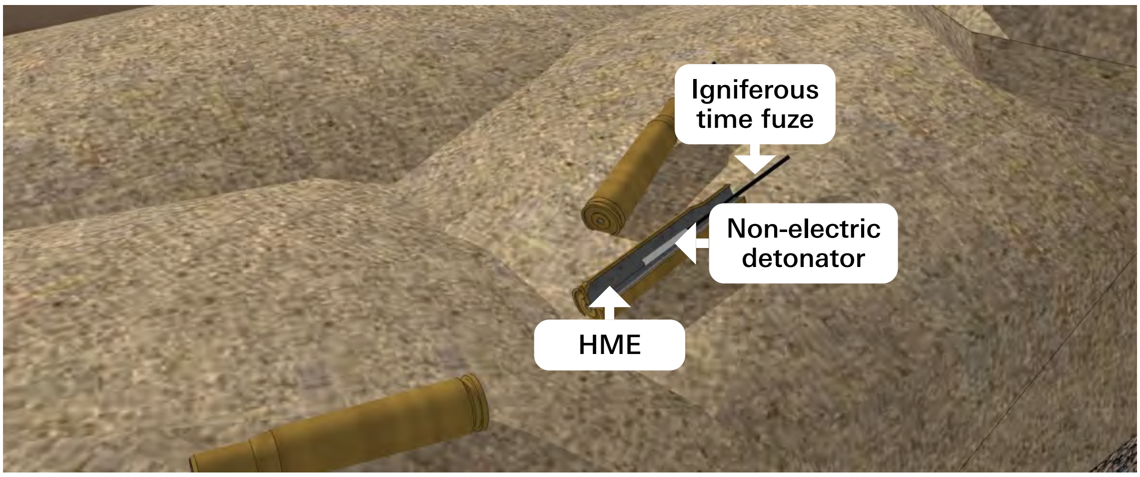


Image 11. Image showing the cross-section of an igniferous hand-thrown IED utilising a cartridge case as the body

2.2. COMMAND IEDs

Command IEDs allow an armed group to retain full control over the IED until the moment it is initiated. This key characteristic provides advantages by reducing the possibility of the device inadvertently initiating and causing unintentional casualties. It also means that resources are not wasted. Maintaining control of the IED enables freedom of movement for the armed group that placed the IED, but not for their opponents.

- The principle advantage of all command IEDs is that the device can be initiated at the optimum moment.
- The principle disadvantage of all command IEDs is that they must be continually observed by someone who has control and can function the device at the required moment.

There are many different types of command IED. The main division is between physical and non-physical link command IEDs. This guide provides specific details of:

- Non-physical link – radio controlled IEDs (RCIEDs)
- Physical link – command wire IEDs
- Physical link – command pull IEDs

2.2.1. RCIEDs

RCIEDs use a radio frequency (RF) transmission to initiate an IED with no requirement for a physical link between the firing point and contact point.

Key advantages include:

- The firer is not restricted to a single fixed point to initiate the IED;
- Can be deployed very quickly with no requirement to emplace a physical link;
- Reduced possibility of a follow-up attack on the individuals at the firing point.

Key disadvantages include:

- Can be affected by jamming, preventing it from functioning as intended;
- Can be subject to spurious or deliberately generated RF signals, causing the IED to detonate;
- Requires access to suitable technology and training.

The following series of images shows an RCIED with a directional fragmentation charge located at a vulnerable point (VP) created by a slowdown point (sharp bend) and an adjacent aiming marker (tree).

WARNING. The scenario is set in the context of the IED having recently been emplaced. MA organisations would be responding to this type of IED only if it was abandoned after the conflict.

Image 1. Vehicle slowing down as it turns the corner. Note the tree opposite acting as an aiming marker

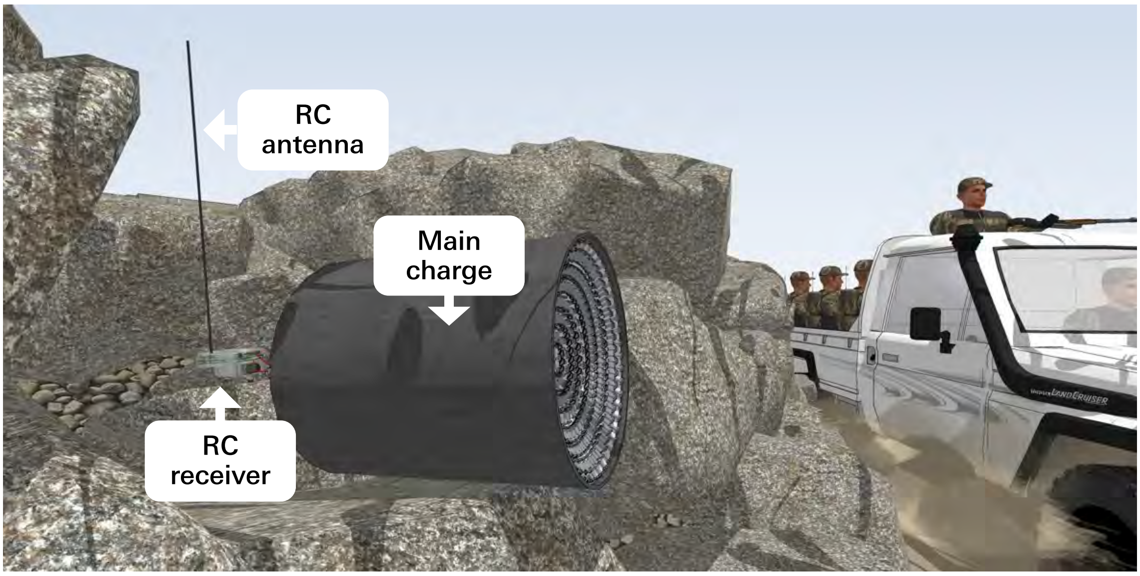


Image 2. An RC initiated directional fragmentation charge. Note that it has been placed in an elevated position to deliver maximum effect against its intended target

Image 3. Note the compact nature of an RCIED, making rapid emplacement possible

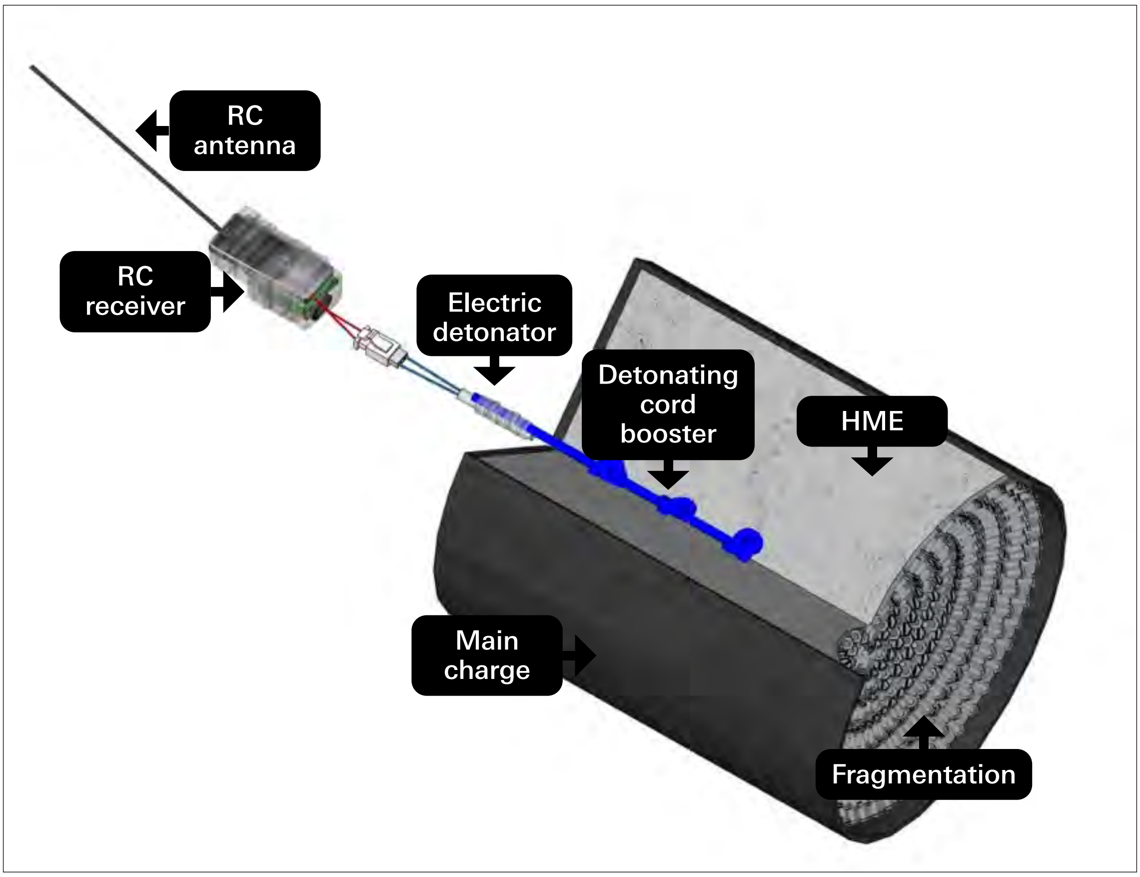


Image 4. Cross-section of an RCIED incorporating a directional fragmentation charge

2.2.2. COMMAND WIRE

A command wire IED is an electrically initiated IED that has a physical link between a firing point and contact point.

Key advantages include:

- A simple IED that requires no additional electronic circuitry;
- Not affected by jamming devices and is less susceptible to spurious RF signals;
- Can be operated with very basic levels of training.

Key disadvantages include:

- The firer is normally limited to a fixed firing point;
- Can take time to emplace due to the physical link;
- Uses significant quantities of electrical wire.

The following series of images illustrates the use of a command wire IED with a large blast main charge.

WARNING. The scenario is set in the context of the IED having recently been emplaced. MA organisations would be responding to this type of IED only if it was abandoned after the conflict.

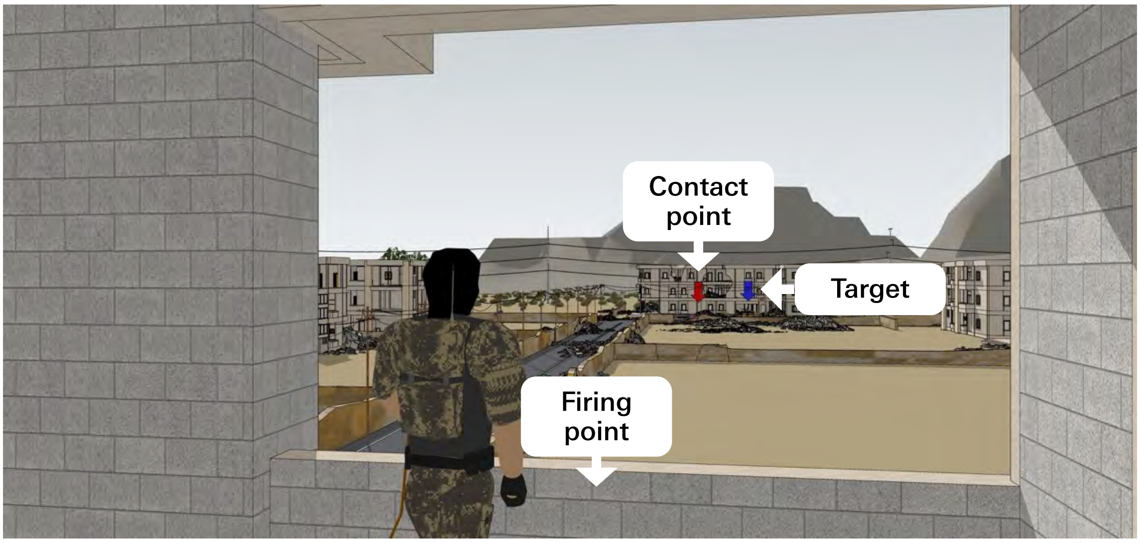


Image 5. Illustrating the line of sight from a firing point to contact point. (Blue arrow represents a potential target approaching a contact point shown by the red arrow)

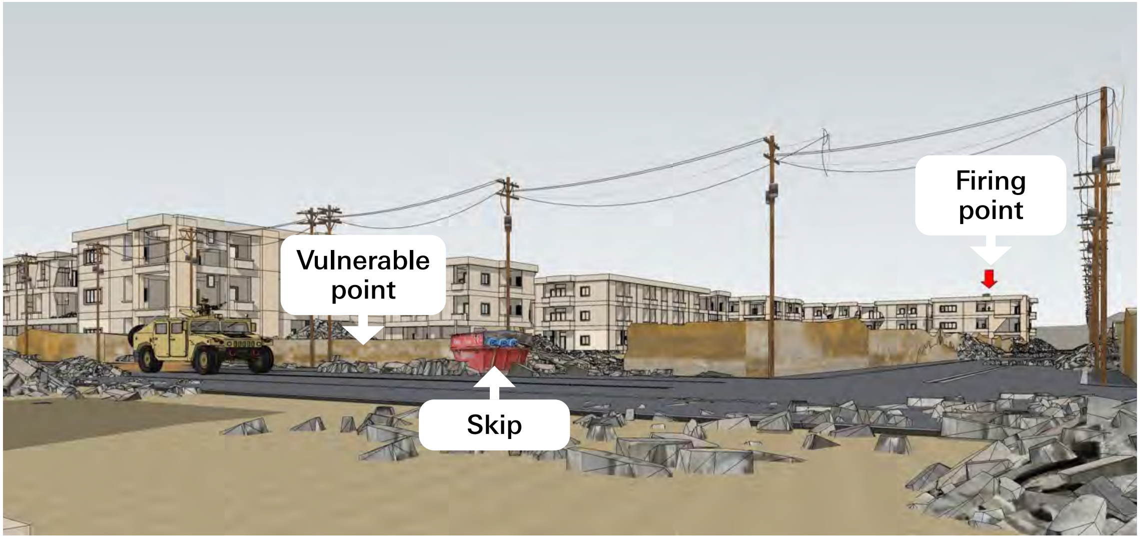


Image 6. A vulnerable point created by rubble on the road forcing vehicles to reduce speed. Note that in this example the skip in which the IED main charges are located is large enough to act as the aiming marker for the firer located by the red arrow

Image 7. Command wire IED main charges at the contact point, camouflaged inside a skip

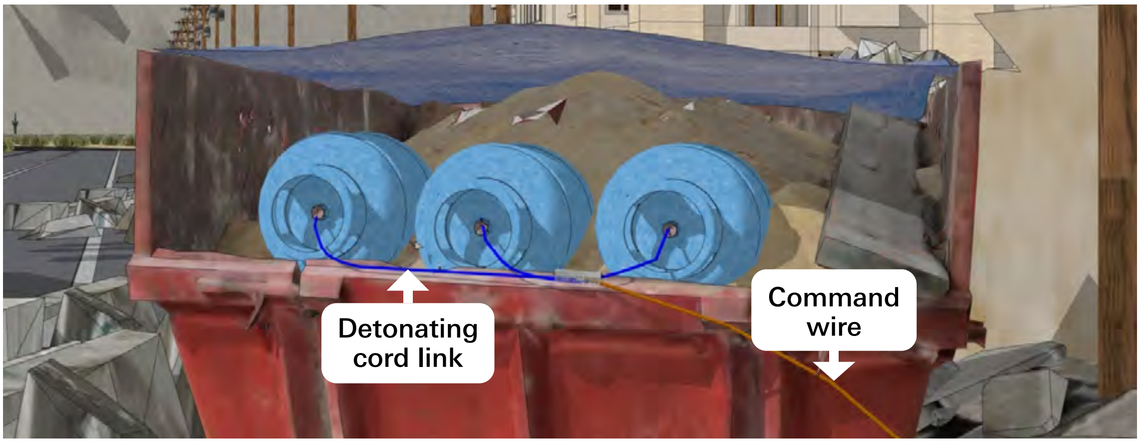


Image 8. Three main charges linked together by detonating cord. This IED could contain over 100 kg of HME

WARNING. Prior to starting any disposal operations consider whether the security conditions are permissible and suitable for MA IEDD.

KEY CONSIDERATIONS FOR AN MA IEDD OPERATOR CONDUCTING AN RSP ON A COMMAND WIRE IED:

- Make assessment of the location of the firing point and contact point;
- Take control of the command wire prior to entering the contact point. This means separating the physical link using remote or semi-remote techniques;
- Always conduct a threat assessment and apply suitable search procedures to mitigate against further VOIEDs as required;
- Conduct detonator safety at the earliest opportunity;
- Always remotely or semi-remotely move all IED components prior to manual handling;
- Never manually pull in command wires by hand.

2.2.3. COMMAND PULL

A command pull IED is another device that has a physical link between firing point and contact point. It is normally an electrically initiated device, however mechanical cocked strikers have been encountered.

Key advantages include:

- Can be emplaced quickly with the majority of the physical pull link surface laid;
- Significantly reduces the amount of electrical wire required compared to a command wire IED;
- Like a command wire IED it can be operated with very basic levels of training and is not susceptible to jamming.

Key disadvantages include:

- As with a command wire the firer is normally limited to a fixed firing point;
- The command pull link can act like a tripwire increasing the IED susceptibility to inadvertent initiation;
- The time taken to pull in slack and cause a switch to close may make it harder to function the device at the optimum moment.

The following series of images illustrates the use of a command pull IED with subsurface main charge.

WARNING. The scenario is set in the context of the IED having recently been emplaced. MA organisations would be responding to this type of IED only if it was abandoned after the conflict.

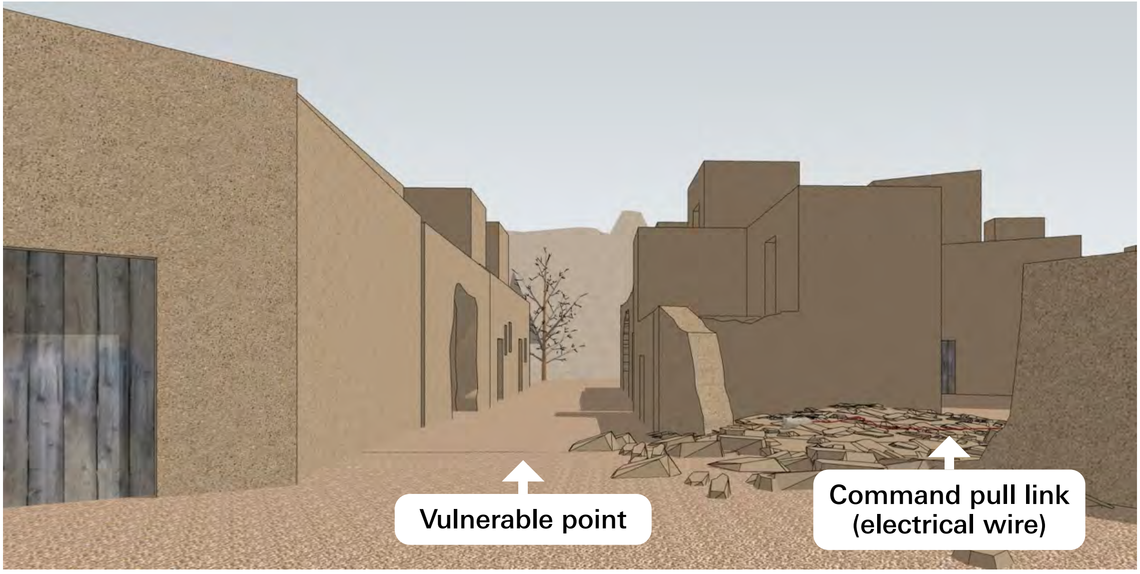


Image 9. Showing a vulnerable point where rubble has fallen over a channelled route and a command pull IED has been emplaced

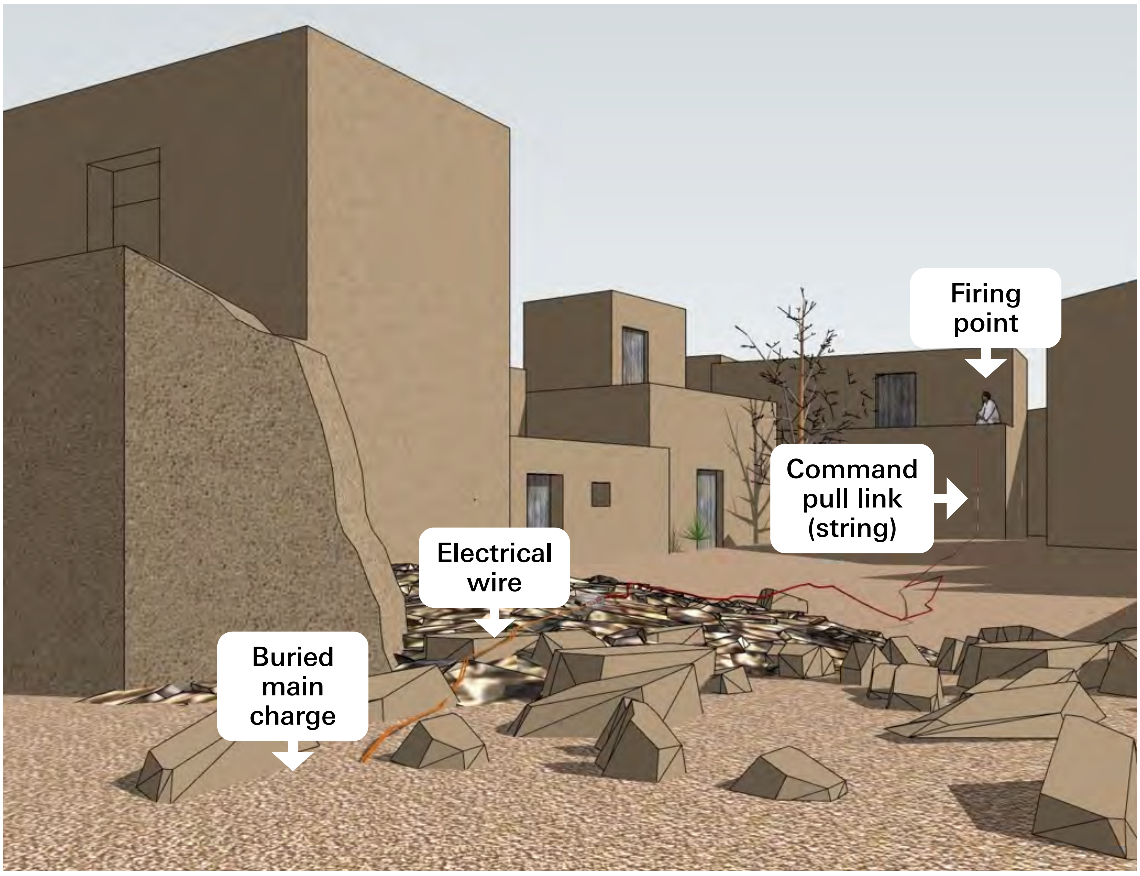


Image 10. Showing the firing point of the command pull IED and the pull links (red string / orange electrical wire) leading to the main charge below ground

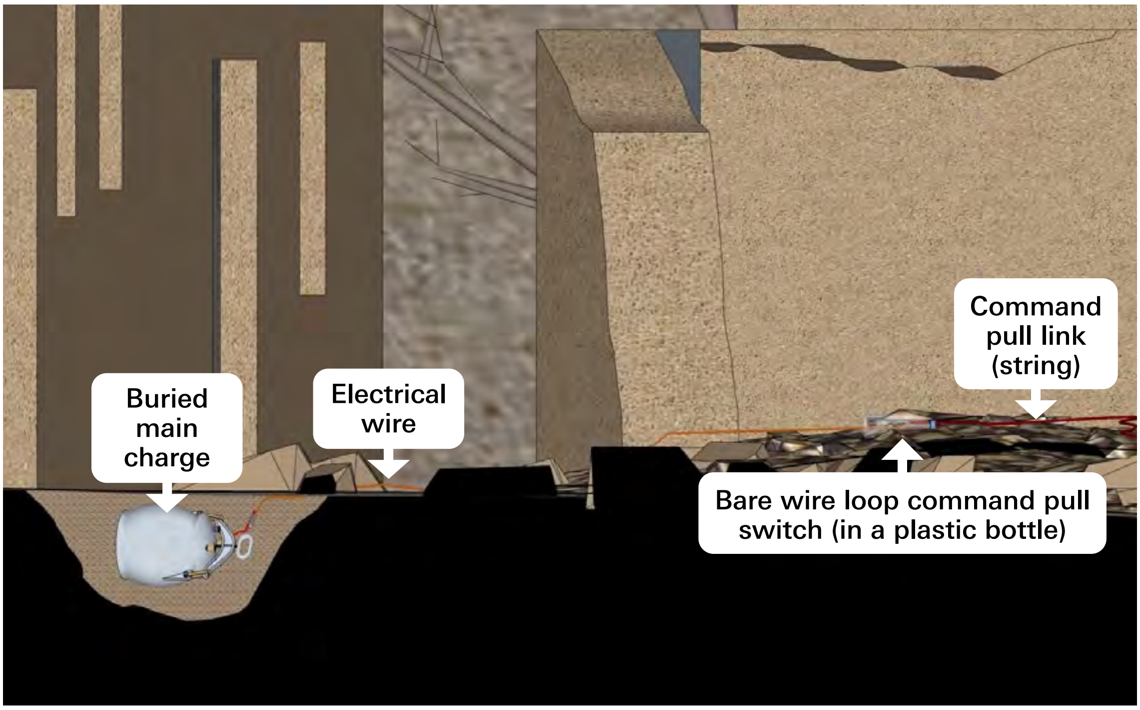


Image 11. Image of a buried main charge from a command pull IED in relation to a bare wire loop command pull switch above ground

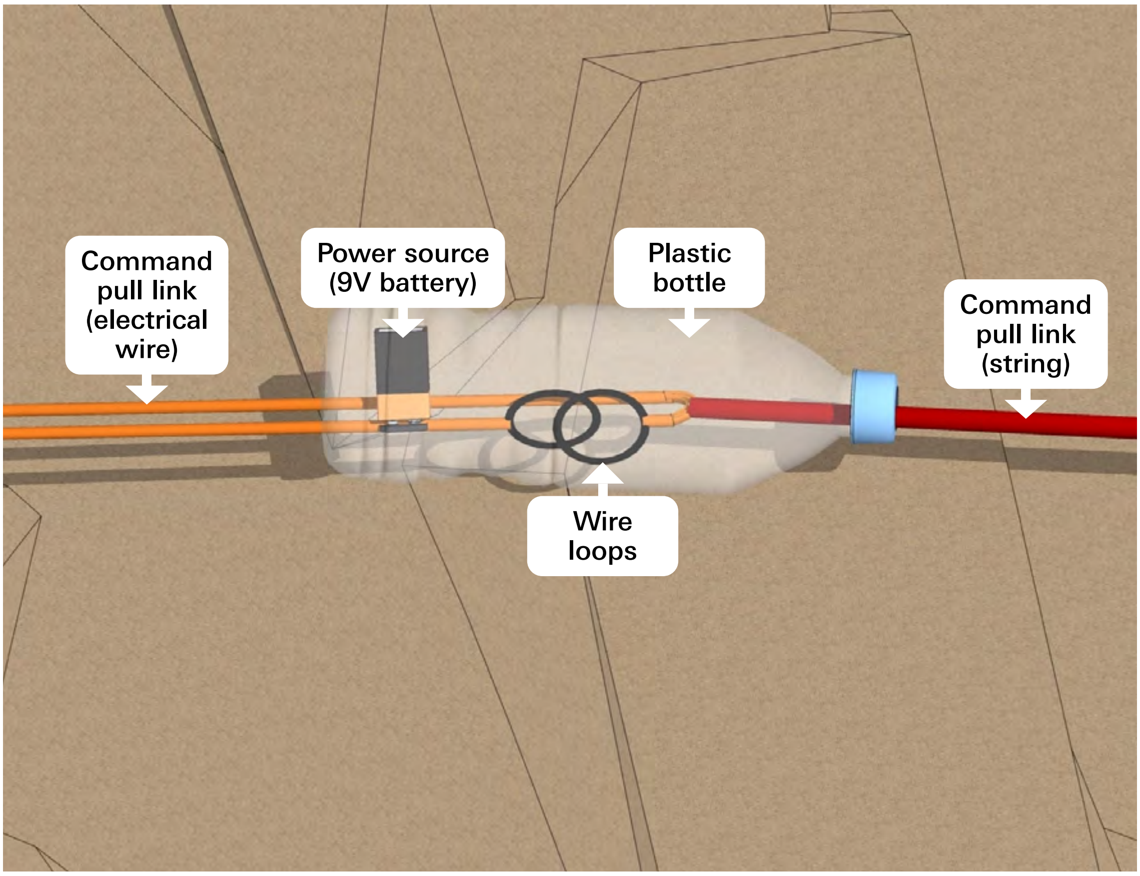


Image 12. Image in detail of the command pull switch

2.3. VICTIM OPERATED IEDs (VOIEDs)

Due the associated humanitarian impact of VOIEDs on communities, they are regularly the focus of MA operations. The reason for this is that they have been deliberately designed to function when a normally safe act is conducted such as walking on the ground or opening a door.

Principle advantages:

- Provides a persistent effect, day and night;
- No requirement for members of the armed group to remain in location or to observe;
- Can remain viable for many years after they are emplaced.

Principle disadvantages:

- Can cause accidental casualties, even long after the conflict has ended;
- Can reduce the mobility of the armed groups that placed the IEDs, unless they have the ability to arm and disarm;
- Can be particularly hazardous to emplace;

VOIEDs can remain concealed for many years after the conflict has ended and can be split into two main subcategories:

- Contact
- Influence

Each of these subcategories can be further subdivided.

2.3.1. CONTACT VOIEDs

Contact VOIEDs require a physical interaction from a victim (person or vehicle) in order to function. In general, there are four subgroups of contact VOIEDs that are commonly encountered by MA organisations:

- Pressure
- Pressure release
- Tension (pull)
- Tension release

2.3.1.1. PRESSURE

Pressure switches are amongst the most common methods used to initiate a VOIED. There are many types and this section describes the following in more detail:

- Pressure plate – high metal content
- Pressure plate – low metal content
- Syringe
- Crush wire (bead)

HIGH METAL CONTENT (HMC) PRESSURE PLATE IED

HMC pressure plates use separated electrical contacts made from metal. The action of the victim exerts pressure that causes these contacts to come together, allowing current to flow in the circuit and the detonator to function. If opposing groups do not use metal detectors to mitigate against IEDs then this type of device can be extremely effective.

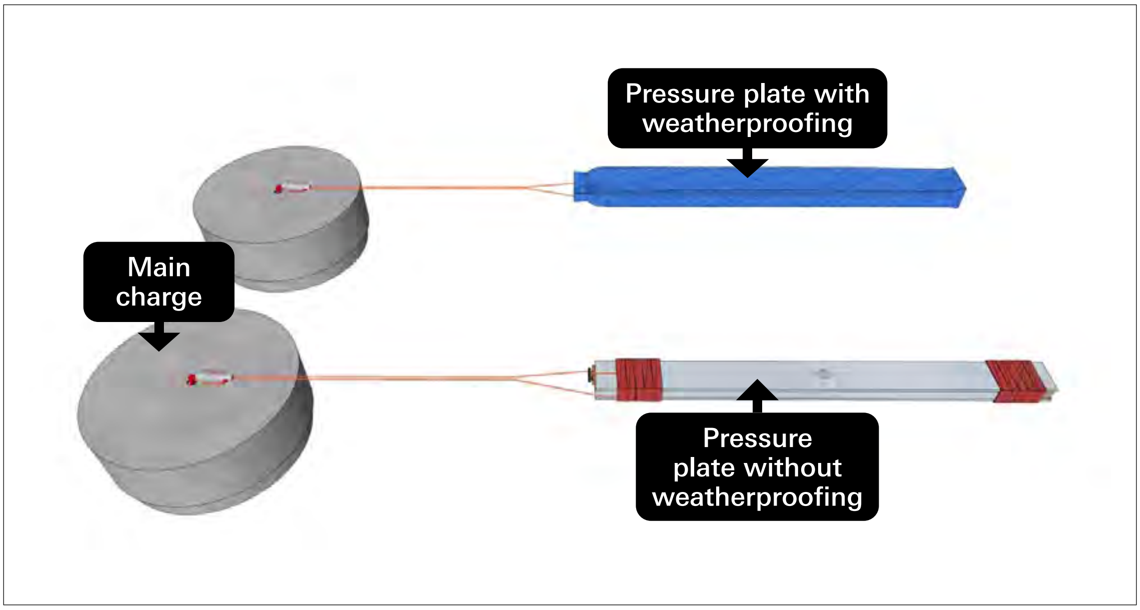


Image 1. Image showing an example of a pressure plate IED (HMC)

LOW METAL CONTENT (LMC) PRESSURE PLATE IED

LMC pressure plates use low or non-metallic electrical contacts in a similar manner to how an HMC pressure plate uses high metal content electrical contacts. Two of the most commonly encountered materials for these LMC contacts are strands of copper wire and carbon rods. Frequently, the battery is the only component with significant metal content and is therefore either remoted from the pressure plate and plastic main charge, or deeply buried.

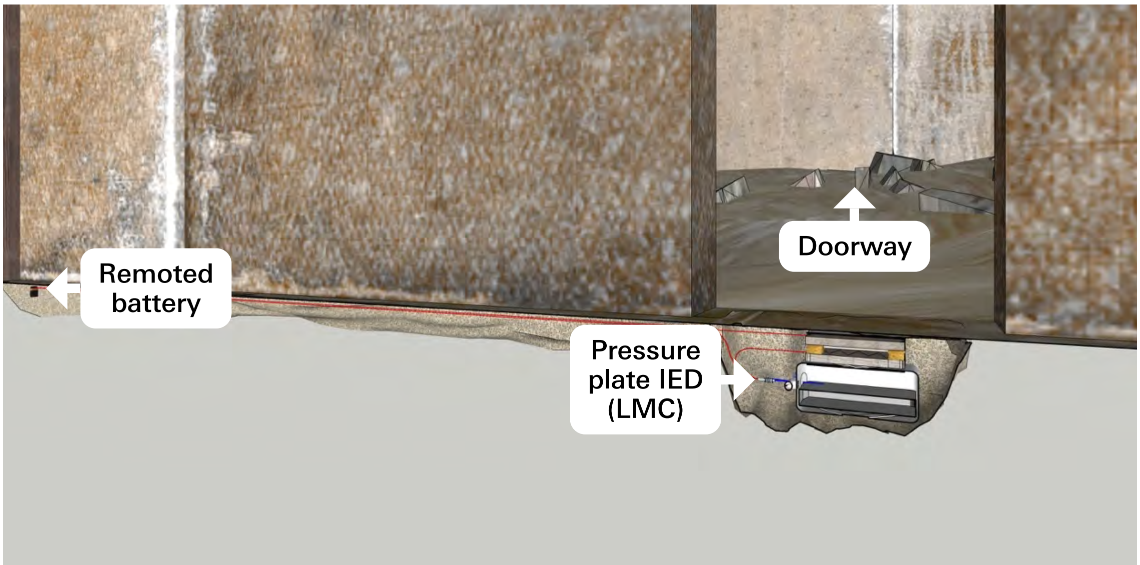


Image 2. Image of a pressure plate IED (LMC) located in a doorway with a remoted battery

A bare wire pressure plate can be constructed by simply removing the insulation from the wire used in the remainder of the circuit. Often the wire will be arranged in a pattern on two wooden boards, held apart at either end by soft spacers. This arrangement will be such that when pressure is applied an electrical connection will be made.

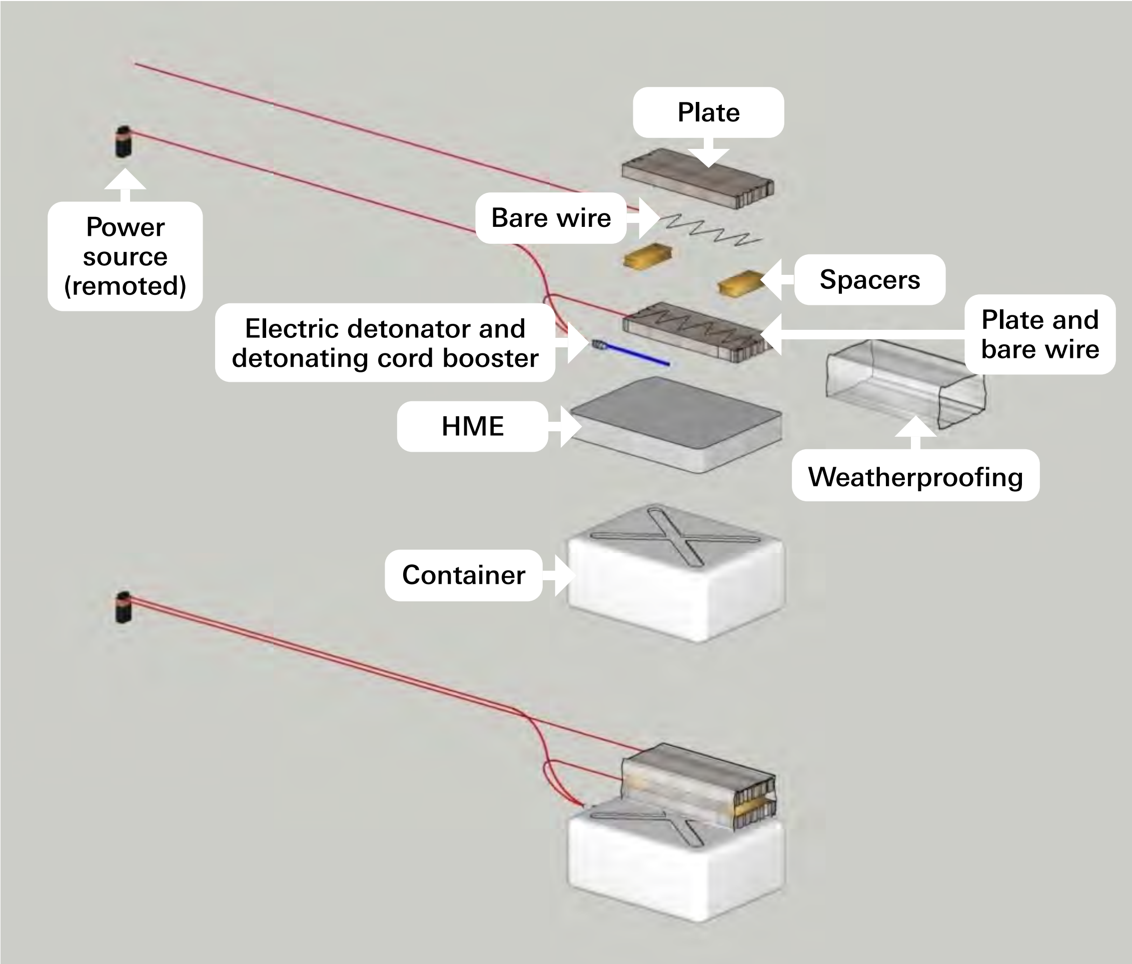


Image 3. Image showing how the components of an LMC bare wire pressure plate with remote power source fit together

Another option that reduces the metal content still further is to use carbon rods. These are commonly available by breaking down some types of batteries. Again, they are often arranged on wooden boards in a manner that consistently makes a connection when pressure is applied. In this example a simple cross formation has been used.

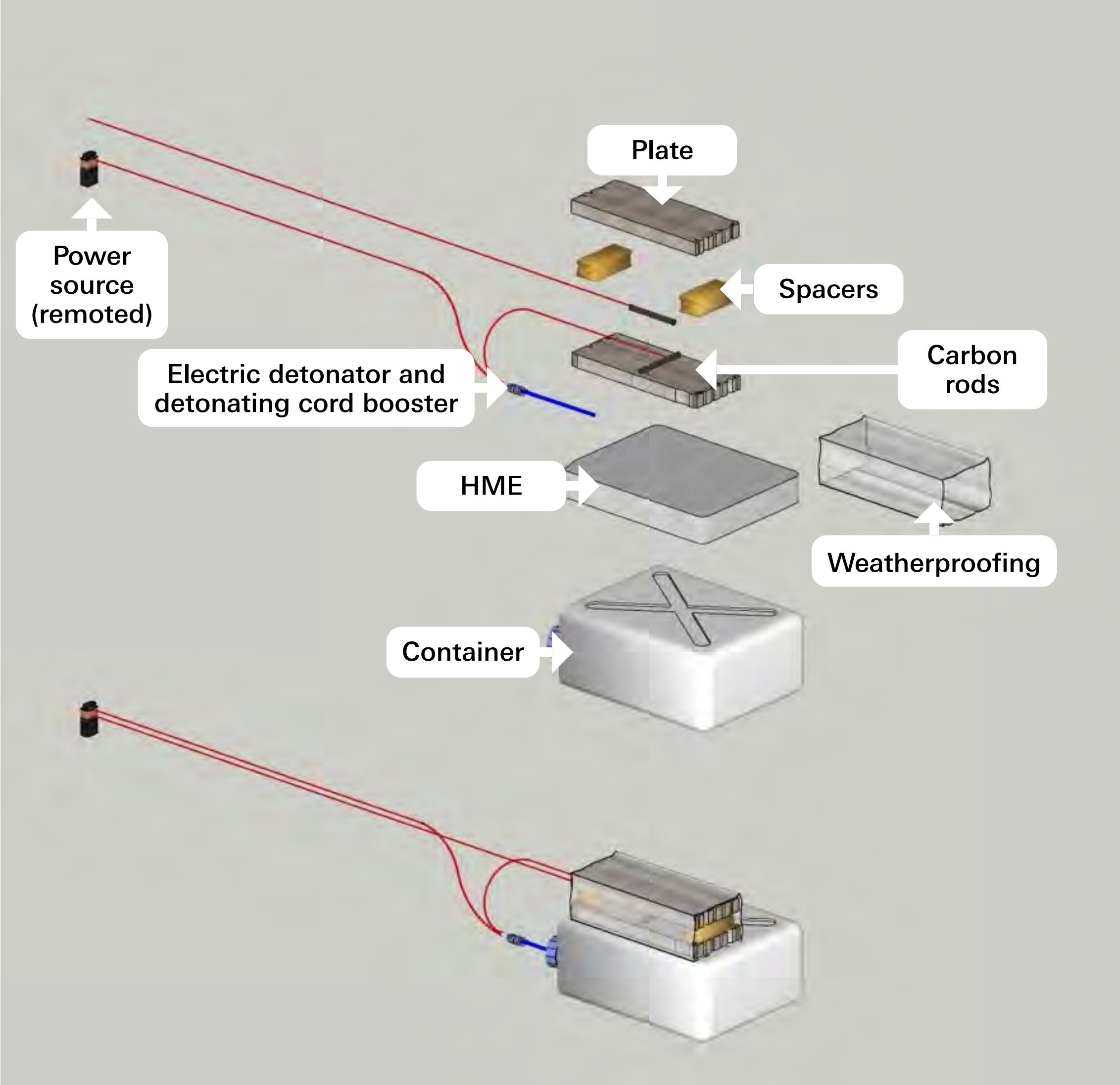


Image 4. Image showing how the components of an LMC carbon rod plate with remote power source fit together

PRESSURE (SYRINGE) VOIED

This is another example of a VOIED that incorporates a normally open switch, this time using a medical syringe. When the victim steps on the syringe it depresses and the two contacts come together, electrical current flows and the IED functions. In this example all components are co-located making it relatively easy to find with a detector.

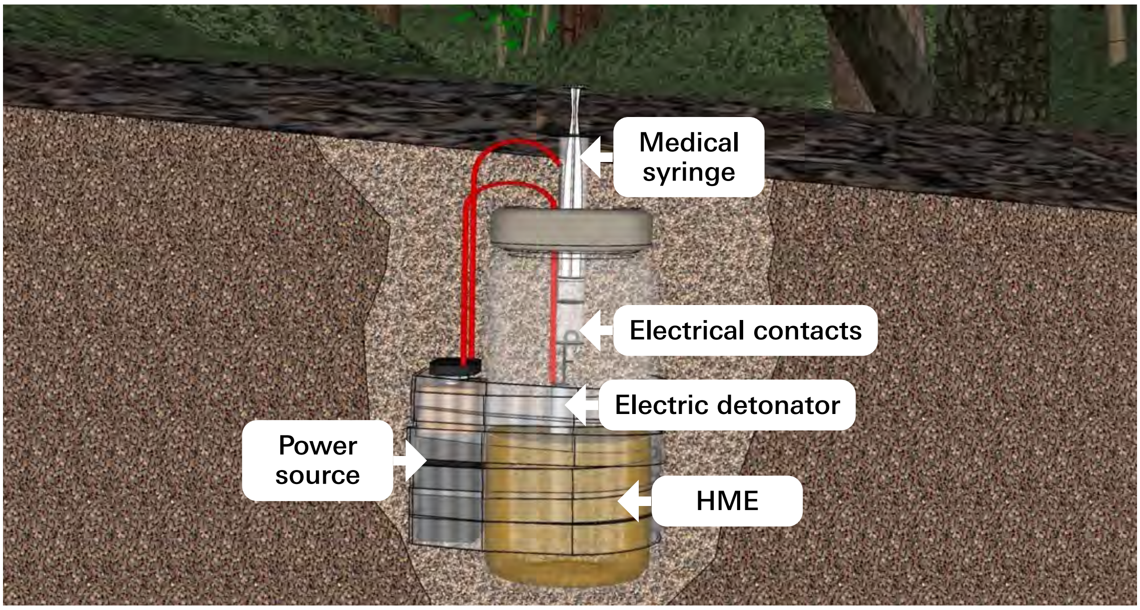


Image 5. Pressure switch consisting of an electrical contact inside a medical syringe

CRUSH WIRE

This type of pressure switch has been commonly encountered in the Middle East. It uses lacquer coated copper wire with multiple small electrical contacts, wired in parallel, that are mounted on soft tubing. As the switches are in parallel, when any of them are depressed, and the connection is made, the IED will function. They can be hard to detect visually and they have a low metal signature making them even harder to detect by other means. The length of the multi-switch wire can easily be made long enough to cross a whole road or more.

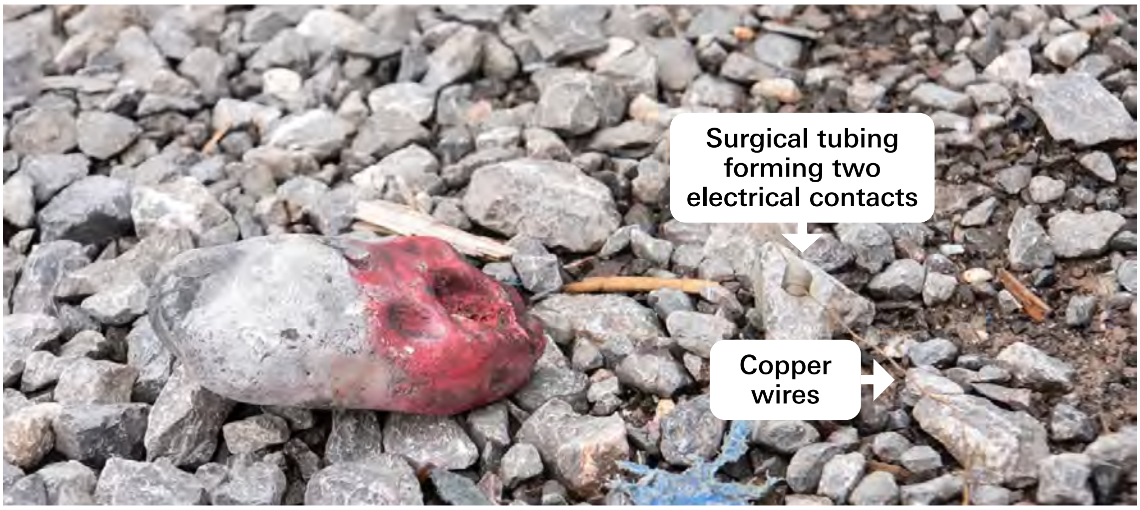


Image 6. Example of a crush wire switch. Note: these two copper wires would be covered with a lacquer insulation, which is removed at the point where it is wrapped around the surgical tubing in order to form two electrical contacts

2.3.1.2. PRESSURE RELEASE

A pressure release switch can be a stand-alone primary firing switch in a VOIED that is designed to target a normally safe action, such as picking something up. It can also be incorporated as a secondary firing switch in an IED to target poor disposal procedures, such as manually picking up the main charges.

They normally incorporate a switch held in an open position, with separated electrical contacts that are trying to close due to the compression of a spring. When a weight is removed the spring is released, the electrical contacts close and the IED functions.

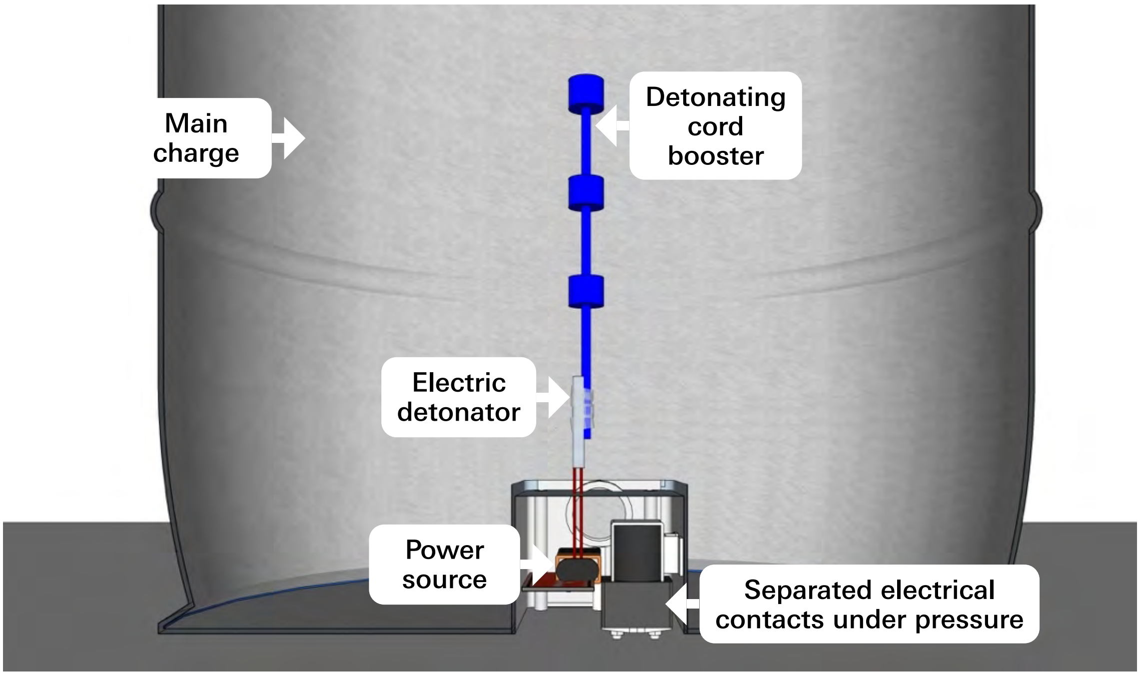


Image 7. Image of a pressure release switch built into the bottom of a main charge

2.3.1.3. TENSION (PULL) VOIED

This is a VOIED that uses the contact of a victim to generate tension – it is also sometimes referred to as a pull IED. Tension VOIED switches can be very simple, such as bare wire loops that are pulled together or insulators that are pulled out from a clothes peg-type mechanism that has been adapted by incorporating electrical contacts.

Other electrical components, such as motorcycle brake light switches and micro switches, have also been incorporated into these types of IEDs. Non-electrical IEDs incorporating cocked strikers that release when a pin is pulled out have been encountered.

The following example is a tripwire (tension) VOIED that is intended to function when a lightly armoured vehicle moves through a vulnerable point.

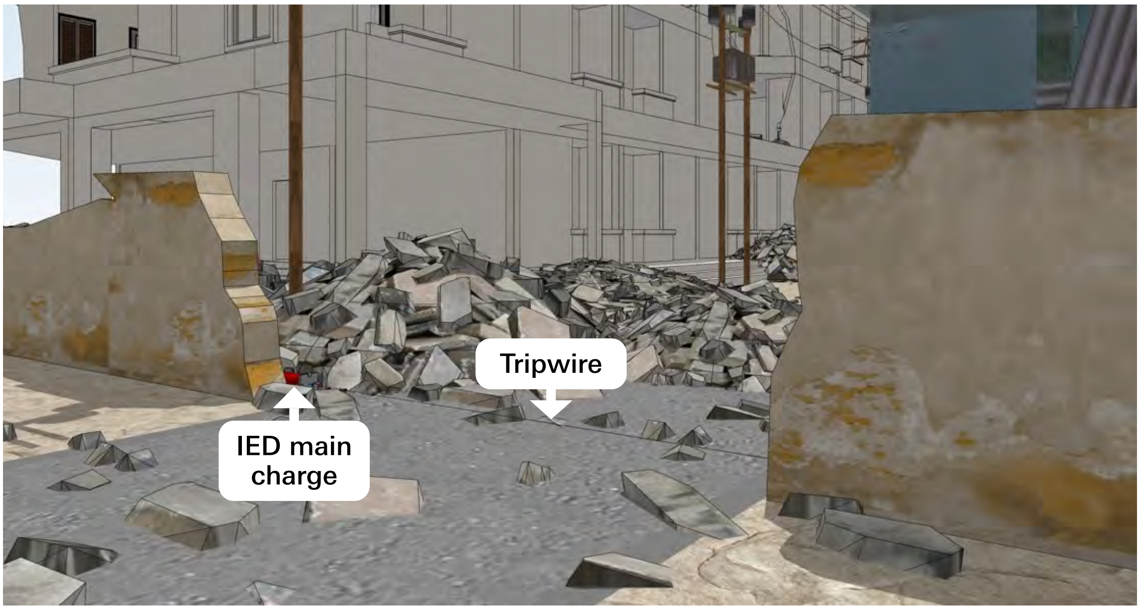


Image 8. Tripwire IED located at an entrance which forms a vulnerable point

This IED consists of a modified fire extinguisher containing an ammonium nitrate and aluminium (ANAL) HME, a knotted detonating cord booster, an electrical detonator, a 9V PP3 battery and a modified clothes peg incorporating electrical contacts held apart by an insulator. When the victim imparts tension on (i.e. pulls) the tripwire the insulator is pulled out of the clothes peg, the electrical contacts close and current can flow, causing the detonator to function.

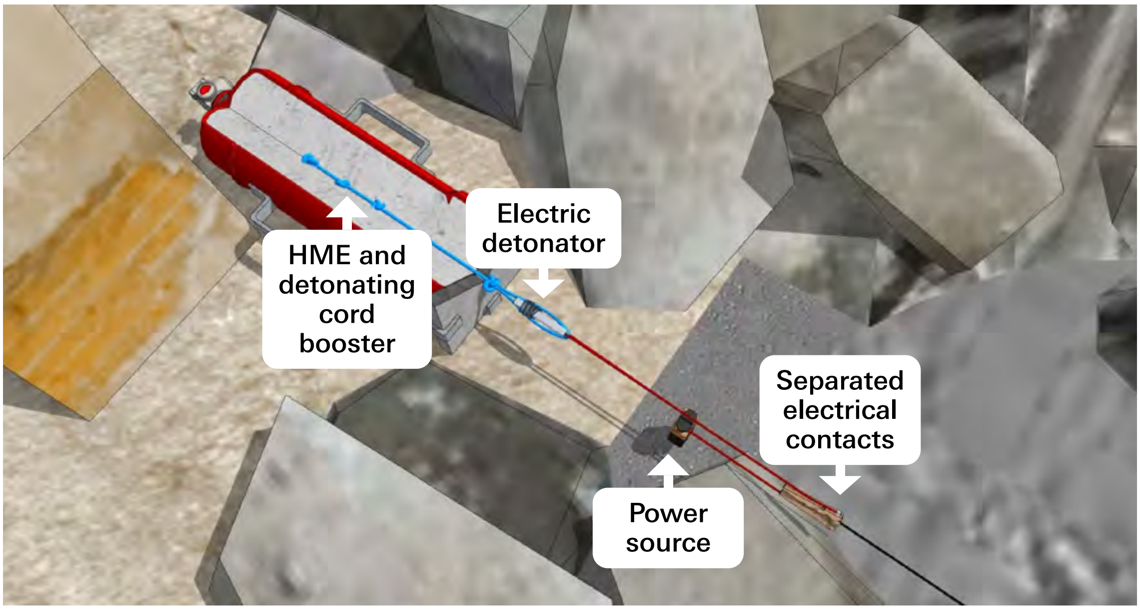


Image 9. Electrical contacts separated by an insulator in the clothes peg. When the wire is pulled the insulator is removed and the IED functions

The main charge in this example is referred to in the UNMAS IED lexicon as a platter charge. It exploits the reduced brisance of the HME, in comparison to military / commercial high explosive (HE), to its advantage. This characteristic means that the explosive power delivers a significant pushing effect.

The armed group has removed the bottom of the fire extinguisher and replaced it with a heavy steel plate. When the denotation occurs, this plate is propelled forward at a relatively high velocity. Therefore, there is a forward projection hazard associated with this main charge. Although this is not a shaped charge it does provide a stand-off capability to target lightly armoured vehicles.

2.3.1.4. TENSION RELEASE VOIED

Tension release VOIEDs incorporate a switch that is held open by tension, normally in a wire, and are similar in design to a pressure release IED.

The following example is a tension release IED protecting a former fighting position. When the target makes contact the tension is released by the wire breaking, a spring causes the switch to close and the electrical connection is complete. This example incorporates an improvised 'claymore' type main charge that is designed to produce fragmentation over a wide area to deliver maximum effect.

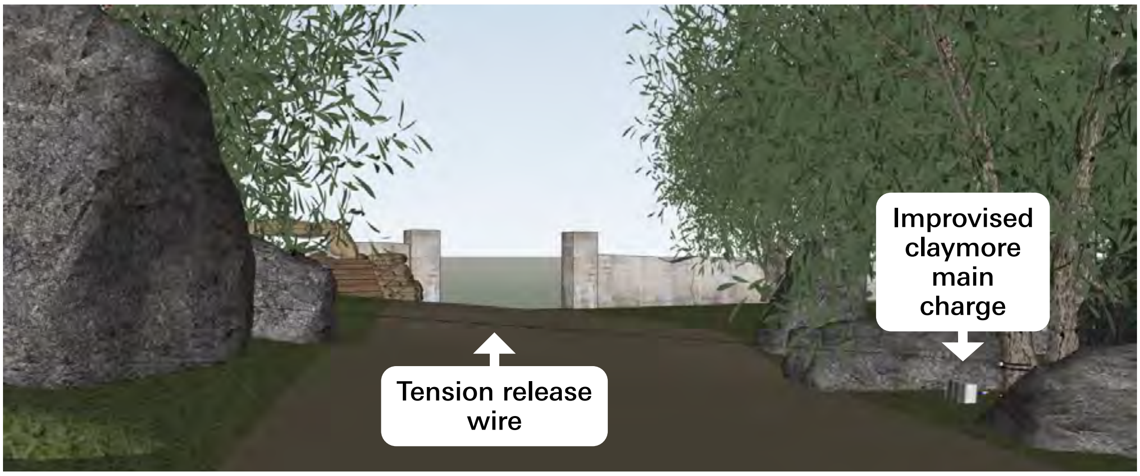


Image 10. Tension release IED positioned to protect a defensive position

The IED consists of a wire under tension running across a road, which is holding open an improvised 'rocker' switch. This switch is constructed from a plastic box with a sprung lid. When the lid is open a microswitch inside the box is in an open position and when the tension is released the lid closes which in turn closes the microswitch, completing the circuit and causing the IED to function.

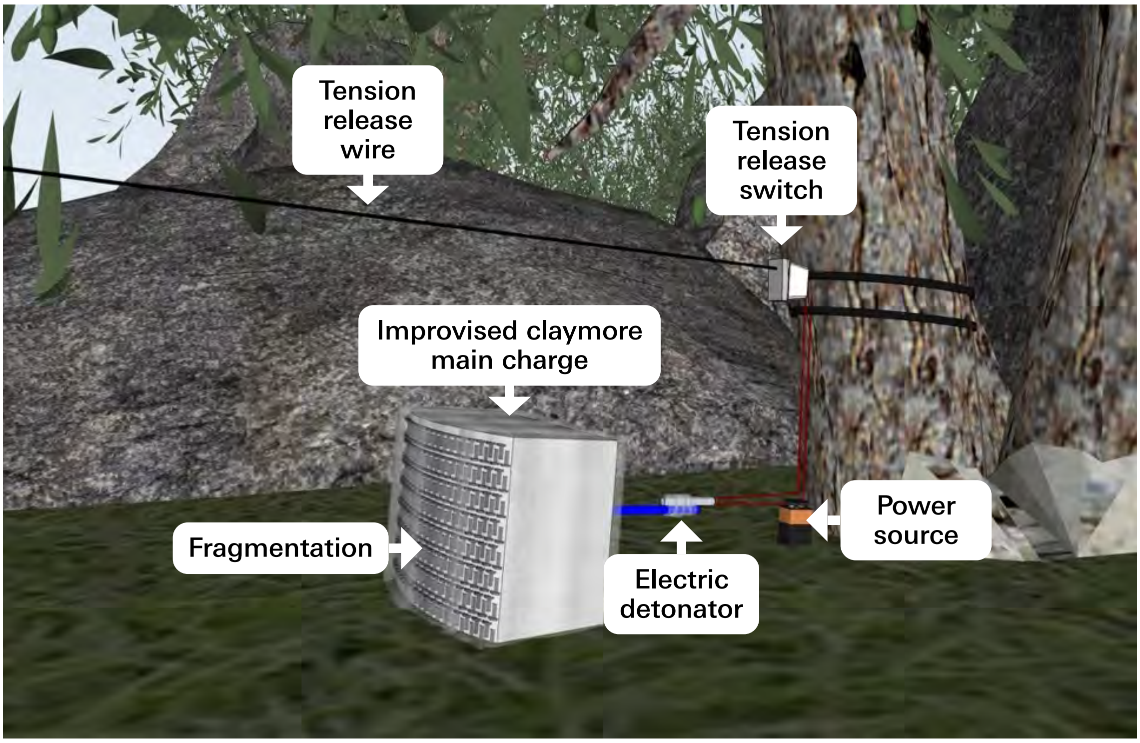


Image 11. Tension release IED components in detail

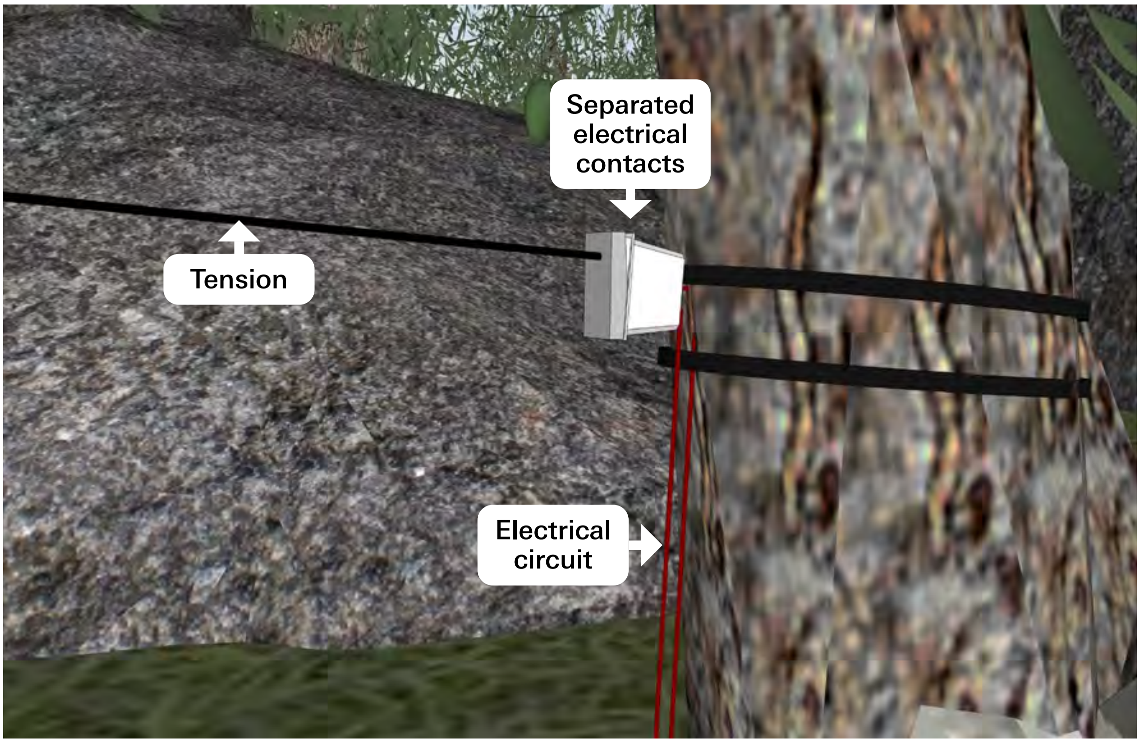


Image 12. This switch is held in position by the tension in the wire

2.3.2. INFLUENCE VOIEDs

There are many different influences that can be used to function a VOIED without the need for the victim to actually come into contact with it. These include:

- Magnetic
- Acoustic
- Seismic
- Heat
- Light

Unlike the majority of contact VOIEDs that the MA sector encounters, influence VOIEDs will normally incorporate a sensor. Most sensors, although not all, will draw electrical current flowing through part of the circuit. Once this battery has been depleted these sensors will no longer be active, however additional batteries and firing switches may still be operational.

Principle advantages:

- Can be incorporated with a means of remote arming, such as a radio controlled (RC) switch. This can combine the advantages of both a command and victim operated IED;
- Can be difficult for an opposing armed group to detect before initiating;
- Flexibility due to wide area coverage or ability to target a very precise point depending on the sensor that is used.

Principle disadvantages:

- Requires more resources and is logistically intensive due to the need for specific components;
- Requires technical training to construct and deploy;
- Generally, less 'persistent' than a contact VOIED due to a draw of current.

PASSIVE INFRARED VOIED ARMED BY RC

One of the most common influence VOIEDs, and the one that the MA sector has probably experienced the most, is the passive infrared (PIR) VOIED.

Image 13. RC armed PIR VOIED camouflaged as a rock located in rubble at a road junction

In this particular example, the PIR VOIED incorporates an RC switch as a safe-to-arm device. This means that the route can remain open to the armed group that emplaced the IED, until a target is present. Even if this target is using a jammer to protect itself from an RCIED, this device can be armed using RC prior to the jammer being effective. When the target vehicle then passes, it influences the PIR causing an output. Additional circuitry is used to step up this output to the required level in order to function the detonator.

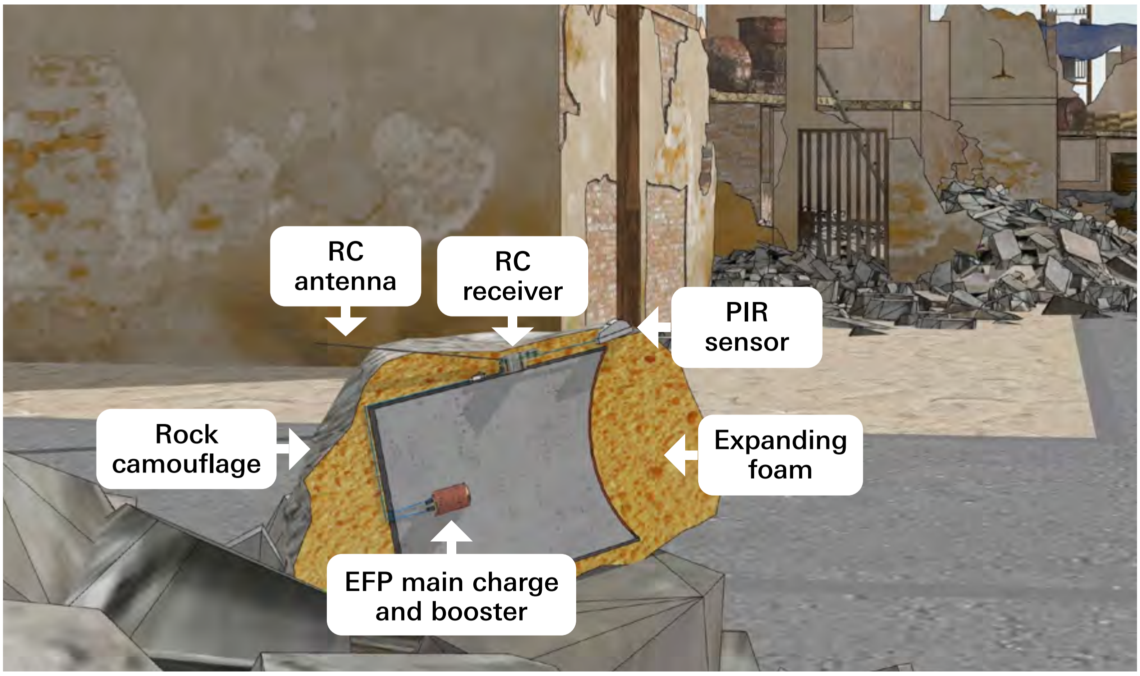


Image 14. Cross-section of an RC armed PIR VOIED

In this example all the IED components have been contained inside expanding foam, which has then been camouflaged to look like a rock, in keeping with the environment in which it has been emplaced. Only the antenna of the RC protruding from the foam and a hole for the PIR sensor are visible. The main charge in this example is an explosively formed projectile (EFP).

2.4. IEDs TARGETING DISPOSAL PROCEDURES

VOIEDs provide an advantage to an armed group seeking to deliberately target IEDD operators. By observing how IEDD tasks are completed they are able to identify patterns that provide opportunities to target certain actions. A suitable IED can then be developed in order to exploit the opportunity identified. Predominately, it is security force IEDD operators, or other personnel conducting 'self-help' disposal, that provide the majority of targetable actions. However, as the armed group that placed the VOIED does not need to be present when the disposal task is being completed for it to be effective, these types of IED can remain a threat after the conflict has ended. They are, therefore, of particular concern to MA organisations.

The following example is used to illustrate the targeting of patterns and specifically manual IEDD actions.

2.4.1. MANUALLY CUTTING DETONATING CORD

The manual cutting of detonating cord is a procedure that has historically been conducted as a form of threat mitigation in conventional mine clearance when booby traps are encountered. The aim has been to reduce the NEQ should a detonation occur. However, there are many types, colours and thicknesses of commercial and military detonating cord, as well as endless options for improvised detonating cord variants, such as surgical tubing filled with booster grade explosives. This means that there is an opportunity to replace detonating cord with another component which very closely resembles it.

The following IED is a 'come on' device intended to resemble a VOIED (crush wire) targeting a doorway. A length of blue cable, similar to a CAT5 cable commonly used to link computer hardware, has been incorporated to resemble detonating cord. A wooden dowel has been taped onto the end of the cable to resemble a detonator.

More CAT5 detonating cord than 'normal' has been left protruding from the main charge, making for an attractive component for an IEDD operator to target.

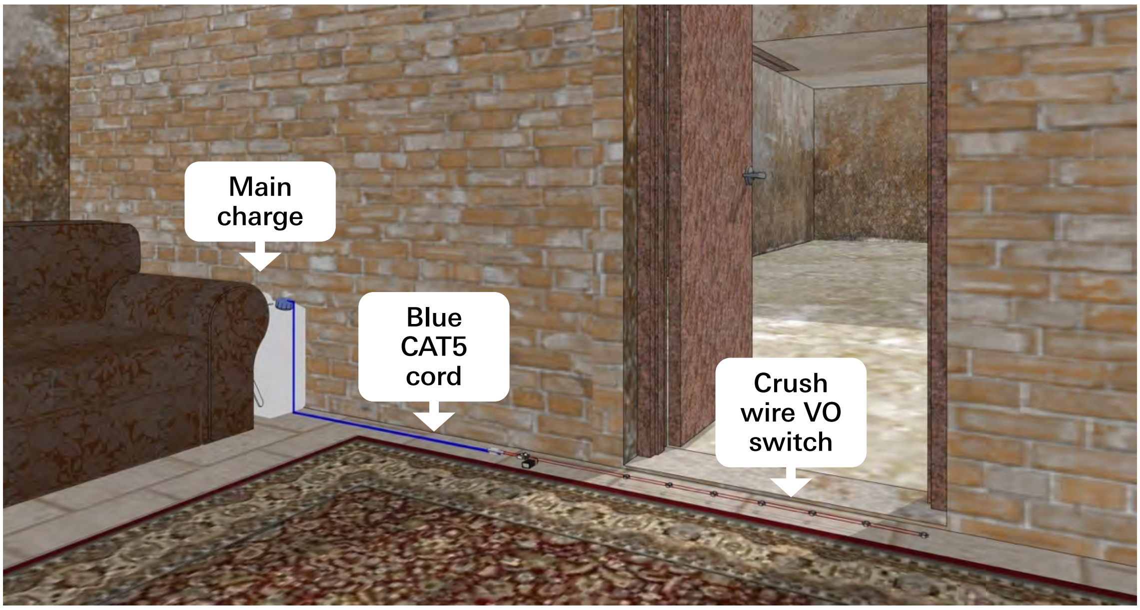


Image 1. Obvious 'come on' IED placed in a doorway, with blue CAT5 cord resembling detonating cord

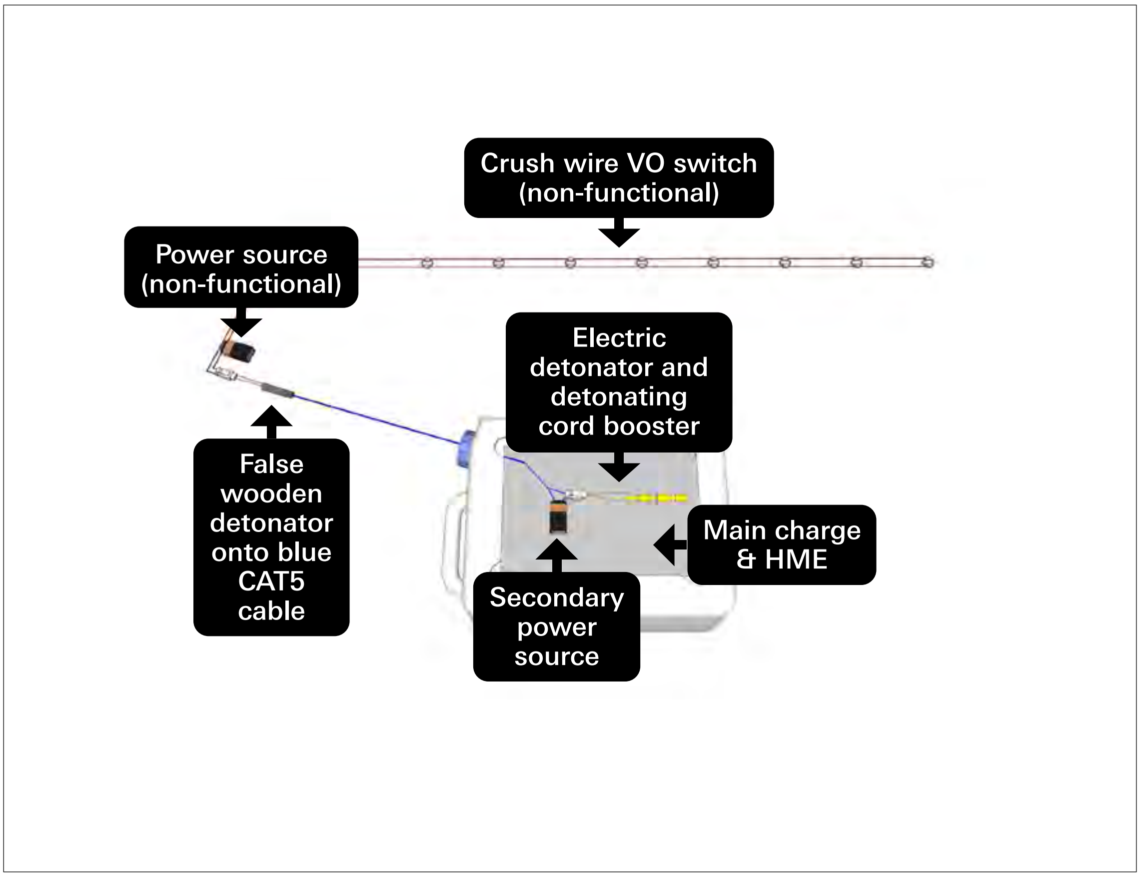


Image 2. 'Come-on' IED in detail

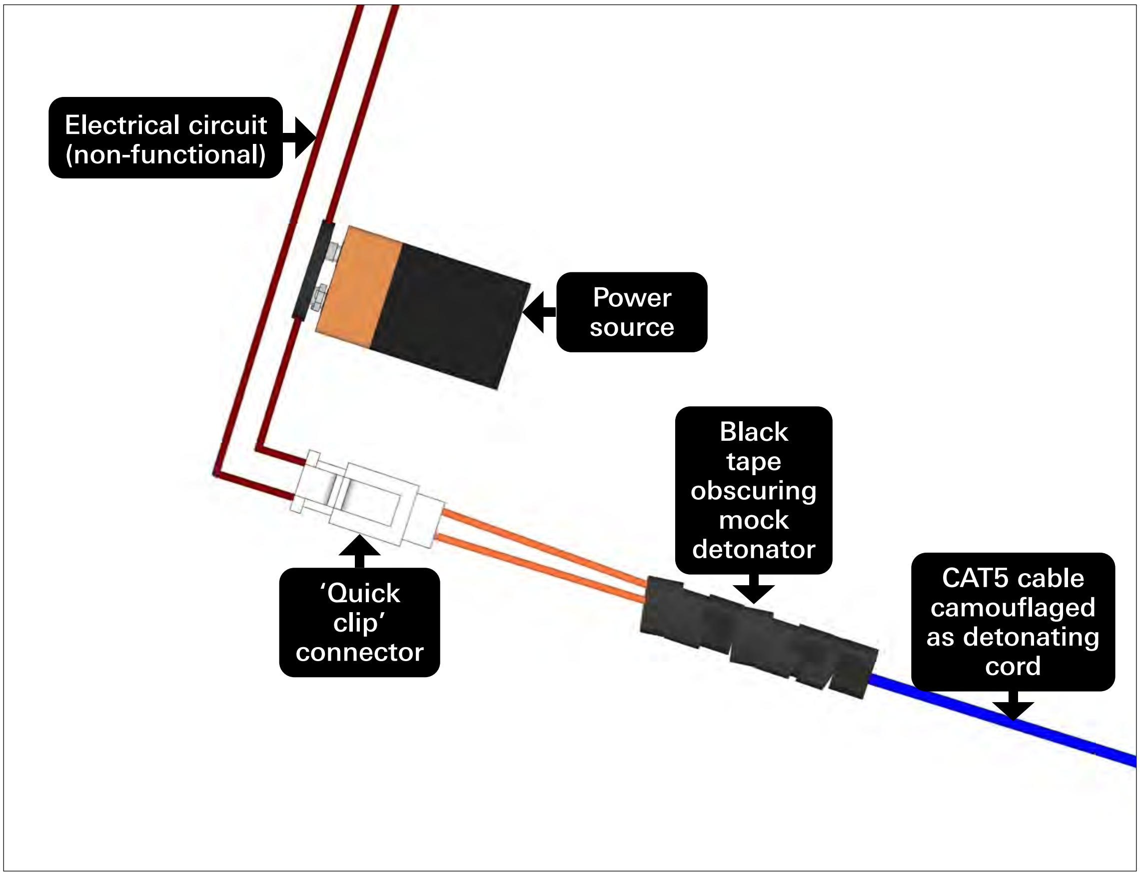


Image 3. Image showing the false wooden detonator completely covered in black tape

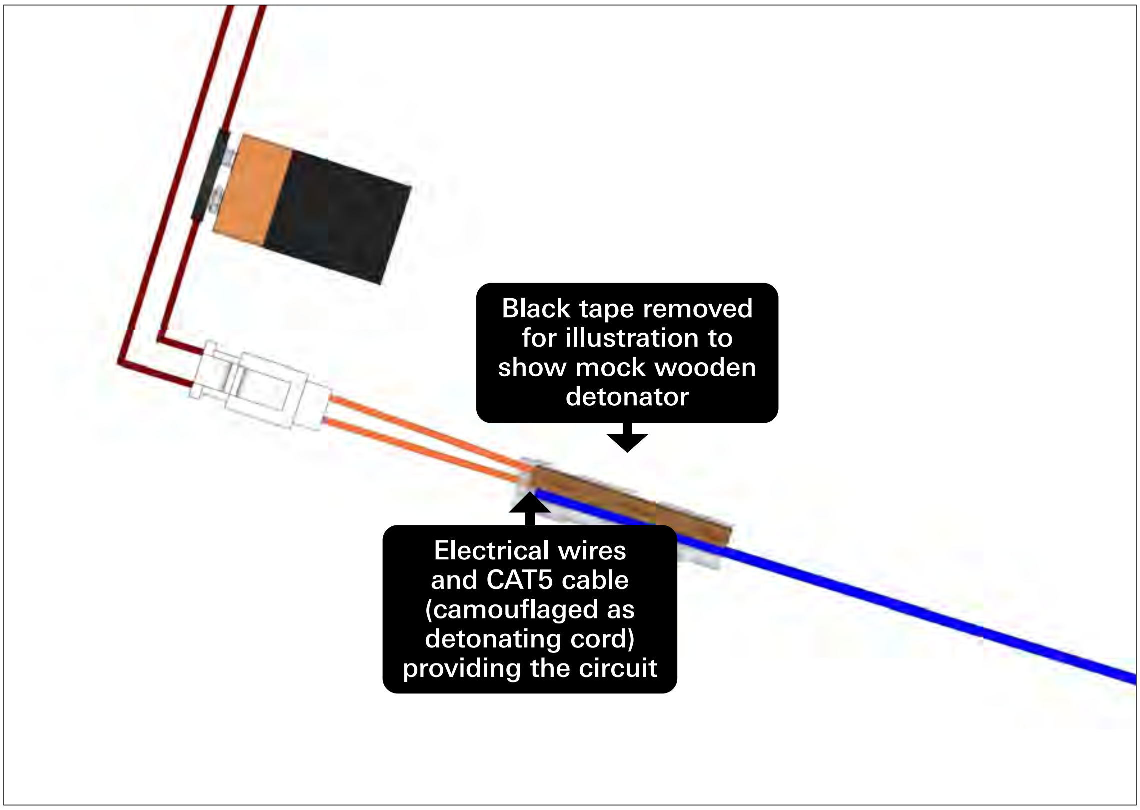


Image 4. A fake detonator attached to blue cable rather than detonating cord

This blue CAT5 cable contains a number of insulated electrical wires, two of which have been selected and incorporated into the IED's circuit. If the blue cable is manually cut using a metal tool, such as wire snips, then the tool itself makes the connection between the two wires, functioning the IED.

> **WARNING. Even a non-metal tool would likely cause a connection by crushing strands of wire together during the cutting process.**

2.5. PERSON BORNE SUICIDE IEDs

The use of person borne suicide IEDs has become a regular occurrence in some modern conflicts. As with all suicide devices they provide an armed group with an instrument of warfare that can move, think and respond to the immediate situation in order to ensure maximum impact by initiating it at the optimum moment and location.

Person borne suicide IEDs can be used in either a covert manner, well concealed in order to evade detection and to gain access to high-profile targets or events, or more overtly as a standard item of issued weaponry in order to provide a final method of attack or to prevent the capture of the person wearing it.

The majority of these types of IED are initiated by the person that is carrying or wearing the device, and these fall inside the command category of IEDs. However, suicide IEDs can also incorporate time, secondary command (such as RC which is often used as a backup), and victim operated anti-removal firing switches.

WARNING. Just because one firing switch can be identified does not mean that secondary switches are not present. An MA IEDD operator must conduct a thorough threat assessment and take all necessary actions to mitigate these threats.

Principle advantages:

- Can move and think in order to react to changes;
- A psychological weapon degrading the morale of an opponent;
- Can be used as an anti-capture weapon.

Principle disadvantages:

- Requires cultural and religious acceptance;
- Requires fighters that are prepared to use this tactic;
- Relatively small main charges – up to backpack size.

In the following example the fighter from a non-state armed group (NSAG) is wearing an overt suicide belt containing approximately 4 kg of military grade explosive. Red detonating cord has been used as a booster which is connected directly to a military grenade type fuze. This mechanical fuze incorporates a cocked striker in conjunction with a stab sensitive detonator. When the pin is pulled the striker moves forward, impinging on the detonator, causing the IED to function.

Image 1. Image of a suicide belt initiated by a MUV (Universal Mine Fuze) type fuze

This suicide IED is deliberately intended to be overtly visible by leaving the detonating cord and switch visible. This may indicate that it was planned to be used in a final violent act and to prevent the wearer from being captured, rather than to be used in an overt attack.

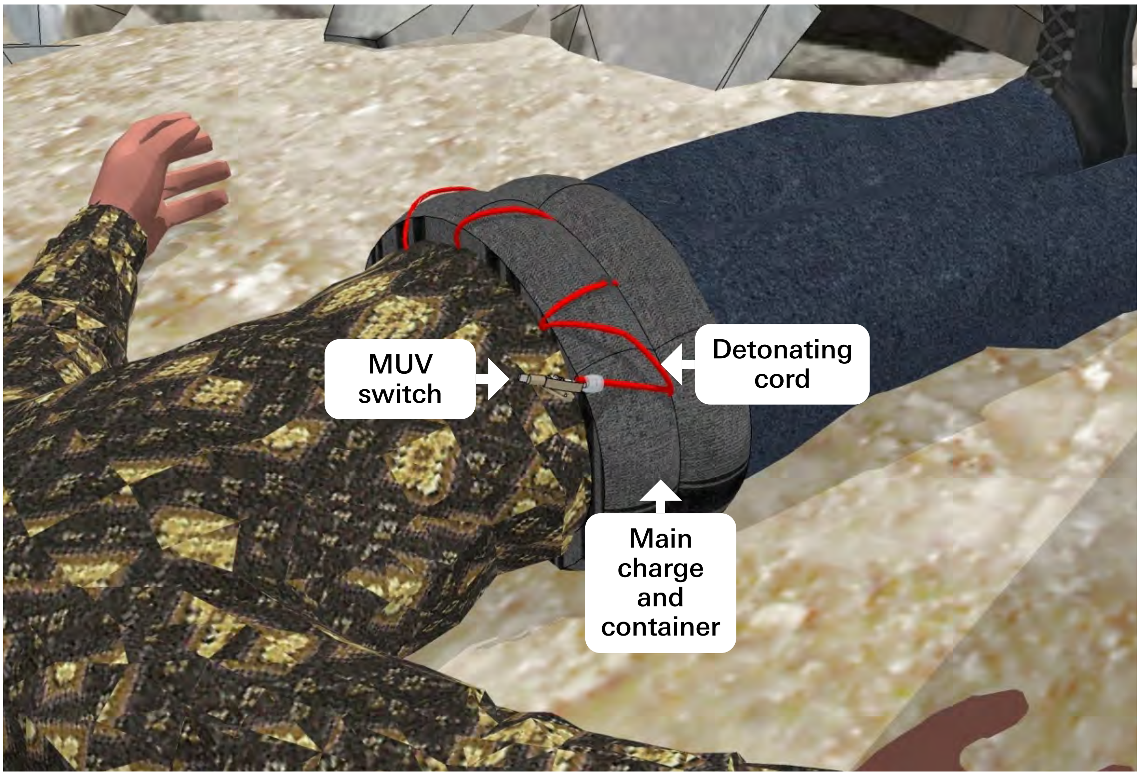


Image 2. Image of the MUV type fuze connected directly to a suicide belt

2.6. PROJECTED IEDs

WARNING. Chapter 3, Section 3 provides guidance on the cordon and evacuation of tasks involving projected IEDs that have been prepared for firing and then abandoned.

Since their conception, projected IEDs have spread and evolved into many forms and have been utilised by most NSAGs. They are coveted as they give the ability to remotely deliver an explosive payload to the target. This could be to achieve an effect from an extended range, or to project a warhead so it detonates on the target for optimum effect. They may incorporate military stores, such as the 107 mm rocket motor, or they may be completely bespoke.

NOTE. Projected IEDs refer to IEDs which project an explosive device, not an IED with a projection hazard such as a directional fragmentation charge. Although both do have a projection hazard, they are distinct from each other.

Projected IEDs have been used in both indirect and direct roles. The following table lists some of the attributes for using projected IEDs in these roles and which type of target they are most suited to.

INDIRECT		DIRECT	
ATTRIBUTES	TYPE OF TARGET	ATTRIBUTES	TYPE OF TARGET
Good for extended range.	Good for attacking large stationary targets like security force bases.	More accurate.	Good for using off route against moving targets.
Can pass over the top of physical barriers.		Less flight time.	
Not as accurate.		Shorter range.	

2.6.1. MEANS OF INITIATION

Usually, projected IEDs are initiated either by 'time' or 'command', enabling the armed group to capitalise on the advantages[1] of these methods of initiation. Although rarely encountered, projected IEDs could be initiated by a victim operated switch, especially in a 'direct fire' type role to target vehicles.

2.6.2. PROJECTILES AND FUZING

A large variety of projectiles and fuzes have been seen with projected IEDs. This clearly reflects how NSAGs will use what is readily available. The projectile can be completely bespoke, including improvised fuzes, or can incorporate pieces of military ordnance in an improvised way. It can even be a combination of them both. Projected IEDs have a wide range of NEQ, from very small all the way up to several hundred kilogrammes.

The fuzing system itself can be improvised or may utilise a military store. Projected IEDs may function on impact, following a delay after impact, or may even function following a delay after firing in order to achieve an airburst. Due to their improvised nature, they are even more prone to failure, or blinds, than conventional ordnance. To combat this, many NSAGs routinely incorporate more than one fuze.

1 See time IEDs and command IEDs in this section for their respective advantages.

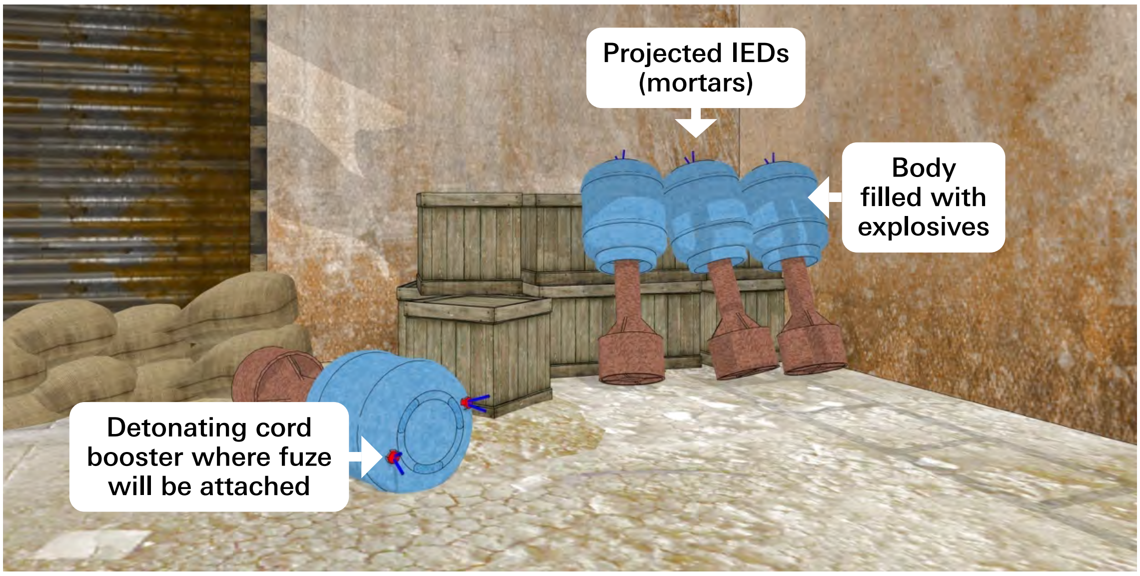


Image 1. Four projected IEDs abandoned prior to use. Note how readily-available gas cylinders have been used to make the body for the explosive fill, each capable of holding 20 to 30 kg of HME. Two fuzes have been utilised to reduce the possibility of a blind.

2.6.3. METHODS OF DEPLOYMENT

Projected IEDs can be launched in a variety of ways. In their simplest form they can be fired from a sloped piece of ground like the bank of a ditch. Clearly this can only be achieved by a rocket and not something which requires a tube, etc. A ground-based system can be used, either completely fabricated or incorporating parts of a military launch system. They can also be mounted on a vehicle giving the armed group the ability to move the system to the desired location.

Projected IEDs can be deployed singularly or in multiples up to a reasonable number. They may be deployed covertly to hide their presence until the point of firing, or overtly if there is no requirement to disguise their location from the local population. It depends on the armed group's intent, capability and opportunity.

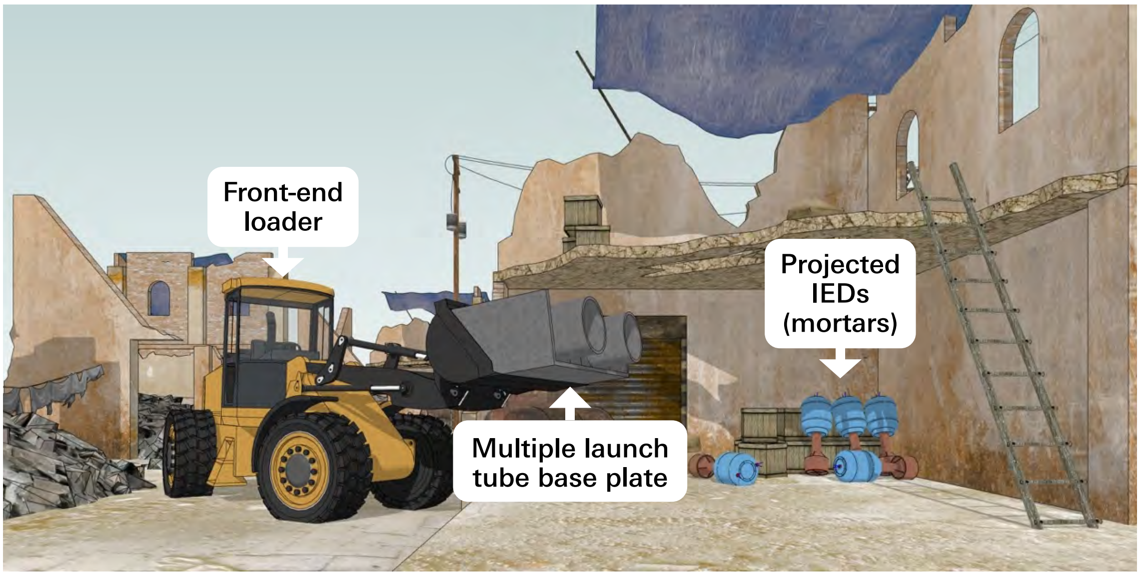


Image 2. Improvised launch system mounted on a front-end loader. This allows the aim to be easily changed and also allows for the system to be readily moved. The launch system consists of multiple launch tubes.

The following images are of a scenario that incorporates an improvised rocket and timer.

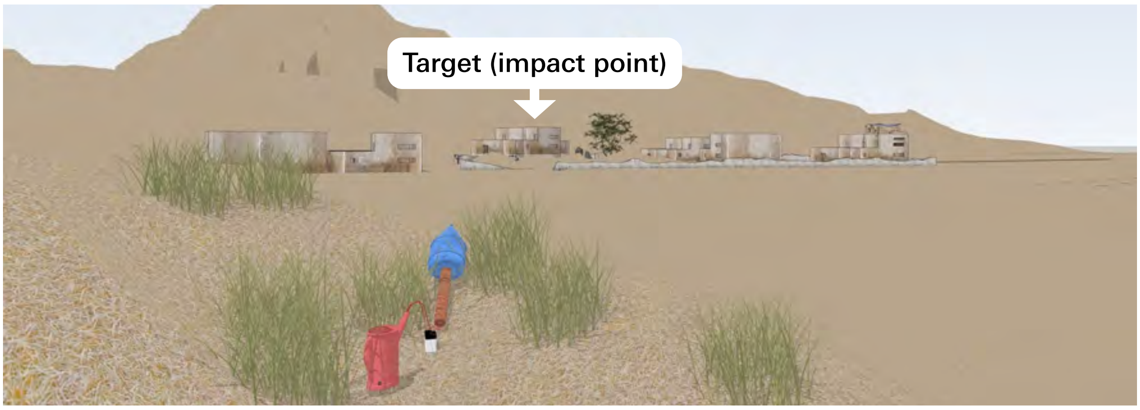


Image 3. Improvised rocket and timer seemingly abandoned facing its intended target

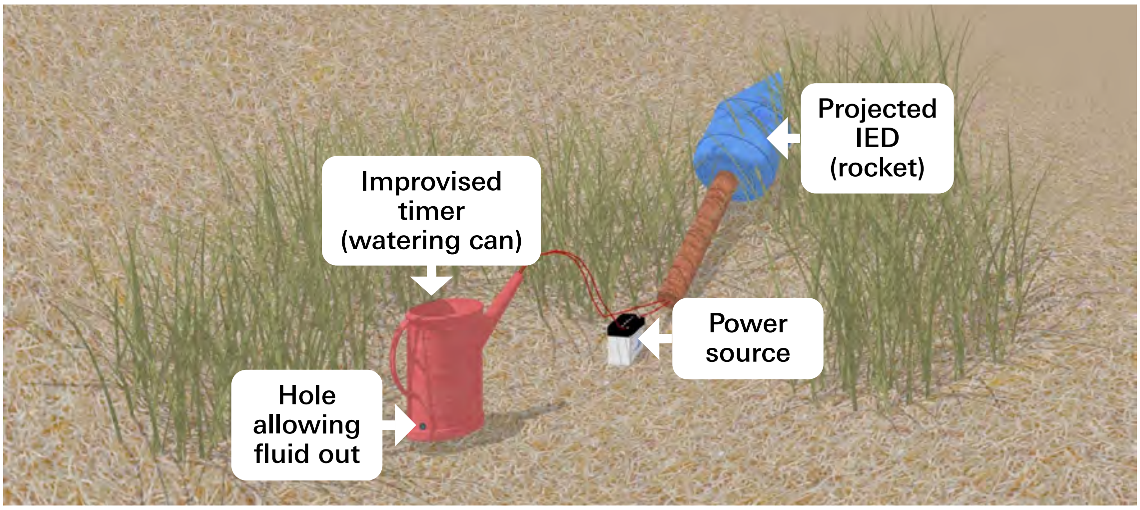


Image 4. Improvised rocket and timer

The timer has been built from a watering can containing liquid. The electrical circuit is broken with one connector floating on top of the liquid and the second connector at the base of the can. A hole is made near the base of the can to let the liquid flow out creating a time delay before the connectors meet, completing the electrical circuit and firing the rocket.

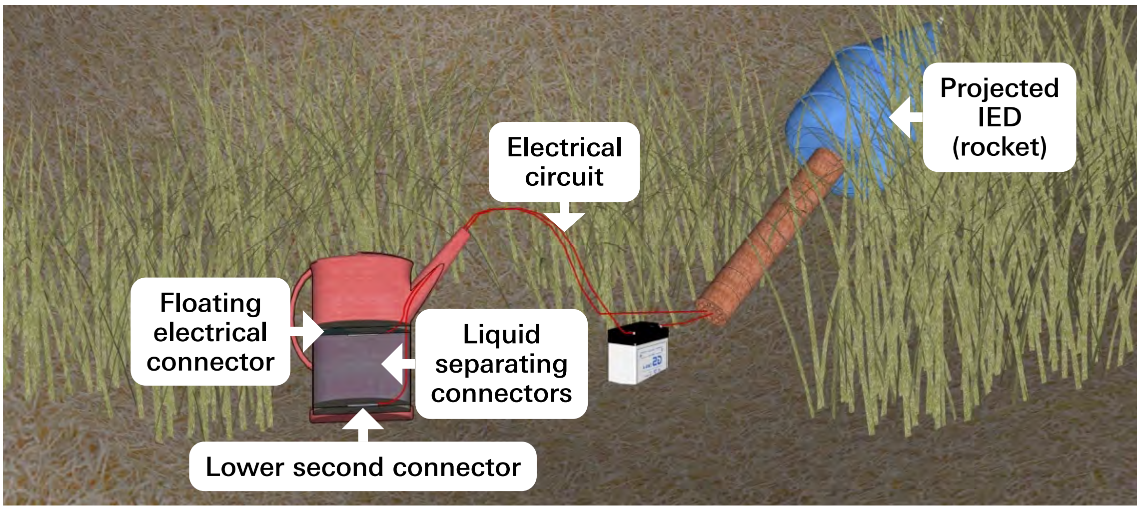


Image 5. Image showing the detail of the projected IED improvised timer

2.6.4. OTHER CONSIDERATIONS

Incidents incorporating projected devices present significant challenges. MA IEDD operators should not be involved in an ongoing active situation. However, given their popularity it is likely that MA organisations will encounter abandoned projected IEDs. Where a projected IED is discovered, MA operators should consider the possibility of further IEDs still in the launch system, blinds on the flight path and blinds in the impact area. This will be entirely situation specific and may not be relevant. The range of these systems varies significantly (up to several kilometres), this by itself can make a projected IED task extremely difficult.

WARNING. It is a common NSAG tactic to place further VOIEDs or AP mines at a launch site to protect the projected IED and / or target security force personnel.

2.7. VEHICLE BORNE IEDs

Vehicle borne IEDs[2] (VBIEDs) first became prevalent in the conflict in Northern Ireland during the 1970s. Armed groups recognised the significant advantages that a mobile container, that is common in everyday use and can transport large IEDs, provided as a weapons system. Over the following 50 years VBIEDs have become prolific in many conflicts, especially those involving NSAGs.

MA organisations may encounter abandoned VBIEDs that have failed to function, were not deployed or were under construction. It is therefore important that MA staff involved in IEDD operations know the types of VBIEDs that may be encountered. This sub-section is not exhaustive but provides some common examples.

WARNING. VBIED disposal can be a complex task and only those MA staff that have the competencies stipulated in IMAS 09.31, and / or relevant NMAS, should be involved in such tasks.

2.7.1. ARMOURED VBIED

Several NSAGs have used armoured VBIEDs. These are normally suicide devices and used as an offensive weapon against high profile targets such as security force bases and checkpoints. Normally, standard civilian vehicles are adapted, with the armour attached locally, although on occasion military armoured vehicles have been used.

Image 1. Large armoured VBIED

In this example a civilian lorry has been modified specifically to attack a well-defended position. The cab of the vehicle has been armoured with sheet metal to afford some protection from small arms and light weapons (SALW) fire.

Generally, VBIED sizes are classed as the following:

NAME OR ABBREVIATION	VEHICLE TYPE
VBIED	Standard size car
Large VBIED (LVBIED)	Van or large goods vehicle (LGV)

2 UNMAS defines a VBIED as "An IED delivered by or concealed in a ground-based vehicle."

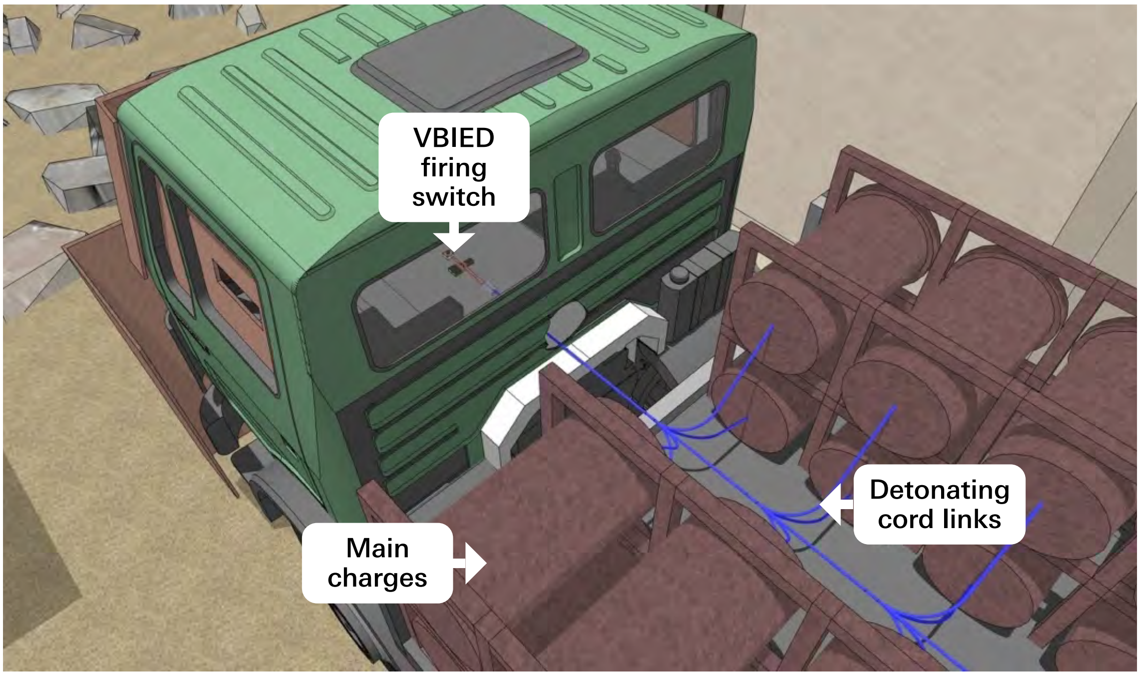


Image 2. Multiple main charges carried in the cargo area of a large armoured VBIED

Multiple main charges have been placed into a purpose-made frame. These have been linked together with blue detonating cord so that they will function simultaneously.

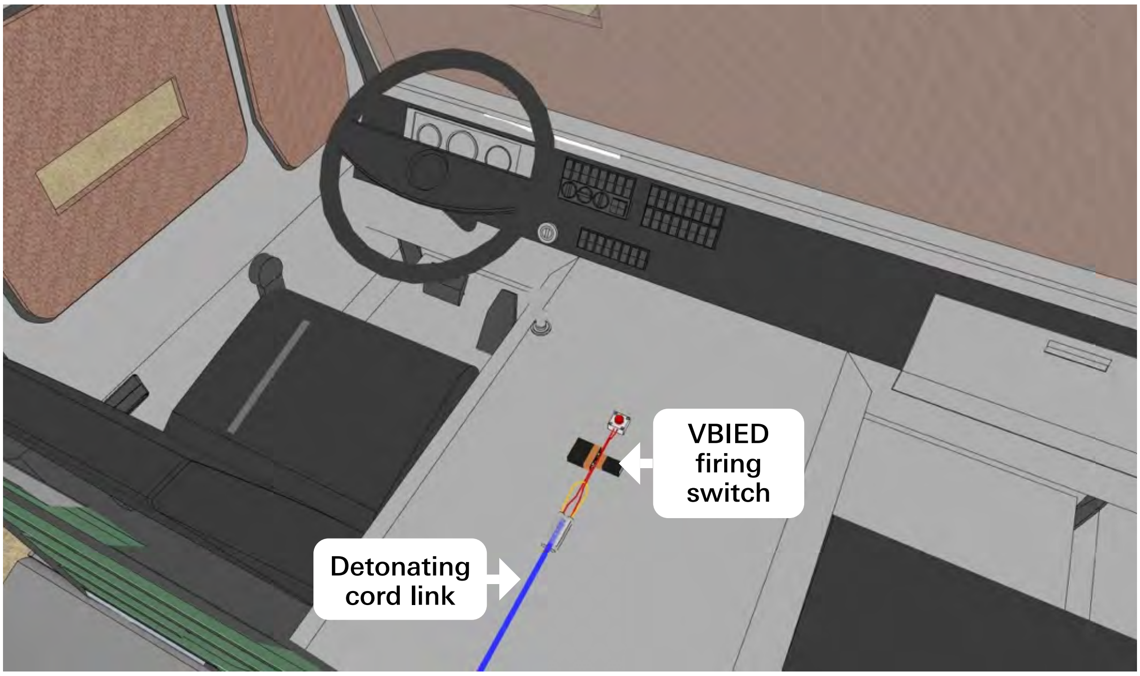


Image 3. Inside the cab of a large armoured VBIED

The detonating cord leads into the cab and will be initiated by the driver at the optimum moment.

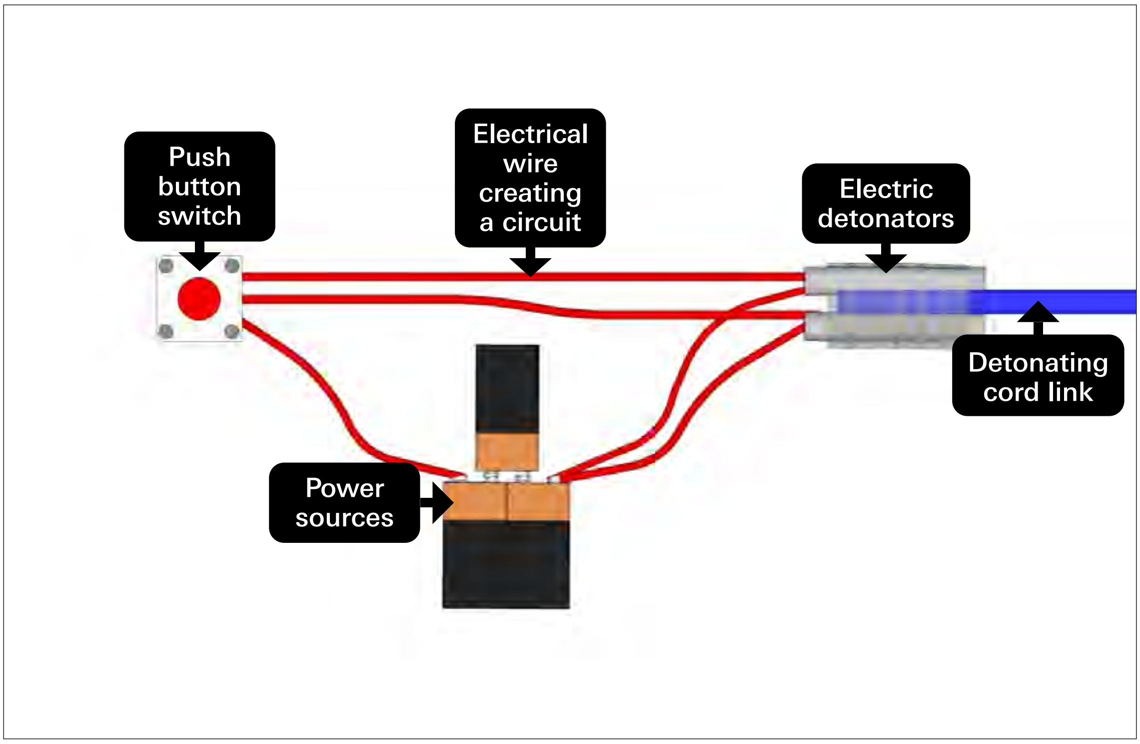


Image 4. Image showing the IED's detonators wired in parallel. This adds redundancy to the circuit

In this example the firing switch is a push button connected to two detonators wired in parallel and a power source of three 9V batteries in series, providing 27 volts. Having the detonators in parallel provides redundancy as, should one not function, then it is still possible for the other to initiate the IED.

Further redundancy would be provided if this VBIED contained additional firing circuits with their own integral firing switches and power sources. The following could be incorporated so that if the driver was incapacitated then the VBIED would still function:

- Time switch.
- RC switch.
- Bump switch – built into the front of the vehicle. This would operate like a horizontal pressure plate and should the VBIED be driven into the target it would function on contact.

A large armoured VBIED requires a lot of resources to construct. Considering this, it is reasonable to expect that armed groups would incorporate some form of redundancy in a large VBIED to ensure it functions successfully.

2.7.2. RC VBIED

VBIEDs are not solely suicide IEDs; they can be utilised with other means of initiation. For example, they can be parked and abandoned at a specific location to be initiated remotely by RC (or other command initiation) or time. If this is the case the vehicle is likely to be 'covert' in the sense that it would not be immediately identifiable as a VBIED.

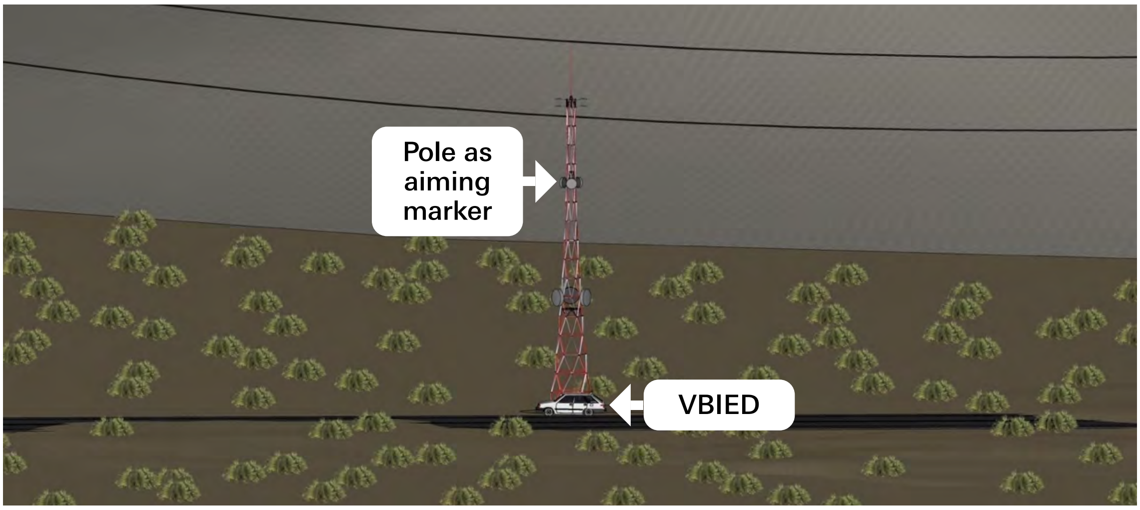


Image 5. RC initiated VBIED positioned adjacent to an aiming marker

In this example a VBIED has been placed adjacent to an aiming marker at a choke point on a main route. The lines of sight into the area are good and the IED is initiated by RC. This location would have been predetermined by the armed group based on it offering an opportunity for them to mount an attack, with the RCIED offering the best capability.

The vehicle enables the armed group to drive an IED with a large blast main charge into position quickly. As it is an RCIED there is no physical link between the firing point and the contact point, meaning that the armed group is not restricted to a single firing point and is therefore less vulnerable for being identified.

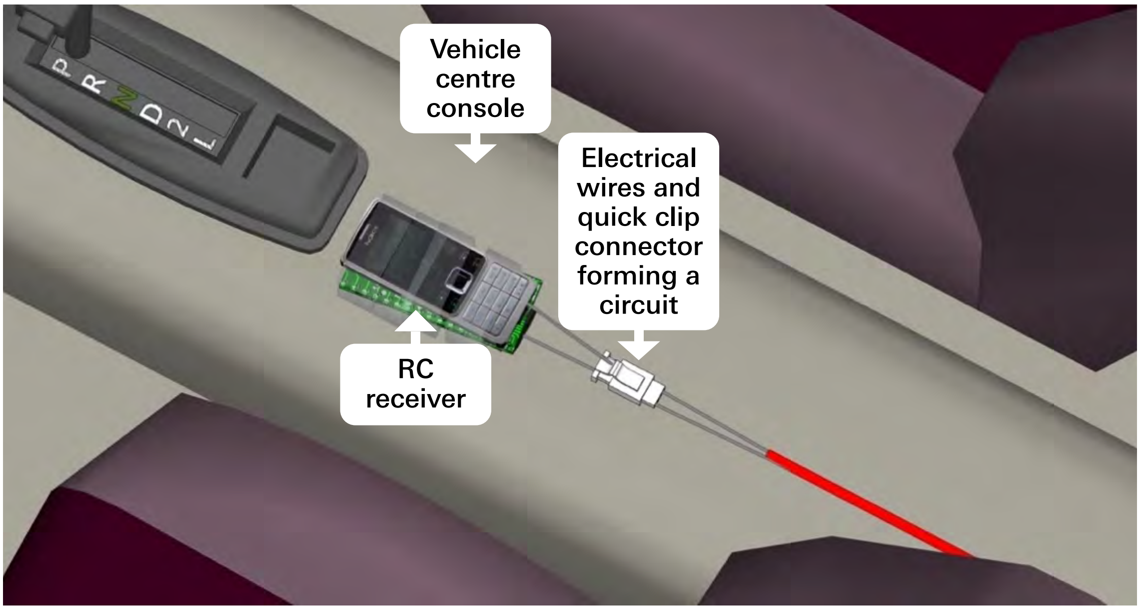


Image 6. Image in detail of the receiver in the VBIED in images 5 and 7 consisting of a mobile phone with add-on circuit and battery

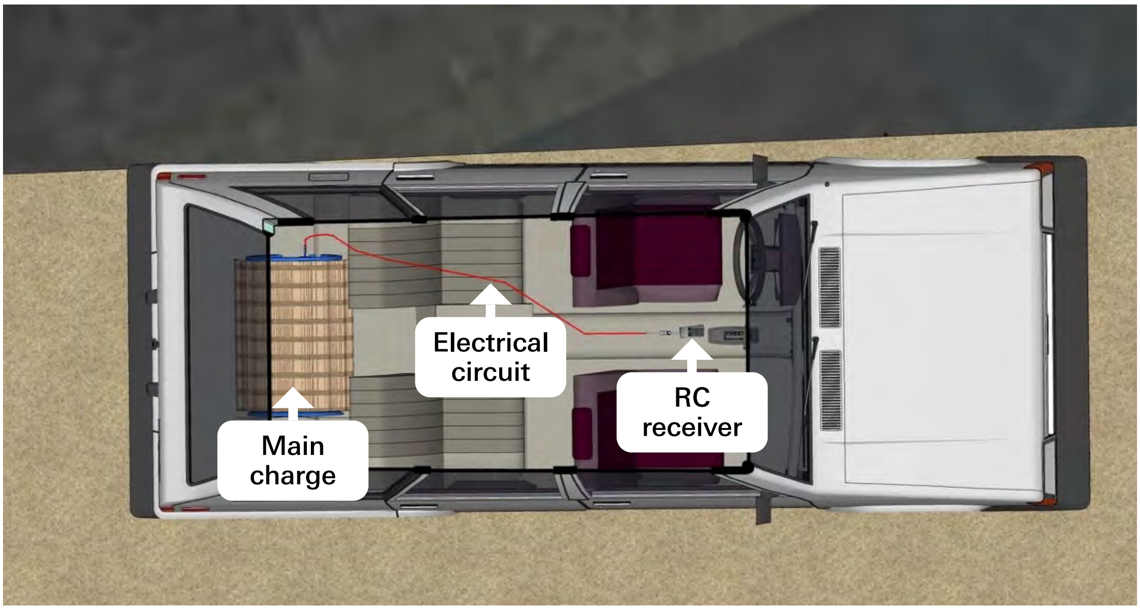


Image 7. Layout of the RC VBIED with the receiver located in the centre console

In this example the receiver is located in the centre console of the vehicle, with a concealed electrical link running under the rear passenger seats and into the trunk.

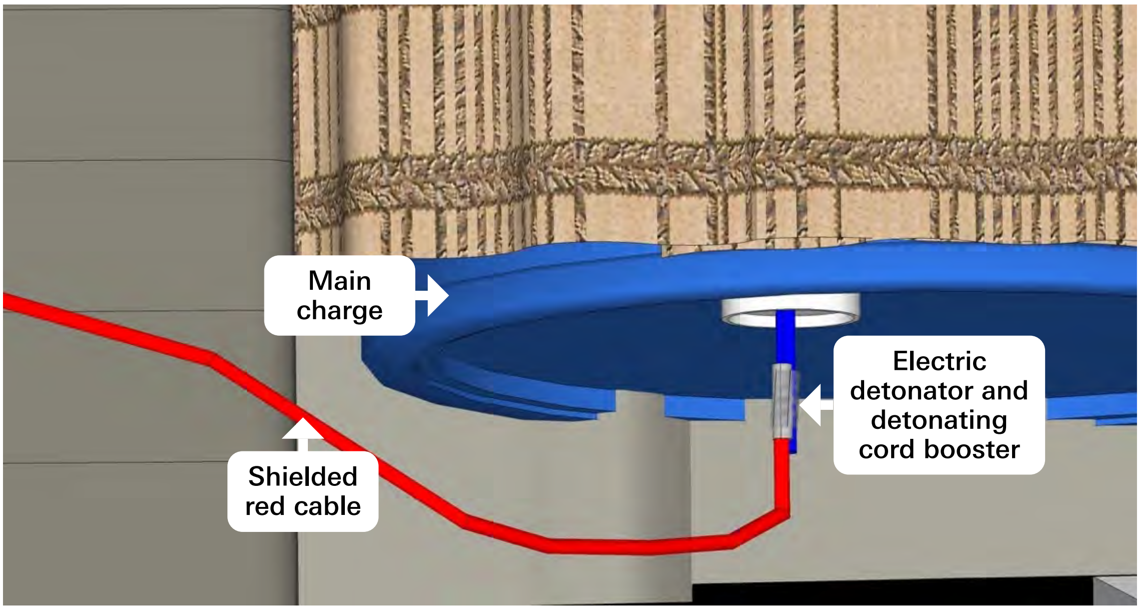


Image 8. Shielded red cable containing two electrical wires attached to a detonator

A shielded cable is used as the electrical link. This contains five independent wires, two of which are connected to the IED's detonator. This in turn is attached to the blue detonating cord booster that enters the main charge through the white cap.

HINT. This main charge could contain several hundred kilogrammes of HME and a possible indicator could be that the vehicle is heavily weighed down at the rear.

2.7.3. COVERT SUICIDE VBIED

Suicide IEDs can also be covert. This enables them to pass undetected in order to reach the intended target. In this example a suicide VBIED has been abandoned after an air strike on the adjacent building killed the NSAG personnel that were planning to use it.

Image 9. Abandoned VBIED in post-conflict context

In order for the vehicle to not appear overly weighed down at the rear the main charges have been distributed throughout the car. These would then have been covered by sheets or the trunk's parcel shelf.

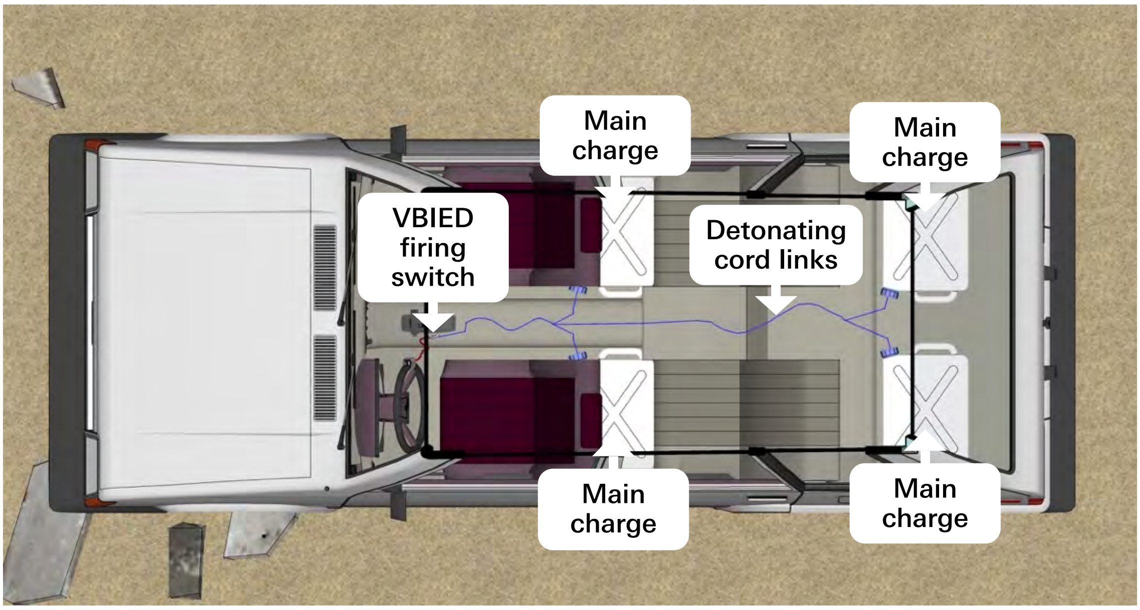


Image 10. Image of the VBIED in detail showing main charges distributed throughout the vehicle

In this example the four plastic main charges, each containing approximately 25 kg of HME, are connected together by blue detonating cord.

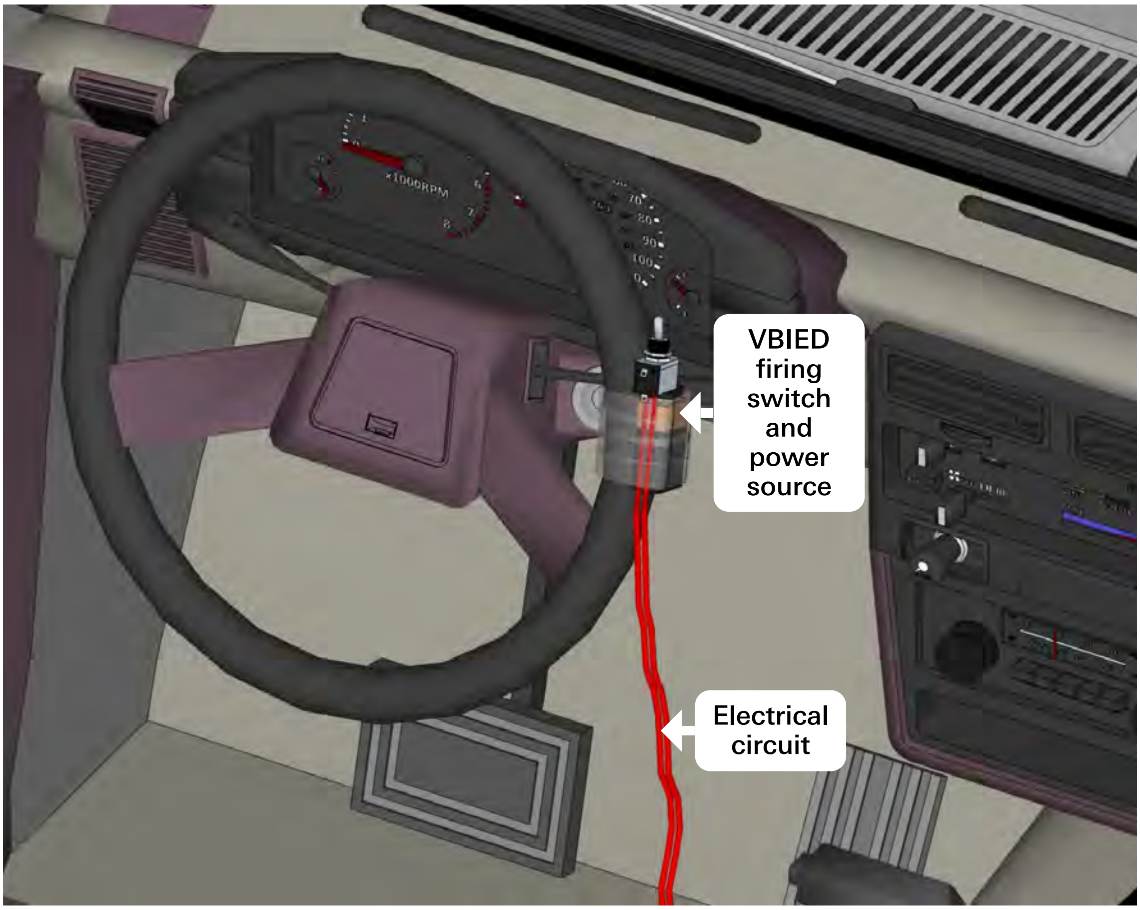


Image 11. Image of VBIED firing switch attached to the steering wheel

The firing switch is also likely to be easily accessible to the driver. In this example a single toggle switch is co-located with a 9V battery and attached to the steering wheel by adhesive tape. Two red electrical wires are in turn connected to the IED's detonator.

3. IEDD TASK CONDUCT

3.1. TASK CONDUCT AND PHASES

IMAS 09.31 Improvised Explosive Device Disposal defines the generic phases of an MA IEDD task as:

- **Phase 1 -** Arrival and initial questioning.
- **Phase 2 -** Detailed questioning and threat assessment.
- **Phase 3 -** Evaluation and planning.
- **Phase 4 -** Task execution.
- **Phase 5 -** Final disposal and reporting.

This section will go into each of these phases in more detail.

3.1.1. PHASE 1 – ARRIVAL AND INITIAL QUESTIONING

Whether an integral component of an MA clearance operation, or arriving independently at a task site, an IEDD operator should perform initial questioning. If arriving independently the IEDD operator will need to establish who is best placed to answer initial questions. This is likely to include the task site manager, team leader or individual searcher / deminer. If the IEDD operator is integrated into the clearance operation, then some of the information may be known to them already. However, at a minimum the searcher / deminer who located the IED should still be questioned.

The aim of the initial questioning is to quickly establish key information that enables the IEDD operator to ensure everyone's safety, including that of the IEDD team, before any further action is taken. Initial questioning ascertains the following:

WHAT?	What has been identified? Colours, materials, position and orientation.
WHERE?	Where is the suspected IED located in relation to the CP and MA staff?
CORDON AND EVACUATION	What cordon and evacuation plan has been implemented? At an MA worksite some cordon and evacuation should already be in place, but the IEDD operator should always check that it is appropriate.
OTHER HAZARDS	Is there anything which could enhance the effects of an explosion or present an additional hazard during the RSP? This may require the cordon to be adjusted and / or require assistance from other agencies. It should also include the gathering of information regarding any damage to infrastructure.
CASUALTY / MEDICAL EVACUATION PLAN	What is the casualty / medical evacuation plan? This should be confirmed by the IEDD operator.

HINT. IEDD operators should use these points to help prevent any important pieces of information being missed.

CORDON AND EVACUATION

The IEDD operator must carry out an assessment of the explosive danger that the suspected IED presents. This should include additional hazards associated with directional and projected IEDs. They must ensure that the cordon and evacuation is sufficient and the CP is sited in a safe area. Where exact information cannot be ascertained, the IEDD operator must use their judgement, erring on the side of caution.

HINT. A common mantra used is "be quick to implement a cordon and slow to reduce it".

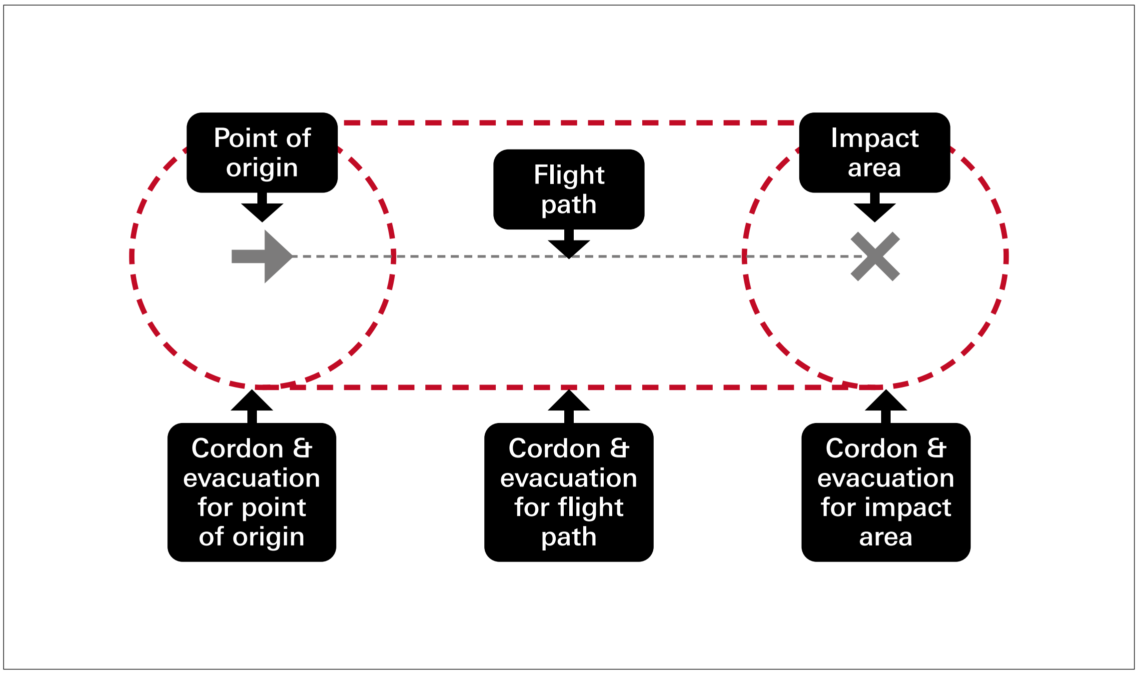
In an urban environment it can be challenging to achieve adequate cordon and evacuation. However, the safety distance can sometimes be reduced following a risk assessment that considers variables such as:

- Protective works
- Approximate NEQ
- Anticipated explosive type
- Pre-existing physical barriers

WARNING. The IEDD operator must ensure that NMAS and accredited organisational SOPs are followed when reducing the size of cordon and evacuation.

Projected IEDs have regularly been used by armed groups to deliver an effect at range. There are a variety of projected IED types and further details can be found in Section 2 of this chapter. The majority of projected IEDs encountered in MA have either been thrown or dropped in the location in which they have been found, or they have been abandoned prior to being prepared for launch. If an MA organisation identifies a projected IED that is ready for launch the priority for evacuation should be:

- Impact area
- Flight path
- Point of origin



There are no prescriptive rules for the extent to which cordon and evacuation should be increased for a projection hazard or reduced for physical barriers. The IEDD operator must use their technical judgement and training, with guidance from their managers and the NMAA. When dealing with unknowns, it can be useful to compare to a similar known item of conventional ordnance and use its performance / effects as a benchmark.

If the CP is inside the explosive danger area, which can be common, then it should be in a protected location.

WARNING. No positive IEDD action should be undertaken until appropriate cordon and evacuation is implemented and the CP is in a safe location.

3.1.2. PHASE 2 – DETAILED QUESTIONING AND THREAT ASSESSMENT

Detailed questioning, along with gathering information from other sources, is used to inform task specific threat assessments. The extent to which detailed questioning is conducted will vary between tasks depending on a number of factors, but it should never be completely skipped. The goal is to gain as much relevant information as possible to enable the most accurate task specific threat assessment to be developed as possible.

There is no template of questions which an IEDD operator can use, as every situation is different, but generally an IEDD operator should establish the following:

WHO?	Who was being targeted?
WHO?	Who placed, dropped or threw the IED(s)?
WHAT?	What type of IED is present and what is its construction?
WHERE?	Where is the IED(s) located including its individual components?
WHEN?	When was the IED placed, discovered and any other significant timings?
WHY?	Why was this type of IED being used?

A matrix is commonly used by IEDD operators to help establish the answer to some of the above points and develop a threat assessment:

	TIME	COMMAND	VICTIM OPERATED
GROUND			
DEVICE			
TARGET			
ARMED GROUP			

The matrix is comprised of four key local factors which are assessed against the three main IED categories or types. A level of likelihood can be assigned for each IED type through questioning of witnesses, application of knowledge on armed group tactics, techniques and procedures, and use of national threat analysis information. The IEDD operator works through each row and assigns a level of likelihood (high, medium or low) which is recorded in each cell.

A brief overview of the four key local factors are:

GROUND	How does the ground lend itself to a time, command or victim operated IED? For example, command would be low risk if there are no available lines of sight to where the IED is located.
DEVICE	What type of IED has been described from witnesses or seen through remote observation?
TARGET	Which type(s) of IED would the intended target be susceptible to?
ARMED GROUP	What were the armed group's capabilities in this area?

The questions will change depending on the scenario, who is being interviewed and other contextual factors, but the goal of being able to assign a level of likelihood remains the same. On completion of the matrix there will be an overriding trend for one or more of the IED threats.

HINT. Avoid leading or closed questions (e.g. "Did you see a battery?"), instead use open questions (e.g. "Can you describe what you saw in as much detail as possible?"). This approach is likely to reveal more information.

For some tasks, completing this table will be very straightforward, for others where there is only limited information, it will be more difficult. Considering the four local factors is useful because it prevents an IEDD operator from overlooking an IED threat which may be present. IEDD operators may want to incorporate additional factors specific to their area of operations.

HINT. It can often be helpful to ask the witness to sketch what they're trying to describe. This is particularly useful to show the location of an IED or its make-up.

As more information becomes available, the IEDD operator should always ask themselves "so what?" and "has the situation changed?". This will invariably lead to further questions, building up more and more information for the threat assessment.

Further guidance on threat assessment can be found at IMAS 07.14 Risk Management in Mine Action, Annex C Threat Analysis.

3.1.3. PHASE 3 – EVALUATION AND PLANNING

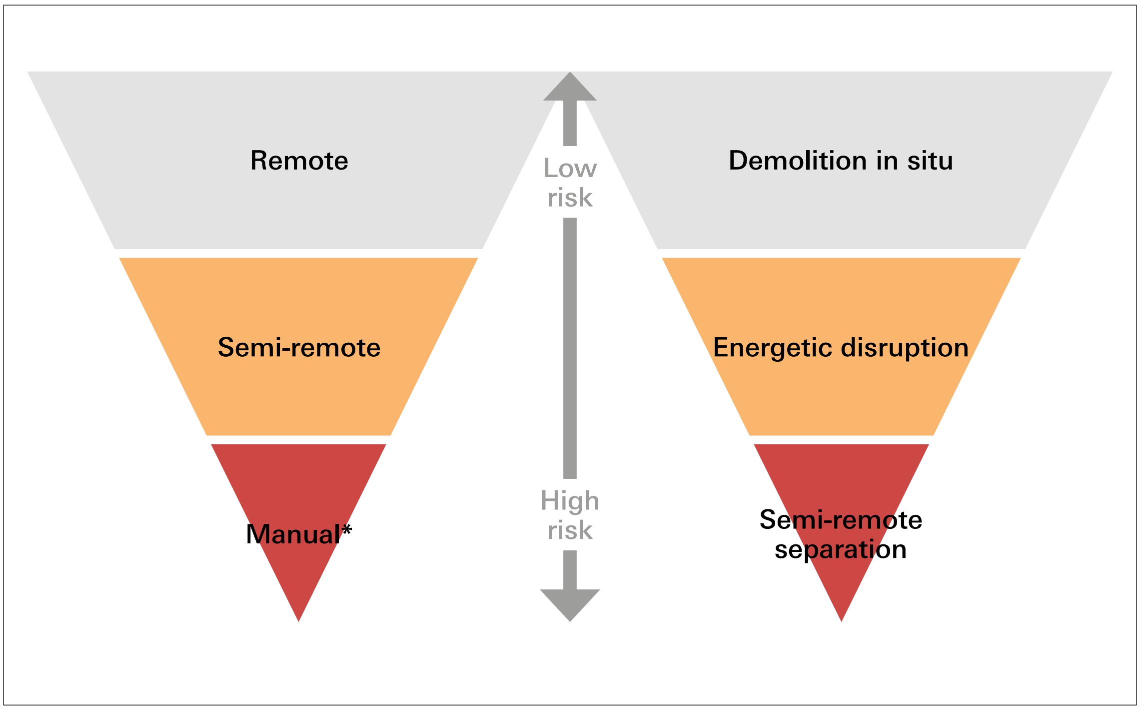
EVALUATION

Evaluation is a continuation of the threat assessment conducted in Phase 2. While not all information may be known, the IEDD operator can make an assessment on the 'most likely' situation, but importantly they must make an assessment on the 'worst case' situation and the potential 'best case' situation as well. IMAS 09.31 for IEDD, Chapter 6.3 defines what the evaluation should include:

KEY CONSIDERATIONS	EXPLANATION
METHOD OF INITIATION (TIME, COMMAND, VICTIM OPERATED).	This is arguably the most important piece of information to be derived from the threat assessment. By correctly identifying the method of initiation the IEDD operator puts themselves in a strong position to safely dispose of the IED. **WARNING. Consideration should be given to the risk of more than one method of initiation being present.**
THE LAYOUT AND POSITION OF COMPONENT PARTS.	By evaluating this correctly the IEDD operator knows the position of the components they want to target and, importantly, the location of items they want to avoid (e.g. the firing switch in the case of VOIEDs). It may also enable the IEDD operator to add a degree of safety by taking positive action from a safer location or a more accessible position (e.g. semi-remotely cutting a command wire far away from the main charge).
TYPE(S) OF SWITCH(ES).	This is particularly important with VOIEDs as different switches have different capabilities and means of detection. It ensures that the correct detection equipment and procedures are being used for the threat that is being faced.
TYPE(S) OF MAIN CHARGE(S) INCLUDING NEQ AND FRAGMENTATION HAZARD.	It is extremely important, in order to ensure public safety, that the IEDD operator has implemented sufficient cordon and evacuation for the size(s) of main charge(s) and additional hazards, such as fragmentation or projection. Where the exact size is not known the operator should assume the worst case.
NUMBER AND TYPE OF INITIATORS (DETONATORS) AND, IF POSSIBLE, THE TYPE AND COLOUR OF ELECTRICAL LEADS.	Removing all the initiators is part of the disposal process. Multiple initiators could mean the armed group is incorporating redundancy or that multiple switches are present on independent circuits. Improvised initiators can be extremely sensitive and may have plastic bodies which will not be detected with a metal detector. Having an idea of the type and colour of the electrical detonator leads will give an indication of the location of the detonator(s). This is extremely useful for buried IEDs or where a detonator is sealed inside the main charge.
NUMBER, TYPE AND CONFIGURATION OF POWER SOURCES.	The power source is the primary target when trying to achieve neutralisation by disruption. This information indicates the size of metallic signature that the power source will present. This is extremely important when using detectors to locate the power source of a buried VOIED. Multiple independent power sources are likely to indicate that more than one switch is present. The power output may also indicate the armed group's intent. For example, large power sources might be used if the armed group wants the IED to be viable for longer or the IED may require more power due to the length of a command wire.

With this information it is likely the IEDD operator will identify more than one possible course of action to achieve disposal. Using the guidance of the MA IEDD philosophies, general principles and available resources, they must decide which is the most appropriate.

The following risk pyramids can be used as a guide to evaluate the suitability of possible courses of action. The course of action which can be performed by the techniques and procedures higher up the risk pyramids will generally be safer and therefore preferred.



*** This is NOT referring to manual neutralisation but actions such as separating any tape holding lengths of detonating cord together.**

PLANNING

Once the most suitable course of action has been identified a plan can be formulated. This should be done in the CP to minimise time inside the explosive danger area and to allow for a clear thought process in a safe area.

WARNING. Do not be tempted to plan whilst beside the IED as there is heightened mental stress and it is dangerous.

Plan as much of the task in advance as is feasible. If possible, this should cover the whole task from start to finish. However, there will be occasions when not all the information is known until some form of positive action has been taken, after which the plan should be reviewed and developed further, ideally back in the CP.

Breaking the execution or RSP down into phases aids in drafting the plan. Record what will be undertaken at each phase and assess what are the 'most likely' and 'worst case' outcomes. Plan for the 'most likely' but ensure there is a contingency for the 'worst case'. Noting down the plan will make it easier to review and identify any gaps. It will also make the task more efficient as the IMAS Level 2 IEDD assistant operator can prepare the equipment for the next phase in advance. It is recommended that each phase of the plan aligns with an approach, whether by remote or manual means.

Below is an example plan:

<table>
<tr><th>PHASE</th><th>ACTION CONDUCTED</th><th>MOST LIKELY OUTCOME</th><th>WORST CASE OUTCOME</th><th>EQUIPMENT</th></tr>
<tr><td>Remote 1</td><td>Disruption</td><td>Neutralisation of power source</td><td>Device detonates</td><td>ROV with loaded barrel disruptor</td></tr>
<tr><td>Remote 2</td><td>Confirm disruption</td><td>Component separation</td><td>No disruption – repeat Remote 1</td><td>None</td></tr>
<tr><td rowspan="3">Manual 1</td><td>Confirm disruption</td><td rowspan="3">Disruption successful</td><td rowspan="3">Disruption has failed – place manual disruptor</td><td>Torch
disruptor</td></tr>
<tr><td>Conduct detonator safety</td><td>Detonator safety equipment (insulation tape, scalpel, snips, detonator recovery container)</td></tr>
<tr><td>Set H&L to semi-remotely remove main charge</td><td>H&L (line, change of direction, strop, karabiner)</td></tr>
<tr><td>Continues as required…</td><td>Continues as required…</td><td>Continues as required…</td><td>Continues as required…</td><td>Continues as required…</td></tr>
</table>

HINT. Write the plan on a task site whiteboard as this will make it easier to make amendments or updates.

As the task progresses more information may become available through further questioning, remote observation or first-hand experience. There should be continual evaluation conducted throughout the task to allow this new information to be incorporated into the plan.

WARNING. Endeavor to return to using remote means wherever possible.

COMMUNICATION OF THE IEDD CLEARANCE PLAN

The IEDD operator will need to be capable of communicating the plan. The level of detail required will depend on who is being briefed. Below is guidance on what to include in briefings for different groups:

MA management staff for a referral. To deviate from an approved clearance plan, principles or mandatory actions the IEDD operator will need to make a referral to their management for permission. It is unlikely the manager will be at the worksite and the briefing will need to be given over a mobile phone or other communication device. This makes the briefing more difficult and it will need to be clear, structured, accurate and succinct. There is no set structure, although the following is a guide on how it could be done:

- Explain the scenario and situation covering all relevant points, keeping it succinct;
- State what is being requested to be deviated from with regards the approved clearance plan;
- Give the justification for the deviation.

IEDD team and medical responders. These key personnel require a thorough brief as they are intimately involved in the task and may have to respond to an emergency. The IEDD operator should brief the detail of the plan and the actions to be taken should something unexpected occur (often referred to as 'actions on'). It should also cover any other key information. At a minimum it should include:

- The location of the device, CP, medical point and sentries / cordon;
- The approach route to the device;
- 'Actions on' in the event of an unexpected explosion or accident;
- Casualty evacuation procedures from the device to CP, CP to hospital, etc;
- Outline of the planned technical RSP and approximate time required;
- Communication methods between the IEDD operator, the cordon commander / point of contact and team members;
- Details of any secondary hazards in the area (e.g. petrol stations, power lines, etc.).

After each approach the IEDD operator should ensure that the team is briefed and advised on any changes to the plan before a subsequent approach is attempted.

Sentries and other supporting personnel / agencies. These personnel require an overview of the plan, not the detail. They must be briefed on their role and responsibilities for the task and actions to be taken ('actions on') should something unexpected occur. There needs to be an effective system for two-way communication with the sentries. It is recommended they are updated throughout the task, especially when positive action is about to be taken so they are not surprised should an event occur and do not inadvertently respond to it. The sentries will interact with the community and often be approached with questions about the work being undertaken. They should be briefed on what to say and give an estimation for how long the task will take. It is recommended the brief should include:

- Overview of the plan and their role in it;
- How they can communicate with the IEDD team;
- What to do if they see the cordon has been breached;
- What to do should there be an unexpected explosion. This may include what not to do (i.e. run into the danger area);
- Any other 'actions on';
- What to say if approached by the community;
- When it is expected the task will be completed and the cordon removed;
- Warning before positive action is conducted;
- Warning before a controlled explosion.

3.1.4. PHASE 4 – TASK EXECUTION

Once the plan has been formulated it must be implemented in a safe, effective and efficient manner. While it is not possible to give a prescriptive guide on how every IEDD task will be executed, there are good practices which can be applied in addition to the guiding philosophy and general principles that were covered in Section 1 of this chapter:

CP selection and approach routes. A CP must first and foremost be in a safe area if the IED were to function, and located away from any other hazards which may be present. Preferably, it should also be out of direct 'line of sight' of the expected device. Further considerations include:

- Is it possible to execute the plan from that location?
- Is it close enough that firing cables and pulling lines will reach the device (without compromising safety)?
- Does it have adequate approach routes for the IEDD operator and / or an ROV (if used) without requiring undue exertion?
- The IEDD operator will be carrying equipment and wearing PPE. If the approach route is not adequate then the CP can be moved to a more favourable location if required.

Improvised detonators. These can be extremely sensitive, much more so than commercial or military detonators. They must be handled with extreme care and it is advised they are disposed of at the task site.

Projected IEDs. The priority for clearance of a projected IED is the reverse of the priority for cordon and evacuation. They should be cleared as follows:

- Point of origin.
- Flight path.
- Impact area.

By clearing in this order, it avoids a projected IED being launched whilst the IEDD operator is in the flight path or impact area.

Main charges with directional effects. Cordon and evacuation should already have been implemented, which accounts for this additional hazard. When remotely or semi-remotely moving a directional IED main charge, care must be taken not to change its orientation to one which is inappropriate for the cordon and evacuation that is in place. At a suitable point in the task, if safe to do so, it should be orientated in a manner that removes the directional hazard.

Enhancements. IED main charges can have a variety of enhancements which present additional hazards. For example, the addition of petroleum to create a blast incendiary effect, or industrial chlorine cannisters to add a chemical effect. The IEDD operator must identify these enhancements and take appropriate mitigation measures. It is also very important they are still within the operator's scope of works. For example, where chemical enhancements have been identified it is unlikely this will still be the responsibility of a humanitarian MA IEDD operator.

As a guide, when dealing with a fuel enhancement consider the following:

- Wear flameproof clothing (hood, mask, overalls, gloves) in addition to normal PPE;
- Carry a fire extinguisher on manual approaches;
- Have additional firefighting equipment in the CP, or if possible, request support from a local firefighting unit.

IEDD TASK EXECUTION EXAMPLES

Example 1: VOIED – Tripwire

An IED search team has identified a tripwire on a track. It has been suspended between two plastic drums that form a vulnerable point and the searcher that identified it could also see what they believed to be an item of conventional ordnance behind one of the drums, camouflaged by some vegetation. The search team marked the tripwire before returning to the CP and requesting an IEDD operator who had been working with a different team in an adjacent confirmed hazardous area (CHA).

On arrival, the IEDD operator conducts the first three phases of an IEDD task (arrival and initial questioning, detailed questioning and threat assessment, and evaluation and planning). As the IEDD operator has no access to an ROV they conduct long-range observation with binoculars. The operator then conducts a manual approach going no further than the point that has already been searched. The IEDD operator is able to see the tripwire and, by changing their position, the suspected main charge (item of conventional ordnance noted above) located behind the blue drum.

WARNING. The operator should not lean over the tripwire or outside the previously cleared area to get a better view.

Image 1. IEDD operator inspecting the IED from the previously cleared area. Visor lifted to increase visual observation

Image 2. IEDD operator checking both ends of the tripwire. Binoculars are being used to assist

WARNING. When dealing with a tripwire check both ends before any positive action is taken. This is to ensure there are not two IEDs connected to the same tripwire.

The IEDD operator needs to access the IED but knows not to work over the switch (tripwire). They decide to use an unobvious route and clear a path through the foliage. Whilst this is more time consuming, it is safer due to the low risk of encountering further IED components since the armed group would not expect someone to use this route.

Image 3. IEDD operator clearing a safe route to the IED. To do this they will need to remove foliage as they clear

Now the IEDD operator is in a position where they can place their bottle disruptor. The size of bottle and quantity of explosives has been matched to the target and placed as close as possible without touching. On this occasion they are not conducting demolition in situ, as they do not have access to bulk explosives.

Image 4. IEDD operator placing a bottle disruptor

The IEDD operator returns to the CP and confirms with the sentries that the cordon has not been breached. The IEDD operator then warns the sentries, other supporting agencies and the community, that a controlled explosion is imminent. Following the bottle disruptor being functioned a safe waiting time of at least of 10 minutes is applied. During this waiting time remote options could be used, if available. In this example the IEDD operator uses binoculars from the CP and is able to confidently observe that the main charge has been moved and it no longer appears to have anything else attached.

WARNING. The IEDD operator will still bring another bottle disruptor on their next approach. This is to guard against a mistake in the interpretation of what they have seen through the binoculars.

On the next approach the IEDD operator visually confirms that disruption has been successful. All the components have been separated and sufficiently moved by the disruptor so that they can be handled, including the main charge. As part of the confirmation process the IEDD operator checks the ground where the IED was originally located. The IEDD operator will now search up to the main charge and conduct detonator safety. Following that, the remainder of the IED components can be searched and recovered.

Image 5. IEDD operator manually confirming disruption. A torch is being used to aid in conducting confirmation

Example 2: VOIED – Pressure plate with linked main charges

A search team has identified a suspect item adjacent to a building. The building's doorway forms a vulnerable point which the threat assessment indicates would be the most likely location for a firing switch to be located. Before searching through the doorway, the searcher first searched to the right-hand side of the doorway. During this they located what they believed to be detonating cord hidden in the sand at the foot of the wall. They have marked the item with a red 'T' and requested an IEDD operator to assist.

On arrival, the IEDD operator conducts the first three phases of an IEDD task (arrival and initial questioning, detailed questioning and threat assessment, and evaluation and planning). They develop their own task specific threat assessment, building on the one already applied by the search team. The IEDD operator assessment is that this is a VOIED with the switch in the doorway. The IED had been placed to target security forces for when they assaulted the building and is no longer part of an active conflict. The opportunity the armed group targeted on this occasion was the security forces pattern to 'stack up' against walls prior to making entry. The IEDD operator assesses the item that has been identified to indeed be an explosive link from a main charge in the doorway to an additional main charge buried somewhere along the wall or at the corner.

The IEDD operator conducts a manual approach and visually inspects the item uncovered by the search team. They also visually identify a ground sign at the corner of the building which they assess might be the location of a main charge.

Image 6. Visual search

The operator further investigates the item located by the search team and confirms it is detonating cord.

Image 7. Further investigation using a fingertip search of the item found by the search team

From their threat assessment the IEDD operator decides not to follow the detonating cord to the doorway, as this is where they assess the switch, probably pressure plate, to be located. Instead they follow the detonating cord in the other direction towards the corner where they assess a main charge is located. The IEDD operator increases their safe working area so they have enough room to trace the detonating cord. When tracing the detonating cord, a fingertip search is used every 30 – 45 cm, to 'bounce' the detonating cord. It is not fingertip searched and exposed along its entire length.

Image 8. Tracing the detonating cord by fingertip searching at intervals

While tracing the detonating cord the operator uses a metal detector to aid in locating the main charge.

Image 9. Metal detector used in prone position

After receiving a large detector signal the IEDD operator uses a smaller handheld metal detector to delineate the buried item. The IEDD operator assesses this to be a main charge.

Image 10. Handheld detector used to delineate metal signature

Confirmation is conducted through fingertip search. It reveals a metallic main charge linked to the detonating cord. The IEDD operator notices the detonating cord is joined by a taped junction.

Image 11. Fingertip search of metal signature reveals a main charge consistent with the threat assessment

A sharp knife is used to slice the tape and separate the junction, thereby interrupting the explosive chain. This does not make the IED safe but is intended to reduce the quantity of explosives that would function should there be an unintended detonation.

Image 12. Separating a taped junction

Image 13. Junction separated with enough distance (>10 cm) between the strands of detonating cord to prevent a detonation from propagating

The operator conducts a 360-degree fingertip search of the main charge to ensure there are no further links to other main charges.

Image 14. 360-degree fingertip search of main charge

The other side of the doorway is searched to check if there are any further main charges on the opposite side as this is also a possible 'stack up' point for assaulting forces. This is done by metal detector and fingertip search.

Image 15. The primary metal detector used to search other likely main charge locations

Image 16. Fingertip search for non-metallic / non-detectable links

Nothing is found and now the doorway must be searched. Extreme caution is used as this is where the IEDD operator is expecting the switch (pressure plate) to be located, based on the task specific threat assessment. Even though they have taken action to sever an explosive link and reduce the NEQ, it is highly likely a viable IED is still present.

A metal detector is used to search the area and delineate the metal signature. This starts with the primary detector used in a standing position and then a wand style metal detector used in a prone position, that helps delineate the subsurface components as accurately as possible.

Image 17. A wand type metal detector is used, to more accurately delineate the subsurface components

This is followed by a fingertip search to confirm the items.

Image 18. Fingertip search towards the centre of the metal signature

The fingertip search reveals a pressure plate and main charge. The IEDD operator uses their judgement to decide which side of the IED to investigate first to find a target. They have decided on this occasion to go first to the side closest to the detonating cord link, as it is assessed as being more likely that this is where the detector will be located.

Image 19. A paint brush is used to assist in removing sand

During the search the detonator and leads are exposed. The IEDD operator places a semi-remote cutting tool and returns to the CP. Prior to conducting positive action, the IEDD operator checks with the sentries that the cordon has not been breached, then warns them and other supporting agencies that positive action is about to be conducted. A minimum of a 10-minute safe waiting period (soak) is applied between each positive action and a subsequent manual approach.

Image 20. Placing semi-remote cutter against single detonator lead. (Red cable is a strop)

Image 21. Insulating detonator lead

Image 22. Placing semi-remote cutter against second detonator lead. (Red cable is a strop)

Image 23. Insulating second detonator lead

Image 24. Conducting detonator safety

Through the threat assessment the operator is confident there are no further unknown components. They can now use H&L techniques to semi-remotely remove and clear all components.

3.1.5. PHASE 5 - FINAL DISPOSAL AND REPORTING

FINAL DISPOSAL

All IED components containing explosives will need to be subject to final disposal actions. The preferred method for this is by explosive demolition. This highlights an additional benefit of conducting destruction in situ as this disposal procedure eliminates the requirement for final disposal.

Even when it may not be possible to conduct demolition of an IED in situ, the situation may permit for explosive demolition nearby in a local disposal area with no, or only minor, changes to the cordon that was enforced for the RSP. This eliminates transportation and storage difficulties.

Where explosive components need to be transported and / or stored for subsequent disposal, NMAS must be applied. If national standards do not exist, MA organisations should apply the general principles given in IMAS 10.50 Storage, transportation and handling of explosives. Collecting explosive IED components for subsequent bulk demolition is logistically a more efficient approach than disposing of all items individually. The advantages are apparent when large quantities of IEDs are being disposed of, or when working in an urban environment in which finding an appropriate disposal site locally is difficult.

One item that may present significant difficulty with handling, transportation and storage is an improvised detonator. Where demolition in situ of an IED main charge is not possible, consideration should be given to demolition of the improvised detonator only, which will have a smaller NEQ and is therefore likely to pose less of an issue.

Other disposal techniques which can be used, although with limitations, are:

- **Disposal by burning (low order techniques).** Useful when a high order technique is not suitable. However, effectiveness of this technique varies greatly depending on the type, quantity and condition of the explosives. It takes far more time to complete the procedure, whilst still requiring the same size cordon as for a high order technique. It is advisable to only dispose of small quantities at a time.
- **Mechanical breakdown.** The use of a demining machine to break apart the IED main charges is a potential option when they are not deemed safe to transport by other means. However, the remaining bulk explosive must be dealt with appropriately, and with the high probability that toxic chemicals are present, due consideration to environmental factors is essential.

REPORTING

Gathering technical information on IEDs and reporting it is an essential process in an MA IED clearance operation. This technical data informs many other processes from national threat analysis, tasking, planning, search and disposal. IMAS 05.10 Information Management for Mine Action gives guidance on information collection and analysis. An IEDD operator will be responsible for three main reports:

Post disposal reporting to the search team. On completion of a disposal task it is recommended the IEDD operator gives a verbal report on the IED to the search team. It is advised that at a minimum it should include:

- Method of initiation;
- Description of main components (particularly firing switches);
- Depth, layout and orientation of components.

Where possible, the IEDD operator should show the search team the recovered components. This will aid in recognising components specific to the task site. It will also aid supervisors in ensuring that detectors are set to the appropriate sensitivity and, if necessary, amend the operational threat assessment and clearance plan.

Image 25. MA training showing the IEDD operator briefing searcher / deminer on the rendered safe IED prior to the search recommencing

First look report. This is a brief report to highlight a significant or unusual IED or IED components, to the relevant organisation. The aim is to swiftly inform others who may encounter the same IED. A more detailed report follows when time permits.

IEDD report. This is a standard report which documents the disposal of an IED. It will contain pertinent information about the IED, its location, the scenario and method of disposal. The NMAA may stipulate what information is required in the IEDD report and issue a standardised format. If this is not the case, MA organisations are advised to develop a standardised IEDD report to be used.

3.1.6. RC DEVICES AND COUNTER-MEASURES

Image 26. An RCIED placed at an access gate. Note how difficult it is to see the yellow antenna which runs up the gate post (highlighted in red)

Armed groups use RCIEDs due to the advantages they offer, and their use has become more common as the availability of the required technology has increased. There is now a multitude of transmitters (Tx) and receivers (Rx), operating over a wide range of frequencies, commonly incorporated into RCIEDs. These can be commercial items which have been modified, or entirely custom-made Tx and Rx that have no other purpose than for use in an IED.

The use of RC is not limited to solely initiating an IED, it can be used in conjunction with other types of firing switches, for example arming a VOIED. It can also be used as a backup, or secondary switch, such as for a suicide IED. Whilst humanitarian IEDD operators should not be working in areas where active targeting using RCIEDs is occurring, they are likely to be called upon to dispose of abandoned RCIEDs. RCIEDs have an inherent risk of unintentional initiation from spurious radio frequencies or an innocent third party coincidentally using a matched Tx. An example of this would be a mobile phone used as the Rx in an RCIED, receiving a promotional text which functions the device. Armed groups may take steps to try and prevent this, but the effectiveness of these measures cannot be guaranteed. MA organisations may want to consider the use of electronic counter-measures (ECM) as a means of controlling the RF environment and preventing an unintentional explosion.

ECMs have primarily been utilised by the security forces, but their utility is recognised by other organisations. As such, commercial ECM options are available for purchase. A threat analysis / threat assessment and equipment requirement assessment should be conducted before purchasing ECM equipment.

REMEMBER. Different ECM equipment covers different RC threats. Use the correct equipment for the threat.

RCIED TASK CONDUCT

RCIED identified through questioning and threat assessment. During the questioning and threat assessment phase of the task it may be confirmed that an RCIED is present or that there is a high risk of one. This eventuality should be covered in the mandatory actions of the MA organisation's SOPs and these should be followed.

RCIED discovered during a manual approach. If an unexpected RCIED or a component part associated with an RCIED (e.g. an antenna) is discovered during a manual approach, the IEDD operator should immediately return to the CP. They should not prolong their time in the danger area to conduct further investigation.

Rendering safe an RCIED. It is highly recommended the following approach is adopted when disposing of RCIEDs:

- Remote action is taken before any manual approach.
- If available, ECM protection is considered.

3.2. HOME-MADE EXPLOSIVES

This section is a basic aid to assist in identifying the most common HMEs and recognising HME production facilities; it is NOT an all-inclusive guide. There are other HMEs not mentioned and substitute precursors which can be used.

WARNING. All explosives are sensitive to shock / impact, heat, friction and electrostatic discharge. Some HMEs are incredibly sensitive compared to military and commercial explosives and extreme caution should always be taken.

HMEs consist of an oxidant and a fuel, which are physically (by percentage weight) or chemically (by stoichiometry) mixed. The table below gives examples and common sources for oxidants and fuels used in HMEs (not an exhaustive list).

EXAMPLES OF OXIDANTS USED IN HMEs AND THEIR USES		EXAMPLES OF FUELS USED IN HMEs AND THEIR USES	
Ammonium nitrate	Agricultural fertiliser	Sugar	Icing sugar
Sodium chlorate	Weed killer	Glycerine	Anti-freeze
Potassium chlorate	Match-heads (non-safety type)	Fuel oil	Diesel
Potassium permanganate	Disinfectant	Aluminium powder	Paint
Hydrogen peroxide	Hair bleach	Nitrobenzene	Pesticide

WARNING. HME precursor chemicals can be dangerous themselves. Use caution and if necessary appropriate PPE when handling.

3.2.1. AMMONIUM NITRATE- (AN) BASED HMEs

AN is frequently used by NSAGs due to its availability from fertiliser. AN can be mixed with several fuels to produce an effective HME. Grinders and blenders are often used in its production.

WARNING. Ammonium nitrate itself is explosive if subjected to heat and / or confinement.

Prevalent examples of AN-based HMEs are:

Ammonium nitrate & aluminium (ANAL)

Identifiers	Silver / grey powder or granules. Odourless, may have a slight ammonia smell.
Figure of insensitivity[3] (FoI)	Approx. 200.
Notes	Suffers from moisture absorption. No booster required if initiated with good quality detonator.

Ammonium nitrate & fuel oil (ANFO)

Identifiers	Off-white to light pink granules or prills. Off-white to light grey granules or prills. Off-white to brown granules or prills. Diesel or other fuel oil odour.
Figure of Insensitivity (FoI)	Approx. 200.
Notes	Suffers from moisture absorption. Requires a booster charge to detonate.

Ammonium nitrate & sugar (ANS)

Identifiers	White powder. Off-white to light brown powder. Odourless, may have a slight sweet smell. Can attract insects due to the sugar.
Figure of Insensitivity (FoI)	Approx. 200.
Notes	Suffers from moisture absorption. Requires a booster charge to detonate.

3 Figure of Insensitivity is a measure of an explosive's sensitivity. It is measured on an inverse scale with TNT having an FoI of 100.

3.2.2. ORGANIC PEROXIDE-BASED HMEs (OPS)

A very sensitive HME where precursors can be sourced easily. No requirement for a detonator due to it being a primary explosive. Colour can vary depending on the precursors or additives used.

WARNING. As the FoIs below suggest, OP-based HMEs are EXTREMELY SENSITIVE. Use extreme caution and only handle if absolutely necessary. Even heat from direct sunlight can cause an explosion.

Two of the most common OP-based HMEs are:

Hexamethylene triperoxide diamine (HMTD)

Identifiers	Clear to white crystals or powder.
Figure of Insensitivity (FoI)	Approx. 5.
Notes	Extremely sensitive and susceptible to electrostatic discharge. Due to its sensitivity from heat, it may be stored in a cool place like a fridge. Very toxic, ensure area is well ventilated. Use impermeable PPE.

Triacetone triperoxide (TATP)

Identifiers	Clear to white crystals or powder.
Figure of Insensitivity (FoI)	Approx. 5.
Notes	Extremely sensitive and susceptible to electrostatic discharge. Due to its sensitivity from heat, it may be stored in a cool place like a fridge. Very toxic, ensure area is well ventilated. Use impermeable PPE.

3.2.3. POTASSIUM CHLORATE-BASED HMEs

Potassium chlorate is used in the manufacture of textiles and matches, as well as other applications. By itself it is an odourless white crystal or powder which can be mixed with a fuel to form an explosive. Most potassium chlorate-based explosives are sensitive to shock and friction, making them dangerous to handle.

Potassium chlorate and fuel oil (PCFO)

Identifiers	Diesel or other fuel oil odour.
Figure of Insensitivity (FoI)	Varies.
Notes	Can be initiated with a detonator, does not require a booster.

3.2.4. HME PRODUCTION EQUIPMENT

The equipment used in the production of HMEs will vary depending on the HME, quantity being produced, and the availability of any equipment. The equipment can come from a variety of sources including scientific apparatus, tools repurposed from another industry or even improvised from readily available supplies. The table below gives possible examples of equipment which may be used in the production of HME.

ACTIVITY	EXAMPLE EQUIPMENT
Mixing	Spatula, other hand mixing utensil
	Food mixer
	Laboratory magnetic stirrer
	Mechanical mixer
Filtering	Filter paper e.g. coffee filter paper
	Tights / stockings
	Filter funnels
Grinding	Pestle and mortar
	Coffee grinder
	Ball or rod mill
	Mechanical grinder
Heating	Camping stove
	Portable electric hob
	Slow cooker
	Laboratory hot plate
Cooling	Laboratory cooling bath
	Bucket with ice water
	Bathtub with running cold water
Distilling	Laboratory distillation apparatus
	Improvised distiller
Protective equipment	Safety goggles / glasses
	Face shield
	Dust mask, half mask, full face respirator
	Heavy rubber gloves, latex / kitchen gloves
	Rubber apron, overalls
	Rubber / wellington boots
	Ventilation equipment, desk fan, ducting, etc.
Miscellaneous equipment	Thermometer
	Measuring cylinder / jug
	pH tester / paper
	Kitchen roll, plastic sheeting, other paper to cover surfaces
	Assorted containers / jars, cooking pans, funnels
	Written instructions, notes

3.2.5. IDENTIFYING HME PRODUCTION FACILITIES

WARNING. A safe and accurate assessment takes time – DO NOT RUSH.

When viewing a potential HME production facility, it is important to take an overview of all the equipment and chemicals, as most have more than one legitimate use and individually they are unlikely to indicate the production of HME. Each scene will be different as there are many possibilities for equipment and precursor chemicals. It is not possible to give a definitive list, and technical training and experience must be used when making an assessment. Consider the situation around the potential production site as this may aid in the identification of an HME production facility. There may also be other equipment associated with the production of IEDs present such as batteries, wire, soldering equipment, etc.

Caution should always be used before entering a potential production facility and consideration should be given to both explosive and non-explosive hazards. Precursor chemicals used in the production of HME can be hazardous in themselves and it is likely there will also be unknown chemicals present, with even those in marked containers possibly having changed.

Image 1. Image of precursor chemicals in field conditions

MA staff should ask questions before entering a site to identify potential hazards early. Nothing should be touched until it has been considered safe to do so. Be cautious before entering any confined space and consider the ventilation, equipment and planning that is required.

Image 2. Image of a commercially available explosive test kit (ATG Kriminaltechnik GmbH ©)

Commercial test kits for the identification of HMEs are available which may aid MA organisations in making a correct assessment. However, they do have limitations and, with so many options available at different price points, the MA organisation should assess if and which is appropriate for the tasks that they are conducting.

4. IEDD TECHNIQUES AND PROCEDURES

4.1. MA IEDD EQUIPMENT OPTIONS

4.1.1. INTRODUCTION

There is no definitive equipment list covering all MA IEDD operations. Equipment requirements are particular to the context, national threat analysis and operational threat assessment for the IEDD activities that will be conducted by an MA programme.

MA organisations should conduct equipment requirement assessments to develop an appropriate and cost-effective equipment schedule for programmes conducting IEDD. It is often the case that certain IEDD equipment, normally required by UN troop-contributing countries conducting peace support operations in non-permissive environments, is not required by MA organisations conducting IEDD in post-conflict environments.

IMAS 09.31 IEDD, Annex B provides a recommended minimum equipment schedule, with a list of additional items for consideration through programme specific assessments.

4.1.2. CONSIDERATIONS

Guidance for the procurement, research, test and evaluation of MA equipment and technology can be found at:

- IMAS 03.10 Guide to the procurement of mine action equipment
- IMAS 03.20 The procurement process
- IMAS 03.30 Guide to the research of mine action technology
- IMAS 03.40 Test and evaluation of mine action equipment

In addition to the guidance given in the above IMAS, MA IEDD organisations may want to consider the following during equipment procurement:

- IEDD equipment is readily available for purchase from multiple suppliers. This availability has utility for specialist items but can lead to high procurement costs and problems with import restrictions. Certain IEDD equipment can be locally purchased, avoiding these difficulties.
- Reliability is an important factor when selecting IEDD equipment. Failure or breakage will prolong the IEDD operator's time in the danger area or require unnecessary manual approaches.
- Due diligence should be applied when integrating equipment into an overall MA IEDD capability to ensure that what is procured is compatible with other equipment. Here are some example questions that may be considered:
    - Will detectors and PPE be interoperable?
    - Can the equipment be transported manually?
    - Is maintenance simple?
    - Do H&L ancillaries fit onto cables?
    - Is it necessary to buy other new equipment to integrate the new item(s)?

Image 1. Locally produced H&L kit. Individual items have been locally purchased to build an overall kit. Note how the items are of good quality / reliability to prevent unnecessary failures / breakages

4.2. ROV ACTIONS INCLUDING MANIPULATOR, DISRUPTOR AND CUTTER

Image 1. Remotely operated vehicle (ROV) fitted with barrel disruptor, manipulator and wire cutter

4.2.1. INTRODUCTION

Remotely operated vehicles (ROVs) improve safety by providing a platform from which a variety of IEDD techniques and procedures can be performed without an IEDD operator having to enter the danger area. When available, an IEDD operator should seek to employ an ROV if it is appropriate for the circumstances.

There are many types of commercial ROVs available, which vary in size, weight and specification. Unfortunately, there is not one type of ROV which meets all demands. An MA organisation must analyse the IED environment in which it is working to determine the type of ROV most suitable.

4.2.2. WHY IS THE USE OF ROVS 'GOOD PRACTICE'?

Primarily, they comply with the IMAS 09.31 guiding philosophy of 'preservation of life' and can aid in the "restoration of the situation to normality as quickly as possible". ROVs also assist in observing the IEDD general principles: "Remote (if available) and semi-remote actions should be conducted to neutralise and/or dispose [of] IEDs" and "All IED components should be moved remotely or semi-remotely prior to manual handling."

ADVANTAGES OF ROVs

- Reduces the IEDD operator's exposure to risk, as positive actions can be conducted without the need for a manual approach;
- Enables remote viewing of the device and area through onboard cameras. This also allows positive actions to be observed and confirmed remotely. This significantly aids in the IEDD operators planning as the task progresses;
- Many positive IEDD actions can be conducted by the ROV, with only one safe waiting period required prior to manual confirmation that the IED has been rendered safe. Such action returns the situation to normal far more quickly than manual or semi-remote techniques, which would require a safe waiting time to be applied between each positive EOD action.

DISADVANTAGES OF ROVs

- Expensive and slow to procure, with associated import implications;
- Terrain can limit the mobility and range over which an ROV can be used effectively;
- Access due to the location of an IED can reduce effectiveness;
- Requires regular maintenance and servicing with associated through-life costs;
- Additional training burden;
- Could be damaged when conducting IEDD procedures, incurring expense.

4.2.3. ACTIONS THAT CAN BE CONDUCTED BY AN ROV

There are many actions which can be performed by an ROV, limited only by the ROV's capabilities and the operator's ability. Many commercially available ROVs offer additional attachments to increase the ROV's utility. Generally, the actions conducted by the ROV will fall into the following categories:

- Conducting explosive ordnance reconnaissance (EOR) of the IED and its surroundings;
- Placing an energetic disposal tool such as a disruptor or explosive donor charge;
- Manipulating objects.

EOR

This is a highly beneficial capability provided by an ROV and enables the IEDD operator to conduct remote observation of the immediate surroundings from the safety of the CP to provide enhanced appreciation of the situation. ROVs have the advantage over most un-manned aerial vehicles by being able to conduct intrusive EOR. This means that seemingly innocuous items / obstructions can be moved to gain better access.

Image 2. ROV conducting EOR of an EFP array placed at the roadside

PLACING / FIRING EXPLOSIVE EOD TOOLS

ROVs can be used in conjunction with energetic EOD tools for the disposal and rendering safe of IEDs. This can be achieved in a variety of ways, with some ROVs being equipped with an onboard barrel disruptor. When this is not available, the ROV's manipulator can be utilised to place other energetic tools such as a bottle disruptor, vehicle extractor / disruptor or explosive donor charges.

Some ROVs are equipped with onboard firing circuits enabling disruptors and other tools to be fired through the ROV's base station using a radio control link. When this would damage the ROV, or if that feature is not available, other procedures can be adopted. This may include dragging a firing cable or deploying a remote firing device.

HINT. When an ROV is fitted with onboard disruptors it is good practice to deploy them all loaded and charged (i.e. if there are two disruptors then both should be prepared for firing).

4.2.4. MANIPULATING OBJECTS

Another extremely useful capability of an ROV is its ability to conduct positive actions remotely through the manipulation of objects. This can include separating components such as electrical links or parts of an explosive chain and moving components to help ensure they are safe prior to manual handling.

The ROV can conduct multiple positive actions on numerous items, far greater than that which could be achieved during one manual approach with an H&L. This can greatly reduce the duration of the task, returning the situation to normal far more quickly and with less safe waiting periods being observed.

Image 3. ROV locating an electrical link

Image 4. ROV semi-remotely cutting an electrical link

Image 5. ROV moving an EFP array. Note: the operator is keeping the EFP's pointing in a safe direction. The detonating cord sits in a groove in the manipulator jaws and is not gripped by the manipulator

HINT. Care must be taken not to crush sensitive explosive objects (e.g. detonators, detonating cord, etc.) with the manipulator or other parts of the ROV.

RETURN TO REMOTE

There will be tasks that cannot be fully completed remotely. Throughout these tasks the IEDD operator should always endeavour to return to using the ROV wherever possible.

Examples of this include:

- Following an H&L action the ROV can be used for remote confirmation. Confirmation may indicate that the ROV can conduct the next positive action. This eliminates the requirement for the IEDD operator to re-enter the danger area.
- Conducting a manual approach to lift an ROV over an obstruction, then returning to the CP to conduct the task remotely.

4.3. HOOK AND LINE

4.3.1. INTRODUCTION

Hook and line (H&L) provides an MA IEDD operator with the ability to semi-remotely conduct positive actions. Such actions include moving IED component parts to help ensure that they are safe to manually handle, and separating components such as electrical links or parts of an explosive chain during an RSP.

H&L requires an IEDD operator to leave the safety of the CP and enter the explosive danger area in order to manually place or connect the line in a non-intrusive manner. The IEDD operator then returns to the CP prior to the line being pulled and the positive action conducted. It can be used when ROVs are not available, or when their use would not be suitable due to the operational conditions.

H&L equipment is an essential component of any MA IEDD team. There are many commercially available kits that meet a range of requirements and budgets. However, the majority of items in an H&L kit can be procured or manufactured locally, with limited need to resource specialised components externally.

4.3.2. WHY IS THE USE OF HOOK AND LINE 'GOOD PRACTICE'?

H&L complies with the IMAS 09.31 guiding philosophy of 'preservation of life' by observing the IEDD general principles: "Remote (if available) and semi-remote actions should be conducted to neutralise and/or dispose [of] IEDs", and "All IED components should be moved remotely or semi-remotely prior to manual handling."

ADVANTAGES OF HOOK AND LINE

- Provides the ability to conduct positive actions safely when ROVs are not available;
- Highly adaptable with a wide range of utility;
- Can be used on multiple target objects concurrently;
- Relatively inexpensive;
- Limited / no import issues;
- Can often be locally procured;
- Minimal / easy maintenance and cheap to replace damaged items;
- Can be transported manually or in small vehicles.

DISADVANTAGES OF HOOK AND LINE

- The IEDD operator must enter the danger area to set up the H&L equipment. This may require some degree of interaction with the device, or its immediate surroundings;
- A physical link is required between the CP and device, which can restrict the location of the CP;
- Using H&L to conduct component separation during an RSP presents greater risk than neutralisation by disruption or destruction in situ.

LIMITATIONS OF HOOK AND LINE

The following limitations should be considered when using H&L equipment:

- Length of pulling line – is it long enough?
- Load-bearing capacity of the weakest link / point.
- Route of the pulling line – will it move freely?
- Ability to safely attach H&L equipment?
- Sufficient H&L equipment for the task?

HINT. H&L is very much a skills-based technique, which requires proficiency to maximise its potential. It is essential for IEDD operators to routinely practice H&L techniques to maximise its capabilities.

STEP 1 – PLANNING AND PREPARATION

The IEDD operator should plan H&L procedures before leaving the CP. This will minimise the time inside the danger area and ensure the right equipment is taken over. During any plan, the IEDD operator should always consider what are the most likely, and the worst case, scenarios and formulate a plan which covers both eventualities.

HINT. When inexperienced with using H&L equipment, it may aid the IEDD operator to draw out their plan, specifically the use of pulleys, blocks and tackles to gain optimum purchase on the item they intend to interact with.

During each stage of H&L employment, the IEDD operator should aim to achieve as much as is practicably possible without overstretching and causing failure. Whenever possible, preparation of H&L equipment should be conducted in the safety of the CP. This will minimise time in the danger area and simplify H&L placement.

HINT. Keep it simple. H&L is most effective and less prone to failure when its use is kept simple.

The H&L system is only as strong as its weakest link. Whilst it is unlikely the IEDD operator will know the exact weight of the object to be moved, they should make an assessment and ensure it is within the load-bearing capacity of the weakest piece of H&L equipment being used. For example, if a main charge weighs approximately 20 kg and the H&L rope has a pulling capacity of 150 kg, yet the karabiner being used to attach the rope to the main charge only has a capacity of 15 kg, then the H&L system has a weak point. In this situation the karabiner will break, making it necessary to conduct a further manual approach. H&L equipment should not be knowingly used to fail and the IEDD operator should plan effectively to ensure repeatable success.

HINT. Using multiple lines can increase productivity during H&L procedures. This can be further multiplied by the use of 'lazy lines'. These are additional lines attached to multiple target objects, with one main line attached to all of them and pulled simultaneously.

STEP 2 – PLACEMENT

H&L equipment must be placed with no disturbance to the intended target. For subsurface IEDs minimal excavation via a fingertip search may be required, but no part of the IED should be disturbed.

> HINT. A good way to help avoid disturbing the target when attaching an H&L is to attach a strop with a slack line onto the target first, then attach the main line to the slack line after. This is often less intrusive than fastening the main line directly to the target.

Quite often an IEDD operator may change direction of the H&L rope when advancing towards the IED from the CP and rarely is the journey a straight line from CP to IED. These changes enable the main line to be threaded through pully blocks or other attachments to provide the most ergonomic method of attaching the H&L to the target. The IEDD operator should ensure there is plenty of slack in the main line before attaching it to the target item. This ensures that should the main line be disturbed, say by the IEDD operator snagging it on the way back to the CP, then the target is not moved. It is also good practice for the IEDD operator to avoid stepping on the main line since this may reduce its pulling capacity over time.

> WARNING. Depending on the stage of the task, there may be a requirement to bring an additional person into the danger area to assist with carrying and placing equipment if this cannot be done by one person. However, only the IEDD operator should be in the danger area when attaching the H&L equipment to the target object.

> REMEMBER. The main line should be laid out from the CP as the IEDD operator advances to the target. It should NOT be connected to the target and laid out by the IEDD operator as they return to the CP.

Image 1. H&L prepared and awaiting attachment of the main line on a strop. Note the prepared slack in the main line and a tether secured to a hard point to cause the container to open

STEP 3 – SAFE POSITIVE ACTION

The positive action of pulling the H&L equipment must be conducted in a safe manner. It is important that the community and MA staff have been moved outside the explosive danger area and that an effective cordon is in place. If any MA staff remain inside the explosive danger area they must be suitably protected in the CP. Prior to conducting positive actions, all relevant personnel should be informed that an explosion may occur. This is to prevent people mistakenly thinking that an accident has occurred and inadvertently responding to it.

WARNING. When conducting positive IEDD action with H&L there is the possibility that the IED may function. Suitable cordon and evacuation must be in place and any MA staff remaining inside the explosive danger area must be suitably protected.

The IEDD operator should have an appreciation of how far and with what force the line needs to be pulled to achieve the desired effect. Heavier loads might require additional personnel to assist in the pull, or mechanical advantage to be employed. For extremely heavy loads, and only when suitably strong H&L equipment is available, a vehicle may be used.

WARNING. H&L equipment can suddenly fail. When pulling by hand ensure a balanced and sturdy stance is used to prevent falls. When a large force is being exerted, especially if a vehicle is being used, the main line may fail causing it to whip back. Ensure personnel are standing in a safe position so as not to be hit by a whipping line.

STEP 4 – CONFIRMATION OF SEMI-REMOTE ACTION

NOTE. The confirmation process is not complete until the IEDD operator has manually confirmed the positive action at the target.

Confirmation of the positive action is an important process that ideally should be done remotely using an ROV or UAV. If these are not available, then the use of handheld optics such as binoculars is advisable, from as far away as practically possible. A safe waiting period must be applied between the positive action and a subsequent manual approach.

NOTE. When moving objects, their original location should be checked on the next manual approach.

WARNING. Safe confirmation of positive actions is critically important. If available, the use of an ROV or UAV should be considered to confirm that positive action has been achieved before re-entering the danger area.

4.3.3. H&L EXAMPLES

USING H&L TO CUT A WIRE

WARNING. When conducting H&L techniques to neutralise an IED, extreme caution must be exercised. H&L involves more interaction than other techniques, such as neutralisation through water-based disruption, and therefore generally carries more risk.

In the following scenario a searcher has located a pressure plate. This has been marked and avoided by the IEDD operator who has then located the lead from a detonator attached to an offset main charge.

Image 2. Preparing an H&L cutter. Here the IEDD operator has opted to attach the line before placement as they have assessed this to be a better course of action in this situation

Image 3. Placing the cutter. Note how the IEDD operator is maintaining control throughout to prevent disturbance of the target wire

Image 4. Scene immediately prior to conducting positive action

Image 5. Line being pulled

Image 6. Post positive action, the cutter has cleanly cut the target wire

USING H&L TO REMOVE A BURIED MAIN CHARGE

Image 7. The IEDD operator has attached a strop to the handle of a buried main charge and inserted a spade into cleared ground. This will give an elevated pivot point and aid in removing the main charge

HINT. Other items can be used instead of a spade to give an elevated pivot point, such as a pickaxe.

Image 8. The IEDD operator attaching the line to the strop. Note: the line has been secured to the spade handle and the spade leans slightly forward

Image 9. Line being pulled

Image 10. Using the spade to create an elevated pivot point aids in removing the main charge by lifting and pulling it

Image 11. Post positive action, the main charge has been successfully removed

USING H&L TO REMOVE A HEAVY CASED MAIN CHARGE FROM A VEHICLE

The MA IEDD operator intends to gently remove the heavy cased main charge from the vehicle and not just drop it on the floor. To achieve this, they have attached two lines to the main charge, one to lift it and the other to pull it clear of the vehicle. The trunk has been fixed open with a pole and a pully secured to the edge.

Image 12. H&L set up with the IEDD operator having returned to the CP

Image 13. The red line is used to lift the main charge then the white line is used to pull the main charge clear of the vehicle

Image 14. The red line is slowly released to gently lower the main charge onto the ground

USING H&L TO OPEN VEHICLE DOORS

Two lines are being used to open the side doors of a vehicle. For simplicity, and to help prevent failure, one main line is used with each door. They have both been set the same.

Image 15. Lines have been independently attached to each door using 'mole grip' spanners

Image 16. The first line successfully opens the front door

Image 17. The second line successfully opens the rear door

4.4. BARREL DISRUPTORS

4.4.1. INTRODUCTION

The primary purpose of an IEDD disrupter is to neutralise an IED as part of a render safe procedure. Disruptors can also be used to 'remotely open' a suspect item to expose the contents, while 'render safe' means to penetrate, cut, or separate the components so that the device is neutralised and cannot function as originally intended.

Barrel disruptors are normally powered by a cartridge containing a low explosive (propellant) that forces a high velocity charge (usually water) out of the barrel to separate IED components in a manner that has a low probability of the device functioning. Disruptors are most effective against electrically initiated IEDs, especially when the battery (power source) can be effectively targeted. Barrel disruptors can be placed semi-remotely, which requires the MA IEDD operator to manually place the disruptor as close to the IED as possible without disturbing it, or using a remotely operated vehicle.

Water is the most common load to be fired by barrel disruptors, however some manufacturers use other substances like gel to improve stand-off. There are also recoilless disruptors available which work in a similar fashion to recoilless rifles. This sub-section will focus on the most common types of barrel disruptors and their application in MA. The user may need to modify this information to suit the technical specifications of the barrel disruptor that they are using.

4.4.2. TWO TYPES OF DISRUPTION

General disruption. A shot that is aligned to the general area of the IED to cause the maximum possibility of disruption as a whole.

Selective disruption. A shot that is aligned at a selected item (usually the power supply) to cause targeted disruption of that item.

4.4.3. WHY IS THE USE OF BARREL DISRUPTORS 'GOOD PRACTICE'?

The use of barrel disruptors complies with the IMAS 09.31 IEDD principle "Water based energetic disruption of the power source(s) is the preferred means of neutralisation." This is because interaction with the IED is minimised and the time the MA IEDD operator is inside the danger area is kept to a minimum. This is directly linked with the primary IMAS IEDD guiding philosophy of 'preservation of life'.

ADVANTAGES OF BARREL DISRUPTORS

- Safe, effective and efficient means to achieve the neutralisation of an IED;
- Minimises interaction with the IED;
- Reduces time inside the explosive danger area;
- Delivers a consistent effect;
- Value for money – can be re-used many times and if required some cartridges can be re-used and re-loaded;
- Does not require the procurement, storage and transportation permissions associated with high explosives;
- Water and manufactured gels are non-flammable and as such do not present any secondary incendiary hazards during disruption.

DISADVANTAGES OF BARREL DISRUPTORS

- Could have a forward danger area greater than the danger area of the IED (dependent on the disruptor / energetics / charge used and the angle of the barrel);
- Importation (or the research, design and local manufacturing) of the disruptor is required;
- If used in conjunction with an ROV, the ROV needs to be designed to carry a barrel disruptor or serious damage could occur from the recoil;
- If larger general disruption is required, then a barrel disruptor will not be as effective as a bottle charge disruptor.

4.4.4. LIMITATIONS OF BARREL DISRUPTORS

The following limitations should be considered when using disruptors:

- Spaced casings (air gaps / box within a box).
- Metal containers.
- Heavy gauge plastics.
- Soft fabric containers.
- Multi wrapped packages.
- Large devices.

MATCH THE DISRUPTOR TO THE TARGET

The appropriate size / power of a disruptor should be selected for the size of the intended target. The user manual for the barrel disruptor should define its capabilities. The MA IEDD operator should practice using the barrel disruptor against different training devices to give a first-hand appreciation of capabilities and limitations prior to operational use.

HINT. Double disruptor shot. This is when two disruptors are fired simultaneously at the same target. It provides a significantly enhanced result when disrupting a large item and the location of the IED's power source is unknown.

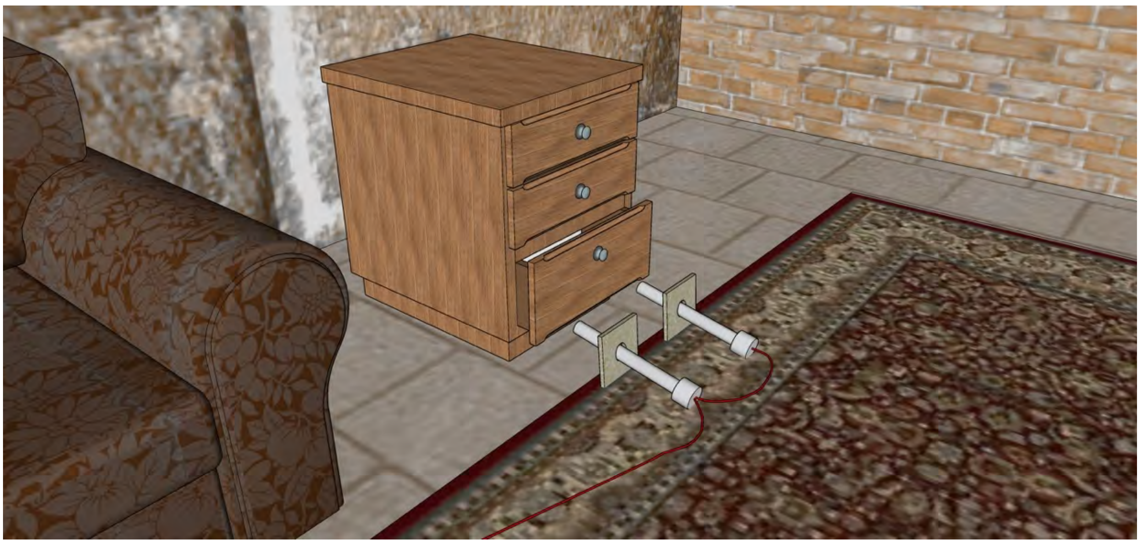


Image 1. Image of a double disruptor shot. Note the parallel placement of the barrels, wired in series

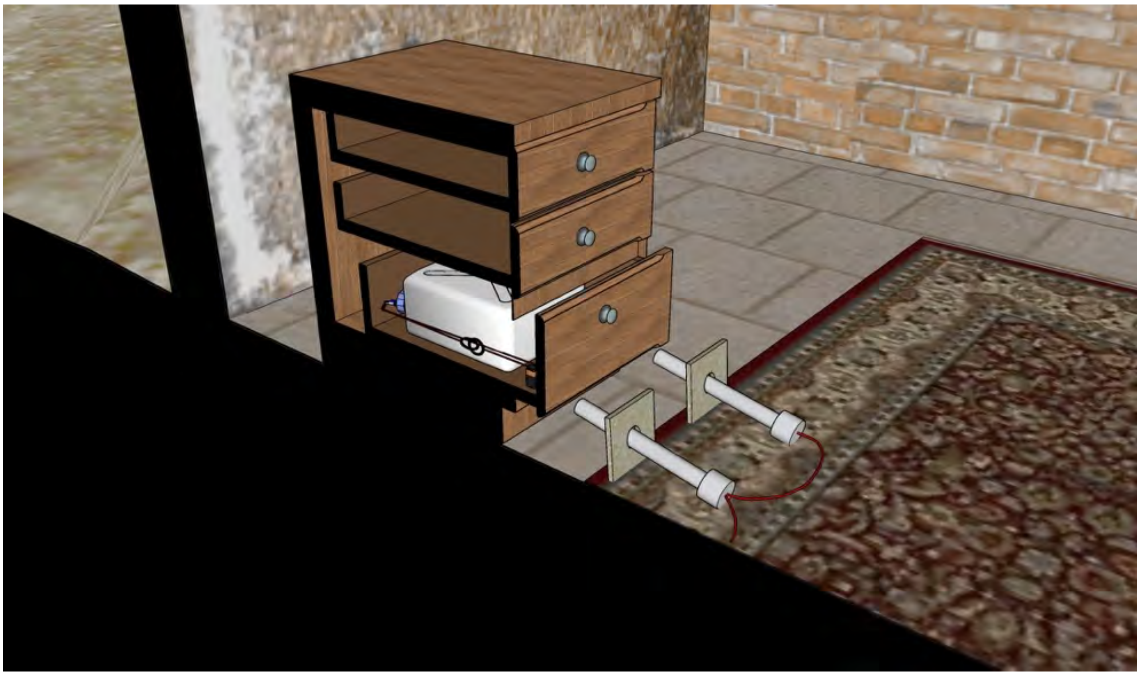


Image 2. Image showing a victim operated IED inside a drawer. Although the battery is visible in the image its precise location is not known to the IEDD operator. However, this is still the safest technique to achieve neutralisation

HINT. When conducting a double disruptor shot the disruptors MUST be wired in series. This ensures both disruptors fire simultaneously, and in the unlikely event one disruptor fails to fire, then neither disruptor will fire. Such an approach prevents partial disruption of the IED, which could place it in a more dangerous state.

WARNING. Ensure that the shots are aligned parallel to each other and do not cross. This will reduce the possibility of unintentional functioning of the device during disruptive neutralisation.

STAND-OFF SHOTS

At times it may be prudent for the MA IEDD operator to place the barrel disruptor at an increased distance from the target, further than the optimum stand-off range. These are often referred to as 'stand-off shots' and should only be conducted in limited circumstances. The MA IEDD operator needs to be aware that when this occurs, there will be a reduction in performance. Generally, the more stand-off increases, the further the reduction in performance.

4.4.5. USE OF BARREL DISRUPTORS

STEP 1 – PREPARATION, CHARGING AND LOADING

The following is a recommended sequence for the preparation, charging and loading of barrel disruptors:

1. **Preparation.** Barrel disruptors should be stored in a clean and serviceable condition so that they are ready for use when required. It is advisable to have a small quantity of cartridges prepared for immediate use. This should be defined in the MA organisation's SOPs.
2. **Charging.** This is the process of charging / filling the disruptor with water. The exact procedure differs between models and will be defined in the manufacturer's user instructions. Generally, there will be a defined quantity of water held within the barrel by use of light plastic bungs or pistons.
3. **Loading.** The barrel disruptor is loaded with a cartridge and the breach is secured. For electrically fired disruptors, this is also when the disruptor is wired to the firing cable. Once loaded, the disruptor has a forward projection hazard and usually a rearward recoil hazard.

WARNING. Barrel disruptors are a directional weapon and should be loaded from the side.

WARNING. Most barrel disruptors are electrically initiated which means that RF precautions should be adopted. These include minimising the potential background RF around the area where loading is taking place (no mobile phones or radios within a specified distance).

HINT. Organisational procedures should stipulate that breeches are only attached to the disruptor when they are loaded. For all other occasions the breeches should be removed to show they are unloaded and safe.

STEP 2 – SAFE DEPLOYMENT FROM THE CONTROL POINT

The barrel disruptor is deployed from the CP to the target by the MA IEDD operator in its loaded state. This is to minimise the time the MA IEDD operator is in the danger area. Care must be taken to ensure the disruptor remains pointing in a safe direction. If the disruptor being used has a rearward hazard, then care should be taken to keep this in a safe direction as far as possible.

Image 3. The MA IEDD operator has approached the IED and placed the barrel disruptor pointing in a safe direction until they are ready to position it

WARNING. Always point a loaded disruptor in a safe direction. This will keep the disruptor out of the way with the front and rear pointing in safe directions, and means it will not have to pass through the CP when deployed by the IEDD operator.

HINT. Load and store the disruptor at the exit point of the CP by the IEDD operator by ensuring it does not point into or directly away from the CP. This avoids it travelling through the CP when deployed by the IEDD operator and ensuring it does not point into or directly away from the CP.

STEP 3 – PLACEMENT

Barrel disruptors should be placed to achieve the best target effect without prolonging the time in the danger area or compromising safety. To aid in the placement of a barrel disruptor commercial stands are available, in addition to locally manufactured and improvised variants. No single type of stand will fit every scenario and the MA IEDD operator will need to become proficient at using a variety of techniques to aid in the correct placement.

HINT. When placing the barrel disruptor, the MA IEDD operator should consider the effects of disruption and where components will fall. Being selective with the orientation of the placement will direct the disrupted components to fall into an area which is much easier for visual confirmation. However, this should not be done at the expense of correct disruptor placement. It is also advisable to consider where the disruptor will recoil to.

Achieving the best target effect from a barrel disruptor:

- Correct distance from the IED (optimum stand-off range will be defined by the manufacturer);
- The longest way through the target. For example, through the diagonal of a briefcase;
- Attack the weakest point of entry such as an area that is designed to or likely to give way;
- Towards a backstop but not hard against it;
- Consider effects of the attack (most suitable weapon, best / worst case).

WARNING. There is an inherent risk with all barrel disruptors that a breech explosion may occur, which may increase if the disruptor has been 'locally' manufactured. This is accounted for in the evacuation and safety distances for a live device and the forward and rear safety distances at other times, including during training. If, for operational reasons, personnel are required to operate inside these distances, this risk should be recognised, and personnel appropriately protected, remaining out of the line of sight and behind suitable protection.

Image 4. Barrel disruptor targeting a buried power source uncovered during a fingertip search. The natural angle of the excavated channel has been used to place the barrel disruptor

Image 5. Barrel disruptor targeting the power source on an abandoned suicide belt. A locally manufactured stand has been used to aid in correct placement

Image 6. An MA IEDD operator using a sandbag as an improvised stand to place a barrel disruptor targeting a legacy IED

STEP 4 – SAFE POSITIVE ACTION

Once the barrel disruptor has been placed, the MA IEDD operator returns to the CP and informs the cordon positions and other agencies that a 'controlled explosion' is about to take place and not to react to it.

WARNING. When the disruptor is fired there is the possibility that the IED may function. Suitable cordon and evacuation must be in place and any MA staff remaining inside the explosive danger area must be suitably protected.

Image 7. The buried power source has been successfully removed from the circuit of a crush wire IED with minimal interaction by the IEDD operator

Image 8. The disruptor has successfully removed the power source from the suicide belt with the additional benefit of moving the belt from its original location. Note the disruptor recoil

Image 9. The whole IED (which contained the power source) has been successfully disrupted

STEP 5 – CONFIRMATION OF DISRUPTION

After firing the disruptor, a safe waiting period must be observed before making a manual approach to confirm that disruption has been successful. The length of this period should be stipulated in the MA organisation's SOPs.

Confirmation of disruption is an important process to ascertain if the shot has been successful. Ideally this should be done remotely with an ROV / UAV or using optics from outside the danger area. The confirmation of the disruption process is not complete until the MA IEDD operator has manually confirmed disruption at the target.

HINT. When returning to the IED to confirm disruption, it is good practice for the MA IEDD operator to return with a second loaded disruptor (if available). That way if disruption has not been completely successful, a second shot can be prepared without the MA IEDD operator having to make repeated manual approaches into the danger area.

WARNING. Safe confirmation of positive actions is critically important. Even if the barrel disruptor was placed manually, the use of an ROV or UAV (if available) should be considered to confirm that disruption has been achieved before re-entering the danger area.

WARNING. Disruption may have resulted in component separation. HOWEVER, components which could cause an inadvertent detonation may be in very close proximity to each other (battery cells and electric detonator leads). The MA IEDD operator must exercise caution during confirmatory actions.

4.5. BOTTLE DISRUPTORS

4.5.1. INTRODUCTION

A bottle disruptor provides a safe and effective tool to neutralise an IED. As with all disruptors they are most effective against electrically initiated IEDs, especially when the battery (power source) can be effectively targeted. Due to the omnidirectional effect, bottle disruptors tend to achieve 'general disruption' as opposed to 'selective disruption' of a specific component. Bottle disruptors can be placed semi-remotely, which requires the MA IEDD operator to manually place the disruptor as close to the IED as possible without disturbing it, or remotely using an ROV.

Bottle disruptors are constructed from a plastic bottle containing water and a quantity of high explosives. The ratio of water to explosives can vary depending on the situation and the nature of the IED that is being neutralised. When the explosive detonates, the water is projected at high velocity in an omnidirectional pattern. The concept is that the projected water separates circuitry faster than the bridge wire in a detonator can react and heat up. Since the separation of components is so rapid there is a low probability of causing an unintentional detonation.

Bottle charges can be locally produced using a standard disposable water bottle in conjunction with high explosives. There are also commercial alternatives available which have an inner tube filled with plastic explosives inserted into a larger water container, this produces more consistent results. In both instances the MA IEDD operator can select the size of bottle and quantity of explosive to achieve the desired effect.

4.5.2. WHY IS THE USE OF BOTTLE DISRUPTORS 'GOOD PRACTICE'?

The use of bottle disruptors complies with the IMAS 09.31 IEDD principle "Water based energetic disruption of the power source(s) is the preferred means of neutralisation." This is because interaction with the IED is minimised and the time the IEDD operator is inside the danger area is kept to a minimum. This is directly linked to the primary IMAS IEDD guiding philosophy of 'preservation of life'.

ADVANTAGES OF BOTTLE DISRUPTORS

- Safe, effective and efficient means to neutralise an IED;
- Minimises interaction with the IED;
- Reduces time inside the explosive danger area;
- Can be placed manually or remotely;
- Increases flexibility as they can easily be matched to the situation and desired effect;
- The bottle disruptor is sacrificial, therefore if disruptive action causes a detonation there are no expensive IEDD tools and equipment to be damaged;
- Water and manufactured gels are non-flammable and as such do not present any secondary incendiary hazards during disruption;
- A cheaper and easier logistical solution than barrel disruptors.

DISADVANTAGES OF BOTTLE DISRUPTORS

- Can be harder to achieve selective disruption than if a barrel disruptor is used;
- May be less effective against hard-cased containers than a barrel disruptor, although this can be offset by increasing explosive NEQ and water mass;
- May deliver a less consistent effect than a barrel disruptor;
- Requires access to, and permission to use, high explosives.

LIMITATIONS OF BOTTLE DISRUPTORS

The following limitations should be considered when using bottle disruptors:

- Spaced casings (air gaps / box within a box).
- Metal containers.
- Heavy gauge plastics.
- Soft fabric containers.
- Multi wrapped packages.

4.5.3. USE OF BOTTLE DISRUPTORS

STEP 1 – PREPARATION

The process of preparing a bottle disrupter for use differs slightly between commercially manufactured and locally produced bottle disruptors. Both are described below. This is not intended to be an exhaustive guide on the preparation of bottle disruptors but a general overview to aid understanding.

Commercial bottle disruptor

The user selects the appropriate size bottle and decides on the quantity of plastic explosives required to achieve the desired effect. The explosives are loaded into an inner chamber which is held centrally in the bottle. Most commercially available bottle disruptors enable the user to alter the explosive quantity. The explosives should be loaded carefully using a non-metallic loading rod to ensure there are no air voids. There are options for using both electrical and non-electrical means of initiation, as well as incorporating a booster. The bottle is then filled with water and the lid secured.

Image 1. Loading plastic explosives into the inner chamber of a commercial bottle disruptor

Image 2. Sealing the inner chamber of a commercial bottle disruptor

Image 3. Inserting the inner chamber and securing the lid on a commercial bottle disruptor. Water will be added prior to use

Locally produced bottle disruptor

A readily available disposable water bottle of the appropriate size is selected. A quantity of detonating cord that will achieve the desired affect is chosen and cut to length. This is then folded in on itself (possibly several times depending on overall length) to enable it to fit in the bottle, and secured with tape. The lid is removed from the water bottle and the detonating cord is inserted with a tail protruding out of the bottle. The user can then either cut a hole in the lid, slide it over the detonating cord tail, attach the lid to the bottle and secure the tail with tape, or simply tape the bottle opening closed securing the detonating cord at the same time.

> HINTS.
> - The bottle should be thin walled plastic, preferably with parallel sides. Avoid bottles made of hard plastic. Single use bottles are ideal.
> - Detonating cord is hygroscopic. It is common practice to tape exposed ends to help prevent moisture ingress. It is also recommended to avoid having an end submerged in water.
> - Ensure when folding the detonating cord that enough is left protruding to form a tail to which a detonator can be attached.
> - There is no stipulated bottle size and quantity of detonating cord. This is chosen by the MA IEDD operator depending on the situation and desired effect of the disruptor. As a general rule though, it is recommended not to go below 500 ml of water and 8 g of net explosive quantity of detonating cord (roughly 65 cm of 12 g/m detonating cord or 4 strands in a bottle).

STEP 2 – DEPLOYMENT AND PLACEMENT

> WARNING. Correct procedures to safely connect the detonator to the explosive chain must be observed.

For manual deployment the bottle disruptor is normally carried by the MA IEDD operator from the CP to the IED **without** a detonator attached. At an appropriate point and distance from the device the IEDD operator then attaches the detonator following the organisation's SOPs. This procedure involves a dynamic risk assessment to ascertain the safest and most appropriate point to balance the risk of completing the explosive chain of the bottle disruptor versus time spent in the explosive danger area. The bottle disruptor is then placed to achieve the optimum effect on the IED without prolonging the time in the danger area or compromising safety.

> HINT. When placing the bottle disruptor, the MA IEDD operator should consider the effects of disruption and where components will fall. The orientation of the placement should, if possible, direct the disrupted components to fall into an area in which it is much easier to subsequently confirm disruption. However, this should not be done at the expense of correct disruptor placement or safety.

Achieving the best target effect from a bottle disruptor:

- Correct distance from the IED – as close as possible to it, without touching.
- Centre of the target.
- Consider the type of target being attacked (most suitable size of bottle and quantity of explosives, best / worst case).
- Towards a backstop but not hard against it.

STEP 3 – SAFE POSITIVE ACTION

The positive action of functioning the bottle disruptor must be conducted in a safe manner. It is important that the community and MA staff are evacuated to outside of the explosive danger area and an effective cordon is put in place. Any MA staff remaining inside the explosive danger area must be suitably protected. Prior to conducting positive action all relevant personnel, including other agencies at the scene, should be informed that a controlled explosion is about to take place. This is to prevent others mistakenly thinking an incident or accident has occurred and inadvertently responding to it.

WARNING. When the disruptor is fired there is the possibility the IED may function. Suitable cordon and evacuation must be in place and any MA staff remaining inside the explosive danger area must be suitably protected.

STEP 4 – CONFIRMATION OF DISRUPTION

Confirmation of disruption is an important procedure that ideally should be done remotely using an ROV or UAV, if available. If ROVs / UAVs are not available, then the use of hand-held optics is advisable before the MA IEDD operator conducts their next manual approach. A safe waiting period must be observed between the positive action and the MA IEDD operator's next manual approach.

NOTE. Confirmation of disruption is not complete until the IEDD operator has manually confirmed disruption at the target.

Following disruption, the IED's components will have been scattered, with some components projected further than others. When confirming disruption, it is important that the IEDD operator does not become focused solely on where the IED had originally been located. Rather, they should scan the wider area with consideration of how the disruptor was placed in relation to the IED and what effect it was likely to have had. With experience, the IEDD operator will gain a good appreciation of where and how far components will be scattered.

HINT. When returning to the IED to confirm disruption, it is good practice for the IEDD operator to return with a second bottle disruptor. If disruption has not been completely successfully, then a second disruptor can be placed without the IEDD operator having to make repeated manual approaches.

WARNING. Safe confirmation of positive actions is critically important. Even if the bottle disruptor was placed manually, the use of an ROV or UAV should be considered, if available, to confirm that disruption has been achieved before re-entering the danger area.

WARNING. Disruption may have resulted in component separation. However, components which could cause an inadvertent detonation might be in VERY CLOSE proximity to each other (battery cells and electric detonator leads). The IEDD operator must exercise caution during confirmatory actions.

4.5.4. BOTTLE CHARGE DISRUPTION

EXAMPLE 1

Demonstration of a commercial bottle disruptor against an anti-lift switch with an integral power source located beneath a 155 mm projectile.

Image 4. Commercial bottle disruptor placed in an excavated channel to target the power source in the anti-lift switch

Image 5. The effect post disruption. Note how the 155 mm projectile has also been moved by the force of the bottle disruptor

Image 6. Recovered components following successful disruption

EXAMPLE 2

500 ml commercial bottle disruptor against a failed timer power unit (TPU) attached to a projectile.

Image 7. IEDD operator placing a commercial bottle disruptor

Image 8. Commercial bottle disruptor placed to target TPU

Image 9. Effect post disruption. Note how the projectile and oil drum have also been moved by the force of the bottle disruptor

EXAMPLE 3

600 ml improvised bottle disruptor against the power source (2 x D Cell batteries) of a tripwire IED.

Image 10. Tripwire IED set across a doorway

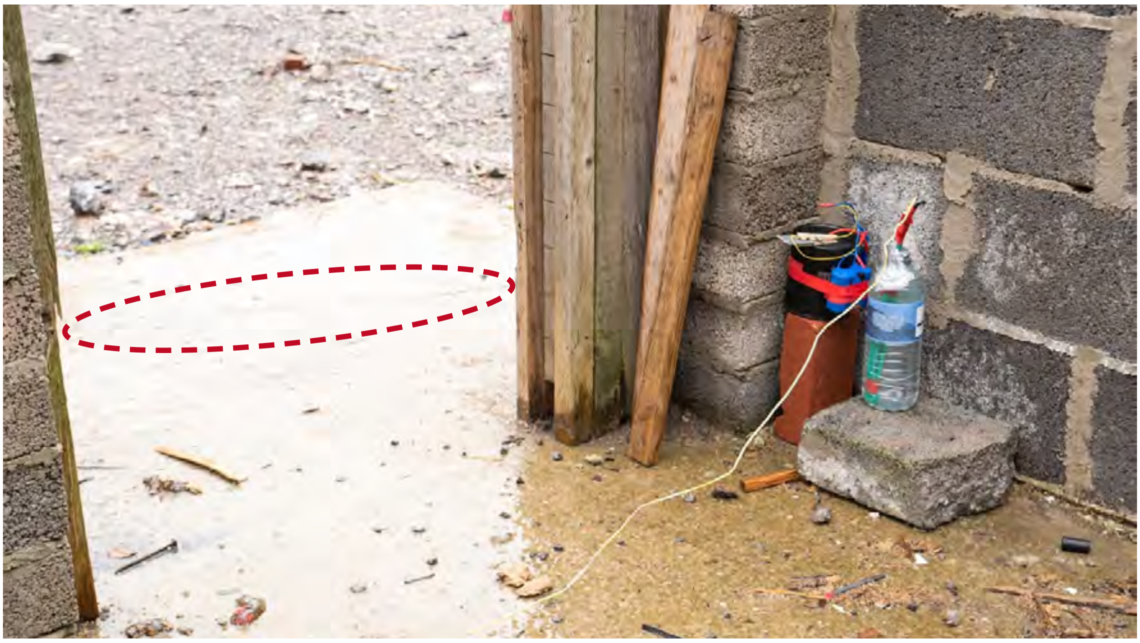


Image 11. Improvised bottle disruptor placed to target power source. A block has been used to aid in placement for a better target effect

REMEMBER. Do not work over the tripwire.

Image 12. Effect post disruption

Image 13. Recovered components following successful disruption

EXAMPLE 4

Improvised bottle disruptor against the displaced and buried power source (2 x PP3 9V batteries) of a PPIED.

The improvised bottle disruptor does remove the power source but is low on force and could have easily failed. Note how the power source is still intact and just the leads have been pulled out of the adhesive tape. This is due to a small bottle with too little detonating cord being used.

Image 14. IEDD operator placing an improvised bottle disruptor to attack the buried power source

Image 15. Power source post disruption. Note how the power source is intact and just the leads have been removed

EXAMPLE 5

Improvised 500 ml bottle disruptor against a 'come on' multi-switch IED. An obvious crush wire with a tilt switch is built into the bottom of the main charge.

Image 16. Disruptor in situ prior to being functioned from the CP

Image 17. The disruptor is functioned from the safety of the CP. Note the amount of heat and flash immediately on detonation

Image 18. As the blast wave grows in size the expanding waterfront suppresses the heat and flash from the detonation

Image 19. As the blast wave pushes out further, components from the IED can be seen to separate

EXAMPLE 6

Improvised 500 ml bottle disruptor against a tripwire IED consisting of a bare wire loop switch, PP3 9V battery and 81 mm mortar.

WARNING. When conducting an RSP on a tripwire IED both ends of the wire must be confirmed prior to positive action to ensure multiple switches are not present.

Image 20. Tripwire IED camouflaged at the base of the blue barrel

Image 21. Improvised 500 ml bottle disruptor functions and the water suppresses the heat and flash

Image 22. IED components are being rapidly separated

Image 23. The placement of the bottle disruptor has been directed against the PP3 9V battery. Disrupted cells can be observed in this image

4.6. SHAPED CHARGES

4.6.1. INTRODUCTION

Shaped charge tools provide an MA IEDD operator with additional options for disposal. Specifically, they can be used to achieve the following:

- **Stand-off disposal.** The disposal of an IED by destruction in situ using a shaped charge which can be placed at an increased stand-off and with obstructions in its path, such as soil or sand.
- **Low order technique.** Disposal by deflagration of the IED main charge when a high order detonation is not desirable.

4.6.2. WHY IS THE USE OF SHAPED CHARGES ‘GOOD PRACTICE’?

When disposing of an IED, destruction in situ is the preferred method. This is normally achieved by the placement of a high explosive donor charge placed “as close to but not touching” the IED’s main charge. This is due to donor explosives needing to be in close proximity to the target to be effective. However, in certain circumstances accessing and exposing the main charge to achieve this placement may pose safety issues for the MA IEDD operator. The use of a shaped charge may overcome these problems as they can be used with increased stand-off and penetrate barriers whilst still achieving a high order disposal.

Image 1. Locally made shaped charge placed to target an IED main charge under a pressure plate which overhangs it on all sides. Using this technique, the IED operator avoids any possible interaction with the firing switch

Image 2. Crater from the high order detonation of the main charge in Image 1

Shaped charges can also provide an advantage when a high order detonation is undesirable due to the damage it will cause to surrounding infrastructure. A shaped charge in this instance could be used as a low order technique to induce deflagration of the IED main charge.

WARNING. Whenever possible, disposal using a high explosive donor charge is the preferred technique as there is less variance in the end result.

4.6.3. USE OF SHAPED CHARGES FOR A STAND-OFF ATTACK

A significant advantage of using shaped charges is their ability to induce a high order detonation from a significant stand-off distance and when the main charge is concealed. This is particularly useful for buried VOIEDs as it minimises the amount of excavation, (possibly eliminating it all together) and significantly reduces the time the MA IEDD operator spends in the vicinity of the IED.

Once the position of the main charge is known, or accurately assessed, the MA IEDD operator can place a shaped charge and retire to the CP. This avoids any interaction with the device and avoids potentially having to work near a firing switch conducting excavation. The shaped charge can pass through barriers such as soil / sand with sufficient energy to penetrate the casing of an IED's main charge and cause a high order detonation.

Image 3. 65 mm shaped charge placed to target a buried metal cased main charge under 100 mm of sand. There is 200 mm stand-off between the shaped charge and the surface of the sand. The main charge has been exposed for the purpose of the picture

Image 4. Scene immediately prior to firing the shaped charge

Image 5. The shaped charge has successfully penetrated the sand and achieved a high order explosion of the buried main charge

When an IED is buried the exact location of the main charge may not be known. In this instance, in order to increase the probability that this technique is successful, multiple shaped charges may be grouped together in an 'array'.

Image 6. ROV remotely placing a shaped charge array to target a buried IED

Image 7. Cross-section showing how the array has been placed to target the buried main charge

4.6.4. USE OF SHAPED CHARGES TO INDUCE DEFLAGRATION

Shaped charges provide an MA IEDD operator with an option to achieve deflagration of the explosives, thus reducing the likelihood that damage will occur. This is a subsonic reaction, rather than a detonation which is supersonic. However, deflagration is generally a 'non-steady reaction', which combined with the variance in the explosive's properties, means that results can be inconsistent.

WARNING. The MA IEDD operator should always plan for a high order detonation. If this is unacceptable, then a different disposal procedure should be used.

Image 8. Shaped charge with magnesium jet forming cone, filled with 50 g of high explosives (DEMEX) placed with 75 mm stand-off from an abandoned IED main charge

Image 9. Deflagration was unsuccessful and the main charge detonated. This highlights the difficulty in achieving deflagration of improvised main charges filled with HME of unknown provenance and unknown position of the detonating cord booster. However, the main charge has been successfully destroyed

4.6.5. SELECTION OF THE APPROPRIATE SHAPED CHARGE FOR THE INTENDED ROLE

There are several factors to consider when selecting the appropriate shaped charge to achieve the desired effect. These include:

- The distance the shaped charge will travel and through what mediums / barriers;
- The type of material and thickness of the IED main charge's casing;
- The type and condition of the IED explosive filling;
- The desired effect – high order detonation or deflagration.

The MA IEDD operator must draw on their training, published documentation, trials and experience when selecting the shaped charge which will give the highest probability of success. There are several variables to consider, however some of these will be fixed by what is available:

- Type of shaped charge to use.
- Size of shaped charge.
- Liner material and thickness.
- Type and quantity of explosive fill for the shaped charge.
- Minimum stand-off distance required.

Section 4.7 of this sub-section gives a basic overview of shaped charge effects.

LINER SELECTION

When considering the liner of a shaped charge there are three main considerations:

- **Shape.** The shape of the liner will give the effect and will normally be either:
  - Jet forming cone (JFC) (Munroe effect) producing an extremely high velocity plasma jet capable of penetrating thick steel plate.
  - Explosively formed projectile (EFP) (Misznay-Schardin effect) projecting a high velocity slug of compact metal.
- **Size.** The size of the liner, particularly its diameter (often referred to as 'charge / cone diameter') effects the penetration depth for JFCs and the range for EFPs (assuming the liner's angles are correct and suitable explosives are used).
- **Material.** The construction material of the liner affects its performance. For EOD applications the use of certain materials like magnesium will assist in igniting a burn.

4.6.6. COMMERCIAL OR LOCALLY MANUFACTURED

User filled shaped charges are commercially available. They come in a variety of sizes with different liner options, and the user is able to select the quantity of explosives to use and the means of initiation. Some have fixed liners whilst others are modular, allowing the user to select the desired liner.

Locally produced shaped charges are a potential option (local laws permitting) and can be very effective. The materials and tools required are easily accessible in most parts of the world.

Whether commercially available or locally developed by an MA organisation, the type of shaped charge should be designed, trialled, tested and evaluated in accordance with IMAS 03.10 Guide to the procurement of mine action equipment and IMAS 03.40 Test and evaluation of mine action equipment. It is good practice to conduct trials, especially with locally produced shaped charges, to provide confidence in performance in relation to the penetration effects and energy transfer to the device. This data could be provided as a pocket book or aide-memoire to MA IEDD operators to improve the decision-making process on site.

Image 10. Cropped 40 mm EFP being locally manufactured

Image 11. Three commercial user filled modular 30 mm shaped charges next to two locally produced 40 mm shaped charges

4.6.7. FILLING AND PLACEMENT

When filling and placing a shaped charge the following points should be observed to aid in achieving a successful result:

- No air voids in the explosive fill. The loading process should be conducted by adding small amounts of explosives at a time and tamping with a non-metallic mandrel;
- Intimate contact between liner and explosive filling;
- Initiate from the rear;
- Use appropriate stand-off. Both the JFC and EFP need space to form in free air;
- Place at 90 degrees to the centre line of the target;
- Do not aim at boosters and detonators when trying to deflagrate;
- Aim at boosters and internal detonators when trying to achieve a high order detonation.

Image 12. Cropped locally made shaped charge being filled with explosives. Note how small pieces are being added and will then be tamped to prevent air voids

Image 13. Locally made shaped charge placed at 90 degrees to the centre line of the target with enough stand-off for the shaped charge to form

4.7. SHAPED CHARGE EFFECTS

The table below gives a basic comparison of the penetration performance of different sized shaped charges and the effectiveness of a simple locally manufactured shaped charge. A bulk high explosive charge has been used to give a baseline. All shaped charges use a copper jet forming cone liner and have been placed at the correct stand-off. All charges have used the same brand of plastic high explosives (DEMEX) used against 10 mm rolled homogenous steel (RHS) plates.

CHARGE	PLACEMENT	EFFECT
20 g bulk high explosives in intimate contact.		 **Total penetration >10 mm RHS**
Locally produced shaped charge, 40 mm diameter copper jet forming cone, 20 g high explosives, 120 mm stand-off.		 **Penetrated 3 x 10 mm RHS plates, partially penetrated 1 x 10 mm RHS plate and 1 x 10 mm plate not penetrated. Total penetration approximately 35 mm RHS**
Commercial user filled shaped charge, 30 mm diameter copper jet forming cone, 20 g high explosives, 100 mm stand-off.		 **Penetrated all 19 x 10 mm RHS plates. Total penetration >190 mm RHS**
Commercial user filled shaped charge, 65 mm diameter copper jet forming cone, 300 g high explosives, 200 mm stand-off.		

4.8. DEMOLITION IN SITU

Image 1. 800 g of ANAL HME being destroyed in situ with a 100 g HE donor charge

4.8.1. INTRODUCTION

"**When feasible, destruction in-situ, using an explosive donor charge targeting the main charge(s) of the IED, is the preferred method of disposal.**"[4] This might not always be achievable due to the likelihood of damage to surrounding infrastructure and property, or the inability of MA organisations to access or have the required permissions to use high explosives.

4.8.2. WHY IS DEMOLITION IN SITU 'GOOD PRACTICE'?

IEDs, by definition, are improvised. As such, their behaviour can be unpredictable. Destruction in situ is a general principle of IEDD in MA and is often considered to be the safest and most efficient method of disposal. As long as the firing switch can be avoided, and the IED's main charge accessed safely, then it should be possible to quickly dispose of an IED by placing a suitable charge of serviceable high explosive as close to its main charge as possible, but not touching, and then detonating it.

> **WARNING. Suitable cordon and evacuation must be in place in accordance with the assessed explosive hazard (blast and fragmentation) danger area, prior to placing the donor charge. Any MA staff remaining inside the explosive danger area must be suitably protected.**

4 IMAS 09.31 IEDD, 5.2 General principles

ADVANTAGES OF DEMOLITION IN SITU

- Minimal interaction time in the immediate area of the IED;
- An efficient disposal procedure, requiring the fewest approaches to be made and the fewest actions conducted;
- IED main charges are not required to be subsequently moved to a final disposal site.

DISADVANTAGES OF DEMOLITION IN SITU

- Requires access to and permission to use high explosives;
- Potential to cause damage to surrounding property and infrastructure;
- Requires safe access to the IED main charge(s) for the placement of the donor charge;
- Can remove ground signs of further IEDs in the immediate area.

WARNING. IEDD operators should not be tempted to use any part of the IED's firing circuit for demolition in situ. This is an unsafe practice. Serviceable explosives and accessories should be used.

When preparing the donor charge, consideration needs to be given to its size. The donor charge needs to be sufficiently large to propagate a detonation wave through the main charge container, but not so large as to enhance the effects of the main charge exploding.

In some instances, it may be possible to remotely place the donor charge using an ROV, which then moves out of the explosive danger area before the charge is initiated. However, MA destruction in situ will normally require the IEDD operator to make a manual approach and place the donor charge by hand.

REMEMBER. The donor charge should be placed as close to the IED main charge as possible, but not touching it.

WARNING. IEDD operators must satisfy themselves that the IED main charge is not explosively linked to another unknown main charge. Potentially, multiple donor charges could be used if multiple main charges are located.

In order to achieve the best placement, the IEDD operator will need to know the location and position of the IED's main charge and formulate a plan on how it can be safely accessed. Generally, for subsurface IEDs some form of excavation will be required to enable a donor charge to be correctly placed. Equally, IED main charges located on the surface or above the surface may mean that the donor charge needs to be elevated. There is no limit to how an IED main charge could be placed and therefore the IEDD operator may need to improvise to ensure correct placement of the donor charge.


Image 2. A channel has been excavated through fingertip search to gain access to an IED main charge consisting of ANAL HME in a plastic container

HINT. Keep it simple. A straightforward method should be planned and used. If it can go wrong, it is likely that it will go wrong!


Image 3. Donor charge placed in the channel as close to but not touching the IED main charge

Once the donor charge has been placed then the final action prior to the IEDD operator returning to the CP is for the detonator to be attached to the detonating cord.

HINT. It is strongly recommended that electrical (or shock tube if available) over non-electrical (safety fuze) means of initiation are used. This is because control is maintained over the demolition right up until the moment of initiation.

WARNING. If non-electrical (safety fuze) initiation is used, the IEDD operator must be confident that the cordon and evacuation can be maintained throughout.

HINT. Direct insertion of the detonator into the donor explosives is not recommended, even if the donor explosives are detonator sensitive. Having a detonating cord link serves two purposes: it enables the donor charge to be positioned and not be moved whilst the detonator is attached and also acts as a booster to the explosive chain.

WARNING. Prior to firing the demolition, the IEDD operator MUST ensure there has been no encroachment into the cordon and evacuation area. These distances MUST still be sufficient for the assessed explosive danger including the donor charge being used.

After firing the demolition and the application of a safe waiting period, the IEDD operator will need to confirm that the IED main charge has been destroyed and recover any remaining non-explosive IED components through appropriate IEDD techniques.

4.8.3. STAND-OFF

It may not always be possible to safely place the donor charge without touching the IED main charge. However, the IEDD operator must not compromise safety and may consider placing the donor charge with increased stand-off. The IEDD operator must be aware that the risk of the detonation not propagating from the donor charge to the IED main charge will increase.

WARNING. This should not be attempted where failure could greatly increase the risk of the IED being left in a more dangerous state.

Increasing the size of the donor charge will help compensate for stand-off, however there is a limit as to how much this will work. The IEDD operator must use their experience and judgement to ascertain if attempting this technique is appropriate.

In the next example a small IED main charge has been placed under a large pressure plate which overhangs the main charge on all sides. It would be unsafe for the IEDD operator to fingertip search further under the pressure plate to place a donor charge. Therefore, the IEDD operator has elected to place the donor charge with a slight increase in stand-off and double the size of the donor charge to help compensate for this increase.

Image 4. IED main charge consisting of ANAL HME in a plastic container under a pressure plate which overhangs it on all sides

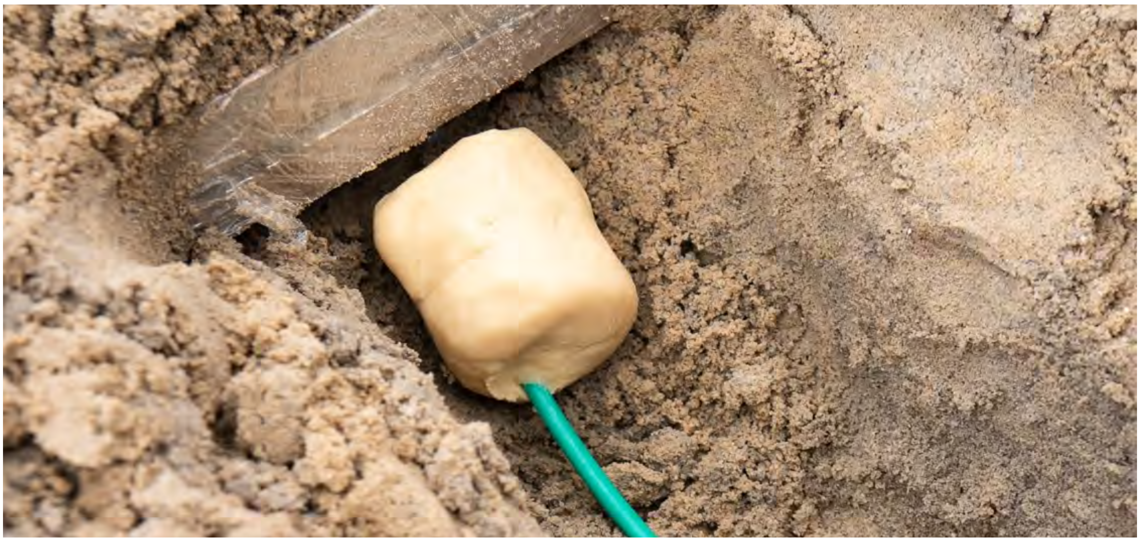


Image 5. Donor charge placed with increased stand-off

Image 6. Crater from a successful high order detonation of the IED main charge

4.9. PYROTECHNIC TORCH / THERMITE LANCE

Image 1. Using a pyrotechnic torch / thermite lance on a main charge containing HME

4.9.1. INTRODUCTION

A pyrotechnic torch, or thermite lance, is an incendiary tool that can be used to dispose of IED main charges. It is intended to achieve a low order burn but can also be used to deliberately cause a high order detonation depending on how it is applied by the IEDD operator.

It is also possible to combine this technique with other tools. For example, during final disposal of heavy cased main charges it is possible that a two-stage process could be used with the casing being explosively or mechanically opened and then the pyrotechnic / thermite tool used against the main fill.

HINT. For large, thin cased main charges when the intention is a low order burn the IEDD operator may consider using multiple pyrotechnic torches / thermite lances.

WARNING. If multiple pyrotechnic torches / thermite lances are used then they MUST be wired in series so that all or none will ignite.

4.9.2. WHY IS THE USE OF A PYROTECHNIC TORCH / THERMITE LANCE 'GOOD PRACTICE'?

A pyrotechnic torch / thermite lance is useful when destruction in situ causing a high order detonation is undesirable. This is normally due to the risk of causing damage to the surrounding infrastructure. A pyrotechnic torch / thermite lance in this instance could be used as a low order technique to induce a burn and dispose of the IED main charge.

When high explosives for a donor charge are unavailable, a pyrotechnic torch / thermite lance can also be used to deliberately target an exposed detonator to achieve a high order detonation. This avoids the extra complications of a low order technique, such as having to apply safe waiting periods after the last sign of smoke, and difficulties of inducing a reliable burn in some explosives.

WARNING. When conducting a burn, the plan must always account for a high order detonation occurring and suitable safety distances must be in place. If a high order detonation is unacceptable then a different disposal technique must be used.

REMEMBER. Where possible, disposal by sympathetic detonation from a high explosive donor charge is the preferred technique. This is because there is less variance in the end result and the associated safety concerns related to igniting a slow burn of the explosives.

ADVANTAGES

- Easier to import, store and transport than high explosives;
- May be easier to gain permission from relevant national authorities;
- Adaptable in its application – can be used to achieve disposal through high order detonation in addition to its intended low order burn.

DISADVANTAGES

- Low order burn cannot be guaranteed;
- Increased time for disposal due to burning taking longer and a lengthier safe waiting (soak) period which must be applied;
- Not as consistent as other disposal methods and carries a greater risk of failure;
- If not used correctly it could leave the IED in a more dangerous state.

4.9.3. USE OF PYROTECHNIC TORCHES / THERMITE LANCES TO ATTEMPT A LOW ORDER BURN

Pyrotechnic torches / thermite lances can be used to induce a low order burn in an IED's main charge. They are designed to melt through thin cased metal and plastic bodies (generally up to around 10 mm thick steel) and induce a burn in the explosive fill. They work best when used against an IED main charge consisting of military ordnance. Results are less consistent when used against HME filled main charges due to higher variables in the explosive fill.

HINT. Pyrotechnic torches / thermite lances are relatively ineffective at inducing a low order burn in ammonium nitrate based HMEs, due to the HME's slow uptake of heat.

When placing a pyrotechnic torch / thermite lance for a low order burn, detonators and boosters should be avoided to minimise the risk of a detonation.

WARNING. Exercise caution before reapproaching a main charge after a low order burn. Explosive fillings may reignite even after the initial smoke has subsided. Ensure the appropriate safe waiting (soak) period is applied.

Image 2. Thermite lance placed to induce a burn in a thin metal cased main charge. Note how the lance has been placed at the rear to avoid the detonating cord

4.9.4. USE OF PYROTECHNIC TORCHES / THERMITE LANCES TO ATTEMPT A HIGH ORDER DETONATION

When no other energetic disposal materials are available for a high order detonation, then the use of a pyrotechnic torch / thermite lance could be considered for this purpose by targeting the detonator, if visible and accessible. The primary explosive in the detonator will likely function from the induced heat and provide the necessary shock for detonation required to function the IED.

WARNING. This is to be used in extreme situations when no other high order disposal materials are available. There is a higher possibility of failure and the IED could be left in a more dangerous state.

Image 3. Thermite lance placed to target the exposed detonator of an IED main charge

Image 4. Crater from a successful high order detonation during trials

4.10. HUMAN REMAINS CLEARANCE

4.10.1. INTRODUCTION

WARNING. MA staff that are called on to help manage human remains should always seek and secure all necessary permissions from government officials, the acceptance of families, the agreement of community leaders and religious authorities. Failure to do so can result in criminal liability, and unnecessary security risks for those involved and the organisation they represent.

There is always the potential of finding human remains during MA operations and dealing with them is an extremely sensitive subject. TNMA 10.10/01 Guidelines on the management of human remains located during mine action operations provides further guidance and should be read in conjunction with this sub-section. The management of human remains is the responsibility of the relevant authorities who should be notified immediately when they are discovered. MA staff may be asked to assist if:

- Human remains lie within a suspected or confirmed hazardous area;
- Conventional explosive ordnance (EO) is present (or suspected) on or within the remains;
- An IED(s) is present (or suspected) on or within close proximity to the remains;
- All or a combination of the above.

WARNING. Unauthorised tampering or handling of human remains is a serious offence in most countries (regardless of any good intentions behind the actions). Human remains may be treated as a CRIME SCENE and corresponding criminal liability may last a long time (i.e. individuals or organisations may be held accountable long after the offence).

This sub-section focuses on the possible EO hazards that may be present on human remains, with a particular emphasis on IEDs. Conventional EO is mentioned for completeness. Other hazards associated with human remains, such as biological hazards and psychological considerations are not covered, and the reader should refer to TNMA 10.10/01.

4.10.2. STAGES FOR THE CLEARANCE OF HUMAN REMAINS

Upon the discovery of human remains, **cease work immediately** in order to preserve the crime scene and **inform the relevant authorities** (civilian, military, religious or municipal) without delay. The following 6-stage plan provides guidance on clearing human remains.

STAGE 1 – REQUESTS AND PERMISSIONS

Only when a request from an appropriate authority is received and the relevant permissions granted should any actions be taken. It is likely that representatives from the relevant authorities will need to be present at the worksite when any actions associated with human remains are undertaken.

STAGE 2 – THREAT ASSESSMENT

A threat assessment must be formulated for the surrounding area and the remains themselves. Consideration should be given to all EO threats which may be present, not just that from IEDs. This may include considerations such as whether or not the remains form part of a VOIED designed to function when they are disturbed. The following list gives some points an IEDD operator may want to consider when formulating a threat assessment for the clearance of human remains:

- Are the remains in a hazardous area (suspected or confirmed)?
- Are the remains from combatants or non-combatants?
- Do combatants have a history of carrying IEDs on their person e.g. suicide belts or improvised grenades?
- Is there a history of corpses being used in conjunction with VOIEDs?
- Are any explosive hazards visible / reported?
- What clothing is present with the remains e.g. military uniform or civilian clothing?
- Is the corpse wearing military load carrying equipment which may contain explosive hazards?
- Has a specific incident occurred in the area?
- Is there a firearm present?
- Does the corpse look out of place where it is situated, or as though it has been tampered with?

HINT. Just because the remains are not wearing military uniform, does not preclude the possibility that an explosive hazard is present. Suicide bombers and some non-state armed groups wear civilian clothing.

STAGE 3 – CLEARANCE OF SURROUNDING AREA

A safe working area needs to be cleared to provide access to the remains. An assessment will need to be made to the extent that this clearance is required and should consider the authorities who will document and recover the remains. It is logical to clear around the remains first, however it is not mandatory to complete the clearance in its entirety before conducting some form of clearance on the body. This will be driven by the threat assessment.

STAGE 4 – CLEARANCE OF THE REMAINS

This should be prioritised with the highest threat area cleared first working to the lowest. There may be multiple threats present: IEDs, conventional ordnance and loaded firearms in an unsafe state. Appropriate techniques should be used for the clearance, which may include semi-remote procedures and the use of radiography equipment. It is unlikely that this step can be completed until the remains have been moved semi-remotely to give access to all sides.

STAGE 5 – SEMI-REMOTE MOVEMENT OF THE REMAINS

Where a residual threat still remains, from either IEDs or abandoned explosive ordnance, then the remains should be moved semi-remotely. This will also enable access to previously inaccessible areas of the remains. This may be made more difficult depending on the state of decomposition.

WARNING. Moving remains is extremely sensitive and consideration should be given to not causing unnecessary distress to others. Ideally it should be done out of sight. The remains should be disturbed no more than is respectfully necessary.

STAGE 6 – CLEARANCE OF WHERE THE REMAINS WERE LOCATED

Before anyone is allowed into the scene, it is important to clear the area underneath where the remains had originally been located. There could be threats which have lain undetected due to being covered by the remains. Do not assume that VOIEDs are absent due to the remains being laid there.

Image 1. There may be multiple explosive hazards present when dealing with human remains. Here a corpse is located in a hazard area wearing a suicide belt, military load carrying equipment, which could hold further explosive hazards, and with a firearm, possibly ready to fire

4.11. USE OF UAVs DURING HUMANITARIAN IEDD

4.11.1. INTRODUCTION

Incorporating unmanned aerial vehicles (UAVs) into humanitarian IEDD tasks is an emerging capability that is increasingly being utilised by the MA sector. UAVs are now widely accessible due to their popularity as recreational items, which has meant that multiple variants that incorporate high quality technology are available at greatly reduced prices.

UAVs offer a range of capabilities that previously were only obtainable by state security forces; the cost, maintenance and training burden prohibited their use in humanitarian operations. However, modern UAVs can be operated by MA staff with very little training, are available almost globally, and are affordable for most budgets.

Currently, UAVs are mainly utilised in humanitarian IEDD as remote viewing platforms. As further developments are made in the UAV field, the capacity of tasks they can perform within the MA IEDD spectrum will certainly increase. There are already prototype UAVs being developed for the commercial market that are capable of conducting positive IEDD actions.

4.11.2. WHY IS THE USE OF UAVs 'GOOD PRACTICE'?

The use of UAVs is deemed good practice as they offer a remote capability, which is always preferred, due to increased safety. The extent of this capability will vary depending on the UAV, but even if it is limited to a remote viewing platform it will still add significant value. In particular, it can perform two key roles: remote explosive ordnance reconnaissance (EOR) of the IED and surrounding area, and remote confirmation of positive actions. Both of these functions greatly improve safety by giving the IEDD operator real time information from a safe location.

As a remote viewing platform, the UAV has some unrivalled abilities over other remote assets. They can access areas which other remote means cannot due to terrain and physical barriers like walls and ditches. Their elevated position offers a unique view of the overall topography enabling more of the environment to be captured on screen, giving a better understanding. They also make remote observation of elevated areas, like rooftops, possible. As an aerial vehicle they can cover ground far quicker than a ground-based vehicle enabling more to be done in less time.

UAVs are not without their drawbacks; adverse weather can restrict their use, generally more so than other remote assets. Also, they cannot normally move obstacles for access or to achieve a clearer view. However, given that their price point is significantly less than a commercial IEDD ROV, they offer a significant capability.

HINT. The UAV manufacturer may have locked their brand of UAV from working in certain parts of the world. This is particularly true for conflict areas, in order to prevent them from being used by armed groups. Generally, the manufacturer can unlock specific UAVs (by serial number) if contacted with the appropriate approval letters. MA organisations should check with the manufacturer before making a purchase.

USE OF UAVs TO CONDUCT EOR

The following example highlights the ability of UAVs to gain access to areas which otherwise may have been impossible to reach using other remote assets. Here an NSAG has placed IEDs in an abandoned hospital to prevent its future use. The hospital has sustained damage from fighting between the NSAG and state security forces. It has been reported to the MA organisation that IEDs are present at several locations throughout the hospital. The debris from the damage to the building has made EOR through ground-based ROVs virtually impossible, especially for the upper floors. However, this has not affected the UAV which can still conduct EOR with ease.

Image 1. Overview of the damage and debris preventing ROV access to the hospital

Image 2. UAV conducting EOR of an IED placed in a doorway on the third floor. This would not be possible with an ROV

USE OF UAVs TO CONFIRM REMOTE AND SEMI-REMOTE ACTIONS

The utility of UAVs as remote viewing platforms makes them ideal assets for the confirmation of positive actions prior to the IEDD operator making a manual approach. Even if the initial positive action was conducted by another remote asset, the UAVs speed to the target area and wider field of view from an aerial position makes them ideal for the confirmation of positive actions.

In the example below a VBIED extractor has been fired to remove a large IED from the trunk of a vehicle. Consequently, the ejected IED components could have landed over a fairly large area. A UAV is deployed to confirm the VBIED extractor has been successful in removing the IED, locate the components and subsequently ascertain if disruption has been achieved. This real time information acquired remotely is invaluable to the IEDD operator and greatly improves safety. In this scenario, even if the VBIED extractor was placed with an ROV, following up with a UAV for confirmation offers advantages.

Image 3. UAV confirming the VBIED extractor has been successful and utilising its wider field of view from an aerial position to locate the IED or IED components and subsequently ascertain if disruption has been achieved

4.12. PORTABLE DIGITAL X-RAY

4.12.1. INTRODUCTION

The use of radiography (X-ray) by MA IEDD operators is a specialist skill specified in the IMAS Test and Evaluation Protocols (T&EP) 09.31/01/2019 for Level 3+ operators. It is not a core skill that all MA IEDD operators will have, nor a capability that all MA programmes can access unless equipment is available. However, depending on the threat and the MA programme's requirements, radiography is a capability that can increase the safety and effectiveness of IED disposal tasks and enable additional information on IED tactics to be gathered.

Radiography is the term given to the process of creating images to view the internal form of an opaque object by exposing the object to radiation. X-rays are the predominant type of radiation used in IEDD applications, as they have many advantages over other types of radiation.

When an object is irradiated (exposed to radiation), the quantity of radiation able to pass through and emerge on the other side will differ according to the thickness and density of the material through which it has passed. These differences between absorbed and emerging radiation can be used to create an image.

Commercially available EOD radiography equipment will usually consist of a portable X-ray generator to produce radiation and project it in a desired direction, and a portable image plate that is placed behind the suspect object to capture the variation in X-ray radiation that has been absorbed or passed through the object. Depending on the equipment, the image is produced in a variety of ways, the most common being as follows:

- Wet film processing where the plate contains a film on which the image is captured. This image can be viewed once developed.
- A phosphorus plate which is placed into a specialist scanner and a digital image is produced on a laptop / tablet screen.
- A digital plate which links to a laptop / tablet by a fixed or wireless link and displays the image on a screen.

WARNING. X-ray sources are inherently dangerous and although their emissions cannot be seen they can impact on health. These effects are cumulative and may manifest themselves many years after exposure. It is essential, therefore, that all personnel involved in the use of X-ray generators are fully conversant with their safe operation and the dangers inherent in their misuse.

4.12.2. WHY IS THE USE OF PORTABLE RADIOGRAPHY 'GOOD PRACTICE'?

Radiography enables an IEDD operator to view the contents of an opaque object / container without unacceptable disturbance or intrusion. It can be utilised to:

- Determine if a suspect object is an IED or component part of an IED;
- Determine if explosive components are present;
- Identify the method of initiation and optimum angle of attack for positive EOD action;
- Prevent damage to property from unnecessary EOD action by confirming if an object is innocuous;
- Provide intelligence on device construction and design.

4.12.3. USE OF PORTABLE RADIOGRAPHY

STEP 1 – STORAGE, MAINTENANCE AND PREPARATION

Only appropriately trained and authorised personnel should be involved in the storage, maintenance and preparation of X-ray equipment. X-ray equipment is generally more delicate than other EOD equipment. It can be easily broken and does not respond well to shock. It should be stored and transported in appropriate storage cases that offer suitable protection.

Prior to use there will be a degree of preparation required which will differ between different brands and models. The IEDD operator should be familiar with these requirements. Usually the equipment will need to be prepared prior to transportation to the task site (batteries charged, etc.) with further actions necessary prior to deployment to the target. As much of the preparation as possible should be done in the CP / safe area prior to moving to the target.

X-ray equipment will require maintenance and servicing, as defined in the maintenance and servicing manual. When not in use, equipment should be secured against unauthorised use.

STEP 2 – DEPLOYMENT

WARNING. NMAAs may have established regulations and requirements around the use of X-ray / radiography equipment. It will be the MA organisation's responsibility to ensure they are aware of any regulations and that they are compliant. This may include exposure limits and wearing an exposure badge.

Items to be X-rayed should be defined in the MA organisation's SOPs. However, it is not possible to cover every situation and produce a definitive list. The IEDD operator will need to use their training and threat assessment to know when it is appropriate.

When deploying radiography, the X-ray generator will be placed a suitable distance in front of the target with the image capture screen behind. Depending on the density of the target to be X-rayed, different control settings will be set into the X-ray generator by the IEDD operator. These control settings will also vary depending on the type of X-ray generator equipment used and how it produces the radiation (via continuous wave or pulsed).

Most user manuals will give a maximum penetration level and a guide for the best settings to use with different targets. However, this will rarely be exhaustive and is only an indication. The IEDD operator will need to draw on their experience and should therefore practice using the equipment on representative inert training IEDs.

Modern radiography equipment for EOD applications has made image capture much easier. Many of the difficulties associated with photographic wet film radiography have been removed through the use of digital radiography and image enhancing software.

HINT. When taking a radiograph, the IEDD operator should consider which plane(s) will yield the best image. They may need to compromise to give access to the image plate and generator. Taking two radiographs at 90 degrees to each other will allow for three-dimensional analysis and interpretation.

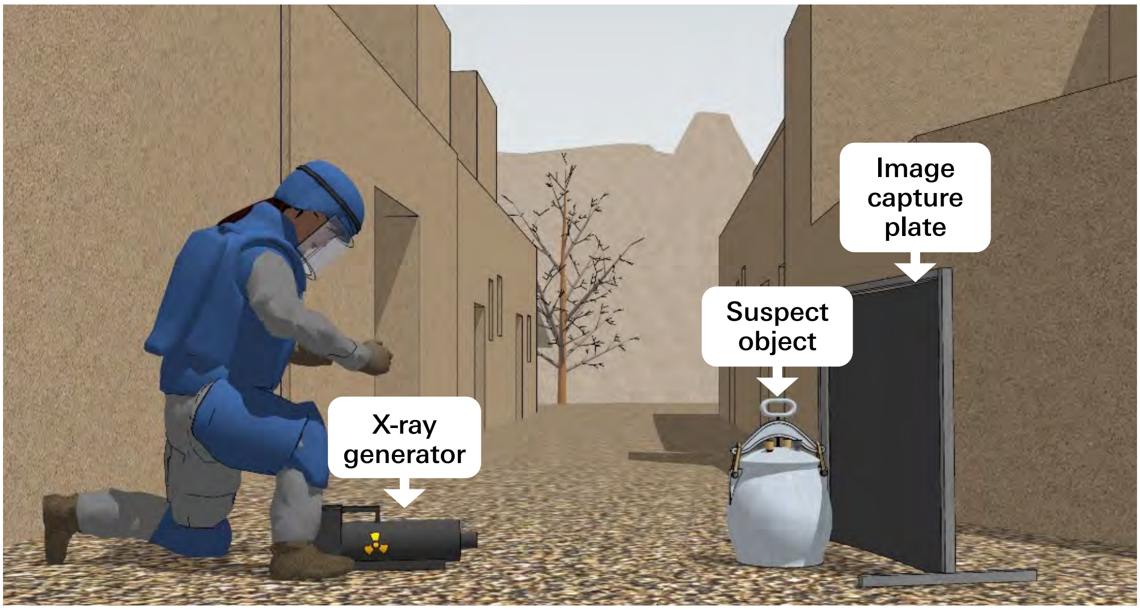


Image 1. Typical set-up for portable radiography

HINT. Often with IEDD radiography equipment the bottom of the suspect object is missed from the image. This is due to the image capture plate being set on the same flat surface as the suspect object and X-ray generator. When appropriate, the item to be X-rayed can be raised slightly so a complete image can be taken.

WARNING. IEDD operators must observe the evacuation area associated with the use of X-ray generators. This will be defined in the manufacturer's user guide.

STEP 3 – ANALYSIS AND INTERPRETATION

HINT. A common occurrence is a tendency to focus on what is already known about the IED components, rather than conducting a thorough systematic evaluation. It is likely that cross referencing with other IEDD operators and team members, with structured and constructive discussion, is likely to help mitigate this issue.

A radiograph is only as effective as the analysis and interpretation of the produced image. It is important that IEDD operators have the appropriate knowledge, skills and attitudes (KSAs) in accordance with T&EP 09.31/01/20. This includes detailed knowledge of IED tactics and construction procedures which will aid in radiograph analysis and interpretation.

HINT. To aid in the identification of components on a radiograph image, IEDD operators can learn by taking radiographs of known IED components in different planes to see how they are displayed.

Components will appear differently on a radiograph as the denser and thicker materials are highlighted, whilst the lighter and thinner materials may not be shown. Therefore, the IEDD operator must analyse and interpret the radiograph to gain an understanding of the IED (if present) and its intended means of initiation. Beyond identifying individual components, the IEDD operator must analyse and interpret the nature and number of components present and the interaction between them.

WARNING. Important elements of an IED may NOT be visible on a radiograph. This is of particular concern with VOIEDs where detents holding a switch open, or fishing line connecting the switch to another item, are unlikely to be shown.

Images seen on a radiograph can be divided into three groups:

- Those which are not caused by radiation (e.g. marks from bad handling, poor procedures or dirty screens). These are referred to as artefacts and should be identified prior to analysis and interpretation;
- Those caused by the external features of IED components; and
- Those caused by internal features of IED components.

Information to accompany a radiograph

It is useful for certain information to accompany radiographs. This may be stipulated by the NMAA or MA organisation's own SOPs and information management plans. The following information should be recorded with a radiograph:

- Task reference number
- Location
- Time and date
- X-ray generator control setting (e.g. number of pulses used) and distance from source
- Description of the item
- IEDD operator's name
- Any other relevant information

4.12.4. CONSIDERATIONS WHEN PROCURING RADIOGRAPHY EQUIPMENT

In addition to the usual considerations when procuring equipment, the MA organisation may find it useful to evaluate the following specifications of potential equipment models:

- Plate size
- Penetration capability of generator
- Ease of placing image capture plate
- Digital or analogue image capture plate
- Ease of developing an image
- Quality of image
- Ability to manipulate an image through software
- Wired or wireless

Typically, it will be a trade-off between the different attributes and the MA organisation must decide what will be most appropriate for them.

4.13. VEHICLE CLEARANCE

4.13.1. INTRODUCTION

Armed groups make use of VBIED's as they offer specific advantages. These include providing an easy method to transport large main charges, being easy to obtain, and not looking out of place in most environments.

Vehicles present a complex set of challenges in MA IEDD due to their variation in design and the ease of concealment of IED components. Vehicle clearance is a combination of search (to find explosive hazards) and IEDD (to dispose of the explosive hazard). Threat assessment is once again essential. It ensures that the IED is not in a conflict situation, dictates the degree to which search needs to be conducted and also the most suitable disposal option. Vehicle clearance is an IMAS IEDD Level 3+ advance skills competency[5] and can be used in conjunction with other associated techniques and procedures such as the use of VBIED disruptors and extractors.

This sub-section is not a prescriptive manual on how to conduct vehicle clearance, but serves to inform a logical methodology. It would not be possible to give one set procedure that covers every possible scenario, as the threat assessment and equipment available will differ. If these tasks are to be conducted, MA organisations should produce SOPs and technical notes that set out the specifics on how vehicle clearance is to be conducted with the equipment available to their IEDD teams.

WARNING. The guidance given here is specific to humanitarian IEDD and legacy IEDs, it is not appropriate for an active conflict scenario. In such contexts neither IMAS nor this guide can be safely applied and the work is the responsibility of the security forces.

4.13.2. WHY IS CONDUCTING VEHICLE CLEARANCE 'GOOD PRACTICE'?

Vehicles offer multiple opportunities for the concealment of IEDs, secondary devices and other explosive hazards such as SALW ammunition. This provides armed groups with lots of possibilities and therefore the threat can be diverse, ranging from the simple to the complex 'come on'[6] style situation. This makes the safe, effective and efficient clearance of a vehicle very difficult for an MA IEDD operator. By adopting dedicated systematic vehicle clearance procedures, an MA IEDD operator can counter these complexities and clear a vehicle in a structured manner.

4.13.3. CLEARANCE

Prior to starting vehicle clearance, the IEDD operator must have conducted a thorough threat assessment (see Chapter 3, Section 2.7. IED Tactics – VBIEDs, for general information). This will inform the priority of clearance and how it will be conducted.

The foundation of vehicle clearance is built on the principle of a structured and systematic procedure. The MA IEDD operator should work in ever decreasing stages, from far to close, top to bottom. This will aid in identifying larger threats first and prevent working solely in one area of the vehicle whilst a greater threat remains undetected in another part.

5 T&EP 09.31/01/2019, Annex B.

6 A style of attack where the target is lured into a specific area to be subsequently attacked.

Throughout a vehicle clearance task, the MA IEDD operator will switch between disposal and searching multiple times depending on the stage of the task and the equipment available. When to switch between the two disciplines is driven by what is currently presenting the largest threat. When a device has been confirmed, this should be dealt with first (not necessarily in its entirety, but to a point where it is safe), before searching to investigate 'suspicions'.

The logical stages for vehicle clearance are broken down below. It must be stressed that these are not rigidly sequential and the MA IEDD operator can move between stages depending on the threat, equipment available and how the task is developing.

STAGE 1 – EOR

EOR should be conducted from a safe distance using an ROV, UAV and / or optics, depending on their availability and the nature of the environment in which the vehicle is located. With some vehicles there may have been no attempt to hide its intended use, as with the armoured suicide VBIEDs.

STAGE 2 – REMOTE

If available, as much of the clearance as possible should initially be conducted with an ROV. The priority is to take remote disposal actions on any known IED and then a remote search of the main load carrying areas (MLCAs) consisting of the trunk, footwells, seats and if applicable the spare wheel well. These should be searched in an order of priority based on where the threat assessment indicates the most likely location of IED components to be. This stage should include opening all doors and as many internal storage compartments as possible.

STAGE 3 – SEMI-REMOTE

The extent of the semi-remote stage will depend on what has been achieved through remote means. Even with the most sophisticated ROV it is typically not possible to achieve all actions remotely and there will usually be an element of semi-remote techniques required. In mine action, ROVs may not be available at all, or not have sufficient capabilities to conduct much in terms of remote clearance.

It is likely that the MA IEDD operator will need to make multiple manual approaches and they must now balance the threat from the known, with the potential threat from the unknown. To do this correctly, a thorough threat assessment is imperative. There will need to be an element of search conducted by the MA IEDD operator to safely work around the vehicle. The skills and techniques outlined in Chapter 2 should be followed.

H&L will be the primary tool used in this stage of vehicle clearance and in the context of MA this may be the primary tool used throughout a vehicle clearance task. Good H&L skills will enable even the most difficult items to be moved or opened. Small amounts of explosives, such as a length of detonating cord, can also be used to aid in opening areas of concealment.

H&L can also be used in conjunction with an ROV to produce more expedient results when there are a lot of small items to be removed from the vehicle. The MA IEDD operator can attach multiple short lines (often referred to as lazy lines) to each object. The line only needs to run to a place where the ROV can grab it easily with its manipulator. This could be to outside the vehicle or somewhere convenient within the vehicle. Balls of tape can be attached to the other end to aid the manipulator to grab the line.

Image 1. IEDD operator conducting confirmation following the semi-remote removal of an IED main charge

HINT. Placing multiple strands (usually 3) of detonating cord along the top of the dashboard and detonating them will remove the dashboard to enable it to be viewed from behind.

STAGE 4 – SYSTEMATIC MANUAL

Image 2. IEDD operator conducting the systematic manual phase of a vehicle clearance task

Vehicle clearance will always entail a manual approach by the MA IEDD operator at some stage in the task and it is essential that a systematic approach is taken. The following is a suggested approach on how it could be undertaken (although it will be heavily influenced by whether the task is being conducted in a CHA or is a spot hazard task):

- **20 metre underside check.** On approaching the vehicle, the MA IEDD operator should stop 20 metres from the vehicle and look underneath for anything obviously suspicious. A high-powered torch may be required for this.
- **20 metre 360 degrees around vehicle.** Depending on the threat in the surrounding area, it may be appropriate for the MA IEDD operator to conduct a 360 degree check around the vehicle at 20 metres to check the area. Whilst MA IEDD operators will not be working on devices where they are intentionally being targeted, this does not preclude legacy devices being present to target security force disposal operations.
- **5 metre 360 degrees around vehicle.** The IEDD operator performs a full loop of the vehicle at 5 metres with the focus on checking the MLCAs and looking for anything else immediately obvious.

Image 3. IEDD operator moving around the vehicle at 5 metres checking the MLCAs

- **1 metre 360 degrees around vehicle.** The MA IEDD operator performs a full loop of the vehicle within 1 metre. They are checking wheel arches, under seats, internal storage compartments, all from outside the vehicle.
- **Detailed underside check.** The MA IEDD operator performs a full loop of the vehicle to check the underside in detail. This will require them to lay on the floor with their head under or very close to the vehicle. A rod or pole with mounted mirror can aid in viewing blind spots and a torch is also extremely helpful. It may be necessary for the MA IEDD operator to remove their helmet or items of PPE to enable access. These must be replaced as soon as the access issue has passed. It is advisable to split the underside into eight distinct points, with four points being behind the wheels and the other four points being the midpoint between the wheels. Each point should be checked in turn. The vehicle should not be touched by the operator until the detailed underside check has been concluded.

HINT. Start the check from the same point for each step. Generally, this will be the trunk as this is the priority to check first.

HINT. Use a torch and mirror to view dark voids and see into dark spaces or blind spots.

- **Interior search.** Break the passenger area down into quarters (i.e. driver's area, front passenger area, left and right rear passenger areas). Be systematic, work from the outside in, top to bottom / bottom to top. As part of this the door should be searched and cleared before the driver / passenger area is checked.

REMEMBER. In addition to looking for anything IED related, look for signs of tampering. Parts which have been removed and then put back may not have been reattached correctly, or they have been worn / damaged in the process. This can aid in identifying hidden IED components.

- **Trunk.** The trunk should be searched in the same manner as the interior including any additional storage areas for jacks, tools, etc.

- **Engine compartment.** In order to search and clear the engine compartment the hood will need to be lifted remotely / semi-remotely. There are various ways this can be achieved depending on the model of the vehicle. H&L is often attached to the interior hood release catch, unless the threat assessment indicates a VOIED threat in the hood, in which case an alternative plan will need to be developed.

During the systematic manual phase any concealed areas should be investigated. If something is required to be moved or opened, then it should be done remotely or semi-remotely. Other tools which can greatly aid in clearing vehicles are X-ray equipment and fibre scopes (see Chapter 2). Both offer useful ways to view inside voids.

4.13.4. MOVING THE VEHICLE AND TASK COMPLETION

It is good practice that suspect vehicles are moved remotely or semi-remotely as part of the clearance. This should include ensuring a jolt is applied to the vehicle and at a minimum it is moved its own length before being removed. The original location will then need to be cleared.

4.14. VBIED DISRUPTORS AND EXTRACTORS

Image 1. Improvised VBIED disruptor firing on test range

4.14.1. INTRODUCTION

VBIEDs may be encountered inside hazardous areas being cleared by MA organisations or reported to them as a spot task. If authorised and accredited as being competent and capable, a mine action IEDD operator may be required to render safe this type of IED.

VBIEDs encountered by MA IEDD operators are likely to be:

- Deployed and functioned as intended.
- Deployed and failed to function as intended.
- Not deployed but construction complete and therefore a viable IED.
- Under construction – may or may not be a viable IED.

WARNING. It is not within the remit of an MA IEDD operator to conduct the render safe of a VBIED in an active conflict scenario. Neither IMAS nor this guide can be safely applied in this context. In such circumstances it is the responsibility of the security forces.

Image 2. Armoured suicide VBIED

VBIEDs are primarily **time** or **command** initiated. Multiple means of initiation are often encountered in suicide VBIEDs, generally as a means of detonating the payload if the driver has been killed, incapacitated, or has last minute thoughts on following an attack through. Victim operated switches and remote-control detonation should always be considered during the threat assessment.

A number of IEDD tools has been developed to counter the threat of VBIEDs in an 'active scenario', enabling them to be disposed of rapidly and remotely. Whilst an MA IEDD operator will not be dealing with VBIEDs in an active scenario, these IEDD tools have utility in the MA context to increase safety and help return the situation to normal as quickly as possible. There are two main types of IEDD tools used:

- **VBIED disruptor.** A disruptor aims at causing large-scale general disruption. These are particularly effective when the exact location of the means of initiation, especially the power source, is not known or cannot be assessed with a high degree of confidence.
- **VBIED extractor.** Designed to extract an IED from a vehicle when the whole device is contained in a specific area such as a car trunk. This tool will also disrupt the IED in the process.

4.14.2. WHY IS THE USE OF VBIED DISRUPTORS AND EXTRACTORS 'GOOD PRACTICE'?

VBIEDs pose a significant challenge during an MA IEDD operation since vehicles offer multiple opportunities for concealment of secondary switches. As such, search and clearance can be extremely time consuming. Even though an 'active' time or command device should not be a threat, the tools, techniques and procedures developed to counter them can increase the safety, efficiency and effectiveness of the task for an MA IEDD operator.

4.14.3. WHEN TO USE A VBIED DISRUPTOR OR EXTRACTOR

A VBIED disruptor is used when the location of the IED's power source is known (or can be assessed with a high level of confidence), is accessible to actions in a one or two stage process and can be targeted effectively. VBIED disruptors work on the same principle as normal disruptors, but on a larger scale. This scale is required to defeat variables such as increased distance between disruptor and target, and barriers between the two. The size of the disruptor means that as well as disrupting the IED there will be significant damage to the vehicle. The advantage of the VBIED disruptor is that the MA IEDD operator does not need to search and interact with the vehicle to locate the power source prior to achieving disruption with a standard size disruptor.

WARNING. VBIED disruptors and extractors are powerful tools and the risk of sympathetic detonation must be considered. The MA IEDD operator should match the disruptor to the target and consider the likely location of detonators and exposed detonating cord. These are sensitive components that are particularly vulnerable to blast pressure and high velocity fragmentation.

VBIED extractors are used when all the components of a VBIED are located together but gaining access for a disruptor is problematic or impossible. Extractors are intended to penetrate the vehicle from the outside with such force that the main charge is extracted from the vehicle.

HINT. VBIED extractors are an extremely useful tool when VBIED disruptors cannot be used due to the location of an IED's components in the vehicle.

WARNING. Although a VBIED extractor will normally separate an IED's component parts in the extraction process, an MA IEDD operator should consider the risk of the IED remaining intact and take appropriate mitigation measures.

4.14.4. UTILISING VBIED DISRUPTORS AND EXTRACTORS

The preferred way to deploy a VBIED disruptor or extractor is remotely. However, when this is not available, manual deployment can be undertaken.

WARNING. The MA IEDD operator's threat assessment MUST identify that the VBIED is a legacy device, not part of an active scenario, before any manual approach to place a disruptor or extractor is performed.

EXAMPLE 1 – IMPROVISED VBIED DISRUPTOR, TWO-STAGE ATTACK

In this example the VBIED consists of an RC pack in the centre console with a wire link to the main charge in the trunk. The main charge consists of two 25-litre containers filled with HME, each with internal detonators. The VBIED disruptor has been made from three commercial 1-litre bottle disruptors, each containing 250 g of commercial high explosive. The bottle disruptors were secured around a wooden pole in a triangular configuration and linked by detonating cord, which runs part-way along the wooden pole.

HINT. Ensuring the detonating cord runs the length of the pole ensures that the detonator can be easily attached by the MA IEDD operator from outside the vehicle once the disruptor is in position.

Image 3. Main charge consisting of 2 x 25-litre containers located in the trunk

Image 4. Each container with independent detonators and wire linked to an RC pack in the centre console

Image 5. RC pack in centre console

Before the disruptor can be placed effectively, access to the vehicle needs to be gained remotely or semi-remotely. For a closed vehicle this will usually entail breaking a side window or placing a cutting charge. Preferably, this should be done without touching the vehicle, however where bespoke window breakers are not available, a detonator may be carefully attached to the window.

WARNING. Extreme caution must be exercised not to exert any force which could alter the state of the vehicle when placing a detonator in this manner, and other options should be investigated prior to conducting this type of action.

Image 6. MA IEDD operator taping a detonator to a side window

Image 7. Window successfully broken by detonator through semi-remote action

The VBIED disruptor can be mounted on an improvised stand, preferably made of wood or other disintegrating material so as not to add to the fragmentation. This is slid through the open window until the VBIED disruptor is suspended in the centre of the passenger area. Care must be taken not to touch the vehicle with the mount whilst placing.

Image 8. Improvised stand being used to place VBIED disruptor in the centre of the passenger area

Image 9. Improvised VBIED disruptor suspended in the centre of the passenger area


Image 10. Commercial VBIED disruptor from image 9 functioning


Image 11. Note the flash from the unsuppressed detonation cord


Image 12. Flash now completely supressed


Image 13. Flash completely supressed and no ignition of a vehicle fire


Image 14. Vehicle post disruptive action HD version from video required


Image 15. MA IEDD operator confirming disruption HD version from video required

Image 16. Tape measure points to the battery from the mobile telephone close to the original location of the RC pack

Image 17. Main charges in the trunk post disruption. Note how the seats have shielded this area and prevented disruption of any items in the trunk

EXAMPLE 2 – IMPROVISED VBIED DISRUPTOR, TWO-STAGE ATTACK

In this VBIED, the IED comprises an RC pack located in the centre console with the main charge in the trunk. The VBIED disruptor has been made from four 1-litre water bottles held in a square configuration. Sandwiched in the centre is 500 g of commercial plastic high explosives with a detonating cord link. This is attached to a wooden pole with the detonating cord running part-way along the pole, allowing for easy attachment of the detonator from outside the vehicle once the disruptor is in place.

Image 18. Improvised stand used to place VBIED disruptor in the centre of the passenger area

Image 19. Detonating cord running from explosive charge to outside the vehicle

Image 20. VBIED disruptor in centre of passenger area

Image 21. Improvised VBIED disruptor functions. Note the flash from the detonating cord but the water has largely suppressed the bulk explosive in the disruptor HD version from video required

Image 22.

Image 23.

Image 24.

Image 25. Disruption of passenger area

Image 26. Tape measure points to power source from RC pack. Remains of RC pack container can be seen below power source

EXAMPLE 3 – COMMERCIAL[7] VBIED EXTRACTOR, SINGLE STAGE UNDER TRUNK ATTACK

The VBIED consists of two 155 mm projectiles linked to an RC pack. Each projectile has an independent electric detonator. All parts of the IED are located in the trunk of the vehicle. The VBIED extractor is a commercial, user filled, extractor. It is filled with water and a choice of explosives. Here 65 x 42 cm strands of 12 g/m detonating cord have been used.

Image 27. All IED components of the VBIED are located in the trunk. The seats have temporarily been folded down for the picture only

7 Although not covered here, improvised VBIED extractors are also possible.

Image 28. Commercial VBIED extractor being prepared with detonating cord

The MA IEDD operator approaches the rear of the vehicle and slides the disruptor under the trunk. Care must be taken to ensure the extractor is lined up correctly and the **rear axle is avoided**.

Image 29. MA IEDD operator manually placing VBIED extractor

Image 30. VBIED extractor in its final position

Image 31. Extractor functions HD version from video required

Image 32. Note how much the water has supressed the flash from the detonation. This reduces the risk of a vehicle fire

Image 33. Content of the trunk starting to be extracted

Image 34. Both projectiles have been extracted and are in the air above the vehicle

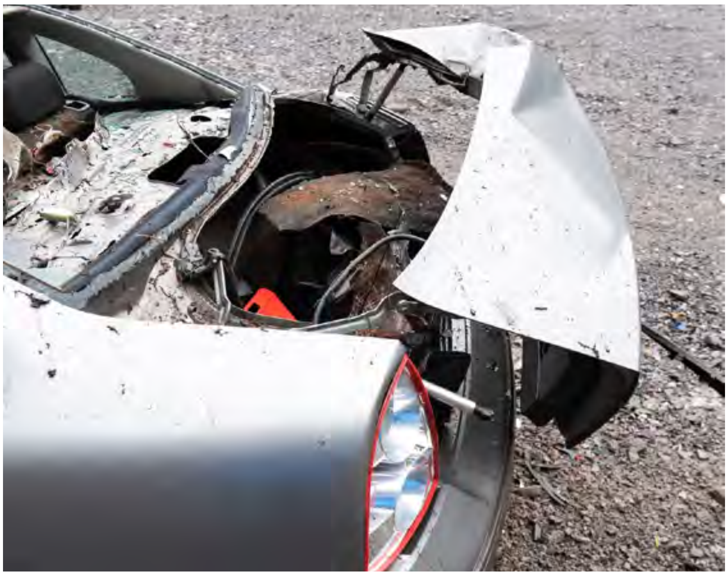


Image 35. Trunk post firing the VBIED extractor

Image 36. Inside the trunk post firing of the VBIED extractor

Image 37. MA IEDD operator inspecting the results of the VBIED extractor

Image 38. Location of the two 155 mm projectiles post firing of the VBIED extractor

4.15. INITIATOR AND DETONATOR SAFETY

4.15.1. INTRODUCTION

Initiator safety is the removal of an initiator(s) from an explosive chain. The majority of IEDs are initiated by a detonator. If the detonator is separated from the main charge or booster then the IED cannot function as intended. This is referred to as 'detonator safety'.

Conducting detonator safety correctly is an important process of an IEDD task and is a requirement before a device can be classed as rendered safe. It should be done at the earliest appropriate point in the RSP.

4.15.2. WHY IS CONDUCTING DETONATOR SAFETY 'GOOD PRACTICE'?

Detonators are filled with a primary explosive which is extremely sensitive to initiation / detonation by impact, friction, electrostatic discharge, or the application of flame. As such, they are a reliable means to start the detonation process in an explosive chain. Until the detonator is removed the IED's main charge remains in an unsafe state, even after component separation of any electrical circuit, mechanical mechanism, or igniferous fuze.

Care must be taken when handling any detonator given that they are likely to be more sensitive to shock and impact than the explosives in the main charge. Extra caution again must be exercised when handling damaged military / commercial detonators, or improvised detonators. In a damaged military / commercial detonator, the primary explosive may be crushed inside the casing, or exposed to the elements. In such a condition, it is inherently more sensitive than normal, and the application of pressure, friction or heat could cause it to function. Similarly, the components of an improvised detonator have not been produced to the same standards of manufacturing as commercial and military detonators. They are therefore unpredictable in terms of their sensitivity and can be extremely responsive to external influences.

WARNING. Unless improvised detonators can be transported in a container which can resist a detonation, it is advised that they are disposed of at the task site.

4.15.3. CONDUCTING DETONATOR SAFETY STEPS

The following steps show how detonator safety is conducted for an electric detonator. Where a non-electric detonator has been used, some steps will not be relevant and can be omitted.

Image 1. Main charge of a suicide belt with an electric detonator attached to the detonating cord. All other IED components have already been removed as part of the RSP

STEP 1 – INSULATION OF EXPOSED LEADS

Image 2. Insulation tape used to insulate leads from static

Image 3. Both leads insulated

STEP 2 – USE OF A HAND SCALPEL TO SEVER PLASTIC ADHESIVE TAPE (PAT)

Image 4. Sharp knife or scalpel used to cut one side of the PAT holding the detonator to the detonating cord. Note: the IEDD operator is cutting away from themselves to avoid injury

Image 5. Detonator is rolled slightly to expose the PAT on the other side. This is then cut in the same manner as above

STEP 3 – REMOVING THE DETONATOR

Image 6. Detonator is now removed from the detonating cord. Note: the IEDD operator is handling the detonator by the base at all times

STEP 4 – PLACING DETONATOR IN SAFE STORAGE

Image 7. Detonator placed in a rigid metal box to screen from RF and protect from damage

5. LEXICON OF ACRONYMS

ADS	Animal detection system
AN	Ammonium nitrate
ANAL	Ammonium nitrate & aluminium
AP	Anti-personnel
APMBC	Anti-Personnel Mine Ban Convention
CHA	Confirmed hazardous area
CP	Control point
CW	Command wire (improvised explosive device)
ECM	Electronic counter-measure
EFP	Explosively formed projectile
EO	Explosive ordnance
EOD	Explosive ordnance disposal
EOR	Explosive ordnance reconnaissance
EORE	Explosive ordnance risk education
ERW	Explosive remnants of war
GIS	Geographic information system
H&L	Hook and line
HE	High explosive(s)
HMC	High metal content
HME	Home-made explosive
IED	Improvised explosive device
IEDD	Improvised explosive device disposal
IM	Information management
IMAS	International Mine Action Standards
IMSMA	Information Management System for Mine Action
JFC	Jet forming cone
KSA	Knowledge, skills and attitude
LMC	Low metal content
MA	Mine action
MLCA	Main load carrying area

NEQ	Net explosive quantity
NMAA	National Mine Action Authority
NMAS	National Mine Action Standards
NSAG	Non-state armed group
NTS	Non-technical survey
OJT	On the job training
PAT	Plastic adhesive tape
PIR	Passive infrared
PPE	Personal protective equipment
PPIED	Pressure plate improvised explosive device
QA	Quality assurance
QC	Quality control
QMS	Quality management system
RC	Radio controlled
RCIED	Radio controlled improvised explosive device
RF	Radio frequency
RHF	Rolled homogenous steel
ROV	Remotely operated vehicle
RSP	Render safe procedure
RX	Receiver
SHA	Suspected hazardous area
SOP	Standard operating procedure
TNMA	Technical Note for Mine Action
TS	Technical survey
TX	Transmission
UAV	Unmanned aerial vehicle
UNMAS	United Nations Mine Action Service
VBIED	Vehicle-borne improvised explosive device
VO	Victim operated
VOIED	Victim operated improvised explosive device
VP	Vulnerable point

CHAPTER 4

IED INDICATORS AND GROUND SIGN AWARENESS HANDBOOK

1. SCOPE

This handbook is intended to be used by mine action (MA) staff trained in accordance with IMAS 09.31 Improvised Explosive Device Disposal (IEDD) and IMAS 09.13 Building Clearance.

It is intended to be focused primarily on improvised explosive device (IED) contamination, especially when non-state armed groups have been part of the conflict, although it will be of use in MA programmes where IED contamination is not present, since many of the same principles can be applied to conventional mines.

This handbook should also inform explosive ordnance risk education (EORE) practitioners in the development of methodologies, approaches and tools that are specific to environments contaminated with IEDs and other explosive ordnance (EO).

WARNING. This document is distributed for use by the mine action community. It is not an International Mine Action Standard (IMAS) although it is intended to comply with the IMAS series. It is subject to change without notice and may not be referred to as an International Standard.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation. Comments should be sent to info@gichd.org

The contents of this document have been drawn from a range of open source information and have been technically validated as far as reasonably possible. Users should be aware of this limitation when utilising the information contained within this document. They should always remember that this is an advisory document only; it is not an authoritative directive.

This handbook does not cover indicators and signs that may apply to IEDs during active armed conflict.

2. USING THIS HANDBOOK

Image 1. An IED component camouflaged in debris identified by MA staff due to a sign (colour change and regularity)

Mine action (MA) organisations have for many years used indicators and signs to assist in the identification of IEDs and other EO during survey and clearance. This handbook aims to provide a handrail to standardise the approaches used by the MA sector in this area by sharing good practice and sectorial norms.

The knowledge and skills associated with both IED indicators and signs, helps MA staff and organisations make better evidence-informed decisions at a variety of levels. At the operational level they can be used as evidence in the categorisation, classification and definition of hazardous areas. At the individual level of a deminer / searcher or IEDD operator they can be used to help make decisions related to how very specific tasks are conducted.

HINT. Ground sign awareness is sometimes simply referred to as the "absence of the normal; presence of the abnormal".

This handbook is split into two sections:

IED INDICATORS

This section examines terrain-based indicators that can be used as part of a threat assessment process. These indicators are frequently used to identify locations where the probability of IED contamination may be higher than in others. This section will be particularly useful during the national threat analysis and operational threat assessment processes described in IMAS 07.14 Risk Management in Mine Action. Image 2 shows a track junction which as a slowdown point is a terrain-based indicator where potential IED contamination may be located. The knowledge and implementation of IED indicators like the one explained, helps to avoid risks, remove risk sources and minimise the likelihood of related incidents in operational threat assessments.

IED SIGNS

This section examines different signs that may indicate an IED is present. This looks at categories of signs, including ground and top signs,[1] how they age, and the processes used to take advantage of signs as a tool in MA. Image 1 provides an example of an IED being identified due to colour and regularity.

Image 2. A track junction creating a slowdown point where command IEDs might be particularly effective. This is an example of an IED indicator.

1 Top signs are IED-related signs that can be found above the surface and in the surrounding environment.

3. IED INDICATORS

3.1. THE BASICS

This section looks at the operational value of different improvised explosive devices (IEDs) in relation to distinctive terrain-based indicators. The aim is to help mine action (MA) staff better categorise and define hazardous areas and to enable assessment of the highest risk areas; those which are most likely to contain IED contamination.

Image 3. High-value weapon systems may indicate contamination

Consider Image 3 showing a high-value anti-aircraft weapon system. If this is identified by MA staff, it could be an indicator that IEDs are present. The intent and capability of the armed group would need to be considered, along with other sources of direct and indirect evidence. For example, the intention of the armed group could be to deny use of this weapon after withdrawing from the area, which would mean that IEDs could be located close to or even be connected to the weapon.

If, however, the intent had been to defend the weapon system while an armed group was using it, then MA staff could consider looking out from the weapon emplacement and making an assessment of approach routes (open areas and roads) where IEDs could have been placed as part of a defensive plan.

Image 4. A building set up for defence

When defending locations, parties to an armed conflict will often develop a combined plan that incorporates both physical obstacles (pre-existing and purpose made) and explosive obstacles. The physical obstacles may include fortified structures or positions such as trenches, barbed wire, roadblocks, bunds, ditches and fixed weapon installations.

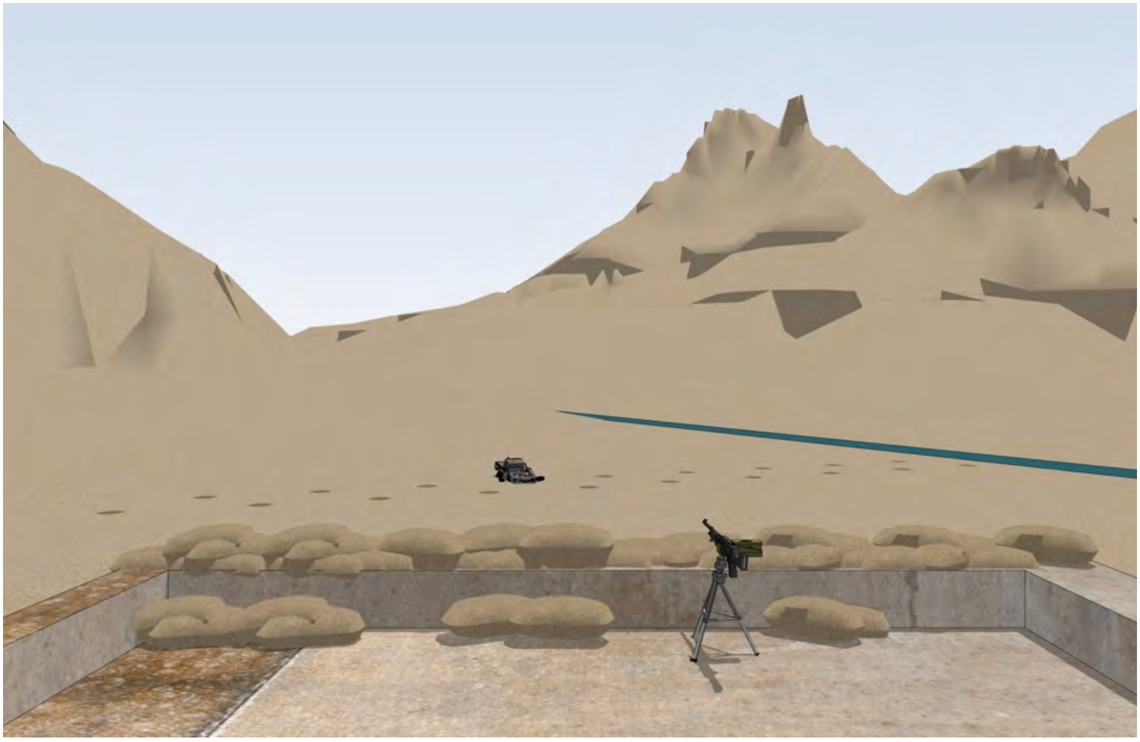


Image 5. A small arms and light weapons (SALW) position monitoring an IED belt to increase its effectiveness as an obstacle

Considering the fortified house in Image 4, if an armed group was defending this strongpoint, they would likely emplace the majority of IEDs at a distance of 50–300 m. This would mean that an explosive obstacle could be covered by SALW fire to increase the effectiveness of the obstacle, while still affording separation between the defensive position and the attacking group. However, if the armed group planned to withdraw, they may have decided to disturb the occupation of the house by placing further IEDs at vulnerable points (VPs) in, and immediately around, the position. These VPs could include the perimeter entrances, pathways, doorways and underneath ground floor windows.

Image 6. Discarded ammunition containers indicate that fighting has occurred in the area

Other IED indicators include discarded military ancillaries such as ammunition containers and packaging, as shown in Image 6 and Image 7. In general, these indicate that fighting has taken place, but more specifically they may also provide further evidence of the nature of the IED contamination that may be present. An example of this would be boxes for conventional projectiles (shells) but no indications that an artillery position was located at the site. These projectiles may have been used as main charges in IEDs.

Image 7. Abandoned ammunition packaging

Image 8. Localised marking that may indicate IED contamination

Other indicators may include the presence of markings intended to warn people of danger. These may be placed by the local community (Image 8) or by state or non-state parties to an armed conflict (Image 9).

Image 9. More formalised variations of hazard marking

3.2. CAGE (CHANNELLING, AIMING MARKERS, GROUND SIGN, ENVIRONMENT)

'CAGE' is an acronym developed by military forces to help personnel recall the properties of a vulnerable point (channelling, aiming (markers), ground sign and environment). CAGE helps to answer the following question:

"Where would it be advantageous for my opponent to use an IED(s)?"

MA staff can then apply this question retrospectively in a post conflict context to consider where would have provided a placement opportunity for an armed group to use an IED(s). This should be considered in conjunction with the intent and capability of the parties to an armed conflict that are assessed to have placed the IED(s). See Annex C of IMAS 07.14 Risk Management in MA for guidance on how to conduct threat assessment.

3.2.1. CHANNELLING

Channelling reduces an opposing armed group's options for manoeuvre, making them more predictable and providing an opportunity to successfully target them with the minimum amount of resources.

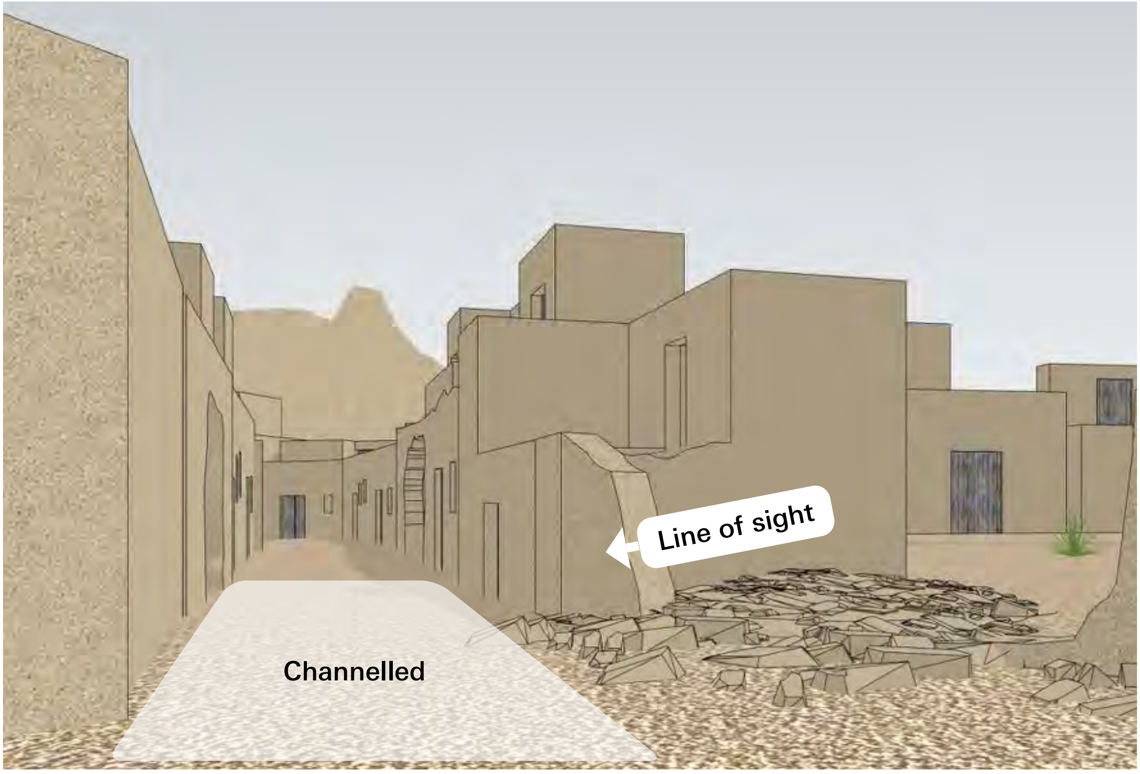


Image 10. A channelled route between compound walls

In image 10 there is a channelled alley or passageway between numerous compounds and houses. As well as victim operated IEDs (VOIEDs), the damaged wall may mean that there was also an opportunity to use a command IED, as there was also a good line of sight into the alley.

HINT. Command IEDs provide the advantage of enabling the route to remain "open" as the IED only functions at the armed group's moment of choosing.

Armed group attacks with conventional weapons in these channelled areas should also be considered as a standard operational practice. Within these channelled areas, possible contamination with unexploded ordnance and explosive remnants of war must be included in the MA staff's threat assessment.

In Image 11 the channelled route between the buildings has reduced lines of sight, therefore the use of command IEDs is less likely. The most probable threat here is from VOIEDs.

Image 11. A channelled road between a series of compounds

Image 12. A narrow path for people moving on foot through a wooded area

Channelling does not just occur in urban areas or on main routes. Image 12 shows an area of dense woodland that would make movement away from the path difficult, even on foot. This would have provided an opportunity for an armed group to have been relatively selective in their targeting, even when using VOIEDs, with only the minimum amount of IED resources required to achieve their intent.

Image 13. An entrance point that has become overgrown

Routes and pathways are not the only terrain features that can accommodate people and vehicles. Other features such as entrances, doorways, relief, rivers and soft ground can have a channelling effect too. Image 13 shows an entrance in the wall of a disused agricultural compound. The area immediately around this location would have been ideal to target opposing parties to an armed conflict with VOIEDs, and might be considered by MA staff as high risk during clearance.

3.2.2. AIMING MARKERS

Image 14. The pole is an example of an aiming marker for a command IED

Aiming markers enable an armed group to target moving vehicles or people at distance, using a command IED. If no aiming marker is present, then it is difficult to achieve the optimum moment of initiation, and the best opportunity for engaging a potential target could be missed. A good line of sight is also required from a firing point, where the person initiating the command IED would be located, to the contact point, where the main charge would have been placed.

> **WARNING. A long column of vehicles, linked IED main charges and other features that create a slowdown point may be incorporated into this type of attack to enhance its effectiveness.**

Image 15. White tape tied to a single lamp post on a main road

Some aiming markers are less obvious, such as in Image 15. Here a piece of white tape has been tied around a lamp post, at the base of which is a radio-controlled IED. Although this might not be effective over a long distance it could be all that is required to differentiate the lamp posts if the firing point and contact point are relatively close together.

HINT. Debris and litter can easily get caught up on street infrastructure. Aiming markers will usually be deliberately placed or fixed in place. Keeping this in mind will aid in identifying aiming markers for command IEDs.

Image 16. Example of a good line of sight into a VP

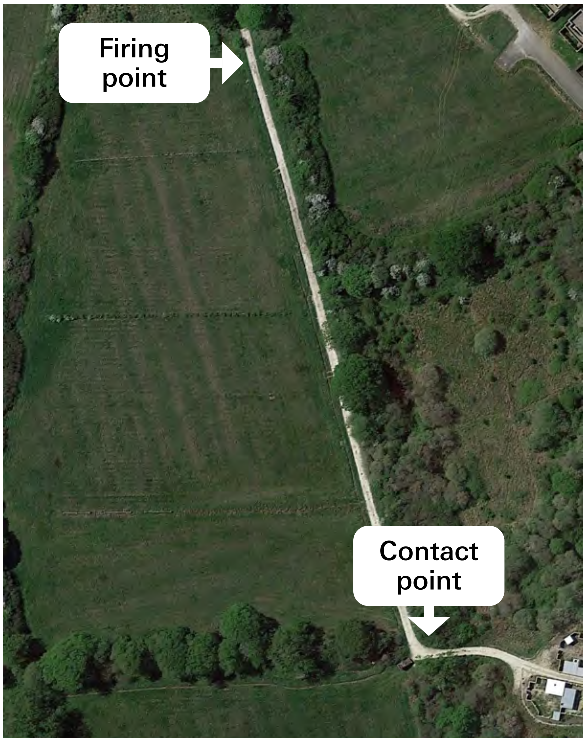


Image 17. Example of a good line of sight into a VP

Aiming markers are often used with command IEDs and therefore a good line of sight between the firing point and the aiming marker located at the contact point is needed. In Image 16 a tracked vehicle is about to move onto a route from open countryside through a constricted access point which forms a VP. Although restricted in other directions there is actually a very good line of sight straight down the road (Image 17).

3.2.3. GROUND SIGNS

Image 18. A ground sign showing a buried IED main charge

Signs are described in detail in Section 2 of this handbook, which looks at the two categories of signs: top signs and ground signs. Signs can be used extensively in the decision-making processes of MA staff throughout survey and clearance of IED contamination.

3.2.4. ENVIRONMENT

Image 19. A normal pattern of life?

Environment is one of the key aspects of understanding IED indicators and is often used by MA staff working in accordance with IMAS 08.10 Non-Technical Survey as part of the collection of direct and indirect evidence.

For example, Image 19 may initially seem to show a normal pattern of life, or positive environment indicator. But why has the field on the right not been ploughed? It could be for a very normal reason, such as it being used for grazing at a different time of year or that resources to farm it are not available at this particular time. It could also be because it is, or there is a fear that it is, contaminated by IEDs.

> **HINT. Identification of these environmental differences can be used by MA staff to inform further questioning of key informants, such as the person driving the tractor.**

Image 20. Post-conflict pattern of life

Environmental considerations may be further amplified in post-conflict urban environments such as the one shown in Image 20. One street has been cleared of rubble, cars, and other debris. Buildings have been repaired, shops have reopened, and vehicles and people are using it, thus it is a positive environmental indicator for development. Why has the same not happened to the other road and why have the adjacent houses not been repaired?

This may simply be because it was not judged to be a priority by the community and will be completed in due course. However, it may also be that this street was a former confrontation line where IEDs have been extensively used and therefore a negative environment. Again, these terrain-based indicators will inform the questioning of key informants by survey teams.

Image 21. A local marker placed by the community to warn of IED contamination

Local customs are part of environmental indicators and understanding them will enable MA staff to use them to best effect. For example, Image 21 shows a local warning sign that has been placed by members of the community. It is very important that MA staff are attuned to these, and that they are not missed. Signs like this one could also have been used by the armed actors to record the location of devices to enable maintenance, such as the renewal of power sources.

Image 22. Aged written warning is visible on the community's warning marker

3.3. THE BIG 5

The Big 5 are a group of terrain-based features that may have provided opportunities for IED emplacement during a conflict. In conjunction with other evidence, these features may be used to good effect when assessing where, inside a suspected hazardous area or confirmed hazardous area, IEDs are most likely to be located and what type(s) they will be.

3.3.1. CULVERT / WADI / FORD / BRIDGE

Image 23. Culverts provide an opportunity for the emplacement of IEDs

Culverts, like the one in Image 23, provide an opportunity to emplace a large main charge under a hard-topped route with relative ease. These features are often associated with command IEDs as the route can remain open to other traffic until a suitable target is present. In the example above, the culvert also creates a slowdown point, channelling a ground move on this very route, further aiding the use of IEDs.

WARNING. If the armed group did not need to use the route and civilian casualties were not an issue, VOIEDs could also be a threat.

Image 24. A bridge providing opportunities to emplace IEDs

Bridges provide many of the same opportunities for IED attacks as culverts, depending on the intent and capability of an armed group. They may also be considered as critical infrastructure, making them a target for large time devices if the intent is to target the structure. These could be military bridge demolition charges or improvised variants.

WARNING. Further IEDs or additional switches may have been placed adjacent to culverts and bridges in order to protect the primary device.

Image 25. A bypass route or ford that may provide an advantage for an armed group when placing IEDs

A bypass route or ford (see Image 25), is a point where vehicles and people will be channelled to move slowly through a defined point or area to avoid a barrier or blockage. Sometimes these may be lower than the route that is being bypassed so the lines of sight will be impaired. Use of the bypass may be restricted by the size and type of vehicles used by an armed group. Due to all these factors, the most likely type of IED to be present at a bypass route or ford is a VOIED, rather than a command-initiated device.

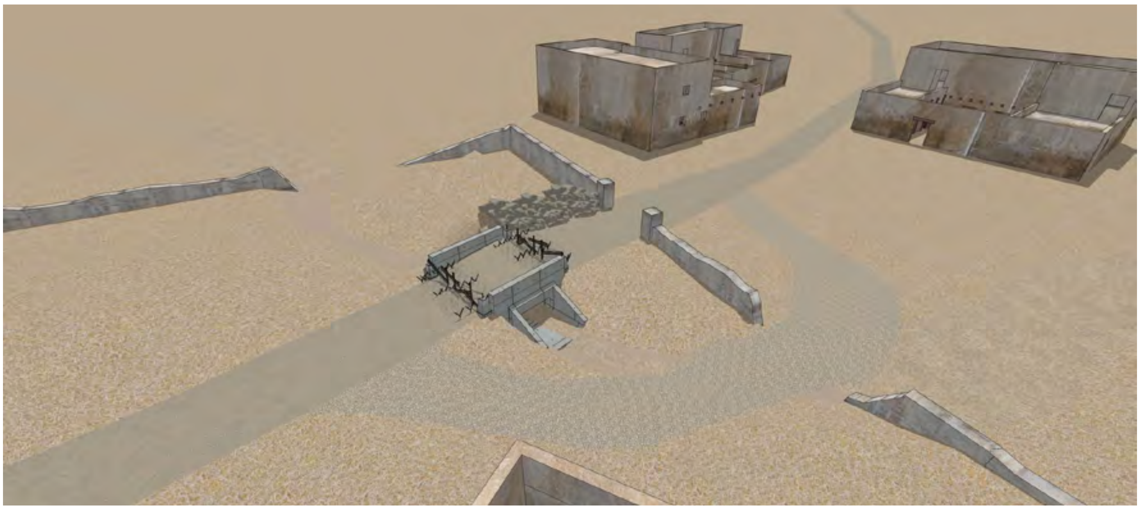


Image 26. Example of a bypass route due to an obstacle that would only apply to certain groups

3.3.2. ASCENT / DESCENT / OBSTACLES

Image 27. Steep banks causing vehicles to slow

Steep ascent and descent will cause people and vehicles to slow and also potentially make them more prominent against the skyline, increasing the distance from which they can be observed. If they also serve as an approach to a dominating feature (as seen in Image 28) they may have been identified as an area of tactical advantage to opposing parties to an armed conflict, and attempts may have been made to deny access to this feature with IEDs.

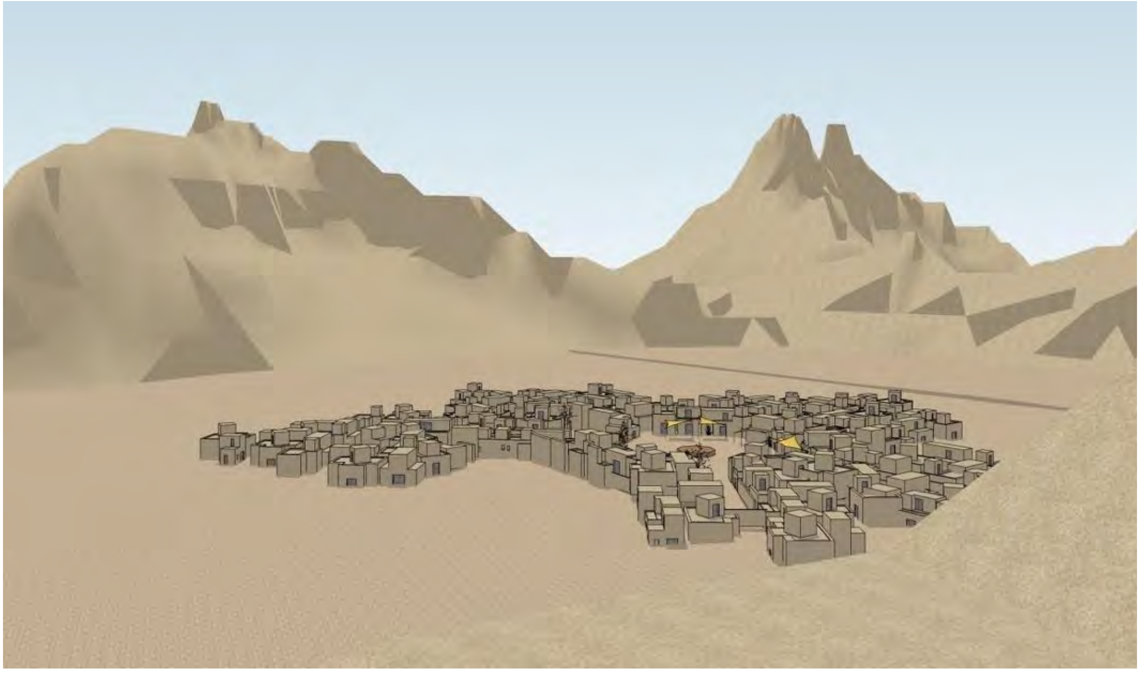


Image 28. Dominating ground in relation to a village

3.3.3. SOFT, SANDY SOIL

Image 29. A change in the ground conditions on a route may provide an opportunity for IED emplacement

This indicator really refers to how the ground conditions will affect how easily an IED can be buried in order to conceal it. An example of this is shown in Image 29 where a tarmac road ends and a gravel track starts. In addition, soft and / or sandy conditions restrict the mobility and speed of vehicles conducting ground moves, presenting opportunities for targeting with command-operated devices.

3.3.4. SHARP BENDS

Image 30. Sharp bends providing opportunities

Sharp bends on roads and routes, as shown in Image 30, will cause vehicles to slow considerably. In particular, this may increase the opportunity for command IEDs.

3.3.5. BOTTLENECKS

Bottlenecks often occur when a route or track changes width, causing vehicles to slow down.

Image 31. Example of a bottleneck

4. IED SIGNS

4.1. CATEGORIES OF SIGNS

There are six primary categories of signs that are fundamental to understand: Regularity, flattening, transfer, colour change, discardables, disturbances.

4.1.1. REGULARITY

Regularity is denoted by straight lines, arches or other geometrical shapes that would not normally be encountered in nature (see Images 32 to 37).

Image 32. A footprint is a clear example of regularity

Image 33. A buried link (wire or detonating cord) producing regularity in short grass

Image 34. It is worth trying to observe from multiple directions.
Note how much clearer this image is than image 33 of the same area

WARNING. Achieving different angles and perspectives for observation must only be done if it is safe to do so.

Image 35. A command wire observed due to colour change
in the regularity seen in images 33 and 34

Image 36. IED components are also often visible through regularity above ground level

Image 37. The explosively formed projectile main charge
from Image 36 with vegetation now removed

4.1.2. FLATTENING

Flattening is caused through human actions that apply pressure to an area. These can be identified through comparison with their immediate surroundings (see Images 38 and 39).

Image 38. Flattening in controlled conditions

Image 39. It is distinctly more difficult to identify flattening in natural surroundings

4.1.3. TRANSFER

Transfer or transference is a deposit (e.g. dust, mud, soil, sand) carried from one area to another.

Image 40. Transference in controlled conditions

Image 41. Transference in natural surroundings

Image 42. Transference often occurs as people move between environments

Image 42 is an example of when a sign can also be used as evidence in other ways. This fresh footprint is a sign that a person has walked on this surface. If multiple footprints are present then this may be suitable evidence, depending on the threat, to discount victim operated improvised explosive devices (VOIEDs) with a sufficient level of confidence.

4.1.4. COLOUR CHANGE

Colour change is the difference in colour from a specific area to its surroundings, as shown in Images 43 to 46. Colour changes may be produced by soil excavation to place devices, or where cut vegetation is used to camouflage devices; the cut vegetation changes colour as it ages over the first 48 hours or so after being cut.

Image 43. Colour change in controlled conditions

Image 44. Colour change in natural conditions

Image 45. Is that normal?

Image 45 shows an artificial rock containing a command IED and can be seen here placed alongside natural rocks on the side of a road. Although well constructed for concealment, it reveals itself as a sign among the natural colours, through colour change.

WARNING. These types of IEDs can be extremely well camouflaged.

Image 46. Photo taken using an unmanned aerial vehicle (UAV) to observe colour change from above

4.1.5. DISCARDABLES

Discardables are items associated with improvised explosive devices (IEDs) (or other explosive ordnance (EO)) that have been left behind either intentionally or otherwise, as can be seen in the examples in Images 47 to 50. Discardables can include IED components, electrical tape, packaging or ancillaries.

Image 47. A discarded battery in controlled conditions

Image 48. Discarded IED main charges in normal conditions

Image 49. A discarded spilt main charge with the home-made explosive (HME) clearly visible

Image 50. Discarded IED switches (pressure plates) leaning against a wall

4.1.6. DISTURBANCES

A disturbance is a change or rearrangement of the normal state of an area caused by the emplacement of an IED; see Images 51 to 54 for examples.

Image 51. A disturbance in controlled conditions

Image 52. A disturbance at an entrance point

Image 53. Note how the sign becomes easier to identify from another angle

WARNING. Achieving a different perspective for observation of a sign must only be done if it is safe to do so.

Image 54. A pressure plate IED was located under the disturbance

4.2. TYPES OF SIGNS

In addition to the six categories explored above, mine action (MA) staff can divide signs into two types according to their position: top signs and ground signs. The dividing line between the two types is normally taken at ankle height.

4.2.1. TOP SIGN

This is a sign above ankle height that can be associated with the emplacement of an IED. This may include:

- Grooves in tiles or paving slabs due to their removal.
- Unusual regularity in walls or ceilings.
- Changes in colour and unnatural position of vegetation.

Image 55. A difficult-to-spot IED component - possible radio-controlled improvised explosive device (RCIED) antenna

Image 56. Observing from different heights and against different backgrounds

Images 55 and 56 provide another example of how observing a sign (in this case a top sign) from different perspectives significantly changes how easily it can be identified. To take this photograph, the individual only moved a distance of 1 m but went from a kneeling to a standing position.

As well as providing evidence of potential post-conflict IED contamination being present, a sign can also provide evidence that contamination may not be present. Image 57 shows recent top sign transference that indicates that a person has climbed a ladder at an infrastructure site. This could lead to the identification and questioning of a key informant who could provide additional evidence that contamination may or may not be present, and a well-informed decision for the appropriate approach could then be made.

Image 57. Transference can even occur as a top sign

4.2.2. GROUND SIGN

This refers to a sign below ankle height and may include:

- Flattening – where IEDs have been buried in soft ground.
- Disturbance – where IEDs have been concealed in tarmac or other hard surfaces.
- Regularity – from command wires or physical links. These could be surface laid or buried.
- Discarded IED components.

Image 58. A disturbance at the corner of a compound where armed group personnel may gather prior to turning the corner

4.3. CLASSIFICATION OF SIGNS

In addition to the categories and types of signs explored above, MA staff can use two classifications of signs, according to the type of evidence the sign provides. The two classifications are ‘conclusive’ and ‘inconclusive’.

4.3.1. CONCLUSIVE

A conclusive sign indicates that an IED is or has been present. This means that it can be classified as direct evidence in the MA land release process. A conclusive sign could include IED discardables or flattening / colour change / disturbance caused by regularly spaced IEDs in a defensive belt.

Image 59. Colour change and regularity showing a conclusive sign

Image 60. Is this a conclusive sign?

Anyone can see that something unusual is present in Image 60 and to the trained and experienced eye a directional fragmentation charge is clearly apparent. This is an example of both regularity and colour change. This sign would be extremely unlikely to be misinterpreted and can be considered conclusive.

4.3.2. INCONCLUSIVE

This is a sign that may or may not be IED related but is considered worth recording for further investigation. This category of sign may be used as indirect evidence in the MA land release process.

Image 61. Is there an inconclusive sign present?

Although Image 61 shows flattening in a position where an IED main charge and / or switch may be, or has been located, there are other reasons this sign could exist. This sign could be misinterpreted and should therefore be regarded as inconclusive.

It is important that MA staff are able to identify when a sign is inconclusive and also be able to cross reference it to other associated signs and indicators. This ability to link signs and indicators together will help increase the confidence in decisions related to whether or not IED contamination is present. It is important that confidence in inconclusive evidence is graded to enable MA staff to better discount a 'false sign'.

How MA staff differentiate between conclusive and inconclusive signs will vary between different IED threats, environments and levels of staff experience related to the application of signs as a source of evidence. For example, during the early stages of an MA response, organisations may require several signs to be recorded and linked together before assigning them as conclusive evidence of IED contamination. As MA organisations and staff develop a greater level of experience, the use of signs will become a more effective tool.

HINT. Inconclusive signs combined with terrain-based indicators such as channelling may increase the level of confidence that IED contamination is present.

4.4. FACTORS THAT AFFECT SIGNS

There are three main factors supplemented by other considerations which can affect the appearance of IED signs: Environment, climatic conditions, age

4.4.1. ENVIRONMENT

The environment in which an IED has been emplaced will have an impact on the sign that is produced. MA staff should have knowledge of what type of a sign is likely to be present for different IED threats, in the different environmental conditions of the programme in which they are working.

The following can be used as a guide:

GRASSLAND

In grassland there may be a colour change between the location where IEDs are located and areas where they are not. Some explosives are highly toxic and are likely to kill or prevent the growth of vegetation, while others may encourage growth.

The regularity of the command wire in Image 62 can be easily seen in medium height grassland. The height of the grass however will conceal the wire from other perspectives, and light levels will significantly alter how easily it can be identified.

Image 62. The regularity of a command wire

ROCKY COUNTRY

Signs may often present themselves as either a disturbance or colour change in rocky conditions. It may also mean that a top sign is more prevalent, as the parties to an armed conflict are not able to dig into the ground and bury IEDs as readily.

Image 63. A disturbance can be easily seen on this rocky ground

FOREST OR WOODLAND

Forest and woodland can be challenging environments for MA organisations trying to use a sign to provide evidence of IED contamination and this difficulty is likely to increase as the sign ages. In these environments what should be considered is how conditions during the conflict would have affected the opportunity of parties to an armed conflict to conduct attacks using IEDs. In dense forest or woodland, mobility even on foot may be difficult and it is important to be able to locate current and former tracks that would have provided opportunities to use IEDs. Therefore, as well as being used to identify IEDs, signs can help identify the terrain-based indicators described in Section 1.

Images 64 and 65 illustrate just how difficult it can be to identify a relatively large above-surface IED component in forest and woodland conditions.

Image 64. There is an IED component part in this image, can you see it?

Image 64 was taken with a high-resolution camera less than 1 m from an IED measuring approximately 25 cm in diameter and of completely different colour to the surrounding environment.

Image 65. Taken from the same distance but a very slightly different perspective

Image 65 was taken from a very slightly different perspective (less than 0.5 m difference). This change has conclusively revealed the IED component.

SANDY SOILS

Sandy soil is often the type of environment in which a sign can be used to best effect. However, it is an environment in which a sign can age relatively quickly, changing its characteristics, and potentially making it easier or harder to determine.

For example, if a pressure plate IED is buried in reasonably hard sandy soil, a disturbance may initially be easier to see than for softer conditions. Over time, the wind and rain reduce how noticeable this disturbance is by redistributing the surface particles, whereas in softer conditions, the sand may recompress over time leaving a very noticeable area of flattening or disturbance.

Image 66. Sandy soil clearly showing disturbance and colour change where an IED main charge is located

4.4.2. CLIMATIC CONDITIONS

In some regions the climatic conditions can change significantly over the course of a year. These changes will, in turn, change the characteristics of a sign, making it easier or harder to use it as evidence. Additionally, the climatic conditions present whilst MA staff are observing signs can also impact the results.

The following climatic conditions should be considered:

DIRECT SUNLIGHT

UV radiation will change how discardables look over time, making them more likely to appear to be an item not associated with IEDs. Conversely, it may cause expansion and bulging of IED main charges, making them easier to identify through signs.

The level of sunlight at the time of observation is extremely important. For example, sunlight coming through a window in a building may increase the degree to which a disturbance in the dust on the floor can been seen.

STRONG WIND

Strong winds can completely remove signs such as discardables or enhance other signs, such as disturbances.

WARNING. Strong winds can also create 'false signs and indicators' by spreading objects like plastic bags that can be misinterpreted as markers or transference signs.

HEAVY RAIN

Heavy rain can cause localised flooding that submerges signs, significantly changing their appearance and making them very hard to identify. It may also cause IED components to rust, degrade or expand, potentially creating new signs even several years after the IED was emplaced.

Image 67. Flattening and regularity where an IED main charge has been submerged under water due to rainfall

4.4.3. THE AGE OF SIGNS

The time that has elapsed between when signs were first made and when they are observed, is one of the most significant factors affecting their application in MA. The longer the amount of time that has passed, the greater the probability that signs will have altered, for better or for worse. Experience and practice will help to overcome this difficulty, and this is explored further below.

4.4.4. OTHER CONSIDERATIONS

In addition to the factors above, there are a number of other considerations that will affect how IED signs can change.

For example, in **built-up areas**, there are many other considerations related to the application of signs, due to high population density. This includes how a sign relates to information gained from the community and how a sign can be incorporated into risk education specific to these environments. Also, there will be even more false signs identified that are extremely difficult to differentiate from true IED signs.

HINT. As visual identification of IEDs in urban environments can often be the primary means of detection, when applied well, both ground signs and top signs can be extremely important tools.

Image 68. Is that normal?

There is a metallic-looking wire protruding from the paving slab in Image 68. It could be difficult to assess whether this is an IED component or an innocent item such as a wire for a doorbell.

HINT. Providing MA staff with training on construction methods specific to a region, as well as the IED threat, can significantly help with the effective application of IED signs in an urban environment.

4.5. DETERMINING THE AGE OF A SIGN

MA staff should be able to take into account how the appearance of a sign changes with age so that confidence can be maintained in the use of a sign in decision-making processes. This is particularly important due to the extended period of time that MA organisations may be conducting survey and clearance after a conflict has ended. This vital skill will assist in the following ways:

- It will enable an approximate time frame to be established as to when IEDs were being used in the area.
- It will prevent overconfidence in the assumption that a lack of a sign means a lack of threat.
- It will assist in determining the level of confidence in signs.

MA staff should have a good understanding of the assessed IED threat and the climatic conditions that have occurred in the period since the IED contamination was left. These factors determine the ageing process of signs.

The following factors affect how signs will change over time.

4.5.1. HARD SIGNS

Examples of a hard sign would be scoring where tiles have been removed, objects dragged on floors or the burying of IEDs into tarmac / hard-top roads. These are likely to be resilient to ageing.

Image 69. A hard sign in an urban environment

A hard sign can occur regularly in urban environments and will last for long periods of time. This can be especially useful as the use of hand-held detectors in these environments can be problematic, increasing the reliance on visual identification.

Image 70. Hardstanding does not mean that you are always safe from VOIEDs

The sign in Image 69 is revealed in Image 70 as being associated with a VOIED placed underneath the paving slab. As IED switches can be easily made for a specific task, this pressure plate would have been tested to be sufficiently strong to support the weight of the slab but would function under the additional weight of a person.

4.5.2. SOFT SIGNS

Sign characteristics in soft soil, mud or sand will be more susceptible to the effects of ageing.

Image 71. Soft conditions can still occur in buildings

4.5.3. EXPOSURE

The degree of exposure to the elements will have differing effects on signs. Signs will change rapidly where there is direct exposure to sunlight, rain or heavy winds.

4.6. INFORMATION GAINED FROM SIGNS

In order for MA staff to make an accurate analysis of the information gained from signs, it is important that they have detailed knowledge of the IED threat including the techniques, tactics and procedures that were used by parties to an armed conflict. MA organisations should ensure that staff receive a comprehensive national threat analysis brief when joining a new programme and that operational updates are regularly provided.

HINT. Examples of when an IED sign has been used as evidence in decision making should be shared widely and in a timely manner.

TACTICS AND DOCTRINE

A thorough understanding of the IED tactics and doctrine of the parties to an armed conflict that were active during a conflict will significantly influence how MA staff can use signs to the best effect in decision making. For example, if defensive belts were commonly used to deny ground, and signs are identified that link to this tactic, a confirmed hazardous area can be defined and categorised with a high level of confidence.

IED TRAITS

These are the attributes that different IEDs are likely to provide in terms of signs. For example, a pressure plate as part of a VOIED stacked directly over a main charge is likely to provide different traits than if a pressure plate is located where a vehicle wheel would pass and the main charge is located directly underneath the likely centre of the vehicle.

INFORMATION GAINED

Depending on the condition of the sign, the following information can be gained:

- Numbers / density of IEDs.
- Type of main charges (blast / fragmentation / directional).
- Type of switches / power sources.
- Layout of components in relation to each other.
- Position of components in relation to the physical terrain of a vulnerable point (VP).

4.7. METHODS OF INTERPRETATION OF SIGNS

The interpretation of signs is a continual process in MA operations, as new signs will be continually observed from initial non-technical survey (NTS) to final completion. In order to make the best possible evidenced-informed decisions, it can help if staff consider the signs that they are presented with as: Facts / Assumptions / Interpretations.

FACTS

MA staff will identify a sign that can be used as direct or indirect evidence in relation to indicators such as VPs and current use of areas by the community. As already described, this is a conclusive sign.

ASSUMPTIONS

Inconclusive signs can be layered together along with IED indicators (see Section 1). Based on training and experience, MA staff will be able to make logical assumptions, up to and including using this as direct evidence.

HINT. Technical survey can be used to confirm an assumption prior to full clearance commencing.

INTERPRETATIONS

This is the logical thought process that MA staff can apply to a particular situation when signs have been observed.

HINT. Being able to link signs together is extremely important. For example, regularity, flattening and transference that are linked together could be graded as strong evidence of IED contamination, providing more confidence than any of these individual signs in isolation.

5. SCENARIO EXAMPLES

5.1. SCENARIO 1 – IRAQ - DEFENSIVE IED BELTS

GENERAL DESCRIPTION

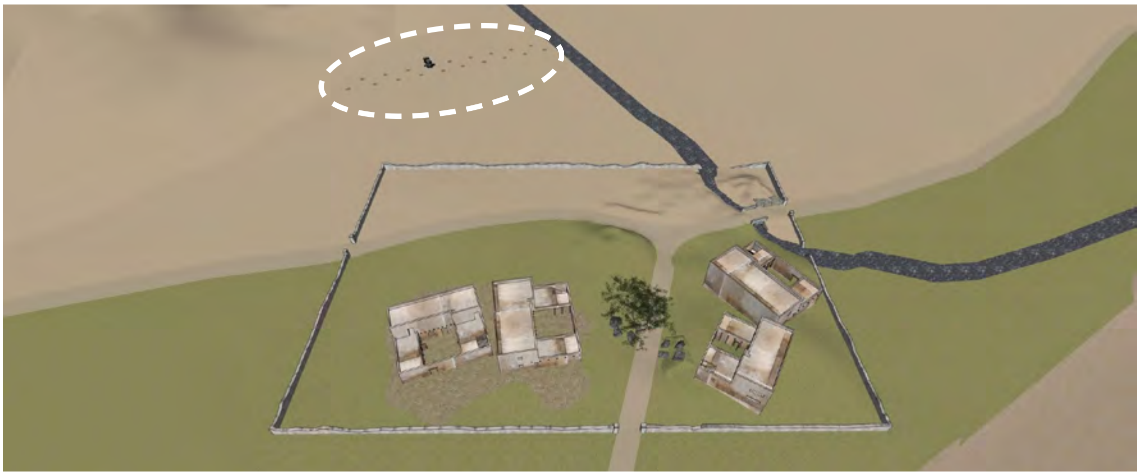


Image 72. Defensive IED belt (highlighted by white dashed line) containing a damaged vehicle, close to a community housing complex (North is up)

An MA operator has received a request to conduct NTS of a community housing complex as shown in Image 72. The housing complex was occupied by a non-state armed group for over 12 months. They were using it as a fortified fighting position to dominate the channelled movement of an opposing armed group between a river and an area of steep relief.

The local community reported that the area inside the walls has been reoccupied by local families for over six months and there have been no issues related to EO. However, the community are concerned about the area to the north, which includes an area of commonly owned land which herds of sheep move over to get to the river.

An MA organisation is tasked to conduct NTS of the common land in the north.

DURING NTS THE FOLLOWING EVIDENCE WAS RECORDED

IED indicators

- There is a VP to the north of the housing complex created by steep relief and a river. During the conflict this would have **channelled** the movement of vehicles and people trying to attack the non-state armed group occupying the housing estate.
- The ground is suitable for wheeled vehicles to move over but soft enough to bury a VOIED in order to conceal it.
- There are no **aiming markers** or tightly restricted VPs, such as **culverts** or **entrance points** in the area to the north.
- There is a destroyed pickup truck with a mount for a heavy machine located approximately 150 m from the northern perimeter wall. The vehicle damage is consistent with a blast main charge functioning directly between the front wheels, which in itself is a **sign**.

IED sign

- Ground sign **disturbance** is noted approximately 150 m to 170 m from the northern wall. The signs appear to be in two rows and with a consistent distance between each area of signs.

OPERATIONAL THREAT ASSESSMENT

A threat assessment consistent with Annex C of IMAS 07.14 Risk Management in Mine Action, based on the evidence of IED indicators and signs recorded during NTS, concludes that:

A defensive belt of VOIEDs is probably located to the north of the housing complex. These are probably VOIEDs (pressure) with the main charge and firing switch offset by approximately 1 m. The main charge likely contains approximately 5–10 kg of explosives.

WARNING. Evidence recorded from other sources such as key informant interviews, national threat analysis and MA reports related to the area would be used to expand this operational threat assessment prior to its inclusion in an IED clearance plan.

A breakdown of the evidence and assessment linkage is as follows:

OPERATIONAL THREAT ASSESSMENT	EVIDENCE	ASSESSMENT
A defensive belt of VOIEDs is probably located to the north of the housing complex.	There is a vulnerable area to the north of the housing complex created by relief that would constrict or **channel** the movement of vehicles assaulting the position.	Time and command-initiated devices are not as effective as multiple VOIEDs in providing a persistent (day & night) effect in vulnerable areas.
	The ground is suitable for wheeled vehicles to move over but has **soft enough soil** to bury a VOIED in order to conceal it.	Confidence in this assessment is increased by the consistency and **regularity of the disturbance**.
	Regularity in areas of **disturbance** are noted approximately 150 m to 170 m from the northern wall. These appear to be in two rows and with a consistent distance between each area of signs.	The distance from the complex's perimeter is linked to an explosive obstacle that is covered by direct fire weapons. This is a known tactic of the non-state armed group that placed the contamination.
These are probably VOIEDs (pressure) with the main charge and firing switch offset by approximately 1 m. The main charge likely contains approximately 5–10 kg of explosives.	There are no **aiming markers** or tightly restricted VPs, such as **culverts** or **entrance points**. There is a destroyed pickup truck with a mount for a heavy machine located approximately 150 m from the northern perimeter wall. The vehicle damage is consistent with a blast main charge functioning directly between the front wheels, which in itself is a **sign**.	The threat of command-initiated devices is further reduced through a lack of opportunity due to the ground not being suitable for the use of this IED capability. Damage to the vehicle is consistent with this quantity of HME function when a wheel makes contact with a pressure plate causing a main charge to detonate in an offset position.

ADDITIONAL IED INDICATORS AND GROUND SIGNS RECORDED DURING IED CLEARANCE ACTIVITIES

When the MA searcher / deminer is 4–5 m away from the sign that was originally recorded as a disturbance they are able to observe the sign in more detail (see Image 73).

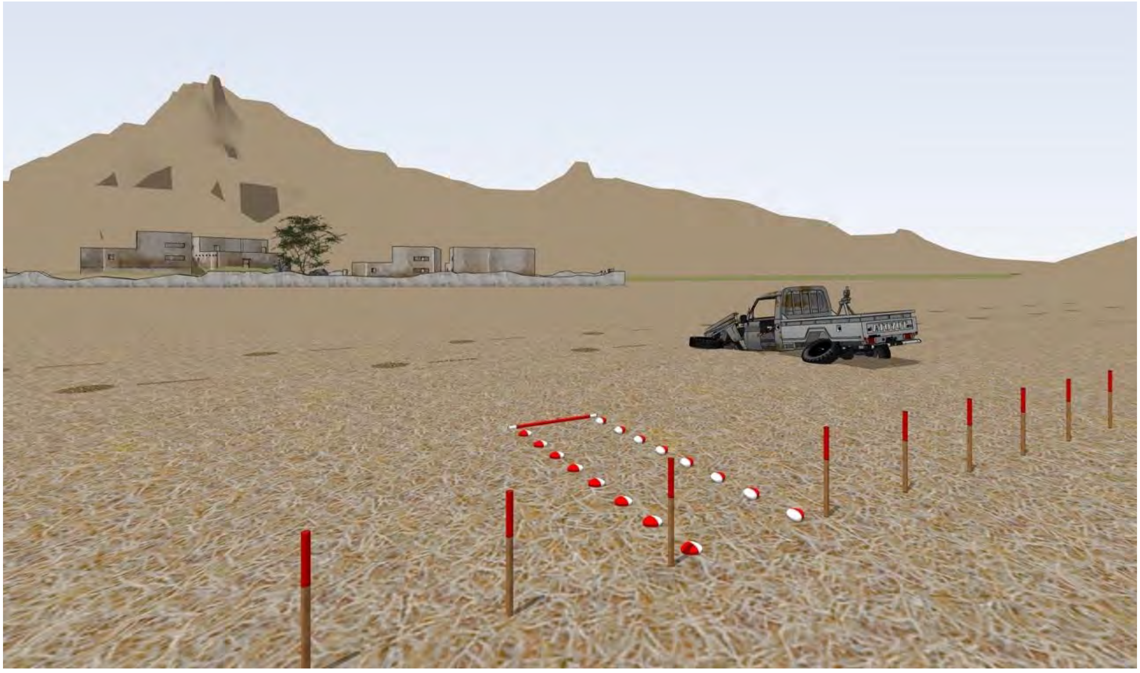


Image 73. Initial clearance lane

The searcher / deminer recorded the following observations:

- An area of **disturbance** approximately 0.5 m to 0.75 m in diameter. This is consistent and assessed to be the location of the main charge.
- 1 m to 1.5 m of **regularity**. This is extremely narrow and is assessed to be the location of an electrical link.
- An area of rectangular **flattening** (0.5 m by 0.2 m). This is assessed to be consistent with the location of a pressure plate switch.

The IED that the searcher / deminer is assessing to be present is:

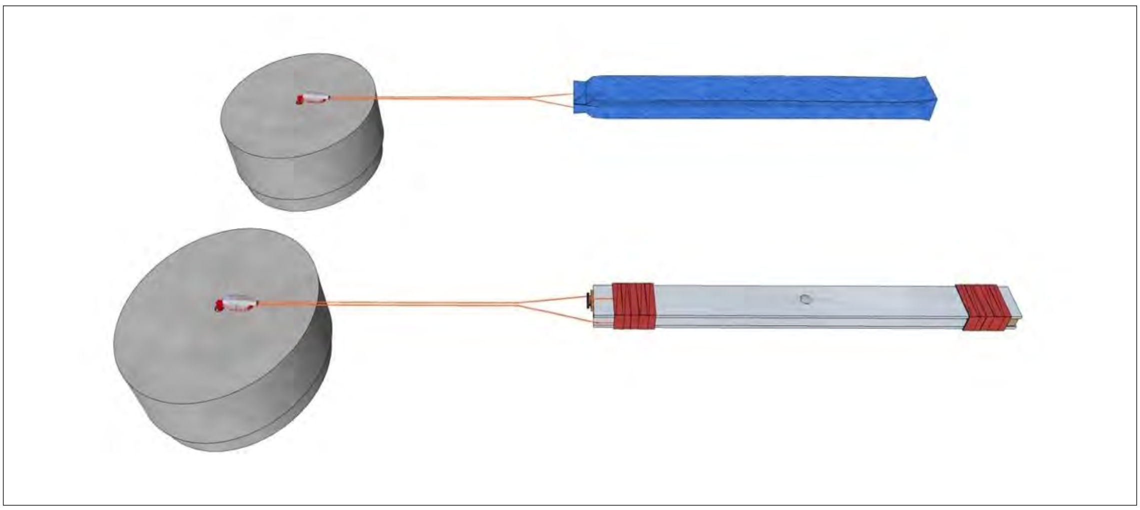


Image 74. The assessed VOIED in detail

The assessed VOIED is a high metal content pressure plate IED. The main charge is concealed in a round canister and is connected to the pressure plate by a wire. The bottom device shows the pressure plate switch removed from its blue weatherproofing. The connection between the visually recognised ground signs and the design of the IED is clearly visible.

Image 75. The assessed VOIED in relation to the ground sign

AFTER REFERRAL WITH THE TEAM LEADER, THE FOLLOWING KEY DECISION IS MADE

The search lane is moved to the left in order to avoid the assessed switch location (see Image 76). This will enable the IED's main charge to be detected and located by the searcher / deminer and for the task to be handed over to an MA improvised explosive device disposal (IEDD) operator.

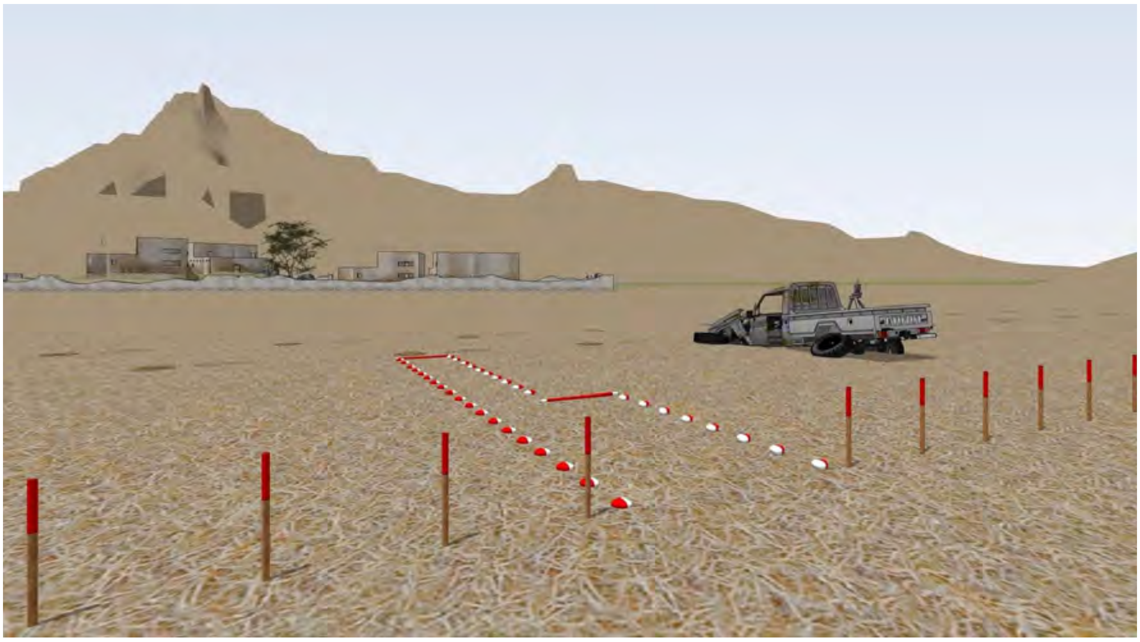


Image 76. Evidence-informed decision on assessment of the sign to avoid the probable location of a pressure plate

5.2. SCENARIO 2 – AFGHANISTAN FOOT PATROL ROUTE

GENERAL DESCRIPTION

Image 77. Aerial photograph showing a section of the patrol area

Image 77 is an aerial photograph that shows where an armed group previously occupied a building (red rectangle) on the outskirts of a village (blue shading). The red line denotes a main route that is currently not being used by the community, even though the conflict has ended.

During the conflict, the route provided a defence opportunity for the armed group that occupied the building, by **channelling** opponent groups as they moved through the village. The local community, some of whom remained in the area during the conflict, reported that there were a number of explosions along the route during the conflict. At the time of conflict, the community were instructed not to use the route between dusk and dawn, as it was 'mined', creating an **IED indicator** of a negative environment.

The conflict in the area ceased six months ago and, gradually, the local population has been moving back into their homes. According to the village elder, whose position has been substantiated by a diverse mix of women, girls, boys and men across the community, there have been two explosive accidents on the route in the last six months.

The community does not use the main route nor a number of interconnecting walkways between compounds. This is causing significant issues especially for families with children.

DURING NTS THE FOLLOWING EVIDENCE WAS RECORDED

IED indicators

- The route running through the middle of the village provided a defensive opportunity for the armed group by **channelling** both their opponent's foot and vehicle patrols. The vehicles that were used during the conflict were lightly armoured 4x4 pickups.
- During NTS a UAV was used to confirm two craters (or **disturbances)** from previous explosions. They are both approximately 3 m in diameter and 0.5 m deep.
- The ground is a mixture of compacted stone and sand and it would be possible to secrete subsurface IEDs in the ground, perceived as a **Big 5** indicator.
- There are no obvious **aiming markers**, but the urbanised area does have constricted areas when moving off the main route to smaller further restricted tracks, some of which would allow small vehicles to access and **channel** considerably.
- There are **warning markers** in the form of fist-sized rocks and stones laid in a line at the two ends of the red line that can be seen in the aerial image.
- The village elder suggested there are areas of **disturbance** at a number of points on the route.

IED signs

- A ground sign **disturbance** can be seen on the track, with what seems to be a **regularity** of linear shape running off into the verge.
- **Discardables** are present in the form of what appears to be a number of VOIED switches and 'palm oil' main charge containers that have been abandoned, as a ground sign near to adjacent buildings.
- Traces of a white granular substance or **discardable** on the surface of the ground commensurate with the type of HME used by the armed group has been found.

OPERATIONAL THREAT ASSESSMENT

A threat assessment consistent with Annex C of IMAS 07.14 Risk Management in Mine Action, based on the evidence of IED indicators and signs recorded during NTS, concludes that:

The main route is most likely contaminated with VOIEDs. These are probably low metal content pressure plate switches with the main charge in the centre of the route and the battery offset in the verge to make detection by opposing groups more difficult. The IED's main charges are likely to be 15–20 kg of HME in a plastic container.

WARNING. Evidence recorded from other sources such as key informant interviews, national threat analysis and MA reports related to the area, would be used to expand this operational threat assessment prior to its inclusion in an IED clearance plan.

A breakdown of the evidence and assessment linkage is as follows:

OPERATIONAL THREAT ASSESSMENT	EVIDENCE	ASSESSMENT
VOIED contamination on the main route running through the village. Most likely to be VOIEDs (pressure) with the power source offset 4–5 m from the switch to hamper detection.	Due to the parties of an armed conflict's (in context) considerate nature towards the community of the area and the evidence that suggests the local community were instructed to not use the route, creating inconclusive evidence of a **negative environment.**	This lends itself to the use of VOIEDs, likely with a remote power source to enable arming and disarming and making it more difficult to detect by reducing the IED's metal content on the route.
	The armed group would have expected opposing forces as the route **channelled** vehicles and people.	
	The conditions allow good placement of IEDs due to the relatively soft ground, a **Big 5 indicator**.	
	Areas of disturbance can be seen on the track with what seems to be linear **regularity** in a **disturbance** running away to the verge (assessed as remote power source).	
The main charge most likely contains approximately 15–20 kg of HME, located in the centre of the route and offset 1 m from the pressure plate switch.	A crater, or **disturbance** from one of the explosions is around 3 m in diameter and 0.5 m deep. It is located in the middle of the route.	This crater is commensurate with a 10–20 kg subsurface HME main charge. During the conflict, the armed group in this area rarely used command-initiated IEDs and the ground in question does not lend itself to such a type of attack due to limited lines of sight.

ADDITIONAL IED INDICATORS AND GROUND SIGNS RECORDED DURING IED CLEARANCE ACTIVITIES

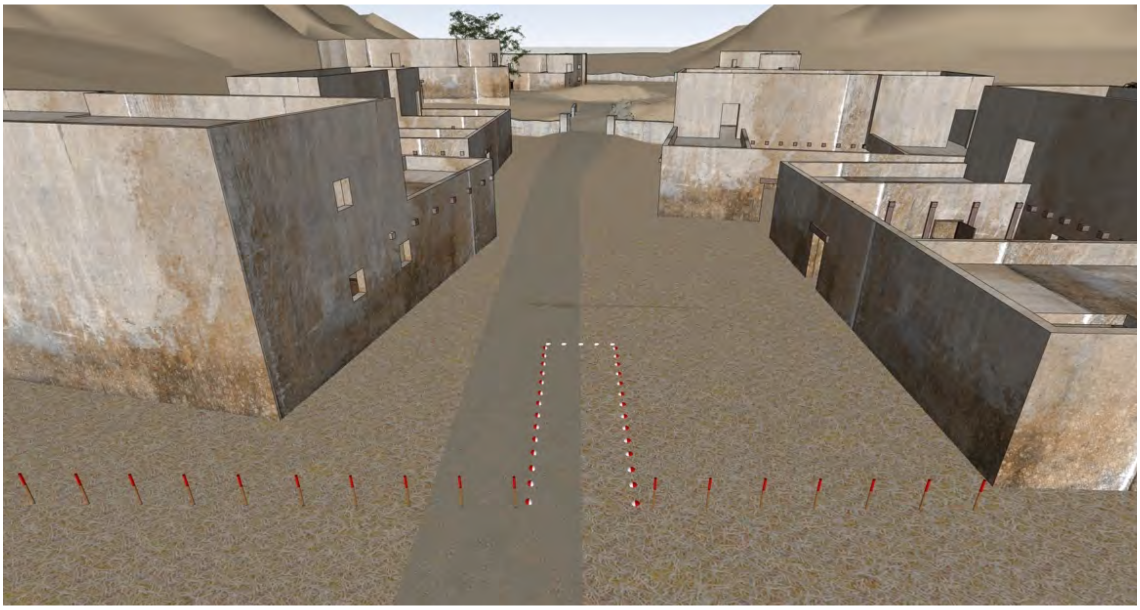


Image 78. Showing the initial 2 m clearance lane towards the ground sign

The MA searcher / deminer made more detailed observations based on the signs that were originally recorded as **disturbances**, from a distance of 4–5 m. The searcher / deminer recorded the following observations:

- An area consistent with the location of the pressure plate switch and main charge.
- 4 m of **regularity**. This is extremely narrow and is assessed to be the location of the remote power source.

THE IED THAT IS ASSESSED TO BE PRESENT IS SHOWN IN THE FOLLOWING IMAGES

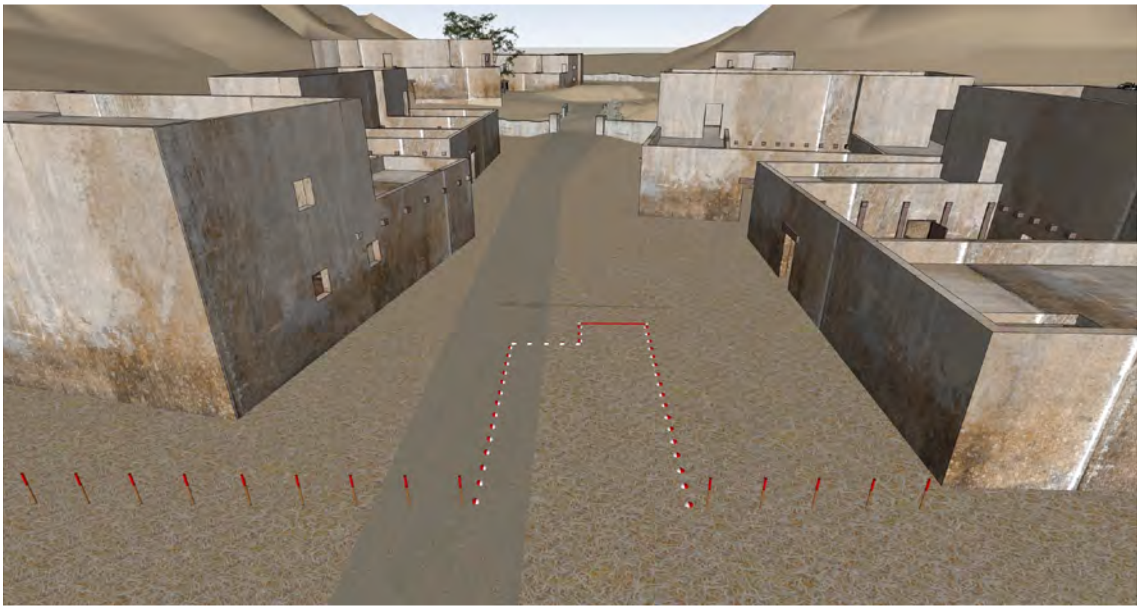


Image 79. The relocated clearance lane with standard MA marking system and assessed VOIED ground sign beyond the end of the lane marker

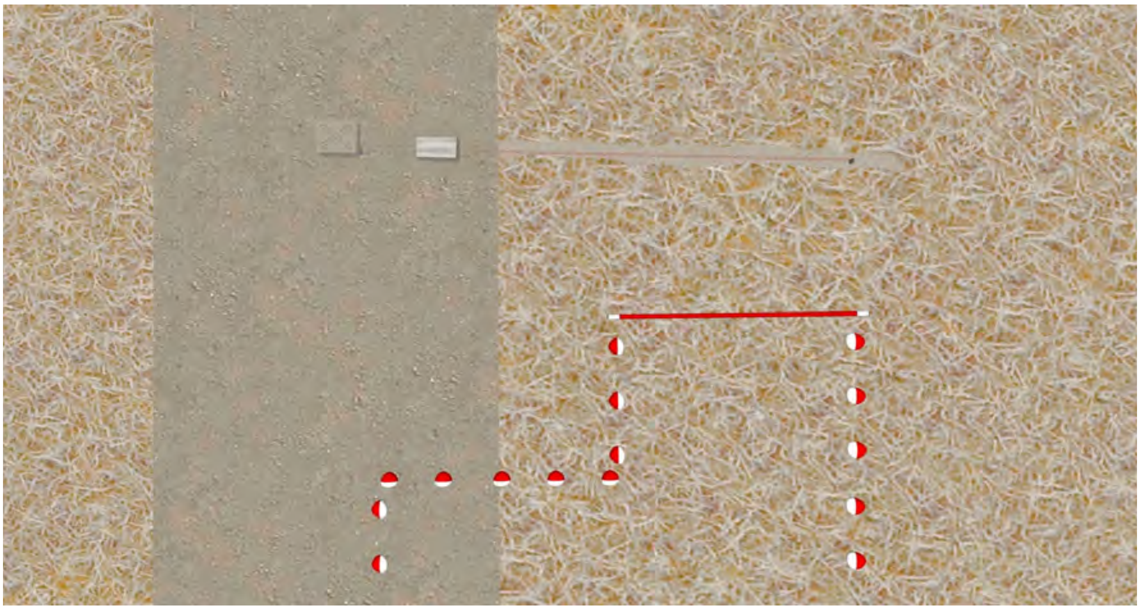


Image 80. Aerial view of clearance lane with standard MA marking system and assessed VOIED beyond the end of the lane marker

AFTER REFERRAL, THE FOLLOWING KEY DECISION IS MADE

The initial clearance lane shown in Image 78 is relocated, as shown in Images 79 and 80, to increase the probability that the first part of the IED encountered is the power source, therefore reducing the risk to the searcher / deminer.

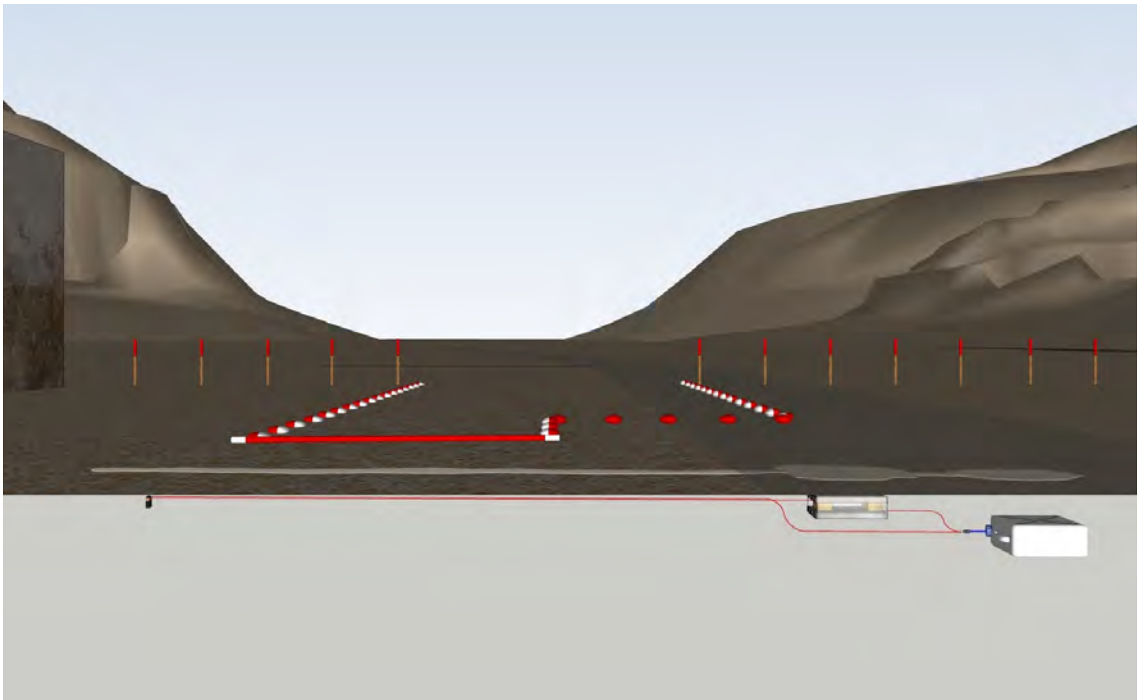


Image 81. The assessed VOIED in the ground displaying the ground sign

5.3. SCENARIO 3 – COMMAND IED

GENERAL DESCRIPTION

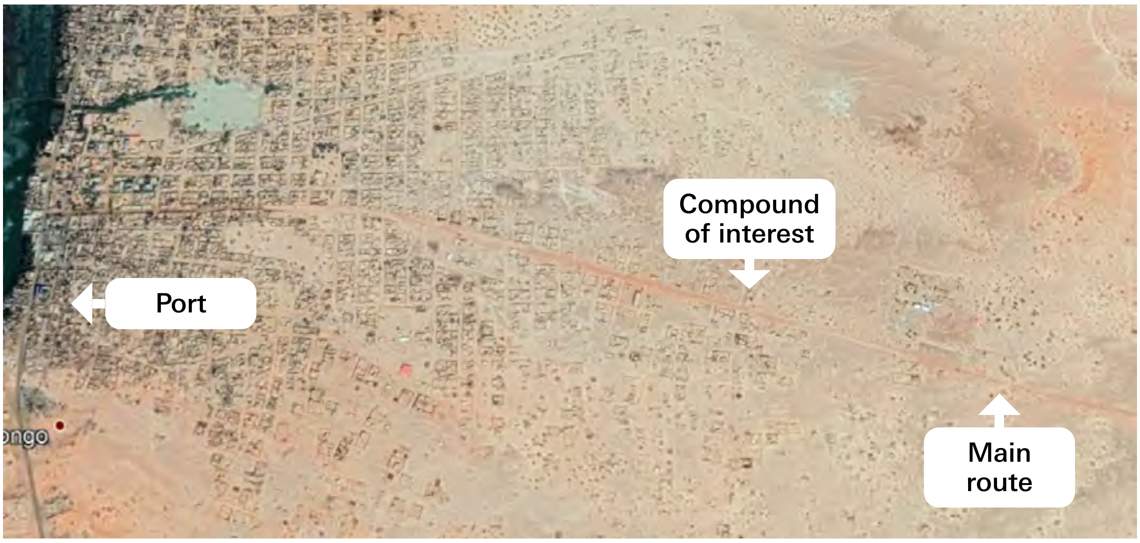


Image 82. Aerial photograph showing main route leading to a port

Image 82 is an aerial photograph showing a semi-urban area through which a main route runs, as a **channelled route,** east-west to a port. As the route gets further away from the port, the density of the surrounding buildings reduces and the terrain becomes open desert.

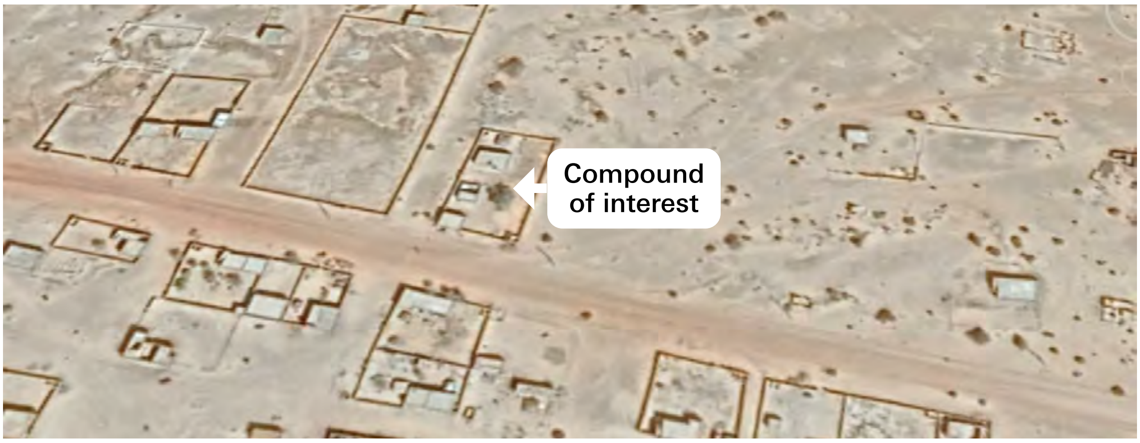


Image 83. Showing compound of interest, which is a concern to the local community

The conflict in the area ended over four months ago and an MA organisation has received a request to conduct NTS of the route leading to the port. The area encompasses an urban-rural interface that acts as the break between the open desert and the more densely urbanised areas around the port. The route is being trafficked by lorries, cars and people, creating evidence of a positive environment. However, there is a compound, adjacent to the route, that is a concern to the local community.

The area was under the control of a non-state armed group for over 12 months and significant areas of the town remain unused. The town's community, many of whom remained in the area during the conflict are worried about the compound, as well as other areas adjacent to the route, believing them to be dangerous. This is especially true in the interface area where a lot of the heavy fighting occurred, creating evidence of a negative environment.

The community's main fear relates to them finding military ordnance and suspicious objects, or **discardables,** that they believe the non-state armed group modified into weapons. There have been reports of explosions, but these mostly occurred in the 30 days after the conflict ended when the community was still identifying areas that were dangerous.

DURING NTS THE FOLLOWING EVIDENCE WAS RECORDED

IED indicators

- The route had a number of vehicles travelling on it during NTS. The compound of interest, highlighted in red in Image 83, was determined as an area the local community did not use (negative **environment CAGE indicator)**.
- Some of the local community stated they were warned not to go near the compound during the conflict, and also advised not to be in the vicinity whilst opposing forces were present.
- A former police officer suggested that during the conflict there were explosions along the route triggered by 'observers'. It was stated that some were effective, and some were not. He once witnessed an explosion occurring just in front of an armed group's vehicle.
- As the route runs into the town from the desert it becomes constricted and **bottle-necked** at the urban–rural interface.
- The ground is compacted sand and it would be viable to emplace subsurface IEDs or main charges (a **Big 5 indicator**).

IED signs

- There is a **top sign** item identified through **colour change** and **regularity** on the compound of interest. This is believed to be an IED component, probably an antenna.

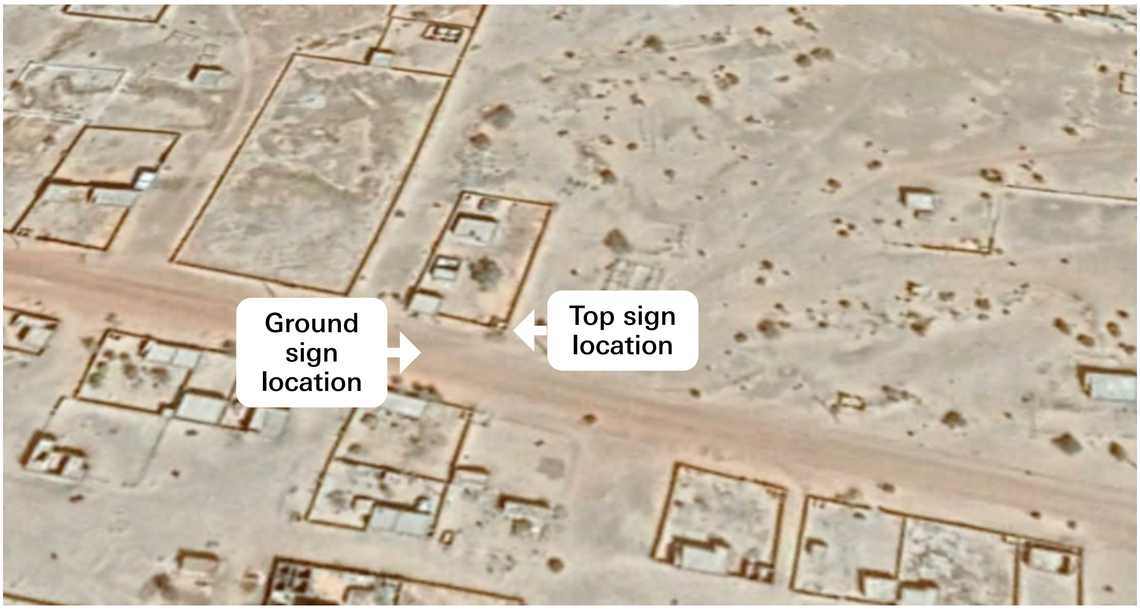


Image 84. Showing the locations of the top sign and ground sign

- Suspicious ground sign **disturbance** can be seen in the area highlighted in blue on Image 84.
- There is **regularity** in the form of a small black wire, around 50 mm in length, protruding upright from the top corner of the south-eastern compound wall.
- There is damage in the vicinity including a compound in an additional nearby VP consistent with explosive fragmentation from military ordnance displaying **regularity** and **colour change,** which could be termed as **discardables** as well.

OPERATIONAL THREAT ASSESSMENT

A threat assessment consistent with Annex C of IMAS 07.14 Risk Management in Mine Action, based on the evidence of IED indicators and signs recorded during NTS, concludes that:

The compound highlighted in the photos is likely to be concealing a receiver for an RCIED with a potential main charge in the middle of the track. The main charge is likely to be a medium-sized charge and is potentially military ordnance.

WARNING. Evidence recorded from other sources such as key informant interviews, national threat analysis and MA reports related to the area would be used to expand this operational threat assessment prior to its inclusion in an IED clearance plan.

A breakdown of the evidence and assessment linkage is as follows:

OPERATIONAL THREAT ASSESSMENT	EVIDENCE	ASSESSMENT
Most likely command- initiated devices in the area. Probable RCIED in the area of the highlighted compound.	During the conflict, the armed group and the local community had a relatively amicable relationship or **environment** with no known accidental IED incidents. The highlighted compound is on the northern side of the route and the ground directly adjacent presents a **bottleneck** effect where the desert links to the urbanised area. The route presents the main vehicular access to the port, which was of strategic value. The ground is viable for IED secretion due to its nature of compacted sand which is interspersed with **loose soil**. There are areas of **top signs** around the compound including a potential past explosion contact point which may include a nearby compound and also a wire protruding from the corner of a compound.	The area around the red compound is a VP due to the **channelling** from the desert that enables a good **line of sight** to a contact point on the route. Command-initiated devices offer more control to the armed group than VOIEDs. With no known accidental IED incidents against the local population in the area and considering information from key informants, it is highly likely that any IEDs will be command-initiated and most likely RCIEDs as the opposing forces had no means to mitigate their use. The urban-rural interface environment would have had a lower **pattern of life** in comparison to the more densely populated areas, presenting an opportunity to better target opposing forces without the threat of local population casualties. This assessment is commensurate with armed group tactics within this area.
The main charge is likely to be a medium-sized charge and is potentially military ordnance.	Military ordnance or **discardables** found by local population in other areas. Damage or **disturbances** in VPs nearby from the result of an explosion, consistent with military ordnance fragmentation.	Military ordnance is available to this armed group and offers superior explosive qualities, beneficial if targeting vehicles. Opposing forces did not mitigate the risk of IEDs by searching with metal detectors. The use of plastic container main charges was not necessary.

ADDITIONAL IED INDICATORS AND GROUND SIGNS RECORDED DURING IED CLEARANCE ACTIVITIES

Image 85. Image showing the sign in detail. Note the wire protruding from the corner

When the MA searcher / deminer is 4–5 m from the sign that was originally reported at the south-eastern corner, it is interpreted as follows:

- A wire projecting from above the corner junction of the wall by approximately 100 mm. This is assessed to be the receiver element of an RCIED. There is also a potential wire running down the wall. This is identified by **colour change** (red).
- A linear area of **disturbance** running from the corner into the road. Assessed to be an electrical link.
- The circular **disturbance** on the route is assessed to conceal the IED's main charge.

AFTER REFERRAL THE FOLLOWING KEY DECISION IS MADE

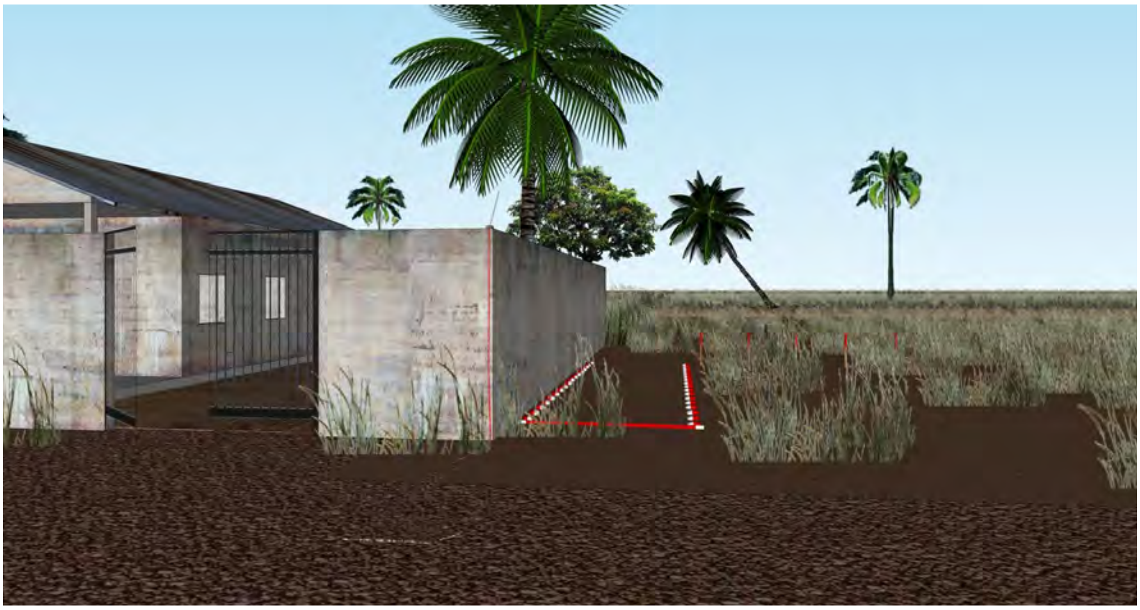


Image 86. Image of relocated clearance lane

The search lane is relocated to the side of the compound to gain safe access and to ensure that the receiver / power source is the first part of the IED to be encountered (Image 86). Once these components are located, the task can be handed over to an MA IEDD operator.

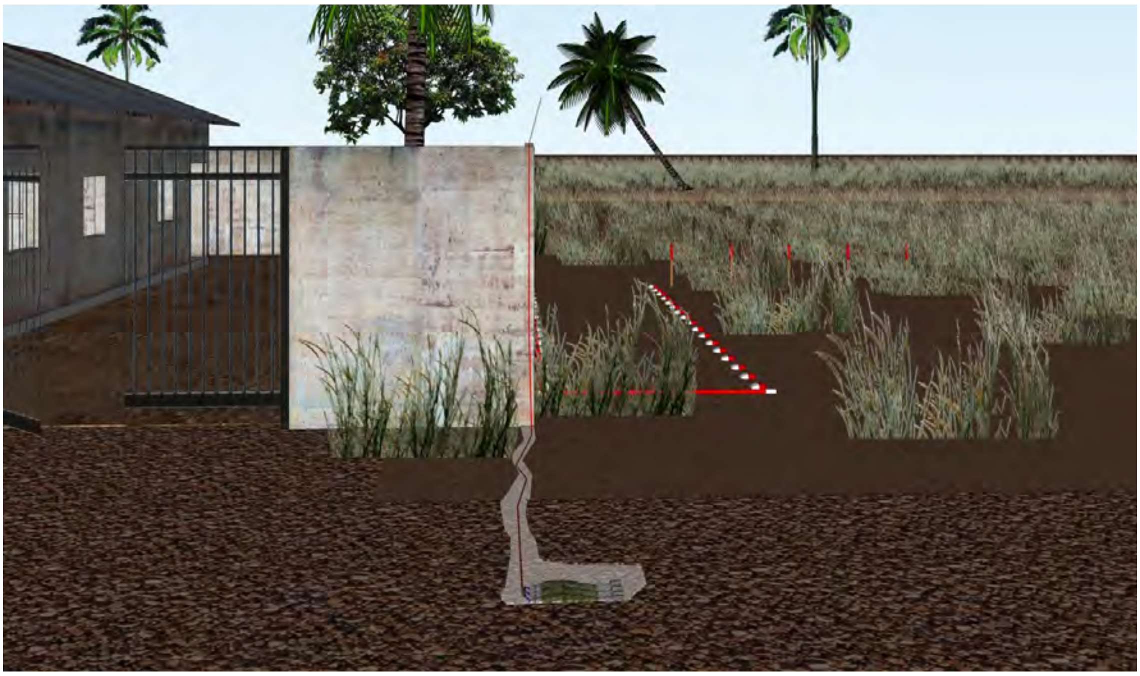


Image 87. Image showing the IED main charge in the road

6. CONCLUSION

Knowledge of IED-related indicators and signs and their application play an important role in strengthening safety measures.

Knowledge and skills required to identify IED-related threats not only assist MA personnel in survey and clearance but are useful for a wide range of humanitarian aid workers and first responders operating in an IED threat environment.

Recognising IED indicators and ground signs can be essential for risk management on different levels, as well as making evidence-based decisions and identifying hazards.

The aim of this collection of good practice and sectorial norms is to assist in all these aspects, with the goal of increasing confidence, mitigating risks, increasing efficiency for MA personnel, programmes and the affected population.

7. LEXICON OF ACRONYMS

CAGE	Channelling, aiming markers, ground sign and environment
EO	Explosive ordnance
ERW	Explosive remnants of war
HME	Home-made explosive
IED	Improvised explosive device
IEDD	Improvised explosive device disposal
IMAS	International Mine Action Standards
MA	Mine action
NTS	Non-technical survey
RCIED	Radio-controlled improvised explosive device
SALW	Small arms and light weapons
UNMAS	United Nations Mine Action Service
UXO	Unexploded ordnance
VOIED	Victim operated improvised explosive device
VP	Vulnerable point

8. GLOSSARY OF TERMS

Clearance. In the context of mine action, the term refers to tasks or actions to ensure the removal and/or the destruction of all Explosive Ordnance from a specified area to a specified depth or other agreed parameters as stipulated by the NMAA/Tasking Authority. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Command (IED). A type of switch that is activated by the attacker in order to control the moment of initiation. **(Source: UNMAS IED Lexicon)**

Conclusive Sign. A conclusive sign indicates that an IED is or has been present. This can mean that it is classified as direct evidence in the land release process. **<u>(Not defined in IMAS)</u>**

Confirmed Hazardous Area (CHA). Refers to an area where the presence of mine/ERW contamination has been confirmed on the basis of direct evidence of the presence of mines/ERW. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Explosively Formed Projectile (EFP). Specially designed main charge configuration incorporating an explosive charge with a concave metal liner which by the force of the charge reshapes the plate into a high velocity metal slug capable of penetrating armor. **(Source: UNMAS IED Lexicon)**

> Note: In some literature, an EFP can sometimes be called an explosively formed penetrator, or a self-forging fragment.

Explosive Ordnance (EO). Interpreted as encompassing mine action's response to the following munitions:

- Mines
- Cluster munitions
- Unexploded ordnance
- Abandoned ordnance
- Booby-traps
- Improvised explosive devices

> Note: Improvised explosive devices (IEDs) meeting the definition of mines, booby-traps or other devices fall under the scope of mine action, when their clearance is undertaken for humanitarian purposes and in areas where active hostilities have ceased. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Explosive Ordnance Disposal (EOD). The detection, identification, evaluation, render safe, recovery and disposal of EO. EOD may be undertaken:

- As a routine part of mine clearance operations, upon discovery of EO;
- To dispose of ERW discovered outside hazardous areas, (this may be a single item of ERW, or a larger number inside a specific area); or
- To dispose of EO which has become hazardous by deterioration, damage or attempted destruction. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Explosive Remnants of War (ERW). Unexploded Ordnance (UXO) and Abandoned Explosive Ordnance (AXO). [CCW Protocol V]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

High Risk Area. An identifiable area that is typically mined in a Confirmed Hazardous Area, or an area that is described by a non-technical survey as being more likely to be mined or to contain ERW than others. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Home Made Explosive (HME). A combination of commercially available ingredients combined to create an explosive substance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Humanitarian Principles. A set of principles that guides humanitarian action, which include the principles of humanity, neutrality, impartiality and independence.

> Note: See **IMAS 01.10 (6.2)** for more on humanitarian principles in mine action. These principles are endorsed in UN resolutions 46/182 and 58/114 and considered the foundation for humanitarian action [UNOCHA]. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Identification Procedures. Those actions taken to establish the make-up and characteristics of an item of EO. **(Source: UN IEDD Standards (May 2018))**

Improvised Explosive Device (IED). A device placed or fabricated in an improvised manner incorporating explosive material, destructive, lethal, noxious, incendiary, pyrotechnic materials or chemicals designed to destroy, disfigure, distract or harass. They may incorporate military stores but are normally devised from non-military components **[IATG 01.40:2011]**.

> Note: An IED may meet the definition of a mine, booby trap, and/or other type of explosive ordnance depending on its construction. These devices may also be referred to as improvised, artisanal, or locally manufactured mines, booby traps, or other types of explosive ordnance. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

IED Disposal (IEDD). The location, identification, rendering safe and final disposal of IEDs. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Inconclusive Sign. This is a sign that may or may not be IED related but is considered worth recording for further investigation. This category of sign may be used as indirect evidence in the land release process. **(Not defined in IMAS)**

Key Informants. All men, women and children who have relatively good knowledge on the hazardous areas in and around their community.

> Note: Key informants may include, but are not limited to, community leaders, mine-affected individuals, schoolteachers, religious leaders etc. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Land Release. In the context of mine action, the term describes the process of applying "all reasonable effort" to identify, define, and remove all presence and suspicion of Explosive Ordnance through non-technical survey, technical survey and/or clearance. The criteria for "all reasonable effort" shall be defined by the NMAA. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Main Charge. The explosive charge which is provided to accomplish the end result in a munition. Examples for end results are: bursting a casing to provide blast and fragmentation; splitting a canister to dispense sub-munitions; or producing other effects for which it may be designed. **(Source UNMAS IED Lexicon)**

Main Charge Configuration. The arrangement or design of the main charge and other materials (usually metal) to create an effective weapon to attack personnel, vehicles, or structures. **(Source UNMAS IED lexicon)**

Mine action (MA). Activities which aim to reduce the social, economic and environmental impact of mines, and ERW including unexploded sub-munitions.

Note: Mine action is not just about demining; it is also about people and societies, and how they are affected by landmines and ERW contamination. The objective of mine action is to reduce the risk from landmines and ERW to a level where people can live safely; in which economic, social and health development can occur free from the constraints imposed by landmine and ERW contamination, and in which the victims' different needs can be addressed. Mine action comprises five complementary groups of activities:

1. Explosive ordnance risk education;
2. Humanitarian demining, i.e. mine and ERW survey, mapping, marking and clearance;
3. Victim assistance, including rehabilitation and reintegration;
4. Stockpile destruction; and
5. Advocacy against the use of anti-personnel mines.

A number of other enabling activities are required to support these five components of mine action, including: assessment and planning, the mobilisation and prioritisation of resources, information management, human skills development and management training, quality management, and the application of effective, appropriate and safe equipment. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Mine action organisation. Refers to any organisation (government, military, commercial or NGO/civil society) responsible for implementing mine action projects or tasks. The mine action organisation may be a prime contractor, subcontractor, consultant or agent. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Non-Technical Survey (NTS). Refers to the collection and analysis of data, without the use of technical interventions, about the presence, type, distribution and surrounding environment of explosive ordnance contamination, in order to better define where explosive ordnance contamination is present and where it is not, and to support land release prioritisation and decision-making processes through the provision of evidence. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Power Source. A device that either stores or releases electrical or mechanical energy. The key elements of information about a power source are its type / source, number of batteries and their configuration (series or parallel), its voltage (if electrical) and how it is connected to close an IED switch. **(Source UNMAS IED Lexicon)**

Pressure. A switch designed to function when pressure is applied in a predetermined direction (plate, tube, plunger, crush wire). **(Source UNMAS IED Lexicon)**

Sensor. A switch used to detect change in heat, light, movement, vibration, electromagnetic frequency, sound or magnetic field. **(Source UNMAS IED Lexicon)**

Suspected Hazardous Area (SHA). An area where there is reasonable suspicion of explosive ordnance contamination on the basis of indirect evidence of the presence of mines/ERW. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Switch. A device for making, breaking, or changing a connection in an IED. A single switch can have multiple functions (i.e. arming and firing). **(Source UNMAS IED Lexicon)**

Time. A type of switch that functions after a period of time. **(Source IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Unexploded Ordnance (UXO). Explosive ordnance that has been primed, fuzed, armed or otherwise prepared for use, or has been used. It may have been fired, dropped, launched or projected yet remains unexploded either through malfunction, design or for any other reason. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Victim Operated. A type of switch designed to be initiated by a victim's presence, proximity, contact or activity causing a device to function that may injure or kill one or more persons. **(Source: IMAS 04.10 Second Edition, Amendment 10, February 2019)**

Vulnerable Point (VP). Specific points where it is particularly advantageous for an aggressor to position an ambush, using either IEDs, SALW, or both. VPs are typically characterized by prominent or restrictive feature or choke point on the ground. Several factors pertaining to aggressor capability, intent and local factor use will contribute to the vulnerability of a specific point. **(Source: UN IEDD Standards (May 2018)**

CHAPTER 5

BASIC CHEMISTRY OF EXPLOSIVES AND HAZARDS OF HOME-MADE EXPLOSIVES AND CHEMICAL PRECURSORS

1. INTRODUCTION

The widespread use of improvised explosive devices (IEDs) has been documented extensively by the mine action sector over the last decade[1]. Together with this trend is the use of home-made explosives (HMEs). Although not all IEDs include an HME component, the frequency of their use and the specific operational challenges related to HMEs and their chemical precursors, have highlighted the need to document good practice related to this lesser-known category of explosives.

The importance of addressing HMEs is clear. They pose a threat to human life and to the environment. There is also a significant risk that mine action (MA) personnel will encounter HMEs in affected countries, whether in improvised explosive devices (IEDs), in abandoned manufacturing or storage sites, or as stockpiles of precursor chemicals used in a variety of industries. The severity of the impact of HMEs coupled with a high likelihood of encountering them in certain settings, led to the decision to develop guidance that is focused on HMEs.

Given the risks involved for those in encountering HMEs and potentially interacting with them, the GICHD has developed Chapter 5 of the *Improvised Explosive Device Clearance Good Practice Guide* with the aim of improving the safety of mine action personnel as a first priority, but also ensuring that mine action programmes are dealing with this particular threat effectively to keep communities safe from their effects. This guidance therefore provides an important component of the mine action knowledge necessary to conduct IED search and disposal activities within the IED clearance process in relevant settings.

Our aims for this chapter have been addressed by presenting technical information on HMEs that will promote an increased understanding of these substances, including: the raw materials that compose HMEs; the ability to recognise their presence; the physical and chemical characteristics of HMEs; their potential to generate non-explosive hazards, such as toxicity; and, safety considerations for mine action personnel who are likely to encounter HMEs (such as Personal Protection Equipment (PPE)).

In order to strengthen and reinforce the knowledge about HMEs and their chemical precursors in the MA sector, this publication presents a wide variety of HMEs that can be encountered in operational contexts, and the chemical compositions used in their explosive train. Apart from discussing the more common HME groups (chlorates, perchlorates, nitrates and peroxides), substantial information has been provided on less commonly found mixtures, as well as on improvised pyrotechnics, improvised incendiary compositions and improvised primary explosives.

This chapter is neither a research publication nor a comprehensive technical manual; it rather aims to provide condensed content in an easy-to-read format. Visual aids and images of these chemical compositions are provided throughout the chapter to reinforce the learning process. The content has been chosen to provide practical knowledge to mine action practitioners, based on the most common HME threats they will encounter. Theoretical knowledge of the very basic chemistry of explosives and their chemical precursors provides the foundation of this document. Detailed scientific information, such as complex equations and formula have been avoided. Definitions and derivations have also been simplified to provide only the most essential information for end-users.

It is hoped that the technical knowledge presented in this chapter will be a useful operational resource that enables MA personnel to meet their primary needs for identifying and assessing chemical behaviour, as well as the risks related to non-explosive hazards. At the same time, reliable and accessible technical information also provides the foundations for high quality national standards, operational procedures, and policy documentation. We therefore hope that this chapter also proves useful in terms of developing the frameworks for MA programmes where IEDs are present.

1 The continuing high total recorded since 2014 is mostly the result of a large number of casualties recorded in countries facing intensive armed conflict and involving the largescale use of improvised mines (Landmine Monitor 2020, http://the-monitor.org/media/3168934/LM2020.pdf). While use by states has almost ended globally, significant numbers of anti-personnel mines, especially those of an improvised nature, continue to be laid by non-state armed groups, including in Afghanistan, Colombia, Nigeria, Yemen, several countries in the Sahel, and elsewhere. (Clearing the Mines 2021, Mineactionreview, https://www.mineactionreview.org/assets/downloads/3644_NPA_Clearing_the_Mines_2021.pdf)

1.1. SCOPE

The IED Clearance Good Practice Guide, Chapter 5 – *Basic chemistry of explosives and hazards of home-made explosives and chemical precursors* – is intended for use by MA staff trained in accordance with International Mine Action Standard (IMAS) 09.31 'Improvised Explosive Device Disposal' and IMAS 09.13 'Building Clearance'. It should be of use for humanitarian IED disposal operators but also for MA staff involved in the planning, execution, monitoring and follow-up of IED clearance operations.

This publication should also inform humanitarian aid workers, humanitarian first responders and explosive ordnance risk education practitioners, on the development of methodologies, approaches and tools that are specific to an environment where HMEs and their chemical precursors are present.

In this publication, terminology and definitions are presented in such a way as to be usable and accessible for the daily use of an MA organisation. The reader should be aware that the figures on chemical and physical properties used in this chapter are provided by laboratory trials where the experimental conditions for measurements exist. Under such circumstances, parameters such as fuel ratio or particle size would be known. In real contexts, such variables are unknown, including degradation of the composition through ageing, and for this reason the chemical and physical properties of an HME may differ considerably.

This chapter does not provide detailed guidance on the production process of HMEs, phlegmatisation[2] or disposal procedures.

DISCLAIMER

This publication is distributed for use by the MA community. It is aligned with the IMAS series. It is subject to change without notice and may not be referred to as an International Standard.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation. Comments should be sent to info@gichd.org.

This publication's content has been put together from open-source information and has been assessed for accuracy and authenticity as far as possible. Because of their improvised nature, the parameters of HMEs will always vary. Regarding the properties of improvised explosives, statements in fixed numbers are hard to accomplish. Users should be aware of this limitation when utilising the information contained in this publication and should always remember that this is an advisory document only; it is not an authoritative directive.

This publication is not intended to replace IMAS-compliant training. It is not intended to 'convert' or 'expand' the remit of qualifications. The support of specially trained personnel may be required when encountering chemicals and HMEs.

This publication is not to be used to produce HMEs. It provides information required by the MA sector to increase safety when encountering HMEs or chemicals. Product information (for instance formulas, ingredient ratios) are not included on purpose.

This publication does not replace regulations defined by national standards and laws.

2 A phlegmatiser is a substance added to an explosive to enhance its safety in handling and carriage.

2. EXPLOSIVE MATTER

This section provides an overview of industrially manufactured and improvised explosives. It presents the basic concepts and emphasises hazard-related differences between industrially manufactured and home-made explosives (HMEs). An understanding of this section's content, combined with the basic knowledge of chemicals outlined in section 3 of this chapter, provides a solid basis for the information provided in this guide.

2.1. CONSIDERATIONS REGARDING EXPLOSIVES

2.1.1. CLASSIFICATION OF EXPLOSIVES ACCORDING TO THEIR COMPOSITION

An **explosive** is a substance or mixture of substances which, under external influences, is capable of rapidly releasing energy in the form of gases and heat.[3]

NOTE. An explosion is a sudden release of energy producing a blast effect with the possible projection of fragments. The term explosion encompasses fast combustion, deflagration and detonation.[4]

An explosion is caused within explosive matter if it is stimulated in a certain way. This stimulus can be induced by impact, friction, spark,[5] shock or heat. Furthermore, explosions can occur accidentally, for instance, when coal dust or petrol vapour mixes with air and is ignited by an external heat source.

Explosive (homogenous) compounds[6] are substances that contain an oxidiser and a fuel needed for an explosive reaction within their molecules. They are made of at least two precursor chemicals. During the manufacturing process, the chemical reaction of the raw materials leads to the creation of chemical bonds which combine to form a new homogeneous compound. This compound cannot be separated again by mechanical means (e.g. with a sieve or by dissolution in water). Common examples of industrially produced explosives which meet these requirements at their molecular level are trinitrotoluene (TNT) or Hexogen (RDX). Common examples of HMEs that are compounds are triacetone triperoxide (TATP) or hexamethylene triperoxide diamine (HMTD).

Image 2. Example of an explosive homogeneous compound: TNT (here used as filler for artillery shells) (source: GICHD ©)

3 International Ammunition Technical Guideline (IATG) 1.40, 3rd edition, March 2021.
4 International Ammunition Technical Guideline (IATG) 1.40, 3rd edition, March 2021.
5 Electric sparks are a very hot and fast-acting ignition source.
6 Compounds are homogenous, meaning that the precursor chemicals are bonded on an atomic level. For instance, water H_2O is a homogenous compound of hydrogen H and oxygen O.

Mixtures of substances with explosive properties are made from at least two substances – an oxidiser and a fuel. Their individual components may be present in different aggregate states and / or consist of different substances. Both oxidiser and fuel are required for an explosive reaction. In a mixture, used precursor chemicals do not form a chemical compound, and can be separated again by mechanical means. Apart from some exceptions, standard oxidisers and fuels used in HME mixtures are non-explosive substances. Common commercial explosive mixtures are black powder or flash compositions,[7] common HME mixtures are ammonium nitrate and aluminium (ANAL), or urea nitrate and fuel oil.

Image 3. Black powder (source: Bundeswehr CBRN Defence Command ©)

NOTE. Explosive chemistry is dependent upon the transfer of one or more electrons from one atom to another. An atom losing an electron is said to be 'oxidised' and an atom gaining an electron is 'reduced'. An oxidiser is a substance or compound with an electron deficit and it is a source of oxygen. Within an explosive compound or an explosive mixture, the oxygen provided is required for an explosive reaction to take place. With this prerequisite, no atmospheric oxygen is required for an explosive to detonate (there are exceptions, such as dust explosions or fuel-air explosions for example). Typical solid oxidisers are nitrates, chlorates and perchlorates.

A fuel is a substance or compound that is electron rich and acts within an explosive as a chemical reducing agent. For HMEs, typical fuels contain carbon, hydrogen or nitrogen (or chemical compounds containing these elements) or metals such as aluminium, zinc or magnesium, which donate electrons during the oxidation-reduction reaction.

WARNING. Despite not being classified as explosives, precursor chemicals can pose several other hazards such as flammability, corrosivity or toxicity.

7 A flash composition is a mixture of an oxidiser and a (metallic) fuel which burns bright and quickly and, if confined, produces a loud noise.

2.1.2. CLASSIFICATION OF EXPLOSIVES ACCORDING TO THEIR APPLICATION

Beyond chemical aspects, industrially manufactured explosive matter is defined by its application as industrially used explosive or as military explosive. In addition, explosives can be divided into subcategories according to their application as primary explosives, secondary explosives, propellants or pyrotechnics. Further definitions and explanations will be provided in sub-section 3.1. of this chapter. Table 1 below provides an overview of the variety of explosive matter and its application.

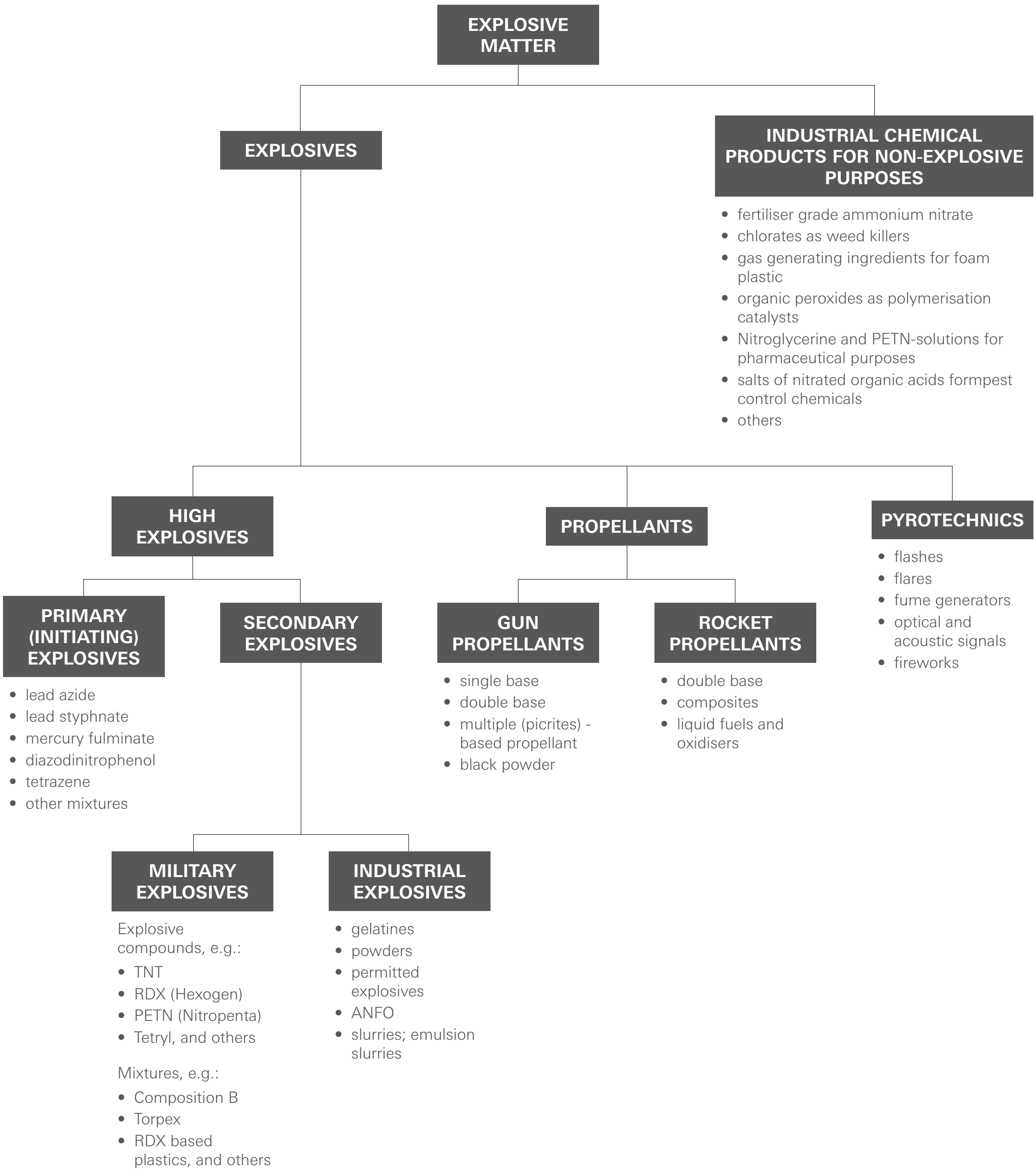


Table 1. Explosive matter and its application[8] (source: Wiley-VCH Verlag GmbH & Co. KGaA ©)

[8] Rudolf Meyer, Josef Köhler and Axel Homburg, *Explosives*. Sixth Edition. (Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, 2007), 134.

Industrially used explosives are designed and produced for commercial applications. An example is the gelatinous mining explosives used in quarries, or pyrotechnic mixtures used in airbags or fireworks. Explosive matter can be used for non-explosive purposes as well. Examples are the use of chlorates in pesticides, the use of ammonium nitrate in fertilisers or the use of nitroglycerine as a vasodilator[9] in medicine.

Military explosives are designed and produced for military purposes. Their performance is adapted to achieve a desired effect with regard to a target, and they may be deployed by an ordnance or a delivery system. Such performances can be:

- To create a high detonation velocity, used for driving metal liners to form shaped charges, for instance;
- To create a large volume of gas, used, for instance, for torpedo warheads, depth charges or sea mines; or
- To create a predictable, constant combustion rate combined with high heat resistance, used in solid rocket propellants, for instance.

Image 4. Example of a military explosive: remnants of a torpedo warhead filled with Torpex (RDX, TNT, aluminium powder and wax) (source: GICHD ©)

Both industrially used and military explosives are internationally and / or nationally standardised. Their manufacturing process follows established protocols and procedures. Their production is constantly monitored by qualified personnel and by using standardised methods. This ensures that their characteristic explosive effects will remain constant whatever their use. In general, this applies to all of their performance throughout their service life.

9 Vasodilators are medications that open (dilate) blood vessels.

2.2. CONSIDERATIONS REGARDING HMEs

2.2.1. BASICS OF HME

HME is predominantly a mixture of commercially available fuels and oxidisers; some homogeneous compositions are encountered as well. Usually, HME is in a solid or liquid state. In some instances, it can be transported as a two-phase system, enabling quick mixing prior to use. As with most military and industrially used explosives, the oxygen necessary for a detonation of HME is found within the mixture or the composition itself. This means that HMEs are largely self-sufficient in oxygen. This is a hugely important distinction from other flammable substances which rely on atmospherically available oxygen. Since the production of an HME does not follow the same stringent manufacturing process as an industrially used or military explosive, it is impossible to assure its performance, reliability and safety.

NOTE. IMAS 04.10 'Glossary of mine action terms, definitions and abbreviations' defines HME as 'a combination of commercially available ingredients combined to create an explosive substance.'

The UNMAS Improvised Explosive Device Lexicon defines HME as 'non-standard explosive mixtures/compounds which have been formulated/synthesized from available ingredients. Most often utilized in the absence of commercial/military explosives.'

2.2.2. HME-RELATED HAZARDS

In the press, as in the news, the term HME is generally used for reports concerning the discovery of main charges or improvised detonators containing HME used in improvised explosive devices (IEDs).

Image 5. Example of different main charges filled with HME
(source: Fondation Suisse de Déminage FSD ©)

However, focusing on this usage limits the perception of HME-related hazards. HMEs are not only used in primary explosives or secondary explosives but in propellants and incendiary or pyrotechnic compositions as well. Apart from their use in improvised explosive devices (IEDs), HMEs and explosive chemical precursors have also been found in:

- Abandoned storage facilities;
- Abandoned manufacturing facilities;
- Transportation assets; and
- HME manufacturing waste.

2.2.3. FACTORS AFFECTING PRODUCTION, SAFETY, RELIABILITY AND PERFORMANCE OF HMEs

In military or commercial explosive design and manufacture, the choice of ingredients basically depends on the effectiveness that a user requires throughout the service life of a product. This effectiveness is very much governed by a combination and balance of **safety**, **reliability** (ability to function as intended) and **performance**. These three attributes are explained below. If safety and reliability cannot be guaranteed or the performance is suboptimal, then sensible trade-offs are applied. A variety of explosives are ruled out as useful for military or commercial explosive applications because the trade-offs are unacceptable, for instance due to a lack of stability of an explosive, or because it is considered unsafe due to the high sensitivity of an explosive to external impulses. Some of the explosives ruled-out by military and commercial users were / are encountered as HMEs.

> **NOTE. TATP is an example of an explosive excluded from industrial use because of its tendency for sublimation and its high friction sensitivity (compared to other (primary) explosives). A common synonym used for TATP by some (illegal) manufactures is Mother of Satan, referring to its sensitivity and (devastating) instability. The mixture of potassium chlorate and paraffin wax, known as 'cheddite' in the early 20th century, is an example of a military explosive overtaken by more powerful compositions in the development of artillery shells.**

Where military ordnance and explosives are accessible, their use is always preferred in the design and manufacture of IEDs because their safety, reliability and performance are guaranteed. There are no requirements for chemical processing, no requirements for special knowledge or the need for equipment required in the manufacturing of HMEs. However, the 21st century has witnessed improvements in stockpile security, humanitarian demining initiatives and the disruption of supply chains by the international community, which has led to the increased use of HMEs. There is such a variety of fuels and oxidisers to choose from, and given that many precursors are used for legitimate purposes, they may not be classed as explosive or incendiary, making international policing extremely difficult. But, when physically or chemically combined, processed or synthesised with other precursors, they can wreak havoc.

HME design, manufacture and use is often fraught with unsafe and sometimes complex chemical procedures. Many explosive products that are used as HMEs have been discounted in military or commercial applications because their performance is not underpinned by safety and reliability. Making effective HMEs is not, therefore, a simple or reliable choice. Some of the reasons for this:

- Strong acids and bases, already toxic and corrosive chemicals themselves, may be required to manufacture, to synthesise or to act as catalysts or reactants;
- Intermediates in a production process can be difficult to control without specific and reliable equipment, this can lead to violent reactions, to self-ignition or even to self-initiation;
- The presence of chemical impurities in manufacturing equipment can make the explosive product more sensitive;

- The availability of the precursor chemicals themselves: cheaper products may have lower purity (for instance leading to the requirement to process larger amounts or the need to add an additional processing step, as lower purity may influence reliability and performance of the product), or the fuel and oxidiser may not be present in the amounts necessary to create an optimum mixture; and

- The physical properties of the precursor chemicals themselves – for instance, particle size, purity, variation in crystal habit can each lead to highly unstable mixtures (at point of manufacture or over time) which can be inadvertently initiated by heat, friction, static electricity, shock or impact.

The consequences of assuming that an improvised explosive has the same physical characteristics as its standardised, industrially produced counterpart could therefore be fatal for mine action (MA) staff or first responders. For example, black powder is a dense mixture of potassium nitrate oxidiser (75% by weight), charcoal fuel (15%) and sulphur fuel (10%). These quantities are published in open-source material and commonly available. Deviations in the quantities of the starting materials, particle size, purity, mixing time, moisture or type of wood used to prepare the charcoal, may all influence the safety, reliability and performance of black powder. These deviations are hardly visible but, in the worst case, may pose additional risks such as an increased sensitivity to friction and heat. The aim of this example is to demonstrate how hard it can be to assess safety, reliability and performance of HMEs, simply based on a comparable commercial product. Apart from the explosive risk, serious health hazards must be taken into consideration when encountering HMEs and their precursor chemicals.

NOTE. The resources, capabilities and knowledge of an HME manufacturer influence the quality and physical characteristics of HME. Consequently, HME can differ greatly from its commercially produced counterpart.

Image 6. Main charges filled with HME of unknown quality and sensitivity posing explosive and non-explosive hazards (source: FSD ©)

The classification of explosive matter according to its application is illustrated in Table 1 in sub-section 2.1.2 above. This classification is used throughout this publication. Where feasible, the system used to classify HMEs in this publication is based on their oxidisers, as these are a significant variable affecting an HME's physical characteristics.

2.3. COMPARATIVE CONSIDERATIONS BETWEEN INDUSTRIALLY MANUFACTURED EXPLOSIVES AND HMEs

Both industrially manufactured explosives and HMEs are produced to be deployed as explosive substances.

For HMEs, two methods can be observed:

- Copying the methods of production for a commercial explosive; and
- Producing an improvised explosive from available fuel and an oxidiser.

The following three images of TNT demonstrate the possible appearance of industrially produced TNT compared to that of home-made TNT.

Image 7. Industrially produced TNT (source: Bundeswehr CBRN Defence Command ©)

Image 8. Industrially produced TNT (source: Bundeswehr CBRN Defence Command ©)

Image 9. Home-made TNT (source: Bundeswehr CBRN Defence Command ©)

2.3.1. INDUSTRIAL MANUFACTURING

Industrially manufactured explosives, regardless of their application in the commercial or military sectors, are produced by experienced chemists and engineers. The products, as well as their synthesis, are standardised. During manufacture the following features are consistent:

- Ratio of ingredients;
- Degree of mixing and purity and volume fraction of the raw materials;
- Density of the explosive produced;
- Particle size;
- Particle shape (or crystal habit); and
- Addition of additives, to stabilise or phlegmatise (desensitise) the explosives, for instance.

Automated production is carried out under strict industrial hygiene conditions and contamination with other substances (leading to high-risk effects of ageing, for instance) is highly unlikely. Such measures are taken for safety and economic reasons, and to maintain the quality and performance of the product during its lifespan.

2.3.2. IMPROVISED MANUFACTURING

The majority of HMEs are locally manufactured by groups or individuals who, in general, are poorly trained to carry out this task compared to the training standards used by industry. They possess the knowledge of 'how' (the manufacturing process itself) and 'why' (such as the necessity for the order of different manufacturing steps) from the internet or from organisational training, manuals and guides ('cookbooks') but do not necessarily have the awareness (the 'what') of potential dangers associated with the production process or final product. The basic knowledge of risk mitigation, of production measures and their application, is often limited compared to industrial standards, drawing attention to the fact that these compositions and mixtures are 'improvised' and therefore unpredictable. However, there are exceptions where highly trained individuals have produced sophisticated improvised explosives, adapting measures of risk mitigation. These exceptions should not be considered as a standard when interacting with HMEs.

The choice of a manufactured HME is mainly determined by the resources available within a supply chain, organisational knowledge and capability, and an improvised explosive's specific purpose (whether an explosive, incendiary or propellant composition / mixture is required).

Image 10. Explosive chemical precursors found in field conditions (source: GICHD ©)

Manufacturers may be forced to improvise to create the required precursors when (laboratory-grade) chemicals are not available. In addition to an already improvised recipe, lack of resources may force them to synthesise precursors or use substitutes containing a concentration of the required chemical substance or compound. For instance, if an oxidiser such as ammonium nitrate is not available then barium nitrate or potassium nitrate could be used. Besides additives, these explosive precursor substitutes may contain impurities that do not affect the intended commercial use of the chosen substitute but which could have dire consequences in an HME. This systematic approach of improvisation by manufacturers is applied when making an improvised explosive, as well as when harvesting a substance from an available mixture, such as harvesting ammonium nitrate from calcium ammonium nitrate fertilisers.

Image 11. A bag of potassium nitrate fertiliser. This fertiliser can be used to harvest potassium chlorate (source: Conflict Armament Research CAR ©)

Improvised explosives can be contaminated with a wide variety of chemical substances, which may act as sensitisers. These impurities, whether they be chemicals such as acids or low melting point solids, such as sulphur, can lead to instability. They can increase the sensitivity of HMEs to friction, burning or detonation, or create unintended side effects such as the production of heat or the formation of dangerous by-products. For instance, if potassium chlorate is contaminated with sulphur or ammonium nitrate, then the sensitivity of the mixture to friction and heat increases considerably. Such contamination can lead to spontaneous explosions of these mixtures during handling and transportation, even at room temperature.

WARNING. Friction creates heat within a composition or a mixture by introducing pressure between crystals and compressing trapped air within voids. These areas of localised heat within explosives can lead to unintended decomposition.[10]

NOTE. Performance and stability of HMEs can differ greatly from the results of a laboratory analysis. Limited resources and lack of knowledge on the part of the HME manufacturer will therefore exacerbate safety risks for MA staff when dealing with improvised explosives. When encountering HMEs, MA staff should always consider that the improvised explosive has not been produced to an industrial standard and should therefore be treated with particular caution.

Industrially manufactured explosives must fulfil certain minimum requirements on performance, sensitivity, stability, thermal behaviour, behaviour in storage, water resistance and consistency, prior to acceptance for use. These minimum requirements may differ in accordance with the norms of a customer (e.g. the military) or a state's regulations.

PERFORMANCE	The physical characterisation of an explosive corresponds to its intended use, for instance, low detonation velocity for mining explosives.
SENSITIVITY	An explosive must be safe to handle. It should be blasting cap (detonator) sensitive or sensitive to flame under the required conditions of its use. Military explosives are required to be as insensitive as possible because of the rigours of service use.
STABILITY AND BEHAVIOUR IN STORAGE	An explosive must remain chemically stable over a certain amount of time, as defined by its purpose and use. For military explosives, this stability span can be up to 10 years or more. Effects of ageing limiting the use of an explosive should not occur within this period. An explosive must not react adversely with the environment, so primary explosive compositions must not react with the metal casing of their blasting cap, for instance, and secondary explosives must not react with their munitions casing.
WATER RESISTANCE	When cartridged, industrial explosives should withstand the effect of two hours in stagnant water. Military explosives should be completely waterproof and withstand saltwater corrosion.
CONSISTENCY	Industrially used explosives should be formable, military explosives should be castable or pressable.
THERMAL BEHAVIOUR	Industrially used explosives are expected to be fully functional in the range of -25° / +60°, and military ones between -40° / +60°.

Table 2. List of requirements for industrially used and military explosives

10 A more detailed explanation can be found in sub-section 3.3.4. *Sensitivity and sensitiveness*.

WARNING. The behaviour of stored HMEs can be influenced by their reactivity. For example, using a copper or brass container with ammonium nitrate[11] or lead azide increases their sensitivity to detonation.

Safety considerations concerning a product and its service lifespan as described, or required for industrially produced explosives, are not a determining factor for HMEs. Improvised explosives are often produced out of acute necessity and are not usually required to remain functional or stable for extended periods of time. The safety considerations for HMEs are therefore limited by the producer's acceptance of risk, such as premature explosion.

HMEs usually suffer more from the effects of ageing in a shorter period than industrially produced explosives. The handling safety and sensitivity of some HMEs is often dependent on humidity, temperature and the degree of contamination present during manufacture. For example, some HMEs requiring the use of nitric acid or sulphuric acid in their production can deflagrate or detonate over time, if excess acid remains in the mixture.

Image 12. VS-500 exhibiting expansion of the HME due to moisture as an effect of ageing (source: FSD ©)

When handling, the safety of improvised explosives should be considered to be lower than that of industrially manufactured explosives. HMEs' sensitivity often exceeds that of industrially manufactured types. In addition to their explosive hazards, both types can pose a serious, sometimes lethal, threat to health due to their toxicity.

11 More information can be found in sub-section 3.2. *Explosive reactions*.

EXAMPLE: COMPARISON OF PRODUCTION PROCEDURES

Even when explosives seem identical, the available resources for manufacturing and the capabilities of the maker to extract and process the raw materials have a significant impact on the final product.

Ammonium nitrate–fuel oil (ANFO) is a widely available commercial explosive used primarily in mining and quarrying operations. Home-made ANFO is used as an improvised explosive in IEDs worldwide.

Commercially explosive ANFO is made from technical-grade ammonium nitrate (density: 0.7–0.9 g/cm^3; non-homogenous prills[12] with a 1 mm diameter) and an organic fuel such as kerosene or diesel. Up to a certain grade, the AN-fuel oil ratio is used to steer the detonation velocity and therefore the explosive performance. Sensitisers can be added to improve the initiation process. Phlegmatisers can also be used to downgrade the detonation velocity.

For HMEs, harvesting fertiliser-grade ammonium nitrate (density: 0.9–0.97 g/cm^3; homogeneous prills with a 2 mm diameter) from nitrogen fertilisers containing ammonium nitrate, is a common approach to sourcing this raw material. Fertiliser-grade ammonium nitrate has a relatively low porosity.[13] These nitrogen fertilisers contain further chemical compounds such as phosphorus, sulphur, potash, urea and cloaking agents to prevent caking.

Regardless of how an ammonium nitrate fertiliser is advertised, HME manufacturers will be able to harvest explosive-grade ammonium nitrate crystal from it when using the proper procedure. A fertiliser's ammonium nitrate content will steer the amount of ammonium nitrate crystals that can be extracted. It is generally limited to below a certain percentage to make HME manufacturing without further processing more difficult. Unlike technical-grade ammonium nitrate, (extracted) fertiliser-grade ammonium nitrate will contain impurities and contamination due to the original manufacturing process.

12 A prill is a pellet or solid globule of a substance formed by the congealing of a liquid during an industrial process.
13 Porosity represents the ratio of void volume to total volume of a substance or mixture of substances.

	TECHNICAL GRADE (TGAN)	HIGH DENSITY / FERTILISER GRADE (HDAN/FGAN)
Description	Prills Coarse and porous Matt white Diameter ~1 mm non-homogenous 	Prills Slick Glossy white Diameter ~2 mm homogenous 
Density	0.7 – 0.9 g/cm^3	0.9 – 0.97 g/cm^3
Remarks	POSSIBLY prills are ground when ready for use HIGHLY LIKELY mixed with a fuel when ready for use ➔ colour changes according to the fuel used AN + aluminium 	HIGHLY LIKELY prills are ground when ready for use HIGHLY LIKELY mixed with a fuel when ready for use ➔ colour changes according to the fuel used AN + fuel oil 

Table 3. Comparison of different grades of ammonium nitrate (source: UNMAS ©)

3. PHYSICAL AND CHEMICAL BASICS REGARDING CHARACTERISTICS OF EXPLOSIVES

This section provides an overview and explanation of key technical terms and definitions used to describe energetic materials and explosive substances. The objective is to create a common understanding of HMEs and industrially manufactured explosives among mine action (MA) staff, first responders, and aid workers, in order to support risk management and operational planning. This section also addresses physical characteristics in relation to safety and sensitivity. Hereafter, the detail and level of complexity of the terminology used is adapted to fulfil the requirements of this guide and may be simpler than that used in scientific publications.

NOTE. The term HME is equated with (or used as a synonym for) primary or secondary explosive. This approach is incorrect since improvised explosive matter is also used in pyrotechnic or propellant applications.

3.1. CLASSIFICATION OF EXPLOSIVES

This sub-section provides a commonly agreed classification of explosives. This knowledge may be of use to identify explosives and their use, to differentiate between hazards or to improve reporting.

Whilst there are several ways to classify explosive substances, a common method is to categorise them by their performance and use (see sub-section 2.1.2, Table 1).

Explosives are categorised as:

- High explosives, that can be subdivided into:
  - Primary explosives;
  - Secondary explosives;
  - Tertiary explosives; and
  - Insensitive explosives.[14]
- Low explosives or propellants; and
- Pyrotechnics.

14 Insensitive explosives are particularly resistant to external stimuli such as mechanical shock or heat. The chance of them detonating unintentionally is very low.

3.1.1. HIGH EXPLOSIVES

In the design of military and industrial explosives, the main issues considered are:

- Whether burning or detonation is required for the explosives to do the necessary work; and
- How easily they are initiated to do this work.

The term '**high explosive**' is used if an explosive detonates instantaneously. The reaction front moves through an explosive with a velocity equal to or higher than the explosive's speed of sound. Large amounts of energy in the form of heat and gas are liberated in microseconds because there is a requirement to 'do work' on the surroundings such as shattering, damaging, bursting, penetrating, lifting / heaving, creating shock waves / air blast / underwater pulses / to project fragmentation over a wide area. The reaction velocity is of the magnitude km/s.

3.1.1.1. PRIMARY EXPLOSIVES

Explosives which are readily initiated by a small stimulus are known as primary explosives (or initiating explosives). They can deflagrate or detonate whether confined or unconfined and the transition from combustion to detonation is extremely rapid. Primary explosives are most often used to initiate reactions whereby their chemistry produces a shock wave (or burn rate) of sufficient magnitude to deflagrate / detonate a less sensitive explosive. Ignition for the majority of primary explosives is via inter-crystalline friction, which leads to the generation of hotspots (spots in an explosive where adiabatic compression of small, occluded gas bubbles generates up to 400°C-500°C heat; these spots exist for 10^{-5} seconds) necessary to commence the explosion process.[15] In general, primary explosives are much more sensitive to friction, heat, sparks and shock than secondary explosives. This characteristic makes them essential to the function of a detonator or blasting cap. Examples of primary explosives are lead styphnate, mercury fulminate, lead azide, dinitrobenzenediazoxide (DDNP), tetrazene, HMTD and TATP, all of which have been used as detonators in HME compositions. However, some primary HME compositions such as TATP and HMTD have been used as both primary and secondary explosives, given their explosive performance.

NOTE. For explosives, the term 'ignition' refers to the commencement of combustion, the term 'initiation' refers to the commencement of a deflagration or detonation reaction.

Image 13. Improvised electric blasting caps containing a primary explosive (source: FSD ©)

15 John E. Field, "Hot Spot Ignition Mechanisms for Explosives," *Acc. Chem. Res.* Issue 1 (1 November 1992): 489–496.

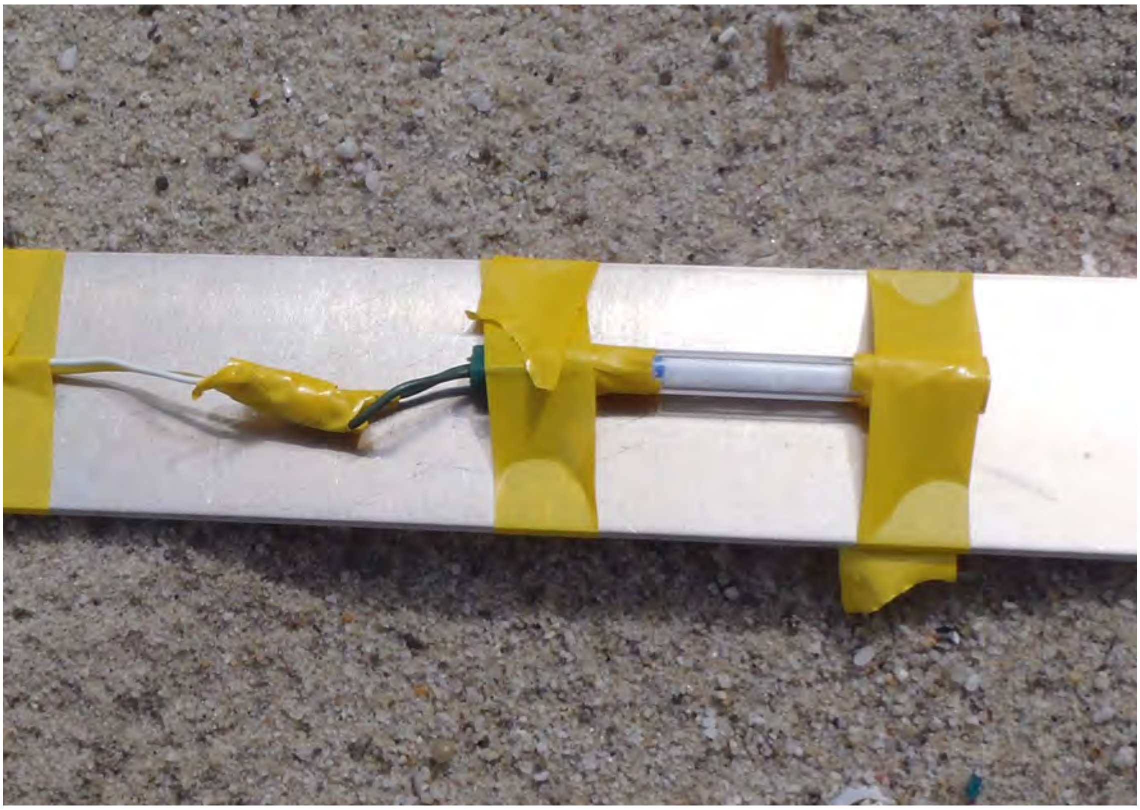


Image 14. An improvised detonator (filler: TATP) on an aluminium witness plate (source: Brimstone Consultancy Limited BCL ©)

Image 15. The effects of an improvised detonator (filler: TATP) on an aluminium witness plate (source: BCL ©)

3.1.1.2. SECONDARY AND TERTIARY EXPLOSIVES

Explosives which require a large stimulus to detonate (that being the impact of a shock wave to bring about detonation) are known as secondary explosives. The requirement of a large stimulus means that secondary explosives cannot be reliably detonated on their own without an external explosive force. Generally, a primary explosive is used to provide the shock to cause detonation. Initiation of secondary explosives is primarily through the compression of small gas spaces between crystals. Secondary explosives are relatively insensitive to heat, kinetic shock, electrostatic discharge and friction, making them safe enough in routine handling, moulding and transport. Some secondary explosives, such as pentaerythritol tetranitrate (PETN), are slightly more sensitive and have a very high detonation velocity – larger than 8400 m/s. Such explosives can be used as booster charges for tertiary explosives. Examples of secondary explosives are octogen (HMX), RDX, TNT and tetryl. Important characteristics defining the performance of secondary explosives are detonation velocity and strength (explosive power). Their power (the ability to do work on the surroundings) is determined by the heat of the explosion itself (the amount of heat available to expand the gaseous products) and the amount of gas produced per unit of volume of the explosive.

NOTE. Whilst secondary explosives used in military or commercial applications are less sensitive than their primary counterparts and are, in general, safe to handle, this does not mean that HMEs with the (assumed) properties of a secondary explosive are automatically safe to handle or less affected by external influences. The presence of impurities, effects of ageing and the mixing of primary and secondary HME compositions within the same main explosive charge makes their performance unpredictable.

Image 16. PETN, a secondary explosive (source: Bundeswehr CBRN Defence Command ©)

Depending on their chemical characteristics or processing method, some secondary explosives are very insensitive and cannot be initiated by a primary explosive using a detonator alone. In this case, a booster made of an explosive that can be initiated by a primary explosive is used to provide enough shock to initiate this secondary explosive. The combination of a detonator with a primary explosive, a booster and a main charge, both with a secondary explosive, is called the detonating or explosive train.

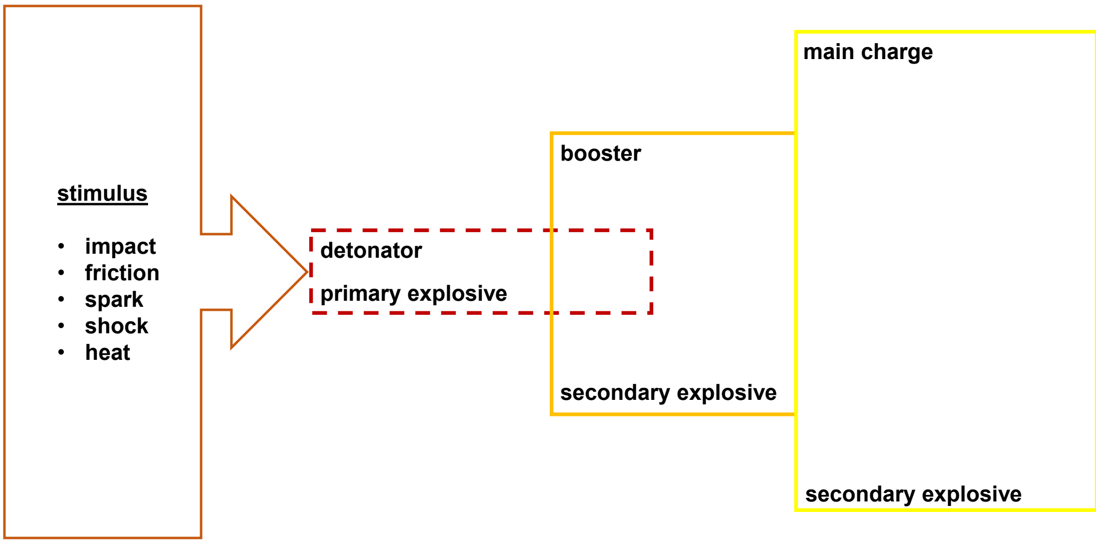


Figure 1. Basic schema of an explosive train. A primary explosive in a detonator is initiated by an external stimulus. As a next step, its detonation initiates a secondary explosive in a booster. The shock wave created by the booster's detonation stimulates a secondary explosive of a main charge, and the main charge detonates. (source: GICHD ©)

Explosives requiring a booster are sometimes referred to as tertiary explosives. Ammonium nitrate mixtures, HMX, nitrotriazolone, guanidine nitrate, nitroguanidine and some hydrogen peroxide-based explosives are commonly considered as tertiary explosives.

Image 17. Boosters for HME main charges made from improvised detonating cord (source: FSD ©)

WARNING. For HMEs that require a primary explosive to be initiated, it should not be assumed that they have a comparable level of (in)sensitivity to military or commercial secondary or tertiary explosives.

NOTE. An explosive train may incorporate a mix of commercial, military and home-made explosives, depending upon supply chain availability and the sensitivity to detonation. For example, ammonium nitrate-based HMEs are insensitive to shock alone and require a booster of more powerful commercial / military explosive (such as tetryl or PETN) to achieve detonation. An illustration of this was in an improvised sea mine used in Yemen, in which the 20.3 kg ammonium nitrate–aluminium main charge was initiated by a 0.7 kg RDX booster and commercial detonator.[16] A critical diameter, which exceeds those of military explosives, is also required to propagate detonation, which is one of the primary reasons why ammonium nitrate-based HMEs are often greater than 20 kg in mass; a useful observation for MA specialists since it separates large devices from those which are ergonomically man-portable (< 20 kg).

3.1.2. LOW EXPLOSIVES OR PROPELLANTS

The term '**low explosive**' is used for explosives (propellants) that decompose by deflagration when unconfined. The reaction front moves through the explosive with a velocity slower than the explosive's speed of sound. Propellants are designed to burn quite rapidly (in the order of milliseconds) under confinement to maximise the volume of hot gases produced. This is normally required to provide thrust, thereby projecting a high explosive or other such material to a specific point where its work is required. The reaction velocity is of the magnitude m/s. Ideally, a propellant's combustion is rapid and predictable. This chemical reaction will take place with the following characteristics:

- Without additional atmospheric oxygen;
- Exothermically; and
- Involving the creation of large volumes of hot gases as the propelling medium.

Propellants are produced in powder, pellet, solid piece or liquid forms. Examples of propellants are nitroguanidine and nitroglycerine compositions for tube fired ammunition or hydrazine, a liquid propellant used in missiles.

WARNING. In general, propellants are designed to rapidly burn or combust. Contamination with other chemical agents, confinement or sudden large-scale mixing of the fuel and the oxidiser of a hypergolic liquid propellant (as used in some rocket motors) can lead to a propellant's explosive decomposition.

16 Letter dated 26 January 2018 from the Panel of Experts on Yemen mandated by Security Council resolution 2342 (2017) addressed to the President of the Security Council. A. Himmiche, F.R. Carvajal, D.R. Gunaratne, G. Johnsen, & A. Wilkinson, p. 170, Table 41.1.

Image 18. Example of the burning behaviour of solid propellants when unconfined (source: GICHD ©)

Image 19. Propellant made of nitrocellulose (source: Bundeswehr CBRN Defence Command ©)

Image 20. Another example of propellant made of nitrocellulose. Drilling holes increases the surface of the prill and, therefore, the burning action. (source: Bundeswehr CBRN Defence Command ©)

3.1.3. PYROTECHNICS

Pyrotechnics are specific mixtures of fuels and oxidisers designed to burn, not deflagrate or detonate. Their reaction velocity is much lower than that of propellant explosives and in the region of mm/s. The heat generated is used to produce a combination of light and colour (flares, fireworks), smoke (obscurants), heat (thermite and thermate), noise (flash bangs and battlefield simulators), working gases (such as in car airbags) and delay compositions (hand grenade fuses, time fuses, safety fuses). Pyrotechnics react exothermically with chemical reactions that are (mostly) non-explosive, self-sustaining and self-contained.

Pyrotechnics are energetic compounds and / or mixtures with different sensitivities by design.

- Pyrotechnics may show detonation-like effects under certain conditions, for instance, if confined.
- Most pyrotechnics are mixtures of a fuel and an oxidiser. Oxidisers are the relevant substance for the strength achievable by a mixed HME.
- Groups of pyrotechnics suffer from ageing effects and have a very limited storage life.

3.2. EXPLOSIVE REACTIONS

This sub-section provides a short summary of explosive reactions. This knowledge should be of use to reinforce an understanding of energetic reactions and to support risk and hazard assessments.

The main energetic reactions to consider for explosives are:

- Combustion;
- Deflagration; and
- Detonation.

Deflagration and detonation are differentiated from usual combustion by their power output, propagation velocity (some mm/s for combustion, several hundred m/s for deflagration and several thousand m/s for detonation) and the oxygen source that they use. Each of these reactions is determined by the chemical characteristics of the energetic material, including the required ignition or initiation energy, the substance's energy density, as well as confinement and the effects of ageing and other deteriorating processes.

Combusting or deflagrating substances decompose through a thermal mechanism that takes place on the surface of the material, whilst detonating substances decompose extremely quickly causing a shock wave. This is summarised in the following figure and tables.

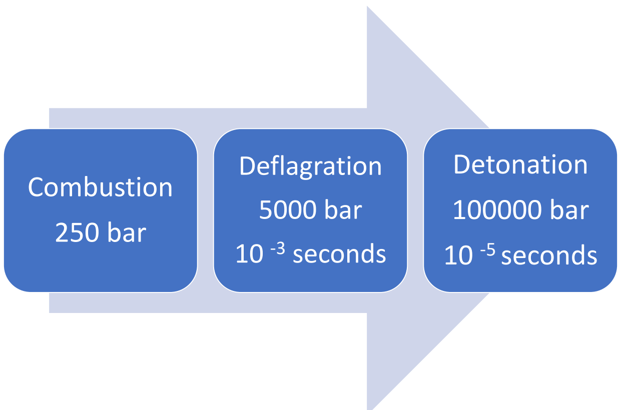


Figure 2. Energetic reactions (source: GICHD ©)

REACTION TYPE	REACTION RATE	POWER OUTPUT AND PRESSURE	OXYGEN SOURCE	EXAMPLE
Combustion	Slow (mm/s)	100 W/cm^3 250 bar	Atmosphere	Burning wood
Deflagration	Subsonic (+100 m/s)	100 W/cm^3 5000 bar	Within compound	Confined black powder
Detonation	Supersonic	1000 W/cm^3 100000 bar	Within compound	TNT

Table 4. Overview of the characteristics of combustion, deflagration and detonation

3.2.1. COMBUSTION

Combustion is a chemical reaction that takes place between an ignited substance and external (e.g. atmospheric) oxygen. The reaction takes place on the surface of the material. Combustion happens within seconds; it is a slow chemical reaction.

Combustion generates heat and smoke and can create a pressure of up to 250 bar.

Energetic substances which decompose via combustion are used in applications such as rocket motors and safety fuses.

3.2.2. DEFLAGRATION

Deflagration takes place when an unconfined substance ignites suddenly when exposed to flame, spark, shock, friction or high temperature.

The substances react faster and are more violent than combustible substances. However, the reaction still takes place on or just above the surface of the material, which recedes layer by layer.

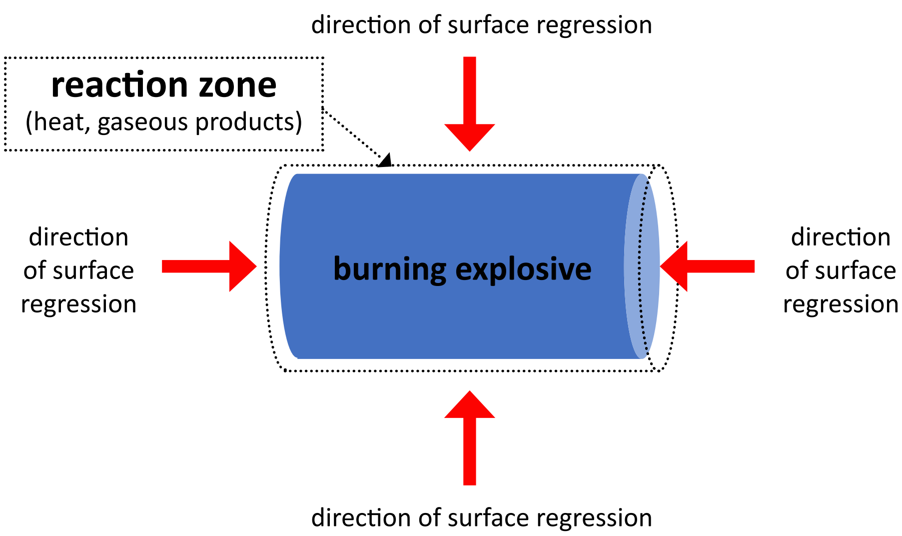


Figure 3. Schema of a burning / deflagrating explosive (source: BCL ©)

Deflagration takes place within milliseconds (10^{-3} sec.); it is considered a fast-chemical reaction, but its speed is still subsonic.

Deflagration generates heat, smoke and pressure of up to 5000 bar.

The effect of substances which decompose via deflagration is used, for instance, as the propellant for small arms ammunition in firearms. The term deflagration is often used to describe a violent burning of an explosive which has failed to detonate.

3.2.3. DETONATION

Detonation takes place when an initiated substance decomposes through a shock wave. It is defined as an extremely fast explosive decomposition, in which an exothermic reaction wave maintains a shock front in the explosive material. The velocity of this shock front can be in the region of 1800–10000 m/s, depending on the explosive. Unlike a deflagration, the rate at which the material decomposes is not governed by the rate of heat transfer at the surface of the material but by the velocity at which the explosive material will propagate the shock wave.

Detonation differs from other forms of combustion in that all the important energy transfer is by mass flow in strong compression waves, with negligible contributions from other processes (such as heat conduction) which are so important in flames. The leading part of a detonation front is a strong shock wave propagating into the explosive. This shock heats the material by compressing it, thus triggering a chemical reaction and a balance is attained such that the chemical reaction supports the shock wave propagation. In this process, material is consumed much faster than in a flame, making detonation easily distinguishable from other combustion processes.

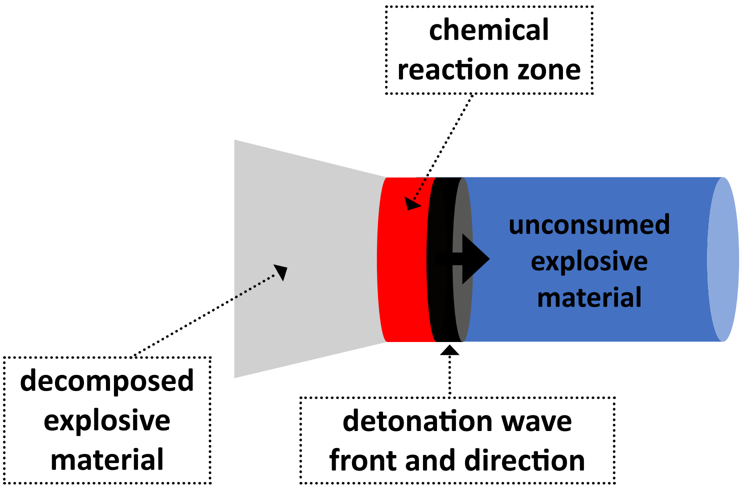


Figure 4. Schema of a detonation event in an explosive material (source: BCL ©)

> ⚠ NOTE. For a detonation to take place, a shock wave must move through the explosive with a velocity that is equal to or exceeds, the velocity of sound in the explosive material.

Detonation takes place within microseconds (10^{-5} sec.); it is considered a highly rapid chemical reaction. Its speed is supersonic, achieving between 1500 m/s (explosives for underground mining activities) to 10050 m/s (CL-20, currently the most powerful known chemical explosive).

A detonation creates a shock wave and pressure exceeding 100000 bar at its origin.

Substances which decompose via detonation are used as high explosives. They are also referred to as detonative explosives.

3.2.4. TRANSITION BETWEEN COMBUSTION – DEFLAGRATION – DETONATION

The transition to detonation can take place via two specific mechanisms in HMEs:

- Burning to detonation; and
- Shock to detonation.

Burning to detonation occurs when the pressure at the burning surface of an explosive accelerates the flame front beyond the velocity of sound of the explosive material under its current conditions. This would be akin to an aircraft exceeding the speed of sound in the air, the point at which the sonic boom is heard. We progress from a deflagration to a detonation, suggesting that there will be a delay to the onset. The delay to the onset of detonation depends on the nature of the explosive, charge density and conditions of confinement. For example, an unconfined explosive may simply burn or deflagrate with no detonation. If, however, the explosive undergoes combustion under confinement then the combustion gases cannot escape. This leads to a build-up of pressure at the surface of the explosive, which increases the burning rate further. If the build-up in pressure at the surface of the explosive accelerates the burning rate to the velocity of sound in the explosive material, then detonation will occur. This is the reason why secondary or tertiary explosives that are confined and are exposed to a fire may detonate.

Initiation by shock wave is used to detonate secondary explosives with primary explosives. In a shock to detonation there is no requirement to precede with a flame front through a burning process. Instead, a high velocity shock wave generated by the ignition source is responsible for the detonation formation process. As the shock wave travels into the explosive, particle compression and adiabatic heating occurs at the shock front. Adiabatic heating and compression liberate energy as the explosive decomposes, thereby accelerating the shock wave further. At some point the velocity of the shock wave may exceed the velocity of sound in the explosive material and detonation will occur. The shock wave will be required to travel a distance along the explosive (millimetres or centimetres even) before it becomes self-propagating but, unlike a burn to detonation, the delay is in microseconds.

3.3. PHYSICAL CHARACTERISTICS OF EXPLOSIVES

The information provided in this sub-section enables an assessment of the stability and sensitivity of an explosive, allowing the potential hazards and risks to be evaluated. Knowledge of the physical characteristics are essential when assessing explosives.

NOTE. Understanding an explosive's sensitivity to stimuli such as impact or friction is essential for safe handling. Sensitivity helps to determine appropriate render safe procedures.[17]

NOTE. Knowledge of an explosive's strength determines the necessary and appropriate protection measures that must be put in place. To achieve comparability, an explosive's strength can be given as a TNT equivalent. The TNT equivalent is not an international system of unites (SI) conform unit of measurement. For instance, black powder has a TNT equivalence of 0.2–0.4, RDX has a TNT equivalence of 1.5.

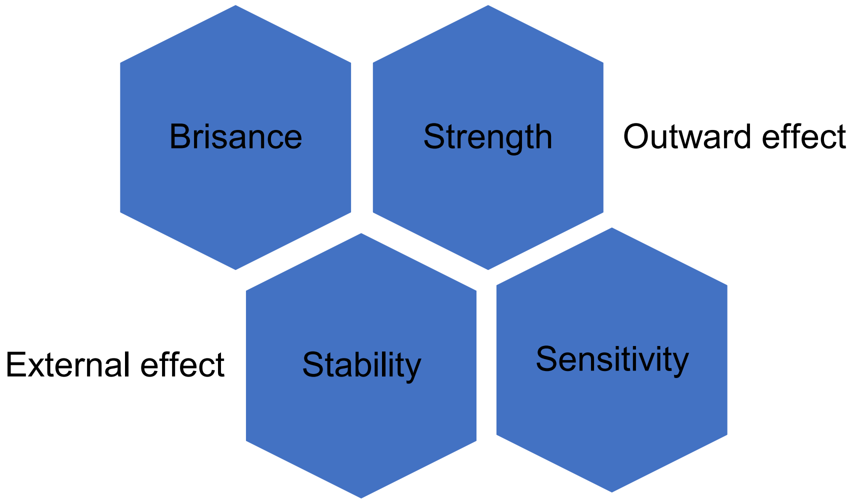


Figure 5. Properties of an explosive (source: GICHD ©)

3.3.1. BRISANCE

Brisance indicates an explosive's shattering ability. Its two main parameters, alongside gas yield and heat of explosion, are detonation velocity and loading density. Loading density is the ratio between explosive weight and the amount of space in which an explosive is detonated (compactness).

High brisance explosives are used in military high explosive applications. Low brisance explosives are used in commercial applications such as quarrying, to separate and lift / heave rock from the surrounding area rather than shatter it.

[17] IMAS 04.10 Render Safe Procedure (RSP): the application of special EOD methods and tools to provide for the interruption of functions or separation of essential components to prevent an unacceptable detonation.

3.3.2. STABILITY

Stability includes both physical and chemical stability. Chemical stability is paramount in evaluating the expected service life of an explosive.

Chemical stability or thermodynamic stability defines the resistance or sensitivity to the decomposition of the chemical structure. A compound that can exist unaltered and unaffected by time is said to be stable.

Physical stability is the ability to remain physically unchanged over time under specified, foreseeable conditions during manufacture, storage, handling and use. Physical stability is of great importance for solid propellants where cracks in the structure increase the surface area, leading to uncontrolled and unpredictable burning. In high explosives such as TNT in artillery shells, cracks in the filling can lead to inadvertent detonation due to the huge setback forces generated during firing.

NOTE. Reactivity is the responsiveness of a substance in terms of stability. A substance is referred to as being less stable when its reactivity is high. Some explosives (for instance picric acid) generate impact-sensitive metal salts within their metal containers when reacting with the metal casing. Copper and brass casings are particularly problematic with some explosive compositions.

3.3.3. STRENGTH

The strength is determined by the gas volume produced and the energy (heat) created by the explosion as well as the detonation velocity. Gas volume determines how much work can be done by an explosive. The heat of the explosion determines the work capacity of an explosive. In general, secondary explosives generate far more heat than primary explosives. A trade-off between gas volume and heat of explosion is used to achieve the desired performance of an explosive. For example, commercially used ammonium nitrate-fuel oil mixtures produce high gas volume but low heat and are therefore useful for blasting work in quarries or mines when rocks must not be shattered. Military explosives like PETN with a high gas volume and a high gas yield are used when an object must be shattered, for instance when destroying concrete bridges.

3.3.4. SENSITIVITY AND SENSITIVENESS

Sensitivity classifies how an explosive can be initiated by external stimuli. Stimuli of importance with regard to explosives are electrostatic discharge (spark), friction, heat and flame, shock and impact. Sensitivity is therefore used to indicate the reliability of the function of an explosive, which is important for handling safety and to determine limitations in the application of an explosive.

Sensitiveness should be distinguished from sensitivity since sensitiveness refers to the accidental initiation of an explosive and the probability of initiation from unwanted stimuli. Since HMEs are not standardised, an understanding of their sensitiveness is hugely important for explosive safety.

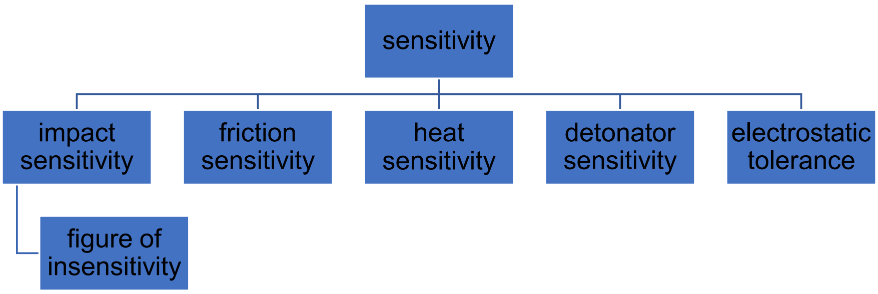


Figure 6. Overview of relevant sensitivities used to describe an explosive's behaviour (source: GICHD ©)

IMPACT SENSITIVITY

Impact sensitivity indicates sensitivity to mechanical impact. The physical unit used is Newton[18] by metre [N m] or Joule [J]. Impact sensitivity is determined under laboratory conditions. A weight is dropped on an explosive sample until the activation energy induced by (increasing) fall height is sufficient to cause the sample to decompose or explode.

The larger the numeric value, the higher the required impact introduced by the initiation energy. TNT has an impact sensitivity of approximately 15 J.[19] In theory, at sea level, a weight of 1.52 kg dropped from a 1-metre height onto a defined TNT sample would cause a reaction. For tetrazene, a primary explosive, the value is within a range of 100–200 g dropped from a 1-metre height which equals 1–2 J. Potassium chlorate–paraffin HME has an impact sensitivity of 2.6 J.[20]

Military explosives are required to be insensitive to bullet impact, a very demanding requirement designed to increase safety.

FRICTION SENSITIVITY

Friction sensitivity indicates sensitivity to mechanically induced friction. Air and impurities (such as grit) are present in any solid or liquid explosive mixture. When a stimulus is applied to a solid HME, such as that experienced during grinding (compression and friction), then pockets of air between particles are compressed. This compression leads to adiabatic heating of 400°C–500°C and the formation of 'hotspots', which may only last for a fraction of a second. Hotspots are volatile reactions at the microscopic crystalline level, their size is 10^{-3} to 10^{-5} mm. These hotspots can raise the temperature of an HME above its ignition temperature, resulting in deflagration or detonation if the energy generated by the hotspots is greater than the energy lost to the surroundings in that period. The same can be said for the presence of impurities. If these impurities are small and sharp / piercing, then only the smallest amount of friction or impact energy is required to produce a hotspot (where localised energy is generated at the interface between impurity and the explosive particle). Some HME compositions (such as TATP or potassium chlorate–sulphur) can thus be extremely sensitive and ignited by the lightest of blows.

18 Newton is the standardised physical unit of measurement for force.
19 1 Newton equals 102 grammes weight at sea level.
20 Determined under laboratory conditions, there will be deviations.

NOTE. Friction can be introduced during the transport of an improvised explosive. The goal must be to exclude or at least minimise external influences on the HME.

The physical unit of friction sensitivity is a Newton [N]. Friction sensitivity is determined under laboratory conditions by placing weights onto explosive samples. The weight used when the sample starts to deflagrate, crack or explode, expresses the level of friction sensitivity. The larger the numeric value (the weight), the higher the resistance of the explosive to friction-induced initiation.

For example, TNT has a friction sensitivity of approximately 353 N. For tetrazene, a primary explosive, the figure is within the range of 5–8 N.

WEIGHT kg	FORCE N	KINETIC ENERGY	
		J/N m	J/N m
	at sea level	weight dropped from 1-metre height	weight dropped from 2-metre height
0.1	0.981	0.981	1.962
0.2	1.962	1.962	3.924
0.3	2.943	2.943	5.886
0.4	3.924	3.924	7.848
0.5	4.905	4.905	9.81
0.6	5.886	5.886	11.772
0.7	6.867	6.867	13.734
0.8	7.848	7.848	15.696
0.9	8.829	8.829	17.658
1	9.81	9.81	19.62
1.5	14.715	14.715	29.43
2	19.62	19.62	39.24
3	29.43	29.43	58.86
4	39.24	39.24	78.48
5	49.05	49.05	98.1
10	98.1	98.1	196.2
20	196.2	196.2	392.4
30	294.3	294.3	588.6
100	981	981	1962

Table 5. Overview of resulting force and energy created by falling weights

HEAT SENSITIVITY

Heat sensitivity measures sensitivity to thermal-induced energy before decomposition or detonation occurs. There are different measurement methods, where an explosive is exposed to heat by flames, sparks, red-hot objects or the initiating flame from a black powder safety fuse.

Apart from the induced thermal energy, the decomposition process is affected by the degree of confinement. The greater the degree of confinement, the faster the decomposition process.

The term 'deflagration point' is used to indicate the temperature at which an explosive begins to deflagrate.

EXAMPLE: FACTORS INFLUENCING HEAT SENSITIVITY AND UNINTENDED INITIATION

Because of the characteristics of hotspots regarding size and lifespan, more energy / heat is required to initiate an explosive via hotspots than from a permanent exposure to flame or red-hot steel. For instance, PETN, a secondary explosive, has an ignition temperature via hotspots between 400°C and 430°C, while the ignition temperature by a permanent heat source (heat sensitivity) is greater than 205°C.

Additives such as tinder or fuel can lower and promote an HME's heat sensitivity. For instance, potassium chlorate compositions are prone to accidental initiation. The first reason is the low melting point (356°C) and decomposition temperature (< 400°C) of potassium chlorate itself. The second is the ignition temperature of the fuel used – the lower the ignition temperature of the fuel, the more sensitive the composition. The addition of sulphur (melting point of 119°C) lowers the ignition temperature of a potassium chlorate–sulphur composition to 220°C. Organic fuels tend to trigger ignition at (or close to) their thermal decomposition temperature. Lactose and diesel provoke ignition temperatures of 195°C and 230°C respectively. The third reason is the presence of impurities that find their way into the composition during manufacture, whether they be substances such as acids, or low melting point solids such as sulphur. Such impurities can lower the melting point further and lead to instability.

CAP (DETONATOR) SENSITIVITY

Cap sensitivity measures the ability of being detonated by a single blasting cap or detonator. There are different measurement methods and tests used.

Cap sensitivity not only depends on an explosive's mixture or composition but can be influenced by its density as well.

ELECTROSTATIC TOLERANCE

Electrostatic tolerance measures sensitivity to initiation by electrical emissions. These can result from an electrostatic discharge, an electronic contact closure or an electric arc.

FIGURE OF INSENSITIVITY (FoI)

FoI is an international standardised approach to express the resistance of an explosive to impact-induced ignition. The lower the value of an explosive's FoI, the more sensitive the explosive. The secondary explosive RDX is used as the reference standard explosive for determination of the FoI. The FoI of RDX is defined as 80.

The FoI is used to classify explosives: **very sensitive** (FoI less than or equal to 50), **sensitive** (FoI greater than 50 and less than 100) and **comparatively insensitive** (FoI greater than 100).

FIGURES OF INSENSITIVITY	
very sensitive	FoI < = 50
sensitive	50 > FoI < 100
comparatively insensitive	FoI > 100

Table 6. Overview of figures of insensitivity

For instance, TNT has an FoI of 152, tetrazene has an FoI of 13. An improvised mixture such as potassium chlorate–sugar can have an FoI anywhere between 30 and 67, depending upon the type of sugar and percentage mix. As such, a potassium chlorate HME can present sensitive or very sensitive characteristics.

Image 20. RDX (source: Bundeswehr CBRN Defence Command ©)

3.3.5. OXYGEN BALANCE

The oxygen balance indicates the amount of molecularly bound oxygen that remains after complete decomposition or, alternatively, the amount of oxygen that is missing to ensure complete decomposition. A negative oxygen balance leads to the formation of toxic gases such as carbon monoxide or sulphur monoxide. If the balance is positive, no toxic gases are formed.

NOTE. The oxygen balance refers to a pure explosive. Regardless of the influence of a well-adjusted oxygen balance on the gases produced, the presence of impurities, especially in HMEs, can lead to the formation of hazardous and toxic gases.

3.3.6. CONFINEMENT

Confinement is known to have a significant influence on the reaction of some explosives to an external heat-related stimulus. Confinement does not allow the gaseous products of combustion to escape, thereby increasing the pressure at the surface of the explosive. This leads to faster burning rates until a critical point is reached whereby deflagration or detonation occurs. Some explosive matter has the tendency to combust when not confined.

Under appropriate conditions (and depending on the heat sensitivity of an explosive), confinement can force secondary explosives exposed to heat to deflagrate or explode, due to increasing gas pressure within the confinement (e.g. a shell casing). For example, when exposed to heat, this effect can cause confined TNT to deflagrate or explode while unconfined TNT will likely combust without an explosive effect. This effect of confinement and heat on explosives is known as hot cook-off.

EXAMPLE: IMPACT OF CONFINEMENT

ILLEGAL APPLICATION:

Black powder has been found in filled inert training hand grenades. The confinement of the hand grenade’s body is sufficient to achieve a sudden increase in pressure generated by the combustion gases trapped inside the cast steel body. When the pressure exceeds a critical level, the cast steel body will fracture and produce a lethal fragmentation pattern. The same can be said for improvised pipe bombs where black powder is initiated within the confines of a sealed steel tube.

Confinement is used for many types of improvised explosive device to improve performance.

ACCIDENT:

Self-initiation is often observed when confined ammunition (e.g. artillery shells) is exposed to high levels of heat. In the case of ordnance which is caught in a fire or exposed to extreme heat, internal pressure increases and can result in deflagration or detonation.

This effect poses a significant threat to first responders as no reaction time can be specified between the start of the fire and the start of decomposition.

WARNING. These effects of confinement reduce the usable time for firefighting.

DISPOSAL PROCEDURES:

Cutting ordnance, such as artillery shells or aerial bombs, with explosive cutting charges is a common low order procedure.[21] The cutting effect of the charge causes a gap in the ammunition casing. Usually, the remaining energy of the cutting charge causes the explosive filling to deflagrate or to combust. When combustion occurs, a transition to deflagration or detonation can take place when the gas yield in a cut casing is higher than the amount of gas that can escape via the cut gap.

21 Explosive ordnance disposal technique applied to achieve safety of an item of ordnance by causing no explosive effect or by causing a significantly lower explosive effect than the effect which the ammunition was designed for.

3.3.7. CONSIDERATIONS REGARDING PHYSICAL CHARACTERISTICS OF HMEs

Physical characteristics are equally as important to HMEs as they are for military and commercial explosives. However, the lack of knowledge regarding the stability and sensitivity of HMEs used in improvised explosive devices poses a significant threat to MA organisations.

As HMEs are produced with whatever raw materials and equipment are available to the maker, their sensitivity and stability are not constant, but influenced by a variety of factors. Reliance focusing on laboratory figures, as is practiced with industrially produced explosives, is not therefore recommended. HMEs are likely to underperform in terms of explosive strength quoted in laboratory figures (since density of loading is generally difficult to replicate) but will likely deflagrate or detonate more readily given the conditions of manufacture.

The ability and capability (also using technical support) to recognise the kind of HME in question, knowledge of its precursors and an understanding of which additives or impurities it could contain, enables MA organisations to conduct a risk assessment based on the expected physical properties and characteristics of a particular type of HME. This provides the opportunity for assessing possible **safe** and **appropriate** courses of action for its render safe.

4. CHEMICAL PRECURSORS

This section identifies chemical precursors for HMEs and their properties, including information on explosive and non-explosive hazards.

NOTE. As most of the chemicals mentioned in this section have legal applications, their presence does not automatically indicate their use in HME production. It is the presence of several chemicals that would lead to this assumption. For example, ammonium nitrate on its own may be of legitimate use, but the presence of fuel oil or aluminium powder in the same facility may suggest possible HME manufacture. The presence of both hydrogen peroxide and acetone would also raise questions since these are key precursors for the manufacture of organic peroxide explosives.

NOTE. Information on the reactivity of chemicals presented here is not exhaustive. This section focuses on the types of chemicals frequently encountered in an HME environment; detailed information is accessible via a chemical's safety data sheets.

HINT. Comprehensive and updated information on chemicals can be found in chemical substance databases, using chemical safety data sheets (SDS) or laboratory chemical safety summary datasheets (LCSS). A large variety of sources can be found using the internet. Two of the online sources consulted to support this chapter are listed below.[22] Both sources are considered to be fully comprehensive and offer a good level of detail. They are open source and are thus available at no cost.

SDS source	Databases on hazardous substances (GESTIS)
LCSS datasheet source	PubChem National Library of Medicine

Image 21 shows TNT contamination of soil by a shell that was shattered by a low order disposal procedure. By consulting a safety data sheet for TNT (example: TNT SDS), knowledge about specific hazards posed by this explosive (e.g. physical properties, toxicological data, toxic effects, first aid measures in case of inhalation or absorption, or procedures for safe handling) can be obtained.

22 Section 16 *Further references* lists additional sources.

Image 21. TNT contamination of soil (source: GICHD ©)

The precursor chemicals presented here are mainly encountered in one of two types of condition: as a pure laboratory-grade chemical or as one ingredient of an industrially processed product, such as ammonium nitrate in fertilisers or aluminium powder in paints. This overview focuses on the use of these chemicals for HME and their explosive and non-explosive hazards, without discussing their origin. Regarding the HMEs and improvised compositions presented below, neither their effectiveness nor the value of their applications are evaluated. The intention here is to provide information about their characteristics and their hazards.

NOTE. Unless otherwise stated, the information provided refers to the pure chemical condition.

WARNING. Substances that produce flammable vapours that may deflagrate or detonate when exposed to an increase in pressure, should not be confined to containers.

WARNING. Absorption, inhalation or ingestion of vapours, liquids or solid components of most of the substances listed may lead to poisoning or may be carcinogenic. Their immediate or long-term effects should not be underestimated. Only possible acute reactions, but not long-term damage, are listed. The lethal dose is not considered. This detailed information can be found in regularly updated chemical substance databases.

The Globally Harmonized System of Classification and Labelling of Chemicals (GHS), developed by the United Nations, defines and classifies the hazards posed by chemical products, and communicates health and safety information on labels and safety data sheets. A goal of the GHS is to define a globally applicable set of rules for classifying hazards as well as the format and content of warning labels. The threshold criteria for GHS classification are health hazards, physical hazards and environmental hazards.

HINT. Regional and / or national warning labels exist in various forms. These should be explored by mine action (MA) staff, based on the country / region they are working in or the country / region of manufacture.

Based on its properties, a chemical's packaging can be marked with one or more GHS hazard pictogram. Every pictogram symbolises a warning linked to specific hazards. For example, the pictogram GHS 08 warns of systemic health hazards. These systemic health hazards are respiratory sensitisation, aspiration hazard, carcinogenicity, germ cell mutagenicity or reproductive toxicity and specific target organ toxicity. The GHS hazard statements (H) specify the initial warning provided by a GHS hazard pictogram and the GHS precautionary statements (P) specify actions to counter these hazards.[23] The statement, hazard and precaution are documented in a chemical's safety data sheet. GHS hazard pictograms are listed in Table 7 below.

NOTE. If GHS classification(s) exist(s) for a chemical, the GHS hazard pictogram(s) addressing the specific hazards is / are included as information in this chapter.

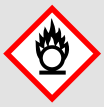
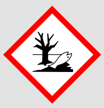
	GHS 01 EXPLODING BOMB • unstable explosive
	GHS 02 FLAME • flammable chemical or mixture
	GHS 03 FLAME OVER CIRCLE • oxidising chemical or mixture
	GHS 05 CORROSION • corrosive chemical category 1
	GHS 06 SKULL AND CROSSBONES • toxic chemical category 1–3
	GHS 07 EXCLAMATION MARK • toxic chemical category 4 • irritant chemical category 2–3 • lower systemic health hazard
	GHS 08 HEALTH HAZARD • systemic health hazard
	GHS 09 ENVIRONMENT • hazard for the environment

Table 7. List of GHS pictograms and their meanings

[23] A comprehensive, detailed overview of the hazard categories and listed H codes and P codes can be found here: https://sitem.herts.ac.uk/aeru/iupac/docs/GHS_EU_Poster.pdf

EXAMPLE: USE OF SAFETY DATA SHEETS AND GHS CLASSIFICATIONS

Hydrogen peroxide is classified by the GHS as an oxidising agent with corrosive and irritant properties. This leads to containers or packaging including hydrogen peroxide being marked with three GHS hazard pictograms:

Consulting the safety data sheet for hydrogen peroxide, the following GHS hazard statements (H) are provided related to its specific hazards:

- H271: May cause fire or explosion; strong oxidiser
  [Danger oxidising liquids; oxidising solids]
- H302: Harmful if swallowed
  [Warning[24] acute toxicity, oral]
- H314: Causes severe skin burns and eye damage
  [Danger skin corrosion / irritation]
- H332: Harmful if inhaled
  [Warning acute toxicity, inhalation]

Precautionary statement codes provided by the SDS:

P210, P220, P221, P260, P261, P264, P270, P271, P280, P283, P301+P312, P301+P330+P331, P303+P361+P353, P304+P312, P304+P340, P305+P351+P338, P306+P360, P310, P312, P321, P330, P363, P370+P378, P371+P380+P375, P405 and P501

- P210: Keep away from heat, hot surfaces, sparks, open flames and other ignition sources – No smoking
- P220: Keep away from clothing and other combustible materials
- P221: Take any precaution to avoid mixing with combustibles/...
- P260: Do not breathe dust / fumes / gas / mist / vapours / spray
- …

The hazard statements and the precaution statements in a chemical´s SDS provides comprehensive information on the hazards posed and the required safety measures.

24 Danger denotes hazards not connected to specific actions; warning denotes hazards connected to specific actions.

It is sometimes not possible to identify the GHS data on a chemical’s packaging / container. Table 8, below, proposes an approach with regard to a first classification of unmarked chemicals.

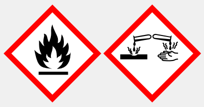
SOLID CHEMICAL	
LIQUID CHEMICAL	As above and including: 

Table 8. The approach with regard to a first classification of unmarked chemicals

Hereinafter, chemicals and HMEs are presented with a focus on information considered to support the mitigation of risks. Given the information available, the content selected here is not exhaustive. When available, the information will include:

- Name, formula, abbreviation(s) and synonym(s);
- Image and GHS hazard pictogram(s);
- Industrial(legal) and private applications;
- Appearance;
- Chemical behaviour including:
    - Flammability;
    - Promotion of existing fires;
    - Hazard of dust explosion;
    - Violent / explosive reactions when in contact with other substances;
    - Corrosive or caustic properties;
- Toxic behaviour including:
    - Risks such as irritation, disorder or severe damage to mucous membranes, skin, eyes, lungs, respiratory tract, blood, inner organs or the central nervous system;
- Materials not to be used / to be used for packaging (for instance due to reactions between the matter and the packaging material);
- Means of firefighting not to be used / to be used, such as water, water jet spray, fire extinguishing foams, fire extinguishing powders or carbon dioxide (CO_2) fire extinguishing systems;
- Hazard level with regard to water supplies.[25]

25 Hazardous to water supplies defines the grade of toxic effect on aquatic life if a chemical enters the water cycle. This includes long-lasting effects and long-term hazards.

4.1. FUNDAMENTALS ON PHYSICAL PARAMETERS

This sub-section presents an overview of physical parameters influencing an HME's brisance, strength, stability and sensitivity.

INGREDIENT RATIO

The ratio between fuel and oxidiser is important for oxygen balance, as it determines whether the amount of oxygen in the explosive is sufficient for complete oxidation. The most efficient explosive mixtures are those with an oxygen balance of zero, or as close to zero as possible (for example, ethylene glycol dinitrate and nitroglycol). An ideal oxygen balance guarantees complete decomposition of the HME and the reduction in production of toxic gases such as carbon monoxide or nitrogen oxide, which occurs when there is insufficient oxygen available (a negative oxygen balance).

The ingredient ratio required in an explosive is determined via a stoichiometric[26] calculation. For example, toxic gases as a by-product of an explosive's use are not desirable in commercial applications such as quarrying and mining. As such, stoichiometry will be used to determine the ratio of chemicals that produce the least toxic gases.

DEGREE OF MIXING

The degree of mixing creates the prerequisite for homogeneous decomposition. Poorly mixed improvised explosives may decompose partially or in an uncontrolled manner. Therefore, ingredients may be scattered, an HME may not react at all or be unpredictable in its combustion or deflagration behaviour. Furthermore, particularly sensitive hotspots can appear within an improvised explosive during mixing, which may lead to unintended detonation.

NOTE. A partial detonation of HME can create further hazards. A safe waiting period following a partial detonation should be observed[27], usually 30 minutes. Explosive evaluation should take into account that remnants of improvised explosives can be scattered across the disposal site, leading to the need for further clearance steps and potential hazards.

WARNING. Although identical oxidisers and fuels can be employed across an entire batch of HME, the physical characteristics of each separate main charge may still differ.

DENSITY

Density denotes the degree of compactness of a substance. Density influences an explosive's brisance significantly. An optimised density ensures maximum detonation velocity. A maximised density does not necessarily equate to maximum detonation velocity. If an HME's density is too high, some improvised explosives may become harder to initiate from external stimuli (such as flame or shock). For some explosives produced industrially, this effect is known as 'dead pressing'. For example, tetrazene, mercury fulminate, DDNP and peroxide-based primary explosives are dead-pressed very easily, causing reliability issues.

26 Chemical calculation of the mass and volume of substances participating in a reaction based on the reaction equation.

27 More information regarding waiting time can be found in the GICHD's *Improvised Explosive Device Clearance Good Practice Guide*, Chapter 3 – Improvised Explosive Device Disposal – Section 1.4 General Principles, Geneva, 2020.

SURFACE AREA (OF THE EXPLOSIVE)

As the oxygen required for an explosive's detonation is bound within the explosive, the amount of explosive that can decompose per unit of time is linked to the affected surface area of the explosive only. As a result, increasing an explosive's surface area will increase sensitivity and reaction rate.

PARTICLE SIZE / PARTICLE SHAPE

The particle size affects an explosive's decomposition rate significantly. As the particle size decreases, the burning rate increases. For an explosive with the ability to transition from combustion to explosion, the particle size (in close coordination with confinement) steers the delay between ignition and detonation. In the case of propellants, the particle size is one parameter that regulates the burning rate. With a decreasing particle size, less energy is required to reach an explosive's ignition temperature, influencing its initiation process as well. Therefore, decreasing particle size makes an explosive more sensitive and easier to initiate. A decreasing particle size allows a better degree of mixing, and fuels can be better blended with the oxidiser leading to a higher brisance, amongst other effects.

The size of an explosive's surface area is not only dependent on particle size but also on its shape. The same explosive with flake-shaped particles has a larger volume to surface area ratio than one with ball-shaped particles of the same size and volume and will have better reactivity. This is due to the fact that a sphere is the geometric body with the smallest surface area in ratio to its volume.

WARNING. In general, a decreasing particle size will increase sensitivity.

CONFINEMENT

Confinement can lead to the transition from combustion to deflagration / detonation. In general, confinement accelerates an improvised explosive's decomposition rate as the evasion of pressure is delayed, hampered or even blocked. The greater the degree of confinement and the more resistant the confining material to energetic effects of decomposition, the higher the probability that the confined explosive will deflagrate or detonate.

CHARGE GEOMETRY AND CRITICAL DIAMETER

To ensure an explosive's decomposition, the charge geometry must correspond at least to the critical diameter of an improvised explosive. The critical diameter is the minimum diameter of a (cylindrical) charge for which detonation of a high explosive still occurs. The critical diameter is very much influenced by the chemical structure of an explosive. Critical diameters for a variety of explosives can be found in relevant literature; they vary considerably, even for the same type of explosive. Among other things, the critical diameter is heavily affected by confinement, particle size, detonation velocity, density or ambient temperature of unreacted explosive. Under laboratory conditions, the critical diameter of ammonium nitrate–fuel oil is 5 cm to 6.35 cm, many times greater than that required for TNT (2mm to 1 cm).

APPEARANCE

In contrast to military explosives, which are mostly readily identified as one uniform component in solid form, the majority of HMEs comprise a mixture of oxidiser and fuel. They can also be solid or liquid. As such, HMEs are more likely to appear in different colours, particle sizes and with varying odours than are military explosives.[28]

28 Typical appearances, including images (if available), are listed with the corresponding chemicals and compounds, below.

Image 22. Appearance of an unknown HME used in a main charge (source: FSD ©)

Image 23. Appearance of an unknown HME used in a main charge (source: BCL-YMACC ©**)**

4.2. ACIDS

This sub-section presents acids that are commonly encountered in the manufacturing of HME.

Acids are required to purify or synthesise substances; they can act as reactants or catalysts. Both organic and inorganic acids are used in the production of HME. The concentration of acids differs depending on the source. For some procedures, a minimum concentration of an acid is required. For instance, acids used for nitration reactions require a concentration from 65% up to 99%. Usually, highly concentrated acids are preferred by the manufacturer (strong acids like sulphuric acid, nitric acid or hydrochloric acid).

WARNING. Acids will burn skin and destroy clothing. If any acid is spilled, it should be washed away with a large quantity of water, and medical attention should be sought as soon as possible. The fumes produced by an acid must not be inhaled.

MA staff may encounter acids at abandoned manufacturing facilities, abandoned storage sites or as manufacturing waste. Acids can be toxic and hazardous to the environment. In general, acids emit toxic fumes and are corrosive to organic and inorganic materials. No water should be mixed with acids, since this can lead to a violent exothermic reaction. The addition of metals to concentrated acids can also lead to a violent exothermic reaction.

NOTE. If an acid must be diluted, the acid should be added to the water, in small quantities and very slowly.

WARNING. Acid residues in an HME can lead to spontaneous self-ignition, for instance in the case of nitrocellulose and some dynamites.

ACETIC ACID – ORGANIC [$C_2H_4O_2$] OR VINEGAR (DILUTED), HYDROGEN ACETATE

Image 24. Acetic acid
(source: Bundeswehr CBRN Defence Command ©)

Acetic acid is important in the chemical industry. It is widely used as a descaling agent, a cleaning agent and in less concentrated forms (i.e. vinegar) for household use. Vinegar rarely contains more than a 5% acid concentration. Acetic acid is one possible precursor for HMTD and TATP.

Acetic acid is a colourless liquid which crystallises at 17°C. It has a strong, sour, vinegar-like odour. The substance is volatile and hygroscopic.

CHEMICAL BEHAVIOUR

Pure liquid acetic acid is flammable. If heated above its flashpoint, its fumes can form explosive mixtures with atmospheric oxygen.

An explosion or violent reaction can occur when acetic acid comes into contact with, for instance, hydrogen peroxide or other strong acids or oxidisers.

TOXIC BEHAVIOUR

Acetic acid has an increasingly irritating (to corrosive) effect on mucous membranes and skin as concentration increases. Severe eye and lung damage can occur when exposed to high concentrations.

Acetic acid should not be stored in containers made of brass, copper, iron or zinc. Suitable containers are made of aluminium, glass or polyethylene (PE).

Acetic acid is slightly hazardous to water supplies.[29]

NOTE. Hygroscopic means readily water-attracting. Hygroscopic substances absorb water vapours even from the air, forming a saturated solution. Hygroscopic solids begin to clump. (The surface of) a material may even plasticise or liquify if enough water is absorbed. Absorption of water can reduce reactivity and sensitivity of the substance affected.

NOTE. Flashpoint is the lowest temperature at which a volatile substance evaporates to form an ignitable mixture with air in the presence of an igneous source and continues burning after the trigger source is removed.[30]

29 Hazardous to water supplies defines the grade of toxic effect on aquatic life if a chemical enters the water cycle. This includes long-lasting effects and long-term hazards.

30 Joaquín Isac-García et al., *Experimental Organic Chemistry – Laboratory Manual* (Academic Press, 2015).

CITRIC ACID – ORGANIC [$C_6H_8O_7$] OR SOUR SALT, CITRON, LEMON ACID


Image 25. Citric acid
(source: Bundeswehr CBRN Defence Command ©)

Citric acid is used to make drinks and food sour, in limescale removers, as a water softener, and in cosmetics and pharmaceutical products. Citric acid is one possible precursor for HMTD.

Citric acid is a white, odourless solid, in powder or crystal form. It is easily soluble in water, where it can result in / produce a faint citrus odour.

CHEMICAL BEHAVIOUR

Pure citric acid is a slight fire hazard when exposed to heat or flame. A violent reaction can occur when citric acid comes into contact with oxidisers, reducing agents or metals, for example. An explosive reaction may result if citric acid is mixed with metal salts.[31] Powdered citric acid can contribute to a dust explosion.[32]

TOXIC BEHAVIOUR

Citric acid can cause irritation and have a caustic effect on the eyes as well as an irritating effect on the upper airways.

Citric acid should not be stored in containers made of base metals. Containers made of glass or steel are acceptable.

There are no known hazards to water and water reservoirs from citric acid.

31 A metal salt is a chemical compound of a metal and an acid.
32 See sub-section 4.4.2. *Solid fuels*.

HYDROCHLORIC ACID – INORGANIC [HCl] OR MURIATIC ACID

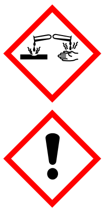


Image 26. Laboratory-grade hydrochloric acid
(source: Bundeswehr CBRN Defence Command ©)

Hydrochloric acid is important for the chemicals, pharmaceutical and galvanic industries, where it is used in highly concentrated forms for the pickling of steel (dissolving metal oxides from steel / iron surfaces). In biology, hydrochloric acid is an important component of the gastric juice of humans and animals. As a strong mineral acid, it is used as a reactant in the manufacture of HMEs.

Hydrochloric acid is a colourless-yellowish liquid with a pungent odour.

CHEMICAL BEHAVIOUR

Hydrochloric acid is highly corrosive and reacts with surrounding atmospheric oxygen, forming caustic acid fumes which are heavier than air. A violent reaction can occur when hydrochloric acid comes into contact with alkali metals and organic materials.

TOXIC BEHAVIOUR

Hydrochloric acid has an irritant and corrosive effect on the eyes, respiratory tract and skin. There is the risk of severe eye and lung damage. It produces choking fumes, which can quickly incapacitate those exposed to it. If swallowed, medical attention should be sought immediately.

Hydrochloric acid should not be stored in containers made of metals. Containers made of glass, PE or polyvinylchloride (PVC) are suitable.

Hydrochloric acid is slightly hazardous to water supplies.

NOTE. Alkali metals are lithium, sodium, potassium, rubidium, caesium and francium. Alkali metals are soft, flammable, very reactive (sometimes explosive) elements. They ignite when heated in air or in combination with oxygen, and react violently on contact with moisture to form hydrogen (which can ignite from the heat of reaction) and corresponding hydroxide smoke (corrosive). Heated alkali metals burn by themselves in atmospheric air and melt. In powder and dust form, alkali metals can self-ignite at room temperature (20°C). In general, alkali metals react very violently on contact with water. They do not sink but float and dance around on the water surface with the appearance of fire and explosions. Their reaction with water forms easily combustible hydrogen gas which can ignite, and strongly corrosive hydroxide. Explosions are possible in closed rooms / confined spaces. Corrosive mixtures that can be formed with water are still effective even when diluted.

HYDROGEN PEROXIDE – INORGANIC [H_2O_2]

Image 27. 30% hydrogen peroxide
(source: Bundeswehr CBRN Defence Command ©)

Hydrogen peroxide has a variety of applications, both in industry and in household use. It is used as a bleaching agent and disinfectant. Concentrated hydrogen peroxide is used in propellants, for instance liquid rocket fuel, and to produce improvised organic peroxide explosives such as HMTD, methyl ethyl ketone peroxide (MEKP) and TATP.

Depending on its concentration, hydrogen peroxide goes from a colourless to a pale blue liquid. It has a low volatility.

CHEMICAL BEHAVIOUR

Hydrogen peroxide itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, sometimes without a further ignition source. It can significantly increase the potency of an existing fire, given the amount of oxygen in its structure. Hydrogen peroxide with a concentration > 8% should not be allowed to come into contact with fabrics or leather.

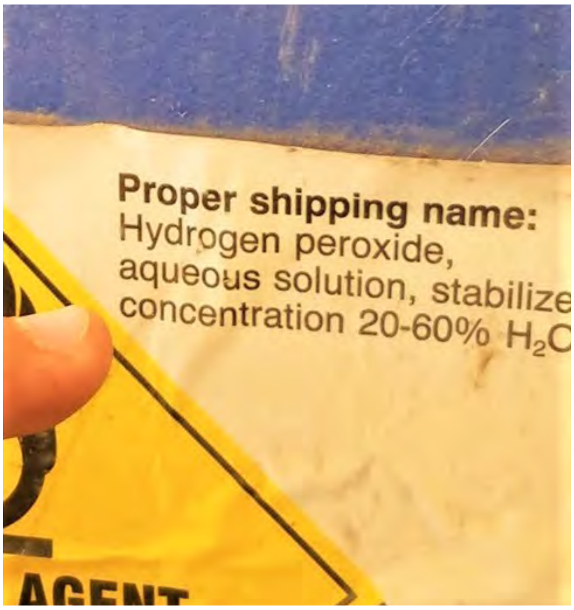


Image 28. A hydrogen peroxide container - field finding
(source: GICHD ©)

An explosion or violent reaction can occur when hydrogen peroxide comes into contact with, for instance, acetone, acetic acid, cotton fibres, flammable substances, glycerine, hydrazine, metallic powders, nitric acid, nitromethane, sulphuric acid or wood.

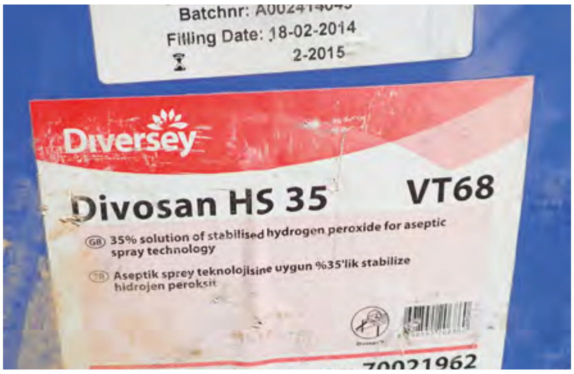


Image 29. A drum of hydrogen peroxide - field finding
(source: CAR ©)

TOXIC BEHAVIOUR

Depending on its concentration, hydrogen peroxide can cause irritation and have a corrosive effect on skin, mucous membranes, eyes, and causes inflammatory changes in the respiratory tract. In extreme cases, it causes lung damage due to a high concentration of vapours / aerosols. If swallowed, hydrogen peroxide can cause fatal gas bubbles in the blood.

Hydrogen peroxide should not be stored in containers made of brass, bronze, copper or iron. Containers made of glass, PE (< 60% concentration) or PVC (< 60% concentration) are acceptable.

Hydrogen peroxide is slightly hazardous to water supplies.

NOTE. Hydrogen peroxide is a powerful oxidiser since its chemical structure contains 94% mass percentage oxygen. Any container of hydrogen peroxide marked as having above 35% concentration should be considered suspicious and be reported.

WARNING. Contact of hydrogen peroxide with organic chemicals (e.g. formic acid) can lead to violent explosive decomposition reactions.

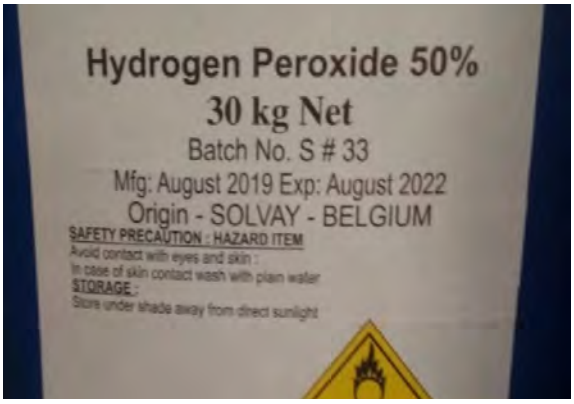


Image 30. 50% hydrogen peroxide observed in Yemen
(source: BCL ©)

NITRIC ACID – INORGANIC [HNO_3] OR AQUA FORTIS, EAU FORTE, HYDROGEN NITRATE, RED FUMING NITRIC ACID (RFNA), WHITE FUMING NITRIC ACID (WFNA)

Image 31. 65% nitric acid
(source: Bundeswehr CBRN Defence Command ©)

Image 32. 100% nitric acid
(source: Bundeswehr CBRN Defence Command ©)

Nitric acid has wide usage in the chemical industry. It is fundamental in the production of many explosives as the principal nitrating agent. It is used to produce nitrates and fertilisers, to separate gold and silver and it is used in the galvanic industry and in the paint industry (nitro paints). Highly concentrated nitric acid is used as an oxidiser in liquid explosives (for instance hellhoffite) or in liquid rocket fuel (RFNA / WFNA). Nitric acid used in the production of explosives has a concentration of between 70% and 99%. The greater the concentration, the more volatile the nitration reaction.

Organic nitrates – the nitrate esters – are compounds that can decompose explosively. Therefore, the esters of polyalcohols can be / are used as explosives.

HINT. The presence of a nitrate source and a strong mineral acid can indicate the manufacturing of nitric acid.

Nitric acid, depending on its concentration, is colourless-yellowish. Under sunlight, it decomposes and turns red. Nitric acid has a pungent odour. It evaporates to give reddish-brown fumes.

CHEMICAL BEHAVIOUR (CONCENTRATION > 65%):

Nitric acid is not flammable but can significantly increase an existing fire. It increases the fire hazard when in contact with flammable substances. Nitric acid is sensitive to the surrounding air. It is a strong oxidiser and a strong acid.

An explosion or violent reaction can occur when nitric acid comes into contact with acetic acid, acetone, ammonia, flammable substances, fuel oil, hydrazine, hydrogen peroxide, metal powders, nitromethane, organic substances with large surfaces (for instance fine sawdust) and potassium chlorate.

WARNING. If nitric acid comes into contact with sawdust, wood wool, cleaning wool, paper, cotton residues, cellulose or other finely dispersed organic materials, toxic nitrous gases (nitrogen oxides) are formed. Depending on the surrounding conditions, fires, spontaneous combustion or even explosions are possible. Gun cotton was accidentally discovered in this way when a cotton rag used to wipe up spilled nitric acid self-combusted as it began to dry out.

TOXIC BEHAVIOUR

Nitric acid has an irritant and corrosive effect on the eyes, respiratory tract and skin. Its fumes can cause choking. Unprotected contact presents a risk of severe eye and lung damage.

Nitric acid should not be stored in containers made of base metals. Usable containers should be made of dark brown glass, PE, polypropylene (PP) or PVC.

Leakage of nitric acid into water, the sewage system or soil must be avoided, as it is severely hazardous to water supplies.

PERCHLORIC ACID – INORGANIC [$HClO_4$]

Image 33. 71% perchloric acid
(source: Bundeswehr CBRN Defence Command ©)

Perchloric acid is used as an analytical reagent and in the production of pesticides, explosives and rocket fuel.

Perchloric acid is a colourless and odourless liquid. It is hygroscopic and volatile and will create toxic and explosive vapours when in contact with air. Perchloric acid with a 50% concentration may explode if heated. This acid may decompose explosively without any recognisable cause.

CHEMICAL BEHAVIOUR (CONCENTRATION BETWEEN 50% AND 72%)

Perchloric acid is not flammable but can act as an oxygen source to an existing fire. It increases the fire hazard when in contact with flammable substances. The reaction with flammable substances can lead to self-ignition. Pure perchloric acid may explode violently when heated above 75°C.

An explosion or violent reaction can occur when the acid comes into contact with alcohol, flammable substances, sulfuric acid, coal, metals, glycerine, sawdust, nitric acid or a heat source.

TOXIC BEHAVIOUR

Perchloric acid has a highly irritant and corrosive effect on mucous membranes and skin. There is a risk of serious, irreversible damage to the eyes.

Perchloric acid should not be stored in containers made of base metals. Usable containers are those made from glass, PE, PP or PVC.

Perchloric acid is slightly hazardous to water supplies.

PICRIC ACID – ORGANIC [$C_6H_3N_3O_7$] OR 2,4,6-TRINITROPHENOL

Image 34. Picric acid
(source: Bundeswehr CBRN Defence Command ©)

Picric acid is a strong acid and a homogenous explosive that was used as one of the main explosive fillers in grenades, mortar bombs and artillery shells at the beginning of the 20th century. Given its tendency to react with metal casings (e.g. artillery shells) resulting in the formation of sensitive, explosive picrate salts, it is no longer used by the military. Today, it is mainly used in primary explosive compositions in detonators.

Picric acid is a light yellow, shiny, bitter-tasting, odourless, crystallised solid. It is hardly soluble in water but soluble in alcohol, ester, benzene and acetone.

CHEMICAL BEHAVIOUR

Picric acid is an explosive solid with an impact sensitivity of 7–8 J and a friction sensitivity of up to 353 N. It reacts by impact or friction, heating (fires) or other ignition sources with rapid decomposition and the formation of large quantities of gas.

An explosion can occur when pure picric acid comes into contact with aluminium, ammonia, metals, oxidisers in general, or potassium.

TOXIC BEHAVIOUR

Absorption of picric acid leads to irritation of the eyes and nasal mucous membranes, colouration of unprotected skin, gastrointestinal discomfort, nervous disorders and damage to the blood, kidneys and liver.

Water is an appropriate fire extinguishing agent for picric acid.

However, picric acid is significantly hazardous to water supplies, and its introduction into water, sewerage systems or soil must be prevented.

WARNING. Picric acid forms picrates with nearly every metal. Picrates have a crystal structure, nearly all have explosive properties. Picrates are more sensitive than picric acid. For less stable picrates, a crack in their crystal structure, for instance caused by shock or friction, induces sufficient energy to cause their explosive decomposition. The sensitivity of many metal picrate salts is such that they can initiate even when wet. For example, a fire in a French ammunition factory in 1916 caused molten picric acid to seep onto the concrete floor. Calcium picrate was formed and detonated during clean up, killing 170 people.[33]

[33] Louis A. Medard, *Accidental Explosions, Volume 2: Types of Explosive Substances*, (New York: John Wiley & Sons, 1989), 739.

SULPHURIC ACID – INORGANIC [H_2SO_4] OR OIL OF VITRIOL

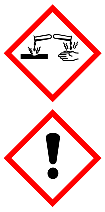


Image 35. 100% sulphuric acid
(source: Bundeswehr CBRN Defence Command ©)

Sulphuric acid is used in lead-acid batteries and some drain cleaners. It is a common catalyst used to manufacture various HMEs.

Sulphuric acid is a colourless and odourless liquid. When impure, it has a brownish colour. It is hygroscopic and not volatile.

CHEMICAL BEHAVIOUR

An explosion or violent reaction can occur when sulphuric acid comes into contact with alkali metals or metals like aluminium (decreasing particle size accelerates the reaction), flammable substances, hydrogen peroxide, chlorates, nitrates, nitric acid. A reaction with water releases toxic fumes.

TOXIC BEHAVIOUR

Sulphuric acid has a highly irritant and corrosive effect on mucous membranes and skin, with the risk of serious, irreversible damage to the eyes and lungs.

Sulfuric acid should not be stored in containers made of base metals. Suitable containers should be made of glass, PE, PP or PVC.

Sulphuric acid is slightly hazardous to water supplies.

> **WARNING. Mixing concentrated sulphuric acid with concentrated caustic soda (sodium hydroxide) leads to such intense heating that the container may boil over and corrosive liquid may spill out.**

4.3. OXIDISERS

This sub-section gives an overview of commonly used oxidisers for the manufacturing of HME, including:

- Group of nitrates (salts and esters of nitric acid);
- Group of chlorates (salts of chloric acid);
- Group of perchlorates (salts of perchloric acid); and
- Oxidisers not belonging to one of the groups listed above.

Oxidisers are substances that are combined with a fuel to produce an energetic material. An oxidiser is a substance with an electron deficit. It provides the source of oxygen needed for an explosion, making the detonation independent from atmospheric oxygen.

The more oxygen bound in the explosive structure, the better the energetic effect. Oxidisers are therefore the significant variable affecting the manufacture of HME and the HME's subsequent physical characteristics and performance.

CHARACTERISTICS

Characteristics of interest for oxidisers are as follows:

- The compound may not be flammable in its own right, requiring a fuel to initiate the process.
- Oxidising agents are generally oxygen-rich ionic solids that decompose at moderate to high temperatures, releasing oxygen gas in the process.
- Many oxidisers are readily available, in reasonably pure form, in an appropriate particle size and at reasonable cost.
- Oxidisers increase the risk of fire when in contact with flammable substances and can significantly worsen an existing fire.
- Oxidisers can react so violently with flammable substances that they cause them to ignite, sometimes just by contact, without the need for a separate ignition source.

WARNING. Oxidising agents can cause fires simply through contact with organic materials such as wood, paper and cardboard.

4.3.1. GROUP OF NITRATES

Nitrates are the salts or the esters of nitric acid. They are quite insensitive to impact and friction, yet, when added to an appropriate fuel like aluminium, they can generate viable explosive mixtures. Some nitrates in their pure form can detonate if given a sufficient impulse such as a shock.

AMMONIUM NITRATE [NH_4NO_3]

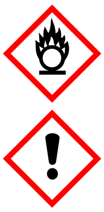


Image 36. Ammonium nitrate prills
(source: Bundeswehr CBRN Defence Command ©)

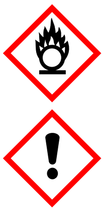


Image 37. Fine ammonium nitrate
(source: Bundeswehr CBRN Defence Command ©)

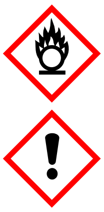


Image 38. Ammonium nitrate crystals
(source: Bundeswehr CBRN Defence Command ©)

Ammonium nitrate is a white crystalline salt of ammonia and nitric acid, used widely in fertilisers, freezing mixtures (cool packs) and anaesthetics (manufacture of nitrous oxide), and is the most important raw material in the manufacture of commercial explosives. Pure, commercial grade ammonium-nitrate contains about 33.5% mass percentage nitrogen. Ammonium nitrate has a melting temperature of around 170°C, decomposes at 210°C and can burn to detonation in large quantities without confinement,[34] as in the recent case of deflagration to detonation of over 2700 tonnes of ammonium nitrate at Beirut Port, on 4th August 2020.

Ammonium nitrate is also used to modify the detonation rate of other explosives, such as nitroglycerine in the so-called ammonia dynamites, or as an oxidising agent in ammonals which are mixtures of ammonium nitrate and powdered aluminium. The vast majority of ammonium nitrate-based HME compositions are generally insensitive to initiation by detonator alone and require confinement and a booster. They have a low detonation velocity, so are unsuitable for driving anti-armour penetrators such as shaped charges and explosively formed projectiles. They are not easily initiated in small quantities but do react to a specific impulse similar to TNT. This is one reason they are used for blast-related applications.

CHEMICAL BEHAVIOUR

Ammonium nitrate itself does not burn but increases the fire hazard when in contact with combustible materials. Ammonium nitrate can significantly promote an existing fire. Dry pure ammonium nitrate can detonate but phlegmatisation with more than 3% water will prevent this from happening.

Ammonium nitrate is extremely hygroscopic and its crystals are often coated with inert substances to prevent liquefaction and caking. Pure ammonium nitrate is difficult to detonate on its own. As such, ammonium nitrate HME is generally a mixture of ammonium nitrate with an organic or metal fuel. The fuel reacts with the excess oxygen liberated during combustion to produce additional gas and heat.

WARNING. Ammonium nitrate is wholly incompatible with chlorates, given the formation of ammonium chlorate – a spontaneous explosive, which is physically unstable in the presence of moisture.

An explosion or violent reaction can occur when pure ammonium nitrate comes into contact with alkali metals, powdered metals (for instance aluminium), acetic acid, ammonium, combustible substances, organic substances, water, chlorates, chlorides, urea, sodium nitrate, sulphur or phosphorus.

TOXIC BEHAVIOUR

Ammonium nitrate is an oxidising substance, which is harmful if swallowed or inhaled and an irritant to the eyes, skin and respiratory system. On decomposition, it produces nitrous oxide, a poisonous by-product of combustion.

Ammonium nitrate is slightly hazardous to water supplies.

34 United States Environmental Protection Agency, *Chemical Advisory: Safe Storage, Handling, and Management of Ammonium Nitrate*. EPA 550-S-13-001, August 2013.

BARIUM NITRATE [$Ba(NO_3)_2$]

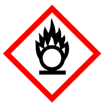


Image 39. Barium nitrate
(source: Bundeswehr CBRN Defence Command ©)

Barium nitrate is mainly used to produce pyrotechnics but has been used with TNT in an explosive called Baratol, or with thermite to form thermate. There is no legitimate household application.

Pure barium nitrate is a colourless, odourless, crystalline substance. It is hygroscopic and soluble in water and produces a green flame when burned with other substances.

CHEMICAL BEHAVIOUR

Barium nitrate itself does not burn but increases fire hazard when in contact with combustible materials. Barium nitrate can significantly worsen an existing fire, being an oxidiser.

An explosion or violent reaction can occur when pure barium nitrate comes into contact with ammonium nitrate, charcoal, thermite, sulphur, combustible substances or acids.

TOXIC BEHAVIOUR

Barium nitrate can have an irritant effect on skin and mucous membranes. If ingested, it can be fatal or lead to muscle cramps and damage to the blood, gastrointestinal tract and cardiovascular system.

Barium nitrate is slightly hazardous to water supplies.

LEAD (II) NITRATE [$Pb(NO_3)_2$]

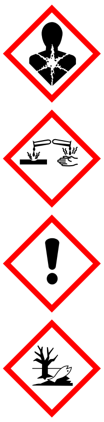


Image 40. Lead (II) nitrate
(source: Bundeswehr CBRN Defence Command ©)

Lead (II) nitrate has no industrial or household use.

Lead (II) nitrate is a grey-white, odourless, crystalline solid or powder. It dissolves very well in water and does not burn as a pure substance.

CHEMICAL BEHAVIOUR

An explosion or violent reaction can occur when pure lead (II) nitrate comes into contact with ammonium, carbon, fine metal powders or combustible organic substances.

TOXIC BEHAVIOUR

Lead (II) nitrate can lead to gastrointestinal, central nervous system and blood function disorders.

Lead (II) nitrate is highly hazardous to water supplies. Therefore, spillage into water, sewage systems or soil, even in small quantities, must be prevented.

POTASSIUM NITRATE [KNO_3] OR SALTPETRE, NITRATE OF POTASH[35]

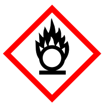


Image 41. Potassium nitrate
(source: Bundeswehr CBRN Defence Command ©)

Potassium nitrate or 'saltpetre' is the oldest recorded solid oxidiser and is a component of black powder. It is used in pyrotechnics, fertilisers and glass melts. It is also used as pickling salt in food preservation.

Potassium nitrate is a colourless-white transparent crystalline substance, with a cool-bitter taste. It is not hygroscopic. The crystals dissolve in water and in glycerine.

Image 42. An example of packaging of potassium nitrate fertiliser (source: CAR ©)

CHEMICAL BEHAVIOUR

Potassium nitrate itself does not burn but increases the fire hazard when in contact with combustible materials. Potassium nitrate can significantly promote an existing fire.

Potassium nitrate will not undergo an explosion by itself, even when a very strong stimulus is applied.

An explosion or violent reaction can occur when pure potassium nitrate comes into contact with powdered metals (e.g. potassium, magnesium) or fuels such as coal, sulphur, red phosphorus, white phosphorus or acid catalysts.

TOXIC BEHAVIOUR

Ingestion of potassium nitrate can lead to gastrointestinal tract problems, headaches, vasodilation and it may disturb methaemoglobin formation.

Potassium nitrate is slightly hazardous to water supplies.

35 Potash or potassium carbonate K_2CO_3 is the salt of carbonic acid.

SILVER NITRATE [$AgNO_3$]

Image 43. Silver nitrate
(source: Bundeswehr CBRN Defence Command ©)

Silver nitrate has a variety of uses in the pharmaceutical and medical industries. It is used in the galvanic industry for silver plating, for mirror silver for instance.

Silver nitrate is a colourless, white-transparent, crystalline substance that tastes extremely bitter. It is soluble in water. It dyes skin or organic tissue black after contact.

CHEMICAL BEHAVIOUR

Silver nitrate itself does not burn but increases fire hazard when in contact with combustible materials. Silver nitrate can significantly promote an existing fire.

An explosion or violent reaction can occur when pure silver nitrate comes into contact with ammonium, coal, combustible substances, hydrogen peroxide, phosphorus, powdered metals (e.g. magnesium), sulphur or nitric acid.

TOXIC BEHAVIOUR

Silver nitrate is highly toxic. It can have an irritant effect on skin and mucous membranes; in the case of oral intake of high doses it can cause gastrointestinal, cardiovascular system and central nervous system disorders.

Silver nitrate is highly hazardous to water supplies, even the introduction of small quantities into water, sewage systems or soil must be prevented.

SODIUM NITRATE [$NaNO_3$] OR SODA

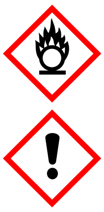


Image 44. Sodium nitrate
(source: Bundeswehr CBRN Defence Command ©)

Sodium nitrate or 'Chile saltpetre' is used in fertilisers, as an oxidiser for glass and enamel, and as a component for explosives, such as rocket propellants.

Sodium nitrate is a white or yellow, odourless, hygroscopic, crystalline substance, which easily dissolves in water.

CHEMICAL BEHAVIOUR

Sodium nitrate itself does not burn but increases the fire hazard when in contact with combustible materials. Sodium nitrate can significantly promote an existing fire. Heat or friction can cause it to ignite.

An explosion or violent reaction can occur when pure sodium nitrate comes into contact with powdered metals, organic substances, charcoal or sulphur.

TOXIC BEHAVIOUR

Sodium nitrate exposure can lead to damage to the gastrointestinal tract and to vasodilation. In case of severe poisoning, it can disturb methaemoglobin formation in the blood.

Sodium nitrate is slightly hazardous to water supplies.

STRONTIUM NITRATE [$Sr(NO_3)_2$]

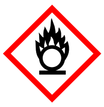


Image 45. Strontium nitrate
(source: Bundeswehr CBRN Defence Command ©)

Strontium nitrate is used in pyrotechnics to produce a red flame. It is also used in gas generators, for example in airbags.

Strontium nitrate is a colourless, white-transparent, crystalline substance. It is easily soluble in water.

CHEMICAL BEHAVIOUR

Strontium nitrate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any other ignition source. Strontium nitrate can significantly promote an existing fire.

An explosion or violent reaction can occur when pure strontium nitrate comes into contact with powdered metals (e.g. magnesium), sulphur and combustible substances.

TOXIC BEHAVIOUR

Strontium nitrate can have an irritant effect on skin and mucous membranes. In case of severe poisoning, for instance in the case of oral intake, potassium nitrate can lead to gastrointestinal tract problems and vasodilation and may disturb methaemoglobin formation.

Strontium nitrate must not be stored in PVC containers.

Strontium nitrate is slightly hazardous to water supplies.

4.3.2. GROUP OF CHLORATES

Chlorates are the salts of chloric acid ($HClO_3$). They are more sensitive to impact than nitrates.

BARIUM CHLORATE [$Ba(ClO_3)_2$]

Barium chlorate is used in pyrotechnics but its importance has diminished because its presence in pyrotechnic mixtures causes high sensitivity to impact and friction. Barium chlorate produces green flames.

Barium chlorate is a colourless, odourless, powder-like or crystalline substance. It is hygroscopic and soluble in water.

CHEMICAL BEHAVIOUR

Barium chlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any other ignition source. Barium chlorate can significantly promote an existing fire.

An explosion or violent reaction can occur when pure barium chlorate comes into contact with acids, combustible substances, concentrated sulphuric acid, organic substances, phosphorus, powdered coal, powdered metal or sulphur.

TOXIC BEHAVIOUR

Barium chlorate can have an irritant effect on skin and mucous membranes. It can lead to muscle cramps, cardiovascular and blood damage, and gastrointestinal tract problems.

Barium chlorate is slightly hazardous to water supplies.

POTASSIUM CHLORATE [$KClO_3$]

Image 46. Potassium chlorate
(source: Bundeswehr CBRN Defence Command ©)

Potassium chlorate is used in pesticides, explosives, fireworks and matches. Impurities such as red phosphorus, sulphur or powdered metal can lead to self-ignition and, depending on the kind of fuels and level of confinement, to detonation. As such, its use in firework compositions has diminished considerably over the years.

Potassium chlorate is a colourless-white, odourless substance that can have a crystalline, powder or granulated form. It dissolves easily in water.

CHEMICAL BEHAVIOUR

Potassium chlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any further ignition source.

Potassium chlorate can significantly promote an existing fire. Intense mixtures with flammable substances such as organic substances or metal powders can explode by friction or slight impact.

An explosion or violent reaction can occur when pure potassium chlorate comes into contact with ammonium, combustible substances, ethanol, organic acids, paraffin, petrol, potassium components, powdered metals (aluminium, magnesium, potassium) or red phosphorus.

TOXIC BEHAVIOUR

Potassium chlorate can cause strongly irritant effects on mucous membranes, especially in the eyes. It can have an irritating effect on skin.

Potassium chlorate is slightly hazardous to water supplies.

Potassium chlorate is frequently used in the manufacture of HMEs. Table 9, below, compares its sensitivity in combination with common additives (fuels) to that of other primary and secondary explosives.

EXPLOSIVE COMPOSITION	MELTING / IGNITION TEMPERATURE OR DEFLAGRATION POINT* (^{o}C)	FoI
Potassium chlorate–ammonium nitrate	< 100*	10 (with the formation of ammonium chlorate)
Mercury fulminate	165*	10
Lead styphnate	275–280*	12
Tetrazene	140*	13
Lead azide	320–360*	20
Nitrocellulose (dried @ 13.4% N)	132	23
Potassium chlorate–sulphur	220	28 (at stoichiometry)
Potassium chlorate–sugar	195	30–67 (depending on type of sugar and percentage mix)
Nitroglycerine	13 (200*)	30
Potassium chlorate–charcoal	335	35 (at stoichiometry)
Potassium chlorate–charcoal–sugar	275	35 (at stoichiometry)
Potassium chlorate–fuel oil	230	50 (at stoichiometry)
PETN	141.3 (202*)	51
RDX	213 (260*)	80
Black powder	450 (for ingredient ratio of 75 / 15 / 10)	90
TNT	80.8 (300*)	152

Table 9. The sensitivity of potassium chlorate and additives compared to other primary and secondary explosives (sorted by FoI) (source: BCL ©)

SODIUM CHLORATE [$NaClO_3$]

Image 47. Sodium chlorate
(source: Bundeswehr CBRN Defence Command ©)

Sodium chlorate is used as a bleaching agent for paper, in welding torches, as a raw material in pesticides and as a chemical oxygen generator (chlorate candles) used in mining or aviation.

Sodium chlorate is a colourless, sometimes pale yellow-white, odourless, crystalline substance. It dissolves in water and is hygroscopic.

CHEMICAL BEHAVIOUR

Sodium chlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any other ignition source. The solid product and even 30% solution in water are powerful oxidising agents.

Sodium chlorate can significantly promote an existing fire. In addition, there is the danger of explosion when it is mixed with organic substances.

An explosion or violent reaction can occur when pure sodium chlorate comes into contact with ammonium salts, combustible substances, concentrated acids, grease, nitro benzol (nitrobenzene), organic substances, oils, phosphorus, powdered metals, sulphuric acid or sulphur.

TOXIC BEHAVIOUR

Sodium chlorate has a low irritant effect on mucous membranes and skin. Absorption via the lungs or the digestive tract can lead to blood and kidney damage.

Sodium chlorate is significantly hazardous to water supplies.

STRONTIUM CHLORATE [$Sr(ClO_3)_2$]

Strontium chlorate is used in pyrotechnics to produce a red flame.

Strontium chlorate is a colourless, odourless, crystalline substance. It dissolves in water and is hygroscopic.

CHEMICAL BEHAVIOUR

Strontium chlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any other ignition source.

Strontium chlorate can significantly promote an existing fire. When heated to decomposition it emits toxic fumes of hydrogen chloride.

TOXIC BEHAVIOUR

Strontium chlorate has a highly irritating effect on mucous membranes, especially in the eyes.

Strontium chlorate is hazardous to water supplies.

4.3.3. GROUP OF PERCHLORATES

Perchlorates are the salts of perchloric acid ($HClO_4$). They are more sensitive to impact and friction than chlorates or nitrates.

AMMONIUM PERCHLORATE [NH_4ClO_4]

Image 48. Ammonium perchlorate
(source: Bundeswehr CBRN Defence Command ©)

Ammonium perchlorate is used with combustible materials in the manufacture of composite rocket propellants. It is also used in the production of explosives and fireworks.

Ammonium perchlorate is a colourless, odourless, crystalline substance but can also appear as light grey or silver-grey crystals. It is soluble in water.

CHEMICAL BEHAVIOUR

In addition to its high sensitivity to impact and friction, ammonium perchlorate is sensitive to heat and other ignition sources (e.g. strong acids). Each of these stimuli may lead to a rapid decomposition with a high gas yield.

Ammonium perchlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any further ignition source. Ammonium perchlorate can significantly promote an existing fire. Mixing ammonium perchlorate with combustible powdery substances may lead to explosions, particularly in confinement.

A violent reaction can occur when pure ammonium perchlorate comes into contact with chlorine, combustible substances, metals (solid and powder), metal salts, nitrates, nitric acid, organic phosphorus, strong acids or sulphur.

TOXIC BEHAVIOUR

Ammonium perchlorate dust and solutions[36] can have an irritating effect on mucous membranes.

Ammonium perchlorate is slightly hazardous to water supplies.

WARNING. Under no circumstances should ammonium perchlorate be stored in combination with chlorate-containing compounds, due to the formation of ammonium chlorate in the presence of moisture. Nor should it be mixed with magnesium since any presence of moisture may cause spontaneous ignition if the heat build-up is sufficient.

36 A solution, in chemistry, is a homogenous mixture of two or more substances in relative amounts that can be varied continuously up to what is called the limit of solubility (Encyclopædia Britannica,Inc. © 2021).

POTASSIUM PERCHLORATE [$KClO_4$]

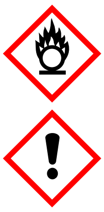


Image 49. Potassium perchlorate
(source: Bundeswehr CBRN Defence Command ©)

Potassium perchlorate has been used in pyrotechnics as the gradual replacement for potassium chlorate.

Potassium perchlorate is a colourless or white, odourless, crystalline substance. It is non-hygroscopic but partially soluble in water.

CHEMICAL BEHAVIOUR

Potassium perchlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any other ignition source. Potassium perchlorate can significantly promote an existing fire.

A violent reaction can occur when pure potassium perchlorate comes into contact with acids, combustible substances, ethanol, organic substances, powdered metals, red phosphorus or sulphur.

TOXIC BEHAVIOUR

Potassium perchlorate dust and solutions can have an irritating effect on mucous membranes.

Potassium perchlorate is slightly hazardous to water supplies.

SODIUM PERCHLORATE [$NaClO_4$]

Image 50. Sodium perchlorate
(source: Bundeswehr CBRN Defence Command ©)

Sodium perchlorate is used for medical purposes, in pyrotechnics and propellants.

Sodium perchlorate is a colourless, odourless, crystalline substance. It is hygroscopic and soluble in water and alcohol.

CHEMICAL BEHAVIOUR

Sodium perchlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, in some cases without any other ignition source.

An explosion or violent reaction can occur when pure sodium perchlorate comes into contact with acids, ethanol, combustible substances, powdered metals or sulphur.

TOXIC BEHAVIOUR

Sodium perchlorate dust and solutions can have an irritating effect on mucous membranes.

Sodium perchlorate should not be stored in metal or PVC containers.

Sodium perchlorate is slightly hazardous to water supplies.

4.3.4. FURTHER OXIDISERS

BARIUM CARBONATE [$BaCO_3$]

Barium carbonate is industrially used to produce glass and ceramics. It is also used as a chemical compound in bait poisons, for instance rat poison.

Barium carbonate is a colourless-white solid, which can be found as a powder or crystal. Barium carbonate is non hygroscopic. It is soluble in ethanol.

CHEMICAL BEHAVIOUR

Barium carbonate does not burn.

A violent reaction can occur when pure barium carbonate comes into contact with strong acids.

TOXIC BEHAVIOUR

Barium carbonate dust can cause irritation to mucous membranes, functional disorders in the central and peripheral nervous systems, muscle paralysis, gastrointestinal, cardiovascular and pulmonary disorders.

Barium carbonate is slightly hazardous to water supplies.

BARIUM PEROXIDE [BaO_2] OR BARIUM SUPEROXIDE

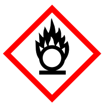


Image 51. Barium peroxide
(source: Bundeswehr CBRN Defence Command ©)

Barium peroxide has two principal applications: as an industrial decolourant or to provide a green flame colour in pyrotechnics.

Barium peroxide is a white, very slightly soluble powder. If the substance is greatly heated, it decomposes to barium oxide. It can be used as both oxidiser and fuel.

CHEMICAL BEHAVIOUR

Barium peroxide itself does not burn but increases the fire hazard when in contact with combustible materials. Barium peroxide may significantly promote an existing fire. There is an explosion hazard when barium peroxide is mixed with flammable substances.

An explosion or violent reaction can occur when pure barium peroxide comes into contact with carbon dioxide, organic substances or powdered metals (aluminium, magnesium). Barium peroxide can cause dust explosions.[37]

TOXIC BEHAVIOUR

Barium peroxide is an irritant to skin and mucous membranes. It can cause gastro-intestinal disorders, muscle and cardiovascular disorders.

Barium peroxide is slightly hazardous to water supplies.

37 See sub-section 4.4.2. *Solid fuels*.

CALCIUM HYPOCHLORITE [$Ca(ClO)_2$] OR C8

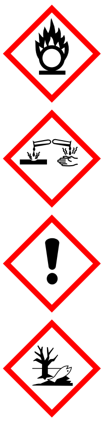


Image 52. Calcium hypochlorite
(source: Bundeswehr CBRN Defence Command ©)

Calcium hypochlorite is used industrially as a bleaching agent, such as in fabrics and paper production. It is also used as a disinfectant for swimming pools. In combination with other substances, it is used for the decontamination of chemical and biological agents.

Calcium hypochlorite is a white, crystalline substance with a strong chlorine odour. It can be found as powder or flat plates / tablets. It is soluble in water.

CHEMICAL BEHAVIOUR

Calcium hypochlorite will decompose when exposed to heat, releasing toxic gases. Calcium hypochlorite itself does not burn but increases fire hazard when in contact with combustible materials. Calcium hypochlorite can significantly promote an existing fire.

An explosion or violent reaction can occur when pure calcium hypochlorite comes into contact with acids, alkali metals, ammonium, nitromethane, organic substances, sulphur, urea or water.

TOXIC BEHAVIOUR

Calcium hypochlorite can cause irritation and has a strong corrosive effect on the eyes, respiratory tract and skin.

Calcium hypochlorite is highly hazardous to water supplies. The leakage of even small quantities into water, sewerage systems or soil must be prevented.

IRON (III) OXIDE [Fe_2O_3] OR OCHRE

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 53. Iron (III) oxide
(source: Bundeswehr CBRN Defence Command ©)

Iron (III) oxide is used as polish for glass and steel, as a colour pigment, on magnetic tapes and in thermite.

Iron (III) oxide is a red-brown, odourless, crystalline powder. Larger crystals are grey-black. It does not dissolve in water and does not burn.

CHEMICAL BEHAVIOUR

An explosion or violent reaction can occur when pure iron (III) oxide comes into contact with hydrogen peroxide, magnesium, powdered aluminium or sodium nitrate.

TOXIC BEHAVIOUR

Iron (III) oxide dust can cause irritation of mucous membranes and the eyes. If orally ingested, it can cause damage to the gastrointestinal tract, liver and cardiovascular system.

Iron (III) oxide is no hazard to water supplies.

POTASSIUM CARBONATE [K_2CO_3] OR POTASH

Image 54. Potassium carbonate
(source: Bundeswehr CBRN Defence Command ©)

Potassium carbonate has a wide variety of uses, for instance in the production of potash glassware, soaps, photographic development, as a leavening agent for baked goods (e.g. gingerbread), as a cleaning agent and to neutralise acids.

Potassium carbonate is a transparent-white powder with no odour. It is hygroscopic, dissolves easily in water and does not burn.

CHEMICAL BEHAVIOUR

An explosive reaction can occur when pure potassium carbonate comes into contact with carbon or powdered calcium.

TOXIC BEHAVIOUR

Potassium carbonate can cause irritation to the eyes, skin and respiratory tract. In an aqueous solution, it becomes strongly alkaline and will cause chemical burns.

Potassium carbonate is slightly hazardous to water supplies.

POTASSIUM PERMANGANATE [$KMnO_4$]

Image 55. Potassium permanganate
(source: Bundeswehr CBRN Defence Command ©)

Potassium permanganate has a wide variety of uses in disinfectants, bleaching agents, the production of saccharin, but also in illegal drug production as it is used to process cocaine. It is listed as an essential medicine by the World Health Organization.

Potassium permanganate is a red-deep purple, crystalline substance with no odour. It dissolves in water, dyeing it purple. Solid crystalline potassium permanganate is more sensitive than its diluted solutions.

CHEMICAL BEHAVIOUR

Potassium permanganate itself does not burn but increases fire hazard when in contact with combustible materials. Potassium permanganate can significantly promote an existing fire.

An explosion or violent reaction can occur when pure potassium permanganate comes into contact with ethanol, ammonium, ammonium nitrate, ammonium perchlorate, combustible substances, concentrated acids, glycerine, hydrochloric acid, hydrogen peroxide, organic substances, phosphorus, sulphur or sulphuric acid.

TOXIC BEHAVIOUR

Potassium permanganate can cause irritation and corrosive effects to mucous membranes. It can cause serious eye damage, leading to corneal opacity.

Potassium permanganate should not be stored in containers made of copper, zinc or brass. Plastics must be tested regarding their resistance to inadvertent reactions, given that some plastics self-ignite when in contact with potassium permanganate.

Potassium permanganate is highly hazardous to water supplies. Leakage of even small quantities into water, sewerage systems or soil must be prevented.

SODIUM SULPHATE [Na_2SO_4]

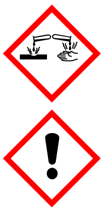


Image 56. Sodium sulphate
(source: Bundeswehr CBRN Defence Command ©)

Sodium sulphate is used to produce glass, sodium silicate or liquid glass, cellulose and pharmaceutical preparations. It is also used in dyeing works to drive the dye into fibre, in washing and rinsing agents.

Sodium sulphate is an odourless, white, crystalline (or powdered) substance. It is hygroscopic and moderately soluble in water and glycerine.

CHEMICAL BEHAVIOUR

Sodium sulphate does not burn.

TOXIC BEHAVIOUR

Sodium sulphate dust and solutions can have an irritating effect on skin and eyes. If aluminium is melted together with sodium or potassium sulphate, a violent reaction or explosion may occur.

Sodium sulphate is slightly hazardous to water supplies.

4.4. FUELS

This sub-section provides an overview of fuels commonly used to manufacture HMEs, and describes their mode of action. Fuels can be solid, liquid or gaseous. Typical fuels found in HMEs contain carbon, hydrogen, nitrogen or chemical compounds including one or more of these chemicals. In addition, inorganic substances and metals are used as fuels as well. Metal fuels are solids but are listed separately in this sub-section due to their specific properties.

CHEMICAL BEHAVIOUR OF FUELS:

- Can be flammable;
- Can significantly increase / promote an existing fire;
- Can increase the risk of fire when in contact with oxidisers, strong acids and metals; and / or
- Can react so violently with oxidisers, strong acids and metals, that they ignite, sometimes without the need for an additional ignition source.

WARNING. Fuel vapours can create an explosive mixture with the surrounding air if heated above their flashpoint. Vapours can be toxic.

WARNING. Some fuels generate vapours that are (slightly) heavier than air and do not disperse in the surrounding atmosphere. Staying grounded, these vapours may travel some distance. If accidentally ignited, they can deflagrate by burning with the surrounding oxygen. Petrol is an example of a fuel with such properties.

FUNCTION OF FUELS (SOLID, LIQUID, GASEOUS) IN DEFLAGRATION AND DETONATION:

When a suitable external stimulus is applied, an oxidiser starts to decompose. It splits up at the molecular level and releases its oxygen in a gaseous state. In this dissociation process, energy is also liberated, in the form of heat. The liberation of gaseous oxygen increases pressure within the decomposition reaction, accelerating it and, therefore, leading to greater gas generation per unit of time. As a result, pressure and heat generation increase continuously. This effect promotes further decomposition.

Under the influence of heat, the gaseous oxygen reacts (oxidises) with the fuel and an oxidation-reduction reaction ensues. With the generation of further heat, the oxidation process forms further gaseous chemical substances with the fuel, such as carbon dioxide CO_2 (reaction: carbon and oxygen), sulphur dioxide SO_2 (reaction: sulphur and oxygen) and carbon monoxide CO (reaction: carbon and oxygen). The formation of each of these gases releases additional energy and increases the pressure of the reaction further, until the available oxygen is used up.

EXAMPLE: THERMAL EXPANSION

When an explosive detonates, the volume of gas (gas yield) produced provides information about the amount of work that an explosive can perform on its surroundings, such as lift, heave or shatter. To define an explosive's brisance, the gas yield is one of the main parameters, together with the heat of explosion, detonation velocity and loading density.

Under standard temperature and pressure, one mole[38] of gas produced will occupy the same volume, regardless of its chemical formula. For example, one mole of RDX will produce 3 moles of carbon monoxide (CO), 3 moles of water (H_2O) and 3 moles of nitrogen (N_2), equating to 9 moles of gas. These 9 moles of gas correspond to 908 litres (l) of gas per kg of RDX. This gas yield will undergo expansion in milliseconds, expanded and accelerated by the influence of the other parameters (such as heat of explosion) ensuring an explosive's destructive work.

Amount of gas produced per 1 kg for various explosives:

1 kg of RDX generates 908 l of gas
1 kg of TNT generates 740 l of gas[39]
1 kg of ammonium nitrate generates 980 l of gas[40]
1 kg of HMTD generates 1097 l of gas[41]
1 kg of ammonium nitrate–icing sugar generates 1001 l of gas[42]
1 kg of lead azide generates 231 l of gas[43]

38 One mole of a chemical compound corresponds to its relative molecular weight in grammes (g). 1 mole of a chemical compound contains about 6.022 x 10^{23} of its atoms / molecules. 1 mole of hydrogen H_2 = 2 g hydrogen H_2, 1 mole of chloride Cl_2 = 71 g chloride Cl_2, 1 mole of ammonium nitrate NH_4NO_3 = 80 gr ammonium nitrate NH_4NO_3.

39 Rudolf Meyer, Josef Köhler and Axel Homburg, *Explosives*. Sixth Edition. (Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, 2007).

40 Meyer et al., *Explosives*.

41 M.A. Ilyushin, I.V. Tselinskii and A.M. Sudarikov, *Development of components for high-energy compositions.* (SPB: LGU im. A. S. Pushkina – SPBGTI(TU), Saint Petersburg, 2006).

42 G.P. Collett, *Home-Made Explosives, A Comprehensive Guide* (UK Ministry of Defence, 2020).

43 J.N. Danilov, M.A. Ilyushin and I.V. Tselinskii *Industrial Explosives Part 1. Initiating explosives* (Saint-Petersburg State Institute of Technology, Saint-Peterburg, 2001).

4.4.1. LIQUID FUELS

Liquid fuels can cause fuel-air explosions. A fuel-air explosion differs from one created by a conventional explosive in that the fuel elements do not carry their own oxygen. For a fuel-air explosion to occur, fuel vapour must be mixed with ambient atmospheric air and when mixing is complete, be initiated by an ignition source. Each type of fuel has a specific lower explosive limit (the minimum ratio of fuel vapour to air below which ignition will not occur – LEL) and an upper explosive limit (the maximum ratio of fuel vapour to air above which ignition will not occur – UEL). For example: nitrobenzene has an LEL of 2% and a UEL of 9%; nitromethane has a 7.3% LEL and 22.2% UEL; hexane a 1.2% LEL and 7.4% UEL (similar to gasoline vapour); and ethylene diamine a 4.2% LEL and a 14.4% UEL.

WARNING. Caution must be applied when dealing with combustible liquid fuels. Combustible liquid fuels can cause fuel-air explosions either by themselves or when they are part of an HME that has been manufactured or stored in a condition where its vapours can mix with the air.

NOTE. A fuel-air explosion can generate sufficient detonation pressure to initiate other explosive compositions in close proximity. This is particularly important when considering fuel-air explosions that may occur in the presence of HME compositions.

AMMONIA [NH_3] OR AZANE, SPIRIT OF HARTSHORN

Image 57. 30% ammonia
(source: Bundeswehr CBRN Defence Command ©)

Ammonia is used as a synthesiser for industrially produced nitrogen-containing products such as fertilisers, explosives and dyes. When pure, it is also used in fertiliser products and cooling aggregates.

Ammonia is a colourless gas which liquefies easily under pressure. It has a pungent, suffocating odour, similar to stale urine. Ammonia dissolves in water and ethanol.

TOXIC BEHAVIOUR

Ammonia can have a strongly irritating / corrosive effect on the eyes, respiratory tract and skin. Contact with the substance may cause severe damage to the eyes, skin and respiratory tract.

Ammonia is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented. Under atmospheric pressure, artificially liquified ammonia will turn gaseous again.

ANILINE [$C_6H_5NH_2$] OR AMINO BENZENE

Image 58. Aniline
(source: Bundeswehr CBRN Defence Command ©)

Aniline is used in the chemical industry and for creating liquid rocket fuels. It is also used with nitromethane in mine clearance applications as liquid explosive in pipes.[44]

Aniline is a colourless, oily liquid that quickly turns brown when exposed to sunlight. It has a slightly sweet amine[45]-like (old fish-like) smell. It dissolves in water and liquid ammonia.

TOXIC BEHAVIOUR

Aniline is a serious blood and nerve toxin leading to disturbance of blood function (methaemoglobin formation) and disturbance of the central nervous system. It can irritate the eyes and mucous membranes.

Suitable fire-extinguishing agents for aniline are water (spray jet), dry extinguishing powder or carbon dioxide. Larger fires should be fought with alcohol-resistant foam or water spray.

Aniline is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

44 Laurence, Edgar A. Stabilized explosive containing nitromethane and amine. US Patent 3239395A filed July 18, 1945, issued March 8, 1966.
45 Amines are explained under ethylene diamine in sub-section 4.4.1.

BENZENE [C_6H_6] OR BENZOL

Image 59. Benzene
(source: Bundeswehr CBRN Defence Command ©)

Benzene is important for the petrochemical industry. It is used in engine fuels, and products from further processing are used to produce paints, plastics, aniline, pesticides, and acetone.

Benzene is a colourless, characteristically aromatic smelling liquid which burns with a strong sooty flame. It is lighter than water and very volatile.

TOXIC BEHAVIOUR

Benzene is carcinogenic and its vapours are toxic. It has a slightly irritant effect on mucous membranes and skin and can lead to central nervous system disorders.

Benzene can be stored in glass or stainless steel. The resistance of plastics must be checked before use.

Suitable extinguishing agents are dry powder, carbon dioxide or alcohol-resistant foam.

Benzene is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

BRAKE FLUID

Image 60. Brake fluid
(source: Bundeswehr CBRN Defence Command ©)

Brake fluid is a hydraulic fluid used for braking systems in vehicles. Common brake fluids used as fuel are compositions of polyglycol compounds. Amongst other things, polyglycols are used as cooling and antifreeze agents.

Brake fluid is a viscous, odourless, colourless-yellow liquid. It is hygroscopic and dissolves in water. Colour can be added by the manufacturer.

TOXIC BEHAVIOUR

If absorbed, brake fluid is toxic and irritates skin and eyes.

Suitable extinguishing agents are water (spray jet), dry powder, carbon dioxide or alcohol-resistant foam.

Brake fluid is hazardous to water supplies.

ETHANOL [C_2H_5OH] OR ETHYL ALCOHOL

Image 61. Ethanol
(source: Bundeswehr CBRN Defence Command ©)

Ethanol of agricultural origin is produced for human consumption. Artificially derived ethanol is used for detergents, paints, cosmetics or biofuels.

Ethanol is a colourless liquid with a weak, sweet, wine-like odour. Pure or concentrated ethanol has a burning taste. It is hygroscopic and soluble in water. Ethanol is highly volatile.

TOXIC BEHAVIOUR

Ethanol has a mildly irritating effect on mucous membranes and skin. It can lead to neurotoxic problems, cardiovascular disorders, metabolic changes and kidney damage.

Suitable extinguishing agents are water (spray jet), dry powder, carbon dioxide or alcohol-resistant foam.

Ethanol is slightly hazardous to water supplies.

ETHYLENE DIAMINE [$C_2H_8N_2$]

Image 62. Ethylene diamine
(source: Bundeswehr CBRN Defence Command ©)

Heavy duty hardeners are used in two-part epoxy resin glue. Hardeners are made of amines, organic compounds and derivatives of ammonia. Ethylene diamine is a commonly used component.

Ethylene diamine is a colourless liquid with an odour of ammonia. It is hygroscopic and dissolves in water. It is moderately volatile. Aqueous solutions, that is to say ethylene diamine mixed with water, are caustic.

TOXIC BEHAVIOUR

Ethylene diamine can cause serious irritation and have a corrosive effect on skin, mucous membranes and respiratory tract.

Ethylene diamine should not be stored in containers made of aluminium or copper, magnesium zinc and their alloys.

Suitable extinguishing agents are water (spray jet), dry powder, carbon dioxide or alcohol-resistant foam.

Ethylene diamine is slightly hazardous to water supplies.

FUEL OIL [75 % $C_{10}H_{20}$ - $C_{15}H_{28}$ AND 25% AROMATIC HYDROCARBONS] SUCH AS HEATING OIL, DIESEL

Image 63. Fuel oil
(source: Bundeswehr CBRN Defence Command ©)

Fuel oil is a mixture of various hydrocarbons, with a boiling point of between 230°C and 350°C. It is used in different mixtures for heating systems and diesel engines.

Fuel oil is a colourless-yellow, oily, viscous liquid with the characteristic odour of hydrocarbons. It is lighter than water and does not dissolve in it. The addition of components with a lower boiling point can significantly reduce the flashpoint of the mixture. Heated fuel oil can ignite without an external ignition source.

TOXIC BEHAVIOUR

Fuel oil can have a severe drying and irritating effect on skin. It causes lung damage through inhalation of higher concentrated aerosols and can cause central nervous system problems.

Suitable extinguishing agents are dry powder, carbon dioxide or sand. Larger fires should be fought with foam or water spray jets.

Fuel oil is highly hazardous to water supplies even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

GLYCERINE [$C_3H_8O_3$] OR GLYCEROL, GLYCYL ALCOHOL, GLYCOL

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 64. Glycerine
(source: Bundeswehr CBRN Defence Command ©)

Glycerine is used to produce explosives like nitroglycerine (NG), synthetic resins and as an intermediate product for pharmaceutical products. It is used in skin care products like soaps, as well as antifreeze, hydraulic fluids and plasticisers.

Glycerine is a viscous, colourless and odourless liquid. It is hygroscopic and soluble in water and ethanol. It has a slightly sweet taste.

TOXIC BEHAVIOUR

Glycerine can cause skin and eye irritation.

Suitable extinguishing agents are water (spray jet), dry powder, carbon dioxide or alcohol-resistant foam.

Glycerine is slightly hazardous to water supplies.

HEXANE [C_6H_{14}] OR ESANI, SKELLYSOLVE B


Image 65. Hexane
(source: Bundeswehr CBRN Defence Command ©)

Hexane is used as a solvent and thinner for fast-drying paints, printing inks and adhesives.

Hexane is a colourless, volatile liquid that is easily ignitable and smells like petrol. Hexane does not dissolve in water and is lighter than water.

TOXIC BEHAVIOUR

Hexane can have an irritating effect on the eyes and upper respiratory tract. It can lead to severe drying and irritation of skin, as well as to central nervous system disorders.

Suitable extinguishing agents are dry powder or carbon dioxide.

Hexane is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

JET FUEL OR JET A-1, TS-1, JP-1, JP-5, JP-9, JP-10, COLLOQUIAL: KEROSENE

Image 66. Jet fuel
(source: Bundeswehr CBRN Defence Command ©)

Jet fuels are petroleum products mainly used in diesel fuels and aircraft engines. They are a mixture of various hydrocarbons such as alkanes, cycloalkanes, aromatics and olefins.

Kerosene is a colourless-yellowish, oily liquid with a typical petroleum-like odour. It does not dissolve in water and it is lighter than water.

TOXIC BEHAVIOUR

Kerosene can cause a severe drying and irritating effect on skin and eyes. Inhalation of highly concentrated aerosols can cause lung damage.

Suitable extinguishing agents are water (spray jet), dry powder, carbon dioxide or foam.

Kerosene is significantly hazardous to water supplies.

METHYL ETHYL KETONE (MEK) [C_4H_8O] OR BUTANONE

Image 67. Butanone
(source: Bundeswehr CBRN Defence Command ©)

Butanone is used as a solvent for paints and resins (such as fibreglass), as a degreasing agent, and as a sterilising agent for medical instruments.

Butanone is a colourless, extremely flammable liquid with an acetone-like smell. It easily dissolves in water, is very volatile and evaporates quickly.

TOXIC BEHAVIOUR

Butanone can cause irritation to skin, eyes, respiratory tract and the central nervous system (drowsiness and dizziness).

Suitable extinguishing agents are water (spray jet), dry powder, carbon dioxide or alcohol-resistant foam.

Butanone is slightly hazardous to water supplies.

NITROBENZENE [$C_6H_5NO_2$] OR NITRO BENZOL, BENZENE, OIL OF MIRBANE

Image 68. Nitrobenzene
(source: Bundeswehr CBRN Defence Command ©)

Nitrobenzene is used by the chemical industry when producing various chemicals, such as aniline or trinitrobenzene. It is used in solvents, as an additive in lubricating oils and explosives, and was used as cheap perfume for curd soaps.

Nitrobenzene is a colourless-yellow, sweet-tasting flammable liquid that smells slightly of bitter almonds or marzipan. It is heavier than water and hardly soluble in water.

TOXIC BEHAVIOUR

Nitrobenzene can cause a disturbance of blood function (methaemoglobin formation) and of the central nervous system, which is followed by blood and liver damage.

Suitable extinguishing agents are dry powder or carbon dioxide.

Nitrobenzene is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

NITROMETHANE [CH_3NO_2]

Image 69. Nitromethane
(source: Bundeswehr CBRN Defence Command ©)

Nitromethane is used in the production of rocket fuels, explosives, insecticides and as an additive for petrol. In the private sector, nitromethane is mostly used as a fuel for combustion engines in model making. Nitromethane is sold in different qualities and concentrations. Hobby-grade nitromethane used as model engine fuel has a concentration of less than 40% and is mixed with other agents such as oil, lubricants, dyes and methanol. Racing fuel-grade nitromethane is generally close to 100%. It is desensitised with methanol to prevent engine detonation.

Nitromethane is a colourless, oily liquid with an aromatic, fruity smell. It is hygroscopic, easily soluble in water and very volatile.

TOXIC BEHAVIOUR

Nitromethane can cause slight irritations of skin and mucous membranes. Higher concentrations can lead to irritations of the respiratory tract and to central nervous system problems.

Containers made of plastic must be tested to check their resistance prior to use.

Suitable extinguishing agents are water (spray jet), alcohol-resistant foam, dry extinguishing powder and carbon dioxide.

Nitromethane is significantly hazardous to water supplies.

PETROLEUM JELLY [PRIMARY $C_{15}H_{15}N$] OR VASELINE® (UNILEVER BRAND NAME)

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 70. Petroleum jelly
(source: Bundeswehr CBRN Defence Command ©)

Vaseline is used in many applications, such as skin ointments, shoe polish, lubricants and leather grease.

Vaseline is a white-light yellow, soft, transparent, ointment-like mixture of aliphatic (non- aromatic) hydrocarbons. It is odourless and tasteless. It does not dissolve in water.

TOXIC BEHAVIOUR

No significant effect.

Vaseline is not hazardous to water supplies.

4.4.2. SOLID FUELS

Solid fuels can generate fine, dispersed dust. Some organic dusts and a variety of metal dusts are flammable and explosive. Deposited dust usually tends to burn, glimmer or smoulder after ignition. Dust suspended and mixed with oxygen in the air can react explosively above a given level of concentration which is known as the lower explosive limit. In general, contact or inhalation of such dust or powders may cause irritation to the eyes, nose, throat and lungs.

NOTE. A dust explosion is the explosion of a suspended mass of very fine combustible dust particles mixed with ambient atmospheric air, which can be triggered by sparks, electrostatic discharge or flames. Such triggers will cause almost any finely powdered organic material to ignite below 500°C.[46] The substance must be in a very finely dispersed form (powder, dust) and be stirred up in the air in sufficient quantities. A sudden explosion can occur because of the high amount of atmospheric oxygen that can react with the large area of surface of the dust particles.

WARNING. As storage and manufacturing areas of HMEs are not subject to safety regulations, MA organisations encountering such infrastructures must be aware of the hazards of dust explosions.

ALUMINIUM SULPHATE [$Al_2(SO_4)_3$]

Aluminium sulphate is used for water purification, foam extinguishing agents and the stain / dye industries.

Aluminium sulphate is a colourless-white, odourless, crystalline solid. It can be found as pellets, crystals, powder or granules. Aluminium sulphate dissolves in water, is not flammable and does not cause dust explosions.

TOXIC BEHAVIOUR

Aluminium sulphate particles can have a strongly irritant effect on mucous membranes, such as in the eyes.

Aluminium sulphate is slightly hazardous to water supplies.

[46] W.E. Baker and M.J. Tang, *Gas, Dust and Hybrid Explosions* (Elsevier Science, 1991).

AMMONIUM SULPHATE [$(NH_4)_2SO_4$]

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 71. Ammonium sulphate
(source: Bundeswehr CBRN Defence Command ©)

Ammonium sulphate is a fertiliser salt produced in large quantities. It is also used in the production of foam extinguishing agents and in the stain / dye industries.

Ammonium sulphate is a colourless, odourless, crystalline solid. It can be found as pellets, crystals, powder or granules. Ammonium sulphate is slightly hygroscopic and dissolves in water. It is not flammable but will become unstable and decompose when exposed to temperatures higher than 235°C.

TOXIC BEHAVIOUR

Ammonium sulphate particles may have an irritant effect on mucous membranes, such as in the eyes. The effects, however, are not documented.

Ammonium sulphate is slightly hazardous to water supplies.

BORON [B]

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet. Boron is used in alloys, pyrotechnics, propellants and in applications needing high stability against physical force, such as in tennis rackets, for example.

Boron forms very hard, grey-black, shiny crystals. Amorphous boron is a brown, odourless powder. It burns in the air with a strong green flame. Boron's reactivity increases with temperature, while its stability decreases. It does not dissolve in water.

TOXIC BEHAVIOUR

Not documented.

Suitable extinguishing agents are dry sand or metal fire extinguishers, unsuitable ones are water and foam.

Boron poses no hazard to water supplies.

CHARCOAL (UP TO 90% CARBON)

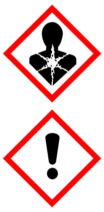


Image 72. Finely ground charcoal
(source: Bundeswehr CBRN Defence Command ©)

Charcoal is used in filters, cleaning agents, disinfectants, medical products, propellants, pyrotechnics and as fuel.

Charcoal is a black, odourless, inorganic carbon compound. It does not dissolve in water. Charcoal is flammable and can burn without creating a flame. It can contribute to dust explosions.

TOXIC BEHAVIOUR

Carbon powder and dust can have an irritating effect on mucous membranes.

Charcoal poses no hazard to water supplies.

COFFEE (SUCROSE & POLYSACCHARIDE)

This organic matter does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 73. Coffee
(source: Bundeswehr CBRN Defence Command ©)

Coffee is extracted from the coffee bean and is a stimulant to the central nervous system.

Ground coffee is a brown to dark brown powder with a sweet-smelling, characteristic odour. It can be used as a component for fuel. Usually, a metal fuel is added to the mixture.

TOXIC BEHAVIOUR

Coffee powders and dust can have an irritating effect on mucous membranes.

Coffee poses no hazard to water supplies.

DEXTRIN $[(C_6H_{10}O_5)_n]$[47]

This organic matter does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 74. Dextrin
(source: Bundeswehr CBRN Defence Command ©)

Dextrin is used in fur glues, food processing, pharmaceutical products, as a pyrotechnic stabiliser, as a binder and a fuel.

Dextrin is a white-yellowish, odourless powder carbohydrate. It is flammable, hard to ignite and dissolves in water.

TOXIC BEHAVIOUR

Not documented.

Dextrin's potential hazard to water supplies is not documented.

47 Dextrin creates chains, meaning the molecules are added, because of this n = 1, 2, 3,….,n+1.

NAPHTHALENE [$C_{10}H_8$] OR CAMPHOR TAR

Image 75. Naphthalene
(source: Bundeswehr CBRN Defence Command ©)

Naphthalene is used to produce colours (dyes), fuels, solvents and pesticides (mothballs).

Naphthalene is a colourless-white, intense-smelling, crystalline, solid hydrocarbon, presenting a tar / mothball smell. Naphthalene can be found as flakes, powder, prills or balls. It does not dissolve in water but can evaporate at room temperature.

TOXIC BEHAVIOUR

Naphthalene can cause weak irritant effects on mucous membranes and skin. It can lead to central nervous system disorders and damage to red blood cells.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder, foam and carbon dioxide.

Naphthalene is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

PARAFFIN [C_nH_{2n+2}] OR WAX, BABY OIL

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 76. Paraffin
(source: Bundeswehr CBRN Defence Command ©)

Paraffin is used in cosmetics, pharmaceutical products, impregnation agents, propellant components and candles.

Paraffin is a white-yellowish, odourless, tasteless, waxy hydrocarbon. It can be found as powder, granules, lumps, oils, liquids. It does not dissolve in water.

TOXIC BEHAVIOUR

Under normal conditions, paraffin poses no threat to health.

Paraffin presents no hazard to water supplies.

SAWDUST

This organic matter does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 77. Sawdust
(source: Bundeswehr CBRN Defence Command ©)

Sawdust is used as insulation, to produce board, as fuel, and has been used as an additive in explosives.

Sawdust can be found as a fine powder, flakes or dust, whose colour and odour depend on the kind of wood used. Fine sawdust can contribute to a dust explosion.

TOXIC BEHAVIOUR

No toxic behaviour has been documented. Inhalation of dust or powder may cause irritation to the eyes, nose, throat and lungs.

No hazards to water supply are documented.

SORBITOL [$C_6H_{14}O_6$] OR GLUCITOL, D-SORBIT

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 78. Bag of sorbitol (source: CAR ©)

Sorbitol is used as a food sweetener and as a carrier for humectants in food production.

Sorbitol is a sweet-tasting, odourless, transparent-whiteish solid. It is easily soluble in water and is hygroscopic. Sorbitol can contribute to a dust explosion.

TOXIC BEHAVIOUR

Under normal conditions, sorbitol poses no threat to health. In case of intolerance, sorbitol intake may cause gastrointestinal problems.

No available research has yet been conducted on sorbitol's water-polluting effect. As a precaution, penetration into subsoil and water supplies must be prevented.

SUCROSE [$C_{12}H_{22}O_{11}$] OR SUGAR

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 79. Loose sucrose crystals
(source: Bundeswehr CBRN Defence Command ©)

Image 80. Sucrose in lump form
(source: Bundeswehr CBRN Defence Command ©)

Sucrose is used as food and as a food additive, as well as in the production of alcohols, glycerines, explosives and fuels.

Image 81. Bag of sugar (sucrose) (source: CAR ©)

Sucrose is a white, crystalline carbohydrate. It is odourless with a sweet taste. Sucrose dissolves in water and ethanol. Sucrose can contribute to a dust explosion.

TOXIC BEHAVIOUR

Not documented.

In large amounts, sucrose is slightly hazardous to water supplies.

4.4.3. METALLIC FUELS

Most metals used for HMEs are self-igniting (pyrophoric) solids.

NOTE. Pyrophoric solids – finely dispersed, fine metallic powders and dust that can heat up in the air, reacting with oxygen and ignite at room temperature without external stimuli. Ignition sensitivity depends, inter alia, on particle size and distribution. The finer the particle, the larger the surface area and the greater the pyrophoricity.

As storage and manufacturing areas of HMEs are not subject to industrial hygiene standards, MA staff encountering such infrastructures must be aware of the hazard of a fuel-air explosion involving metals.

Grinders, food blenders, rock tumblers, and so forth, are used to produce the required fine particles. MA staff encountering any of these devices must be aware that opening may lead to a spontaneous reaction when the fine metal particles come into contact and mix with the inflowing atmospheric oxygen.

Contact with or inhalation of dust or powders may cause irritation to the eyes, nose, throat and lungs.

WARNING. Fine metal powders can react spontaneously and violently when exposed abruptly to atmospheric oxygen.

WARNING. The powder and dust of the metals listed may form flammable gases when they encounter water.

WARNING. Metal powder and dust are sensitive to static discharge and should not be handled without prior earthing procedures.

PURPOSE OF METALS ACTING AS FUELS IN AN ENERGETIC REACTION

Metal fuels reacting with an oxidiser in an energetic reaction produce heat (often more than 2000°C) and a solid metal oxide. For example, aluminium powder's reaction with an oxidiser will produce aluminium oxide (Al_2O_3); magnesium powder's reaction with an oxidiser will produce magnesium oxide (MgO). Unlike other fuels, metal fuels do not contribute to an increase in gas volume during an explosive decomposition but to an increase of the heat of an explosion. The added temperature contributes to a very large thermal expansion of other gaseous products. This accelerated expansion increases the pressure within the reaction. The addition of metals also leads to an increased incendiary effect.

ALUMINIUM [Al]

Image 82. Aluminium
(source: Bundeswehr CBRN Defence Command ©)

Aluminium has a wide range of uses, including in vehicle and aircraft production, in the construction industry, civil and electrical engineering, in the manufacture of everyday objects and food-safe packaging, including foils. Powdered aluminium is needed to produce metallic paints and is also used to manufacture pyrotechnics, thermites, fireworks and explosives.

Aluminium is a silvery-white, shiny, ductile, solid metal. It can be found as a solid, as a flake and as a powder. Its shine fades quickly when exposed to air, due to the formation of aluminium oxide on the surface.

CHEMICAL BEHAVIOUR

Aluminium powder can heat up at room temperature in air without added energy input and finally ignite. Its ignitability depends, among other things, particularly on particle size and degree of distribution. On contact with water, aluminium powder forms flammable gases.

Suitable extinguishing agents for aluminium powder are dry sand or fire extinguishers for metals. Unsuitable extinguishing agents are water, dry powder, foam and carbon dioxide.

No available research has yet been made regarding aluminium's water-polluting effect. Penetration into subsoil and water supplies must be prevented.

Image 83. Aluminium (partially powdered) (source: FSD ©)

Image 84. Drum of aluminium paste (source: CAR ©)

ELECTRON [Mg/Al]

Electron is the technical designation for a magnesium aluminium alloy with 86% magnesium and 14% aluminium. It is made as a solid but can be ground into powder. It was used for the construction of incendiary bombs because of its strong exothermic decomposition. Electron burns to produce temperatures of more than 2200°C, emitting a high intensity flame that can be blinding.

MAGNALIUM [Al/Mg]

Magnalium is the technical designation of an aluminium–magnesium alloy with 2%–5% magnesium and small amounts of other elements such as iron or chrome. It is used as a component of car and plane parts, metal implements and solid metal casings / frames. Powdered magnalium is also used as fuel in pyrotechnics, burning up to high temperatures (as aluminium and magnesium do on their own) and forming yellowish white sparks.

Magnalium is a greyish-white, hard alloy. It can be found as a solid or as a powder. Its strength and resistance to corrosion depend on the aluminium–magnesium ratio.

No available research has yet been made regarding magnalium's water-polluting effects. As a precaution, penetration into subsoil and water supplies must be prevented.

MAGNESIUM [Mg]

Image 85. Magnesium
(source: Bundeswehr CBRN Defence Command ©)

Magnesium is used in the electrical and in the metal processing industries. Because of its energetic properties, it is used as a fire starter and as a component of incendiary ammunition and pyrotechnics (for flares burning in an environment lacking gaseous oxygen, such as under water, for instance). Magnesium alloys are used in products that benefit from being lightweight, such as car seats, casings or housing products such as cameras and power tools.

Magnesium is a silver-white, shiny, ductile, solid metal. It can be found as a solid, pressed and as cuttings. Magnesium burns with a very strong, UV-rich, white light.

CHEMICAL BEHAVIOUR

Magnesium powder can heat up at room temperature in air without added energy input and finally ignite. The ignitability depends, in particular, on particle size and degree of distribution. The substance forms flammable gases on contact with water.

Suitable extinguishing agents for magnesium powder are dry sand or fire extinguishers for metals. Unsuitable extinguishing agents are water, dry powder, foam and carbon dioxide.

No available research has yet been made regarding magnesium’s water-polluting effects. As a precaution, penetration into subsoil and water supplies must be prevented.

SODIUM [Na]

Image 86. Sodium
(source: Bundeswehr CBRN Defence Command ©)

Metallic sodium is used to produce sodium compounds. It is strongly hygroscopic and serves as a drying agent for several applications. Sodium serves as a reducing agent in metallurgy.

Sodium is a silver-white, shiny, waxy metal that is so soft that it can be cut with a knife. Usually, it is covered with a grey-brown crust (sodium hydroxide and sodium carbonate), which protects the sodium underneath. In the air, sodium burns with a yellow flame.

CHEMICAL BEHAVIOUR

Sodium is a flammable substance but difficult to ignite. In contact with water, it forms flammable gases that may ignite spontaneously. Sodium is not volatile.

Suitable extinguishing agents are dry sand, dry cement or fire extinguishers for metals. Unsuitable extinguishing agents are water and carbon dioxide.

Sodium is slightly hazardous to water supplies.

ZINC [Zn]

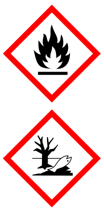


Image 87. Zinc
(source: Bundeswehr CBRN Defence Command ©)

Zinc is used to increase the corrosion resistance of metals, for construction materials and day-to-day objects, in batteries and in the chemical industry. Zinc and zinc compounds are used in pyrotechnics when low combustion temperatures and an easy ignition are desired. Pyrotechnic applications of zinc and zinc compounds are hexachloroethane smokes.

Zinc is a bluish-white metal. In the air it slowly forms 'white rust' (zinc hydroxide carbonate), which protects the zinc underneath. It can be found as a powder. Zinc burns with a green flame.

CHEMICAL BEHAVIOUR

Zinc powder can heat up at room temperature in air without added energy input and finally ignite. The ignitability depends, in particular, on the particle size and degree of distribution. The substance forms flammable gases on contact with water.

WARNING. Humidity increases zinc dust's potential for auto-ignition.

Suitable extinguishing agents for zinc powder are dry sand, clay, sodium hydrogen carbonate and, in exceptional cases (nothing else available), fire extinguishers for metals. Water must not be used as an extinguishing agent.

Zinc powder is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

4.5. ADDITIVES AND CATALYSTS

This sub-section presents substances and components used in the manufacturing of HME that are not acids, fuels or oxidisers or that are to be highlighted because of their significant impact on HME's sensitivity and stability.

4.5.1. SENSITISERS AND TINDER[48]

Sensitisers increase an HME's sensitivity to initiation by flame, spark, heat, shock, friction, etc.

Tinder lowers the ignition temperature of a low explosive.

Chemical sensitisers / tinder are substances or compounds which include amines, red phosphorus, sulphur, metal powders, finely ground glass or grit. A physical sensitiser, such as air voids between explosive crystals, sensitises an explosive mixture without the need for a chemical additive (referring to hotspot ignition).

In general, sensitisers and tinder may also be used as fuels.

WARNING. If an HME which could contain added sensitisers or tinder is encountered, risk mitigation and render safe procedures should be reviewed and adapted to address hazards resulting from its increased sensitivity and / or lowered ignition temperature.

PHOSPHORUS [P] – WHITE PHOSPHORUS AND RED PHOSPHORUS

Phosphorus is used to produce pesticides, fertilisers, matches, flame retardants, smoke-producing pyrotechnics and incendiary ammunition.

WHITE OR YELLOW PHOSPHORUS

Image 88. White phosphorus
(source: Bundeswehr CBRN Defence Command ©)

[48] Tinder: very flammable substance adaptable for use as kindling.

White phosphorus is a white-yellowish, crystal solid with a consistency comparable to wax. It darkens when exposed to light. White phosphorus has a garlic-like odour (as do some phosphorus compounds) and does not dissolve in water. It emits a greenish light (visible in the dark) and white smoke when exposed to air. White phosphorus reacts violently with oxidising agents.

CHEMICAL BEHAVIOUR

White phosphorus is self-igniting on contact with air and sensitive to heat, friction and impact. White phosphorus can heat up independently and will ignite at room temperature in air without any additional energy supply. The ignition temperature in dry air is higher than in moist air (30°C). Its ignition readiness depends, among other things, on the grain size and degree of distribution. White phosphorus burns with a glowing flame.

Ignited phosphorus will not stop burning until it is either completely oxidised or isolated from oxygen in the air. It will burn skin, flesh and tissue and create deep, severe, slow-healing wounds.

TOXIC BEHAVIOUR

White phosphorus can lead to local damage of mucous membranes and skin by destroying tissue (necrosis). It can cause gastrointestinal disorders, liver damage with severe metabolic disorders and damage to heart and kidneys. The smoke of burnt white phosphorus acts as an irritant to the eyes, mucous membranes, skin and respiratory tract / lungs.

Suitable extinguishing agents are water (spray jet) and damp sand. An unsuitable extinguishing agent is carbon dioxide. If possible, burning white phosphorus should be soaked and covered with water or damp sand. Before disposal, residues may have to be subjected to chemical treatment to prevent self-reignition.

WARNING. White phosphorus cannot be permanently extinguished with water; other measures that cut it off from oxygen must be taken, otherwise it will reignite in the air as soon as the water has evaporated.

NOTE. Among possible phosphorus modifications, white phosphorus is the easiest to produce as well as the most toxic and unstable. Both modifications, red and white, will significantly increase an HME's sensitivity.

White phosphorus is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

WARNING. White or yellow phosphorus reacts in humid air by heating and forming hydrogen phosphide (phosphine) and phosphoric acid, accompanied by a garlic odour. These vapours are extremely damaging if inhaled.

RED PHOSPHORUS

Image 89. Red phosphorus
(source: Bundeswehr CBRN Defence Command ©)

Red phosphorus is a deep red-purplish powder. This artificial modification of phosphorus is flammable, odourless and does not dissolve in water.

CHEMICAL BEHAVIOUR

Red phosphorus can be easily ignited by brief exposure to an ignition source and continues to burn after removal from that source. It is considered a dangerous fire hazard. The finer the substance, the greater the risk of ignition, including the hazard of a dust explosion. Although red phosphorus is not self-igniting in air, a low energy impact, friction or electrostatic discharge can cause ignition.

TOXIC BEHAVIOUR

Red phosphorus is considered non-toxic. However, the evaporation of red phosphorus in a fuel-oxidiser mixture results in an extremely toxic vapour. Toxic fumes are also emitted when the red phosphorus is heated. The smoke of burnt red phosphorus vapour is not toxic in small amounts but can act as an irritant to the eyes, skin and respiratory tract.

Suitable extinguishers for small fires are water (spray jet), wet sand or wet fire blankets. Larger fires can be fought with water spray. Unsuitable extinguishing agents are dry extinguishing powder and carbon dioxide.

Red phosphorus is slightly hazardous to water supplies.

WARNING. Red phosphorus reacts in humid air by heating and forming hydrogen phosphide (phosphine) and phosphoric acid, accompanied by a garlic odour. These vapours are extremely damaging if inhaled.

SULPHUR [S] OR BRIMSTONE

Image 90. Sulphur
(source: Bundeswehr CBRN Defence Command ©)

Sulphur is used to produce sulphuric acid, sulphate-based fertilisers, and dyes in the pharmaceutical industry, and as a fuel in pyrotechnics and propellants.

Sulphur is a stable, yellow-pale yellow, solid substance. It can be found as powder or as brittle crystals.

CHEMICAL BEHAVIOUR

Sulphur does not dissolve in water but is soluble in benzene, aniline, tetrachloride and liquid ammonia. Sulphur as a solid is hardly flammable but, once melted, it is easy to ignite. If exposed to heat, it burns in the air with a blue flame.

WARNING. When mixed with HME, sulphur can lower the ignition temperature to less than 200°C, making some HME extremely susceptible to flame and, given sulphur's crystallinity, it also lowers impact sensitivity. For sensitive and less stable HMEs that are contaminated with sulphur, transport-induced friction can lead to spontaneous decomposition. Appropriate disposal methods need to be considered in case of suspected sulphur contamination.

TOXIC BEHAVIOUR

Sulphur can cause irritation to the eyes as well as irritation and inflammatory changes to the mucous membranes of the respiratory tract.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder, foam and carbon dioxide.

Sulphur is slightly hazardous to water supplies.

4.5.2. CATALYSTS, REACTANTS, BINDERS AND PHLEGMATISERS

Catalysts and reactants are used in the production of HMEs.

Catalysts are used to increase the rate of a chemical reaction and thereby cause the chemical equilibrium to be established more quickly. They are not consumed in the process.

Reactants are substances participating in the chemical reaction. A reactant will change on a molecular level. Nearly all acids act as reactants.

Binders are used to hold together and improve the homogeneity of explosive mixtures. Binders can increase the resistance to mechanical impacts, such as that experienced by propellant grains in storage and transport. A break in the propellant grain would alter the burning rate with potentially catastrophic results, so the binder minimises the chances of this occurring. Typical binders are asphalts, plastics or resins.

Phlegmatisers are used to decrease an explosive's susceptibility to friction and impact or moderate cap sensitivity and detonation velocity. They desensitise an explosive. Phlegmatisers can be waxes, which lubricate the explosive crystals and act as a binder as well.

NOTE. Phlegmatisation and dilution decrease the sensitivity and reactivity of HMEs and chemicals. Depending on the substance used (for instance acetone), flammability may increase while the ability to detonate is eliminated. Furthermore, phlegmatisation may influence a disposal method. Some methods such as phlegmatisation with water must not be considered as permanent, as phlegmatisers can evaporate; the effect may not last and a desensitised HME may regain properties similar to those it had prior to processing.

HINT. Phlegmatisers can be used to neutralise an improvised explosive's ability for initiation by decreasing its sensitivity to nearly zero.

WARNING. Both catalysts and reactants are normally neutralised in the production of military or industrial explosives. In HMEs this is not generally the case and as such their presence can increase sensitivity. In some instances, reactants such as nitric acid can lead to auto-ignition of certain HMEs over time.

ACETONE [$(CH_3)_2CO$] OR KETONE PROPANE, PROPANONE, DIMETHYL KETONE

Image 91. Acetone
(source: Bundeswehr CBRN Defence Command ©)

Acetone is a frequently used solvent, for lacquers, acetyl silk but also as nail polish remover, for example. As a gelatinising agent, it plays a role in explosives technology.

Acetone is a colourless, fruit-smelling, highly flammable and highly volatile liquid. Its flashpoint is -20°C.

CHEMICAL BEHAVIOUR

Acetone vapours form explosive mixtures with air at very low mixing concentrations. Acetone dissolves in water.

Explosions and dangerous reactions can occur if acetone comes into contact with acids (e.g. hydrogen peroxide, nitric acid), strong oxidisers and fuels (e.g. boron, sodium).

TOXIC BEHAVIOUR

Acetone can cause an irritating effect to the eyes and the upper respiratory tract. In high concentrations, it can disturb the central nervous system and has a narcotic effect.

Most plastics are not suitable for storing acetone, as it is a solvent.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder and carbon dioxide. Large fires should be fought with alcohol-resistant foam or sprayed water.

Acetone is slightly hazardous to water supplies.

CARBON TETRACHLORIDE [CCl_4] OR TETRACHLORMETHANE, BENZIFORM, TETRAFORM

Image 92. Carbon tetrachloride
(source: Bundeswehr CBRN Defence Command ©)

Carbon tetrachloride is hardly used nowadays because of its toxicity and its impact on the environment. It was used in refrigerators, metal degreasing, as a grain fumigant, in pesticides, as an agent for fire extinguishers and as a dry cleaner for textiles. It is used in improvised carbon tetrachloride explosives and in improvised smoke-generating pyrotechnics.

Carbon tetrachloride is a colourless liquid with an unpleasant sweet stench. It is volatile and does not dissolve in water. Carbon tetrachloride has a degreasing effect and acts as a solvent.

CHEMICAL BEHAVIOUR

Carbon tetrachloride is not flammable but can promote fires and explosions when mixed with other fuels and other reactants. Explosions and dangerous reactions can occur if carbon tetrachloride comes into contact with alkali metals, strong oxidisers or powdered metals.

TOXIC BEHAVIOUR

Carbon tetrachloride can cause a weak to moderate irritant effect on skin and mucous membranes, severe damage to liver and kidneys, as well as central nervous system and gastrointestinal disorders. Inhalation of its fumes can be lethal.

Unsuitable storage containers are made of aluminium, copper, zinc and their alloys, iron and rubber. Suitable containers are made from stainless steel, polytetrafluoroethylene (PTFE / Teflon™)[49] or fluorinated rubber.

Carbon tetrachloride is highly hazardous to water supplies even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

[49] Teflon™ is the trade name for PTFE used by DuPont de Nemours, Inc. Teflon™ is a fairly inert chemical. It is a white, non-combustible, odourless solid that does not dissolve in water. Explosions and dangerous reactions can occur if PTFE / Teflon™ comes into contact with powdered aluminium, alkali metals, flour or strong oxidisers.

COPPER (II) SULPHATE [$CuSO_4$] OR CUPRIC SULPHATE

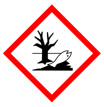


Image 93. Copper sulphate. The dry white powdered copper sulphate becomes blue when in contact with water

Copper sulphate is used in disinfection agents against algae, to produce paints and drying agents and in pyrotechnics, as it burns with a blue-greenish colour.

Copper sulphate is a white-greyish, odourless powder. It easily dissolves in water and is hygroscopic.

CHEMICAL BEHAVIOUR

Copper sulphate is non-flammable and does not produce a dust explosion.

Explosions or dangerous reactions can occur if copper sulphate comes into contact with acetylene, potassium chlorate, powdered magnesium or strong lyes (metal hydroxides).

TOXIC BEHAVIOUR

Copper sulphate can have an irritant to damaging effect on mucous membranes and skin. If ingested it can cause severe gastrointestinal and circulatory disturbances, blood count changes and functional changes leading to kidney and liver damage.

Copper sulphate is highly hazardous to water supplies even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

COTTON [$C_6H_{10}O_5$]

This organic matter does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 94. Cotton
(source: Bundeswehr CBRN Defence Command ©)

The main use for cotton is in the textile industry; however, when treated with nitric acid, pure cotton is used to produce explosives and propellants, especially nitrocellulose and cellulose acetate.

Cotton is a bunch of soft, stretchy, organic fibres. Its colour depends on the species and processing of the harvested fibre. Cotton is not soluble in water.

CHEMICAL BEHAVIOUR

Cotton is flammable. Cotton dust can cause dust explosions.

TOXIC BEHAVIOUR

No particular toxic behaviour is known.

No hazards to water supplies are documented.

ERYTHRITOL [$C_4H_{10}O_4$] OR PHYCITOL, PHYCITE, (VARIETY OF TRADE NAMES)

Image 95. Erythritol
(source: Bundeswehr CBRN Defence Command ©)

Erythritol is a four-carbon sugar that is found in algae, fungi and lichens. It is twice as sweet as sucrose and can be used as a coronary vasodilator. It is used as a sugar substitute and precursor for the military explosives erythritol tetranitrate (ETN) and PETN.

It is a colourless-white, sweet-tasting, odourless, crystalline sugar alcohol.

Image 96. Bag of erythritol
(source: Kräuterhaus Sanct Bernhard ©)

CHEMICAL BEHAVIOUR

Erythritol is flammable, hard to ignite and dissolves in water.

TOXIC BEHAVIOUR

Powder and dust can have an irritating effect on mucous membranes.

Erythritol’s impact on water supplies is not documented.

ETHYLENE GLYCOL [$C_2H_6O_2$] OR GLYCOL ALCOHOL, ANTIFREEZE

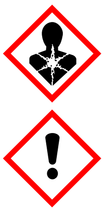


Image 97. Ethylene glycol
(source: Bundeswehr CBRN Defence Command ©)

Ethylene glycol is used as an antifreeze agent for engine cooling water, as a de-icing agent, as a plasticiser in the plastics industry and to produce explosives. It can be a component of hydraulic brake fluid as well.

Ethylene glycol is a colourless, nearly odourless, viscous liquid which is miscible with water. It is hygroscopic and not very volatile. Colour can be added by manufacturers.

CHEMICAL BEHAVIOUR

Dangerous reactions can occur if ethylene glycol comes into contact with fuming nitric acid, potassium permanganate, strong oxidisers or sulphuric acid.

TOXIC BEHAVIOUR

Ethylene glycol can cause minor irritations to mucous membranes and skin. It has a neurotoxic effect and causes cardiovascular disturbances, metabolic changes and kidney damage.

Suitable materials for containers are glass, stainless steel, PE, PTFE, PP and natural rubbers. Plastics must be checked for their resistance before use.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder and carbon dioxide. Larger fires should be fought with alcohol-resistant foam or sprayed water.

Ethylene glycol is hazardous to water supplies.

FORMALDEHYDE [CH_2O] OR METHANAL

Image 98. Formaldehyde
(source: Bundeswehr CBRN Defence Command ©)

Formaldehyde is used to preserve biological preparations and to produce plastics or disinfectants.

Formaldehyde is an almost colourless liquid or gas with a pungent and suffocating odour. It is easily soluble in water.

CHEMICAL BEHAVIOUR

In both gas and liquid form, formaldehyde is extremely flammable and can form explosive mixtures with air.

Explosions and dangerous reactions can occur if formaldehyde comes into contact with hydrochloric acid, hydrogen peroxide, magnesium carbonate, nitric acid, phenol, potassium permanganate, sodium hydroxide or strong oxidisers.

TOXIC BEHAVIOUR

Formaldehyde is very toxic. It can cause an irritating to corrosive effect on the eyes and skin and can cause a skin sensitising effect (dermatitis, allergic reactions, pustular eruptions, etc.). Formaldehyde can lead to irritation of the respiratory tract.

Suitable materials for containers are aluminium, glass, stainless steel or PE.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder and carbon dioxide. Larger fires should be fought with alcohol-resistant foam or sprayed water.

Formaldehyde is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

HEXACHLOROETHANE [C_2Cl_6] OR PERCHLORETHANE, CARBON HEXACHLORIDE

Image 99. Hexachloroethane
(source: Bundeswehr CBRN Defence Command ©)

Hexachloroethane is used in the smelting of non-ferrous metals and to produce high-pressure lubricants. For military applications, it is used in pyrotechnics and as a filling for smoke grenades.

Hexachloroethane is a colourless-white, crystalline powder with a camphor-like odour (strong, fragrant, aromatic-woody, eucalyptus-scented).

CHEMICAL BEHAVIOUR

Hexachloroethane is not flammable and is insoluble in water. It passes into a gas phase without melting and evaporates when exposed to air. Hexachloroethane emits toxic fumes when heated to decomposition.

TOXIC BEHAVIOUR

Hexachloroethane causes irritant effects on mucous membranes and slight irritation to skin. It may cause respiratory damage as well. In high concentrations it causes central nervous system disturbances.

Hexachloroethane is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

HEXAMINE [$C_6H_{12}N_4$] OR ESBIT,[50] FUEL TABLETS, HEXAMETHYLENETETRAMINE, UROTROPINE

Image 100. Hexamine
(source: Bundeswehr CBRN Defence Command ©)

Image 101. Hexamine pressed as an ESBIT block
(source: Bundeswehr CBRN Defence Command ©)

Hexamine is used to produce amino- and phenol-based plastics, as a food preservative and as pressed dry fuel tablets. Hexamine is a white, crystalline powder with a sea-fish[51] odour. It can be found as a powder or tablet.

CHEMICAL BEHAVIOUR

Hexamine is flammable and can be easily ignited by brief exposure to a source of ignition and continues to burn after removal from the source. The finer the hexamine is distributed, the greater the risk of ignition. It can cause dust explosions. Hexamine easily dissolves in water, is hygroscopic and sensitive to moisture.

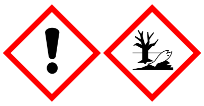
An explosion or violent reaction can occur when hexamine comes into contact with acids (e.g. nitric acid), peroxides or oxidisers.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder, foam and carbon dioxide.

Hexamine is moderately dangerous for water supplies.

50 ESBIT is the abbreviation of 'Erich Schumms Brennstoff in Tablettenform', a former trademark.
51 Amines are descendants of ammonia; they give old(er) fish their characteristic smell. Because of amines, burnt dry fuel like ESBIT smells fishy.

HYDRAZINECARBOXIMIDAMIDE [CH_6N_4] OR AMINOGUANIDINE, PIMAGEDINE, GUANYL HYDRAZINE



Aminoguanidine is used to produce pharmaceutical products and is used in animal husbandry to protect boar spermatozoa against the deleterious effects of oxidative stress. It is used in lotions, shampoos, soaps and toothpastes. Finding pure aminoguanidine can be an indicator of the production of tetrazene. Aminoguanidine nitrates are used for propellants.

Aminoguanidine is a colourless-white, odourless crystalline solid.

CHEMICAL BEHAVIOUR

Aminoguanidine is soluble in water. This substance is flammable but difficult to ignite.

TOXIC BEHAVIOUR

Aminoguanidine causes irritation to mucous membranes and slight irritation to skin. It may cause respiratory damage as well.

Aminoguanidine is moderately dangerous for water supplies.

IODINE [I_2]

Image 102. Iodine
(source: Bundeswehr CBRN Defence Command ©)

Iodine is used for medical applications, such as disinfectants. It can be encountered in the production of improvised primary explosives.

Iodine consists of grey-black, shiny metallic, pungent-smelling, flake-like crystals that gradually evaporate in the air. When rapidly heated, iodine sublimates to form a vile vapour. It is not flammable. Iodine is sparingly soluble in water. It dissolves readily in ethanol to form a brown colour and in benzene to form a red colour.

CHEMICAL BEHAVIOUR

Iodine is considered to be very aggressive in terms of corrosive power; it even decomposes cork and natural rubber. An explosion or violent reaction can occur if it comes into contact with alkali metals, ammonia, ammonia compounds, potassium in combination with shock, potassium iodide, copper tetra amine sulphate, mercury oxide and ethanol / methanol, silver azide, fluorine, combustibles, phosphorus, wet aluminium powder, aluminium powder-ether mixtures, petrol, boron in combination with heat, iron powder, formaldehyde, potassium in combination with heat, lithium, magnesium (powder, wet), metal acetylides / carbides, sulphur, turpentine and wet zinc powder.

TOXIC BEHAVIOUR

Iodine vapour can cause irritating to corrosive effects to the eyes and skin and severe irritation of the respiratory tract (risk of lung damage). In case of oral intake, iodine can cause damage to the digestive tract, disturbance of thyroid function, cardiovascular disorder, metabolic disorders and damage to blood, liver and kidneys.

Iodine is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

MERCURY [Hg]

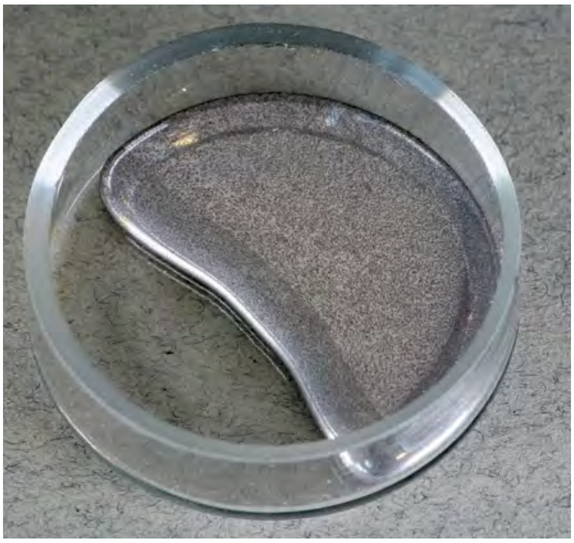


Image 103. Mercury
(source: Bundeswehr CBRN Defence Command ©)

Mercury is used in medical thermometers, switches (e.g. tilt switch) and disinfectants, for electrolysis in the chemical industry, bleaches and different lamps (e.g. fluorescent lamps). The metal can be encountered in areas where cold extraction is carried out. Mercury is required to produce the primary explosive mercury (II) fulminate.

Mercury is a shiny, silvery, odourless, liquid metal. It is non-combustible and does not dissolve in water. Mercury is heavier than water. It is very slightly volatile but may gradually evaporate at room temperature; in closed environments, this may generate hazardous concentrations of mercury in the air.

CHEMICAL BEHAVIOUR

An explosion or violent reaction can occur if mercury comes into contact with alkali metals, amines, ammonium, acetylene, specific metals (e.g. aluminium), nitric acid, nitromethane and oxygen in combination with heat, picric acid or sodium carbide.

HINT. Drops of liquid mercury can be cleaned by using absorbents such as Mercurisorb™.

TOXIC BEHAVIOUR

Metallic mercury and its soluble compounds are very toxic. Mercury vapour causes chronic poisoning that results in restlessness, headaches, forgetfulness, respiratory distress, reaction of the mucous membranes of the eyes, trembling of the hands and eyelids, kidney damage and gradual deterioration of the central nervous system until death. A sign of mercury poisoning is a black mercury fringe on the gums. Soluble mercury compounds in doses of 0.2 g to 1.0 g cause severe symptoms of poisoning, leading to death within days.

WARNING. Metallic mercury is particularly dangerous as a vapour, less so as a finely dispersed liquid and of little danger as a compact liquid droplet. The greatest risk is by inhalation of concentrated vapours, especially from the heated liquid in the case of inadequate ventilation. In this case there is severe danger to life.

Suitable materials for containers are glass, ceramic, stainless steel and iron. Unsuitable materials are aluminium, copper, gold and its alloys, silver and its alloys, tin and its alloys, as well as zinc and zinc alloys.

Mercury is extremely hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

NOTE. The finding of a (large) number of fluorescent lamps can be an indicator that mercury has been harvested to produce HMEs.

METHANOL [CHOH] OR WOOD ALCOHOL, CARBINOL, COLONIAL SPIRITS, METHYLATED SPIRITS

Image 104. Industrial methylated spirits (source: BCL ©)

Methanol is used to manufacture chemicals, to remove water from automotive and aviation fuels, to produce biofuels, as a solvent for paints and plastics and as an ingredient in a wide variety of products such as antifreeze.

Methanol is a colourless liquid with an odour ranging from pleasant to pungent, like that of ethyl alcohol. It is very volatile and easily flammable. Methanol completely mixes with water. Its fumes generate explosive vapours in contact with the air.

CHEMICAL BEHAVIOUR

An explosion or violent reaction can occur when methanol comes into contact with acids (e.g. nitric acid, sulfuric acid), alkali metals, hydrogen peroxide or perchlorates.

TOXIC BEHAVIOUR

Methanol can cause irritation to the eyes, depression of the central nervous system and systemic eye damage.

Unsuitable materials for containers are aluminium, magnesium alloys and zinc alloys. Plastics must be checked for resistance before use.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder and carbon dioxide. Large fires should be fought with alcohol-resistant foam or sprayed water.

Methanol is highly hazardous to water. Penetration into water and sewage systems or soil must be avoided.

NOTE. Toxic methanol is added to ethanol in a number of industrial applications. An addition of methanol allows ethanol to be sold more broadly, without incurring the need for an alcoholic beverage tax (such as for beer, wine or gin). These mixtures are called denatured alcohols or methylated spirits. It is therefore likely that MA staff will come across industrial mixtures of methanol and ethanol, which have a typical purple colour from the denaturing process and are therefore easily recognisable.

NITROCELLULOSE [$(C_6H_7(NO_2)_3O_5)_n$] OR GUN COTTON, CELLULOSE NITRATE, PYROXYLIN

Image 105. Unprocessed nitrocellulose
(source: Bundeswehr CBRN Defence Command ©)

Nitrocellulose is the commonly employed designation for nitrate esters of cellulose (cellulose nitrates). It is used for gunpowder and in the production of explosives. Improvised nitrocellulose, made by the nitration of cotton liners, is likely to contain impurities and excess nitrating agent, making it highly sensitive to heat / flame and auto-ignition over time.

Image 106. Drums used as containers for industrially produced nitrocellulose (source: FSD ©)

Image 107. Label on a drum used as a container for industrially produced nitrocellulose (source: FSD ©)

CHEMICAL BEHAVIOUR

Nitrocellulose is a solid consisting of white fibres. It is classified as an explosive, can self-ignite and can produce dust explosions. Nitrocellulose reacts to friction, heating or other sources of ignition with rapid decomposition and the formation of large quantities of gas. The commercial product must be phlegmatised with water or alcohol. Nitrocellulose with 13.3% nitrogen has an impact sensitivity of 3 J, its friction sensitivity is approx. 353 N. Depending on the moisture agents used, nitrocellulose's flashpoint is between 12°C and 35°C and it starts deflagration at between 160°C and 180°C. All nitrocellulose is soluble in acetone.

An explosion or violent reaction can occur when nitrocellulose comes into contact with acids, alkalis or oxidisers.

TOXIC BEHAVIOUR

Pure nitrocellulose is not toxic, but phlegmatisers, moisture agents, unwashed nitrogen impurities or products of decomposition can generate toxicity.

Nitrocellulose hazards to aquatic life are not documented. Penetration of water and sewage systems or soil should be avoided.

PHENOL [C_6H_5OH]

Image 108. Phenol
(source: Bundeswehr CBRN Defence Command ©)

Phenol is used to produce dyes, pharmaceuticals, disinfectants, plastics and preservatives.

Phenol consists of colourless crystals (but usually reddish due to detergents), which strongly etch skin and cause white spots. It dissolves, to a limited extent, in water and has an intense odour.

CHEMICAL BEHAVIOUR

Phenol is flammable, its vapours may form explosive mixtures with air when the substance is heated above its flashpoint (79°C). Contact with strong oxidisers and acids can lead to explosions or dangerous reactions.

An explosion or violent reaction can occur when phenol comes into contact with aluminium, formaldehyde, hydrogen peroxide, strong lyes or oxidisers.

TOXIC BEHAVIOUR

Phenol can cause corrosive effects on mucous membranes and skin, as well as serious eye damage. It can lead to central nervous system and cardiovascular system disorders and can damage the kidneys.

Suitable materials for containers are glass or stainless steel. Plastics must be checked for their resistance before use. Unsuitable materials are aluminium, copper, zinc and rubber.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder and carbon dioxide. Large fires should be fought with alcohol-resistant foam or sprayed water.

Phenol is hazardous to water supplies.

POTASSIUM CHLORIDE [KCl] OR SYLVITE, NOSALT

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 109. Potassium chloride
(source: Bundeswehr CBRN Defence Command ©)

Potassium chloride is used as a raw material for almost all potassium compounds and is a component of many fertiliser salts. It is used as a flavour enhancer and as a substitute for sodium chlorite in artificial food-grade salts (for instance NoSalt). It is used for the improvised manufacture of potassium chlorate.

Potassium chloride forms colourless-white, very salty-bitter tasting, water soluble crystals and has no odour.

CHEMICAL BEHAVIOUR

The substance is not flammable and cannot cause dust explosions.

Potassium chloride is slightly hazardous to water supplies.

SODIUM HYDROXIDE [NaOH] OR CAUSTIC SODA, LYE, ASCARITE, WHITE CAUSTIC, SODIUM HYDRATE

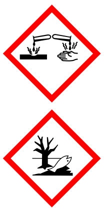


Image 110. Sodium hydroxide
(source: Bundeswehr CBRN Defence Command ©)

Sodium hydroxide is used to produce sodium salts, soaps, detergents, dyestuffs, as a confining liquor and to produce cellulose.

Sodium hydroxide is a white, crystalline, hygroscopic, highly corrosive mass. It can be found in the form of lumps, bars, scales or flakes. Dissolved in water, sodium hydroxide forms highly corrosive caustic soda. It dissipates in air while absorbing moisture and carbon dioxide from the atmosphere.

TOXIC BEHAVIOUR

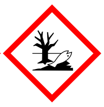
Sodium hydroxide can cause serious irritation and have a corrosive effect on all mucous membranes and skin, upon contact. It can lead to irreversible eye damage (risk of blindness).

Image 111. Bags of caustic soda flakes found in Mosul, Iraq (source: GICHD ©)

Unsuitable materials for containers are aluminium, brass, tin and zinc. Plastics must be checked for their resistance before use.

Sodium hydroxide is slightly hazardous to water supplies.

SODIUM HYPOCHLORITE [NaClO]

Sodium hypochlorite is used in bleaching agents, cleaning and disinfection agents for pools, fabrics and medicines. It is used for the improvised production of chlorates.

Sodium hypochlorite is a yellow liquid with a pungent stench. It can be stored only in aqueous solutions that, depending on their concentration, may be very caustic.

CHEMICAL BEHAVIOUR

Sodium hypochlorite can explode or react violently when in contact with acids, amines, ammonia, oxidisers and urea.

TOXIC BEHAVIOUR

Sodium hypochlorite can cause irritation and a corrosive effect on mucous membranes, the eyes and skin.

Suitable materials for containers are glass, ceramic and PE.

Sodium hypochlorite is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

TETRACHLOROETHYLENE [C_2Cl_4] OR PERC, PERCHLOROETHYLENE, TETRALEX®, TETLEN

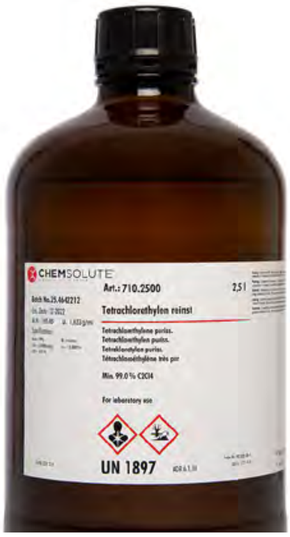


Image 112. Laboratory-grade tetrachloroethylene, 99%
(source: Th. Geyer Ingredients GmbH & Co. KG ©)

Tetrachloroethylene is mainly used as a cleaning solvent in dry cleaning and textile processing and in the manufacture of fluorocarbons. The presence of tetrachloroethylene can be an indicator of the production of improvised liquid explosives.

Tetrachloroethylene is a colourless, volatile, non-flammable liquid, with an ether-like odour that may emit toxic fumes of phosgene when exposed to sunlight or flames.

CHEMICAL BEHAVIOUR

An explosion or violent reaction can occur when tetrachloroethylene comes into contact with alkali metals, strong lyes, strong oxidisers or powdered metals.

TOXIC BEHAVIOUR

Tetrachloroethylene can cause irritation of mucous membranes and skin, impairment of the central nervous system and, with high exposure, impairment of liver and kidney function.

Tetrachloroethylene is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

UREA [$CO(NH_2)_2$]

This chemical does not meet the threshold criteria for GHS classification. However, chemical and toxicology information is available via data sheets on the internet.

Image 113. Urea
(source: Bundeswehr CBRN Defence Command ©)

Urea is used in fertilisers, fire extinguishing powder, de-icing agents, fuel additives (e.g. AdBlue®), cosmetics and medical products. It is a precursor for urea nitrate.

Urea is a white, crystalline powder with a faint ammonia-like odour. It is a non-flammable substance, easily soluble in water and is hygroscopic. Urea cannot cause dust explosions.

CHEMICAL BEHAVIOUR

An explosion or violent reaction can occur when urea comes into contact with ammonium nitrate, hydrogen peroxide, perchlorates (sodium perchlorate), strong oxidisers, sources of chloride or titan tetrachloride.

Urea is slightly hazardous to water supplies.

4.6. EFFECTS OF AGEING

This sub-section presents the issue of ageing, and the effect of ageing on HMEs. This particular process is not well documented in the case of a number of HMEs and so, due to the lack of information, more general observations will be provided.

The effects of ageing impact the performance and safety of all ammunition components.

Besides explosive ordnance itself, fillers and the components of fuzes also age. In general, the effects of ageing on military ordnance are well documented. In this context, diurnal cycling, which is the exposure of ammunition and explosives to the temperature changes induced by day, night and change of season, is known to be a potential issue.

An industrially produced explosive must fulfil stringent criteria in terms of ageing so that accidents in storage, handling and use are minimised throughout its service life. HMEs are not manufactured to such standards. In general, ageing of HMEs should not be equated with an increase in safety, but quite the opposite. Consequently, unidentified HMEs showing signs of ageing must not automatically be considered stable or desensitised.

Image 114. Effects of ageing visible on pyrotechnic time fuzes (source: GICHD ©)

Image 115. Aged artillery shell with anti-personnel effect in sandy soil. The shell was exposed to an explosion 65 years prior to its finding. The greyish-yellow TNT filler, exposed to the environment, is partly visible amongst the fragmentation balls (source: GICHD ©)

Reliable studies on the effects of ageing on the explosive properties of HMEs are rare; where they do exist, most information is classified. Besides exposure to a variety of environmental effects (such as humidity or solar rays, for instance) or a possible chemical decay over time, diurnal cycling can age HMEs.

Whilst some HMEs may lose their explosive properties over time, they may still present specific toxic and caustic hazards. In addition, chemical decay may lead to the strengthening or formation of new toxic or caustic hazards. These effects may be supported or accelerated by the material of a casing or container. In addition, the disintegration of a container may influence further effects of ageing on HMEs much more than on military-grade ammunition.

- Ageing can have a big impact on the stability and sensitivity of HMEs and their precursor chemicals.
- HMEs may corrode and lead to the deterioration of container material, switches, detonator casings and so on.
- The absorption of water can desensitise HMEs; oxidisers or fuels may react with water.
- Chemicals can be affected by heat and solar radiation, which can lead to increased or decreased sensitivity and decreased stability.
- Diurnal cycling (temperature differences between day and night) can break apart explosive fillings within containers, increasing sites for hotspot generation in handling and transport.
- The presence of impurities, explosives used in boosters or additives, can lead to further chemical reactions, creating unstable substances over time.
- Desensitisers and plasticisers can vaporise, increasing sensitivity and decreasing stability.
- Cracks and fractures accelerate the burning behaviour of propellants in an uncontrolled manner.
- Some HMEs can vaporise and recrystallise, or form unstable, reactive salts, some with explosive properties, such as ammonium chlorate and copper azide.
- Some HMEs may have dissolved in water and then solidified again, building more sensitive, unstable structures.
- The concentration of phlegmatisers in an HME can decrease, leading to increased sensitivity.
- Because of the hygroscopic effect, water absorption in an HME can lead to caking, thereby increasing explosive performance (e.g. ammonium nitrate).
- Impurities, for instance in (reused) containers, may accelerate or magnify the effects of ageing as well.

WARNING. The uptake of moisture in the outer exposed layers of some HMEs can lead to the creation of a solid crust when exposed to rain, followed by sun or heat. This can increase the density of an explosive or alter the chemical balance between fuel and oxidiser. To avoid any unwanted energetic decomposition, this crust should not be broken with mechanical force.

Image 116. Cocked striker of a VS-500 corroded by ageing (source: FSD ©)

Image 117. Effects of ageing: aluminium powder after separation from ammonium nitrate (source: FSD ©)

Image 118. Ageing: unknown mining explosive aged after being stored in a non-air-conditioned container in a tropical location for an unknown time. The casing is destroyed and discoloration of the explosive is recognisable. The chemical effects of ageing on the explosive cannot be estimated (source: Stanislav Damjanovic ©)

Image 119. Effects of ageing: recrystallised ammonium nitrate (source: FSD ©)

Image 120. Drum of hydrogen peroxide reused as a canister for an HME main charge. Hydrogen peroxide remnants may influence an HME's ageing as well (source: FSD ©)

5. HOME-MADE EXPLOSIVES

Given the vast number of fuels and oxidisers that may be used in HME manufacture, this section focuses on the main types of HME that mine action (MA) staff may encounter. It will outline their common characteristics, applications and hazards, considering the limitations in obtaining these data.

Sections 3 and 4 of this chapter have provided details on the outward appearance, specific risks and hazards of precursor chemicals, whilst this section will provide information on how variables such as particle size, quality of raw materials, and impurities will affect an HME's chemical properties. Identical HMEs may present different colours, appearance and smell, since manufacturers may attempt to disguise them to hamper search efforts.

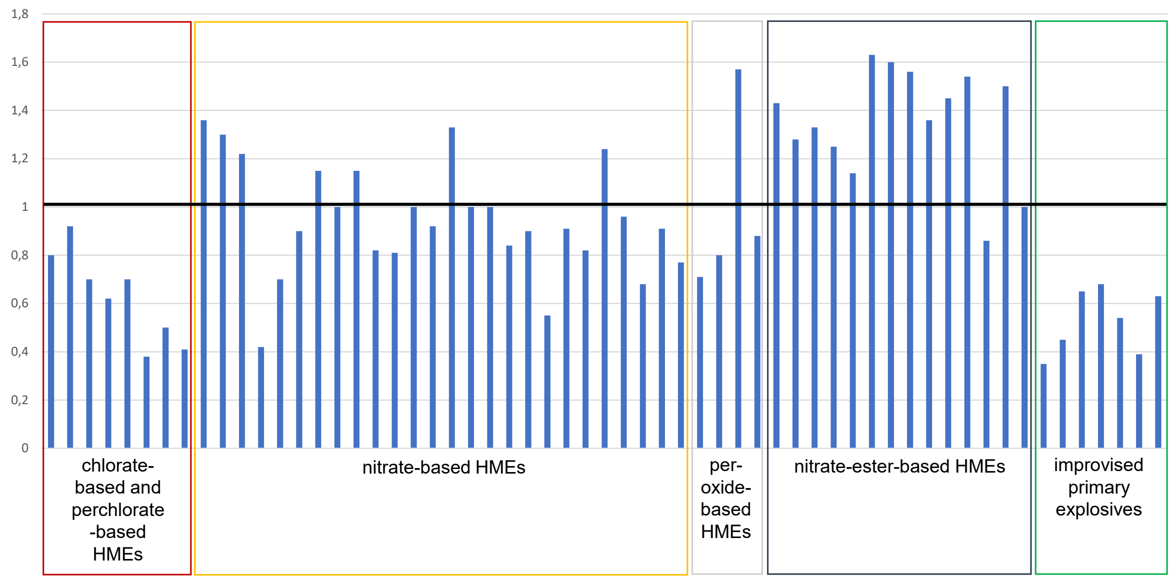


Table 10. Most common groups of high-explosive HMEs, compared to their TNT equivalent (TNT =1) (source: BCL ©)

Table 10 illustrates the variation in performance of many thousands of HME compositions that have been encountered in both military and MA operations globally. Based on the content of Table 10, unknown HME compositions / mixtures should be treated as if they were approximately 1.5 times their TNT equivalent, for evacuation purposes.

NOTE. It is of critical importance to bear in mind that the detonation parameters, sensitivity and stability of HMEs depend greatly on:

- Components' shape, size, porosity;
- Ratio of fuel to oxidiser;
- Water content and impurities;
- Charge diameter;
- Confinement conditions (including type and thickness of container material); and
- Influence of additives.

WARNING. HMEs must not be considered safer to handle just because they are reported as non-cap sensitive.

No safety data sheets are available for the majority of improvised explosives. To emphasise their possible hazards, the GHS classification of their precursor chemicals is added to the enumerations in this section. It can be assumed that HMEs follow at least the same GHS classification as their precursor chemicals. Furthermore, as a warning and a reminder, the pictogram GHS 01 (exploding bomb – unstable explosive) is added as well.

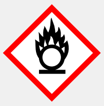
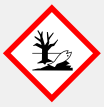
HME – PRECURSOR A – PRECURSOR B – PRECURSOR C			
HME	precursor A	precursor B	precursor C
	  		 

Table 11. Example of GHS classifications of an HME and its precursor chemicals as used in this section

5.1. CHLORATE AND PERCHLORATE-BASED HMEs

Chlorate explosives are explosive mixtures of chloric acid salts (alkali metal chlorates) and carbon-rich organic fuels. They are more sensitive to impact than nitrate-based HMEs.

Claude-Louis Berthollet was the first to discover the energetic properties of potassium chlorate when mixed with fuels. The explosive mixture of potassium chlorate–sulphur–charcoal was introduced as Berthollet powder in 1785. Commercially applied chlorate explosives are 'rack-a-rock' or 'cheddite'. Chlorate explosives (for instance Jonkit or Lyddite) were in use by the military until the Second World War.

Today, chlorates are not used in commercial or military explosives due to their high sensitivity and low performance compared to other, more modern chemicals.

NOTE. The use of chlorate- or perchlorate-based HMEs has increased in countries and / or conflicts where ammonium nitrate is banned as a fertiliser or where its use is regulated by government legislation.

Perchlorate explosives are explosive mixtures of perchloric acid salts and carbon-rich fuels. They are more sensitive to impact and friction than nitrate-based HMEs. Nowadays, commercial perchlorate explosives are no longer produced, as their use is considered uneconomical.

Most mixtures of chlorates / perchlorates and organic fuels are cap sensitive, with the degree of sensitivity depending on the types of organic fuel used:

- nitromethane very sensitive
- oil, diesel sensitive

Perchlorate mixtures are considered more stable than chlorate mixtures but must also be considered extremely sensitive to impact, friction, electric discharge / sparks and heat.

NOTE. When encountering chlorate- or perchlorate-based HMEs, it is essential to be aware of their sensitivity and understand that a presence of impurities (which will make them even more sensitive) is difficult to predict.

5.1.1. POTASSIUM CHLORATE-BASED HMEs

POTASSIUM CHLORATE

Image 121. Potassium chlorate (source: BCL ©)

Potassium chlorate is a stable, white, crystalline solid, with low toxicity, commonly used as an oxidising agent in the preparation of oxygen, and as a disinfectant. It is a powerful oxygen donor with 39.2% oxygen by weight and is the principal component of chlorate-based explosives, incendiaries, primer formulations, pyrotechnics and match head compositions.

Potassium chlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, sometimes without any further ignition source, and can considerably promote an existing fire. Compared to perchlorates or nitrates, potassium chlorate-based HMEs are very sensitive, as Table 8, in section 4, demonstrates.

Potassium chlorate is more sensitive due to its low melting point and low decomposition temperature. Due to these physical characteristics, very little energy is required to start an exothermic decomposition. The process becomes even more volatile if low melting point fuels are also used – under such circumstances, the mixture may explode by friction or light impact.

WARNING. The simultaneous presence of ammonium nitrate and potassium chlorate poses a high risk. Both chemicals react with moisture to form ammonium chlorate, which spontaneously decomposes in an explosive manner. These HMEs should never, under any circumstance, be transported or stored together.

POTASSIUM CHLORATE–ALUMINIUM

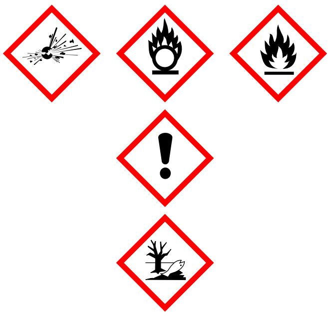


Image 122. Potassium chlorate–aluminium
(source: BCL ©)

This improvised explosive is a grey-silver, dark grey to almost black powder. The finer the aluminium is ground, the more reactive this mixture is and the darker its appearance.

> NOTE. Potassium chlorate mixed with other metal powders will also form HME.

POTASSIUM CHLORATE–ALUMINIUM–SULPHUR

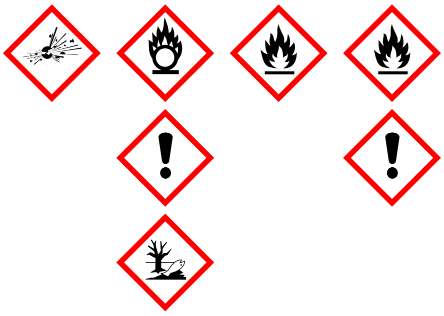
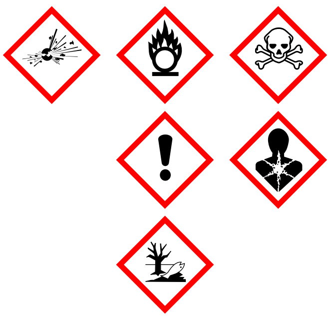


Image 123. Potassium chlorate-aluminium-sulphur
(source: BCL ©)

This improvised explosive is a grey, granular or fine powder mixture. It has a very low ignition temperature. It is very sensitive and unstable.

POTASSIUM CHLORATE–NITROBENZENE OR RACK-A-ROCK



This improvised explosive is a slurry-like mixture that has a yellow-white appearance, with an almond odour. This HME is sensitive to heat, shock and friction.

POTASSIUM CHLORATE–PARAFFIN (BABY OIL) OR PETROLEUM JELLY

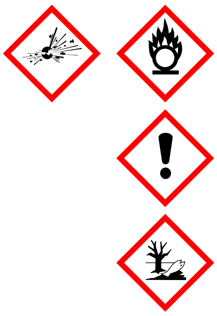


Image 124. Potassium chlorate-petroleum jelly
(source: BCL ©)

Image 125. Potassium chlorate-petroleum jelly
(source: BCL ©)

In both cases (mixed with paraffin or petroleum jelly), this improvised explosive is a whitish, putty-like solid or clump. It is used to make improvised plastic explosives and known as ‘the poor man’s C4’.

Depending on the amount of fuel, the HME is of a plastic to semi-plastic consistency. Both mixtures, potassium chlorate–paraffin and potassium chlorate–petroleum jelly, are considered moderately sensitive to mechanical stimuli. The impact sensitivity of paraffin mixtures is higher than the impact sensitivity of petroleum jelly mixtures.

The oxidiser to fuel ratio alters the strength of the HME. Potassium chlorate–paraffin mixtures reach a detonation velocity of up to 3620 m/s, whilst potassium chlorate–petroleum jelly mixtures reach a detonation velocity of up to 3140 m/s. As a comparison, military-grade C4 (Hexogen with binders and plasticisers) has a detonation velocity of up to 8000 m/s.

POTASSIUM CHLORATE–RED PHOSPHORUS

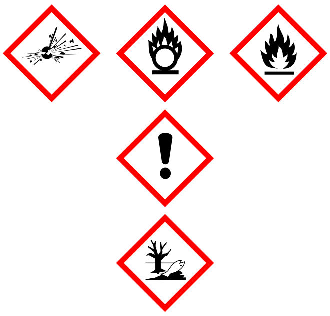


Image 126. Armstrong's mixture
(source: Bundeswehr CBRN Defence Command ©)

This improvised explosive is a red, granular or fine powder mixture also known as 'Armstrong's mixture' which is very unstable and sensitive. Some manufacturers even add sulphur to increase the sensitivity.

Armstrong's mixture is considered one of the most dangerous potassium chlorate mixtures and is one of the common flash compositions (or flash powders). Because of the red phosphorus, it is extremely sensitive to heat and friction and sensitive to electrostatic discharge. It is known to decompose violently during the production process. Extreme care must be taken when handling it as it may detonate from slight shock or touch; its reaction is unpredictable. Armstrong's mixture is used for matches and toy gun caps. This HME can be used as a primary explosive.

Armstrong's mixture is used for metal-free initiation elements. MA staff may encounter this HME when finding mechanical / pressure-initiated or crush sensitive initiators.

WARNING. A mixture of potassium chlorate and red phosphorus must not come into contact with concentrated sulfuric acid, as a violent reaction may occur.

POTASSIUM CHLORATE–SUCROSE / SUGAR

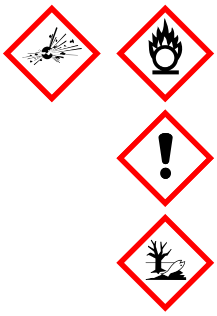


Image 127. Potassium chlorate–cane sugar
(source: BCL ©)

This improvised explosive is a white-grey to brownish-grey, granular or fine powder mixture. The type of sugar used (for instance white vs brown sugar) can change its colour. Commercially, this composition is used in signal smoke charges. It has a low ignition temperature and is considered sensitive.

Combinations of potassium chlorate, sugar and sulphuric acid can be encountered. These mixtures may ignite instantaneously.

5.1.2. SODIUM CHLORATE-BASED HMEs

SODIUM CHLORATE

Pure sodium chlorate has no explosive properties. When mixed with red phosphorus, sulphur or sugar, the reactivity and hazards of sodium chlorate combined with fuels, are considered equal to those of potassium chlorate-based HMEs.

SODIUM CHLORATE–ALUMINIUM

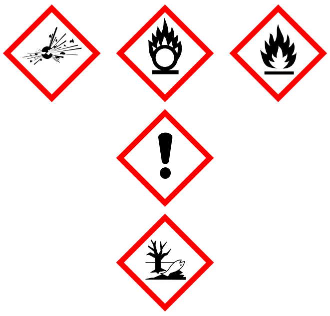


Image 128. Sodium chlorate–aluminium
(source: BCL ©)

This is a silver to black crystalline or granular solid with an undefined odour. It is an explosive and flammable material. Sodium chlorate–aluminium mixtures were historically used for flash powders but have been used as propellants and incendiaries in recent HME compositions. Detonation is highly likely in confinement and with the appropriate critical diameter and loading density.

SODIUM CHLORATE–KEROSENE

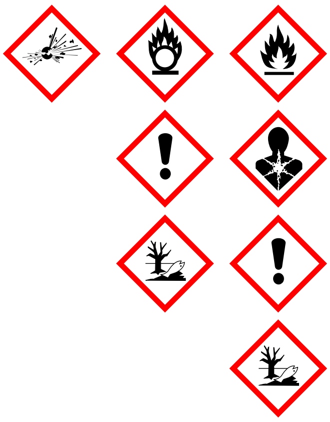


Image 129. Sodium chlorate–kerosene
(source: Bundeswehr CBRN Defence Command ©)

This is a white or yellow-brown crystalline or granular solid with an undefined odour. It is an explosive and flammable material.

SODIUM CHLORATE–NITROBENZENE

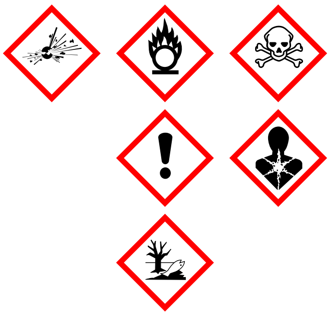


Image 130. Sodium chlorate–nitrobenzene
(source: Bundeswehr CBRN Defence Command ©)

This is a white-yellow, crystalline solid. It may spontaneously ignite when mixed with ammonium nitrate.

> **NOTE. This HME is referred to as 'Co-Op' or 'Co-Op Sugar' because of its use in an attack against the Belfast Co-Operative Society store by the Provisional Irish Republican Army (IRA) in 1972.**

5.1.3. AMMONIUM PERCHLORATE-BASED HMEs

AMMONIUM PERCHLORATE

Ammonium perchlorate is a very reactive solid with explosive properties that reacts upon impact, friction, heating and other sources of ignition, with a violent decomposition forming large quantities of gas. It is easily soluble in water.

Ammonium perchlorate itself does not burn but reacts so violently with flammable substances that it may cause them to ignite without any other source of ignition, and may considerably promote an existing fire. When ammonium perchlorate is mixed with flammable powdery substances, explosions may occur.

Non-stabilised ammonium perchlorate is a dangerous explosive. In a stabilised state (for example with 10% water), it is not explosive but does promote fire. When mixed with organic substances, both stabilised and non-stabilised ammonium perchlorate have explosive properties.

AMMONIUM PERCHLORATE–ALUMINIUM

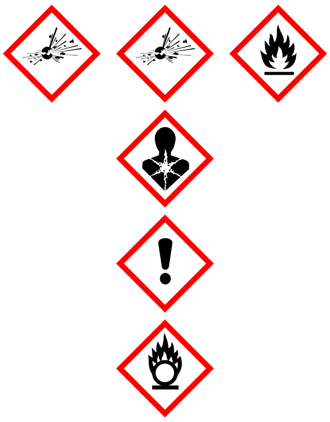


Image 131. Ammonium perchlorate–aluminium
(source: Bundeswehr CBRN Defence Command ©)

This improvised explosive varies from a white, silver or grey to an almost charcoal-coloured granular mixture. The finer the aluminium is ground, the more reactive it is and the darker it looks. This HME is extremely sensitive to heat, shock and friction.

AMMONIUM PERCHLORATE–SOAP

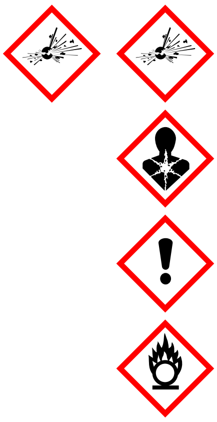


Image 132. Ammonium perchlorate–soap
(source: Bundeswehr CBRN Defence Command ©)

This improvised explosive is a paste / putty-like solid. Depending on the soap used, its colour varies from white, beige, light green to brown. Its odour also varies. This HME is flammable and explosive.

5.1.4. POTASSIUM PERCHLORATE-BASED HMEs

Image 133. Sodium chlorate–petroleum jelly, demonstrating the identical appearance to that of potassium perchlorate–petroleum jelly (source: BCL ©)

Potassium perchlorate–fuel mixtures are slightly less sensitive than potassium chlorate–fuel mixtures given the higher thermal decomposition temperature of the former (610ºC as opposed to 356ºC).

The possible HME mixtures and their performance, are equal to those listed in sub-section 5.1.1. (potassium chlorate-based HMEs) above, (including improvised plastic explosives).

Potassium perchlorate is highly incendiary but has a good shelf life. Mixtures with sulphur, phosphorus and metal powders ignite at low temperatures. These can be made to explode with a simple hammer blow.

NOTE. Potassium / sodium chlorate and potassium / sodium perchlorate HME mixtures are extremely difficult to tell apart without a chemical analysis and similar in appearance (see image 125 and image 133). For this reason, no additional photography is provided of sodium perchlorate or ammonium perchlorate HME mixtures. All compounds that are thought to be of chlorate or perchlorate origin should be treated as potassium chlorate HME mixtures.

5.2. NITRATE-BASED HMEs

Nitrate-based explosives are explosive mixtures of nitric acid salts and carbon-rich liquid or solid fuels. They are quite insensitive to impact and friction, with HME mixtures often requiring a booster, depending on the type of nitrate and fuel used.

Johann Rudolph Glauber[52] was the first person to manufacture ammonium nitrate. The first explosive using ammonium nitrate was patented in 1876 by two Swedish scientists. Military-grade ammonium nitrate was used up until the Second World War in secondary explosives and propellants, such as alumatol, amatex, amatol and ammonal. Ammonium nitrate is used in commercial explosives, such as for mining. These commercial explosives, like ammonia dynamite or ammonia gelignite, are manufactured as powders, prills, gels or slurries. Today, ammonium nitrate's use in HMEs is widespread given its availability worldwide, based on its use in fertilisers.

WARNING. The safety standards for commercial ammonium nitrate explosives (for instance safe to handle, safe to move) must not be considered sufficient for ammonium nitrate-based HMEs. Developing a false sense of safety can be fatal to MA staff.

5.2.1. AMMONIUM NITRATE-BASED HMEs

The majority of ammonium nitrate used in HMEs is harvested from fertilisers, from stolen technical-grade ammonium nitrate (for use as a commercial explosive) or from cool packs from medical supply chains. The use of ammonium nitrate in HMEs is very cheap compared to other oxidisers. This compensates for the disadvantage that some compositions require very large explosive charges to be able to detonate.

Ammonium nitrate is very hygroscopic. In pure powder or crystalline form, it cakes during storage. It is highly soluble in water; for instance, 1.8 kg can be dissolved in 1 litre of 20°C warm water. Pure ammonium nitrate is extremely difficult to detonate on its own. As such, ammonium nitrate-based HMEs are generally mixtures of ammonium nitrate with 2%–10% carbon carriers such as sawdust, oil or coal. Ammonium nitrate is also employed to modify the detonation rate of other explosives, such as nitroglycerine in the so-called ammonia dynamites, or as an oxidising agent in ammonals, which are mixtures of ammonium nitrate and powdered aluminium. In the latter case, the power of ammonium nitrate (heat of explosion and volume of gaseous products produced) is enhanced. It can also be found mixed with TNT, which, in this case, acts as a sensitiser.

WARNING. Ammonium nitrate–potassium chlorate mixtures may also be encountered, and which can become dangerously unstable. Ammonium chlorate, formed on contact of these two substances, tends to detonate spontaneously. It is important to be aware that this formation will occur on contact of ammonium nitrate with any chlorate source. As an effect of ageing, the formation of ammonium chlorate makes the stability of such mixtures impossible to assess; therefore, ammonium nitrate and ammonium chlorate should never be transported or stored together.

52 Glauber was a German pharmacist and chemist who developed different measures to produce acids and salts.

Image 134. Ammonium nitrate–potassium chlorate mixture. Remark: this mixture was processed under laboratory conditions (source: Bundeswehr CBRN Defence Command ©)

Pure ammonium nitrate has an impact sensitivity of 49 J and a friction sensitivity of 353 N, which may increase depending on fuels, additives and impurities. For example, Ammonit3, a commercially used ammonium nitrate explosive with additives including aluminium, has an impact sensitivity of 12 J.

WARNING. Ammonium nitrate is highly reactive with copper and zinc. Such mixtures are very unstable and will explode on heating. MA staff must take this into consideration if / when required to handle, move or dispose of such substances.

The vast majority of ammonium nitrate-based HME mixtures (except ammonium nitrate-aluminium ANAL and ammonium nitrate–nitromethane ANNM) are generally insensitive to initiation by detonator alone and require confinement and a booster. Hence, ammonium nitrate–fuel oil (ANFO), ammonium nitrate–nitrobenzene (ANNIE), ammonium nitrate–sugar (ANS) and ammonium nitrate–icing sugar (ANIS) are termed tertiary explosives. These mixtures have a low detonation velocity (so are unsuitable for driving anti-armour penetrators such as shaped charges and explosively formed projectiles), are not easily initiated in small quantities but do have a specific impulse similar to TNT, which makes them good for blast-related applications. Practical experience of ammonium nitrate HME mixtures (except for ANAL and ANNM) demonstrates that they are insensitive to initiation from 0.5 calibre rounds.

Image 135. Explosive formed projectile plate, Mosul, Iraq
(source: GICHD ©)

Ammonium nitrate is not an ideal explosive, because charges require a high degree of confinement and a large critical diameter. For this reason, charges in excess of 20 kg are usually encountered. Ammonium nitrate with a 1.4 g/cm^3 density is listed with a detonation velocity of 2500 m/s. A higher detonation velocity of up to 3500 m/s can be achieved depending on the fuels used.[53]

SOLID ORGANIC / INORGANIC FUELS

Compared to other HMEs, the production and handling of ammonium nitrate–organic / inorganic solid fuel HME mixtures is considered safe. In general, these HMEs are cap sensitive but require a booster to ensure a complete decomposition. They have low sensitivity and are physically stable.

SOLID METALLIC FUELS

In general, these HMEs are cap sensitive and may not require a booster, since the metal particles create sites of friction promoting the development of hotspots. This behaviour depends on loading density and particle size of the metallic fuel. Ammonium nitrate–metal fuel mixtures have a greater sensitivity than those with organic fuels but still remain physically stable. Viable charges weighing less than 20 kg have been encountered.

LIQUID FUELS

Liquid HME compositions such as ANNM are less physically stable and are cap sensitive.

The sensitivity and strength of ammonium nitrate-based HMEs is very much driven by type of fuel, loading density and the presence of air bubbles (which favours hotspot generation). Liquid fuels can soak effectively into both powder and porous prills displacing the air present in the pores, thus ensuring close contact between fuel and oxidiser. This simplifies an initiation of the explosive mixture compared to other fuels. Powdered fuels cannot soak into powder or porous prills and are therefore not as effective in mixing.

HINT. Quality, content and hazards of industrially packaged chemicals can be investigated using information provided on packaging labels, including pictograms, markings, batch / lot / serial number(s), production dates, barcodes, etc. Depending on the producer, safety data sheets may be available even on a company's website. Therefore, it is good practice to collect all information provided on chemical packaging.

53 UK Defence Evaluation and Research Agency (DERA), Physical and chemical evidence remaining after the explosion of large, improvised bombs (DERA/CES/FEL/CR9802 dated March 1998).

EXAMPLE: LABELLING OF FERTILISERS

Ammonium nitrate is a source of nitrogen in fertilisers but not all fertilisers containing nitrogen use ammonium nitrate. For this reason, it is useful to know the nomenclature used for fertilisers, to be able to assess possible hazards and content. Fertilisers are labelled with a so-called NPK number, a three-digit code that expresses the ratio of three plant nutrients in the following order: nitrogen N; phosphorus P; and potassium K.

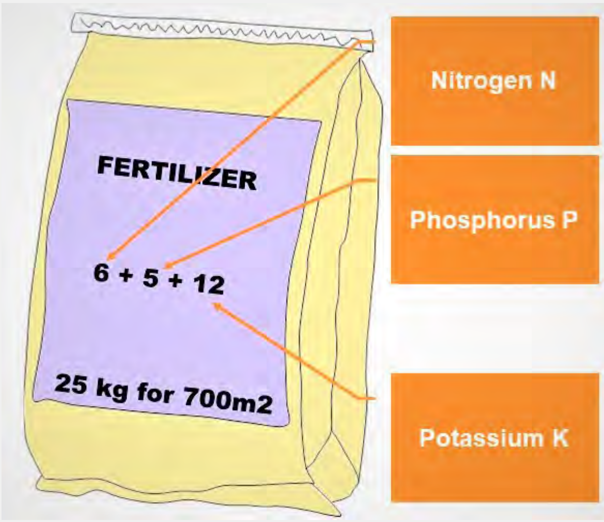


Figure 7. Example of NPK labelling on a bag of fertiliser (source: GICHD ©)

Image 136. Labelling on a bag of potassium nitrate (source: CAR ©)

N refers to the % ratio of nitrogen sources, such as ammonium nitrate or urea.
P refers to the % ratio of phosphorus sources, such as phosphorus pentoxide.
K refers to the % ratio of potassium sources, such as potassium oxide.
The NPK number may be labelled as N-P-K, N:P:K or N+P+K.

Not all fertilisers with nitrogen include ammonium nitrate. The NPK number can reveal the content, as follows:

- Ammonium phosphate NPK 16-20-0
- Ammonium sulphate NPK 21-0-0
- Calcium ammonium nitrate NPK 27-0-0
- Ammonium nitrate NPK 34-0-0
- Urea NPK 46-0-0

The labelling of ammonium nitrate fertilisers can sometimes be misleading. For example, the mass percentage of nitrogen in pure ammonium nitrate is 35%. In this form it is extremely difficult to detonate unless confined and exposed to an appropriate stimulus. Research has shown that if the ammonium nitrate content in a fertiliser is limited to 80% of weight concentration (the mass percentage of nitrogen is 28%) then its ability to detonate is much reduced.

Technical-grade ammonium nitrate will generally contain very high concentrations of ammonium nitrate (above 80%), which is why it is so effective in blasting applications when mixed with fuel oil. It is therefore important to understand the percentage figure that is displayed on any recovered ammonium nitrate packaging, to understand the potency of potential ammonium nitrate-based HME mixtures that may be encountered. Indeed, packaging sometimes indicates the weight concentration, while at other times it displays the nitrogen content. The ammonium nitrate bag in the picture, below, shows ammonium nitrate "AN % 33 N", which means that the fertiliser contains approximately 94% ammonium nitrate by weight (33/35 x 100%), a very good source of ammonium nitrate for HME use.

Image 137. Fertiliser-grade ammonium nitrate recovered in Iraq (source: CAR ©)

Image 138, below, identifies an ammonium nitrate source that states 'not less than 98.5%'. This means that the source of ammonium nitrate is 98.5% ammonium nitrate mixed with other additives. As such, this means that the source contains at least a mass percentage of nitrogen of 34.5% and is therefore way above a mass percentage of nitrogen of 28%, making it another excellent source for HME applications.

Image 138. High nitrogen content fertiliser in a contaminated state (source: BCL-FA ©)

AMMONIUM NITRATE–ALUMINIUM [ANAL]

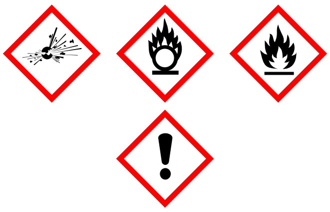


Image 139. Ammonium nitrate–aluminium
(source: Bundeswehr CBRN Defence Command ©)

ANAL is a white-grey or charcoal-coloured, loose prill or granular powder mixture. It is odourless but can have a faint hydrocarbon smell (aromatic, benzine-like) if mixed with fuel oils. ANAL is a very powerful explosive mixture, given that the aluminium adds to the heat of explosion. ANAL is flammable and can be encountered as small charges. It has a higher strength than pure ammonium nitrate.

AMMONIUM NITRATE–FUEL OIL [ANFO OR ANC]

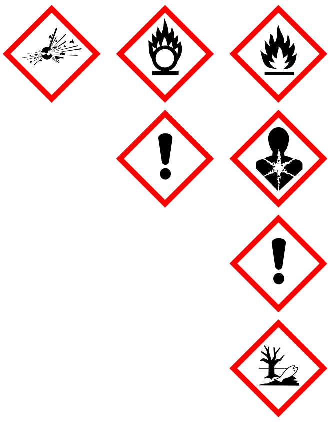


Image 140. Ammonium nitrate prills with fuel oil
(source: Bundeswehr CBRN Defence Command ©)

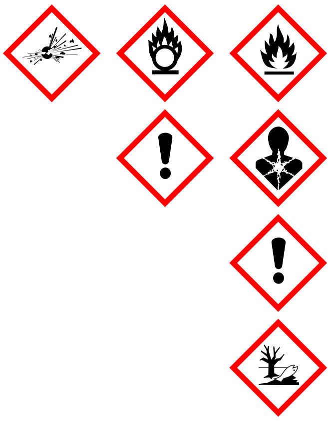


Image 141. Crystalline ammonium nitrate–fuel oil
(source: Bundeswehr CBRN Defence Command ©)

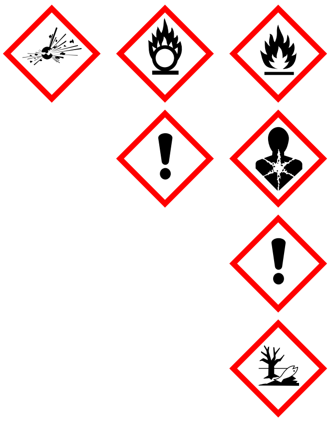


Image 142. Ammonium nitrate–fuel oil with HMTD booster (source: BCL ©)

ANFO can be a cream-coloured, brown, pink or orange HME, depending on the fuel and other additives used. Its appearance can be as prills or a paste-like solid. When mixed with diesel, it can be oily with an ammonia or hydrocarbon smell. ANFO is flammable.

HINT. For the disposal of ANFO, it is essential to be aware that:
- Improvised ANFO is a tertiary explosive and requires a booster.
- Improvised ANFO cannot be initiated in small quantities and requires some measure of confinement.
- Without confinement, it is likely that improvised ANFO may just be scattered over the area due to incomplete detonation, unless there has been significant caking.

AMMONIUM NITRATE–NITROBENZENE [ANNIE]

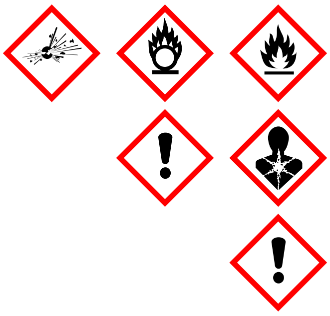


Image 143. Ammonium nitrate–nitrobenzene
(source: Bundeswehr CBRN Defence Command ©)

ANNIE is a cream-yellow or light grey-brown, crystalline solid with a variety of odours depending on the nitrobenzene source. Odours may be almond, marzipan or mild and fruity. In general, the odours are described as unpleasant.

ANNIE is more shock sensitive than ANFO.

AMMONIUM NITRATE–NITROMETHANE [ANNM]

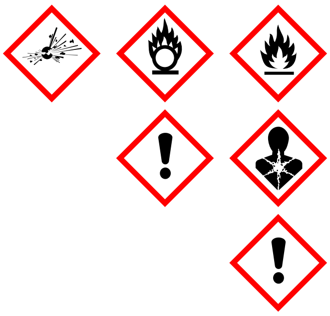
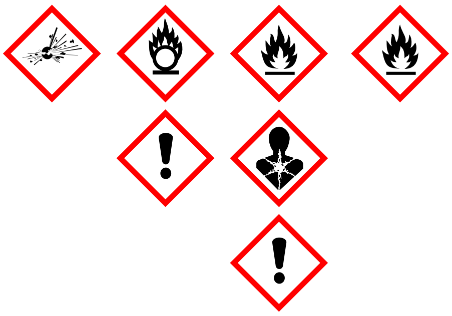


Image 144. Ammonium nitrate–nitromethane
(source: Bundeswehr CBRN Defence Command ©)

This cap-sensitive mixture can be improvised but is commercially available as well, for instance KINEPAK®. Commercial KINEPAK® is a binary explosive, with ammonium nitrate and nitromethane packed separately and mixed prior to use.

ANNM is a white-light pink explosive with the appearance of wet sand or toothpaste when mixed. In general, ammonium nitrate is used as powder. It is considered very insensitive and stable at normal temperatures and pressure, and it is cap sensitive. Contact with combustible materials, metals, metal salts, fuels and oxidisers should be avoided.

AMMONIUM NITRATE–NITROMETHANE–ALUMINIUM [ANMAL]



ANMAL is a white-grey to charcoal-coloured explosive, with the appearance of wet sand or toothpaste when mixed. It is cap sensitive and does not require a booster.

AMMONIUM NITRATE–SUGAR [ANS / ICING SUGAR ANIS]

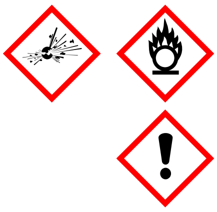


Image 145. Ammonium nitrate–sugar
(source: Bundeswehr CBRN Defence Command ©)

ANS is a white-cream-coloured granular and / or powder mixture; the sugar influences the mixture's appearance. ANS / ANIS requires a booster.

OTHER AMMONIUM NITRATE–FUEL MIXTURES ENCOUNTERED:

AMMONIUM NITRATE–CARBON POWDER

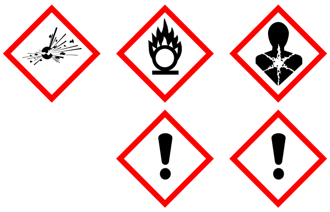


Image 146. Ammonium nitrate–powdered charcoal
(source: Bundeswehr CBRN Defence Command ©)

AMMONIUM NITRATE–MAGNESIUM POWDER

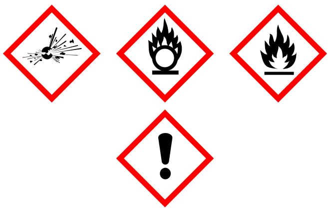


Image 147. Ammonium nitrate–magnesium powder
(source: Bundeswehr CBRN Defence Command ©)

AMMONIUM NITRATE–SAWDUST

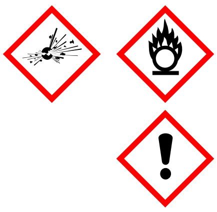


Image 148. Ammonium nitrate–sawdust
(source: Bundeswehr CBRN Defence Command ©)

AMMONIUM NITRATE–TNT [AMATOL]

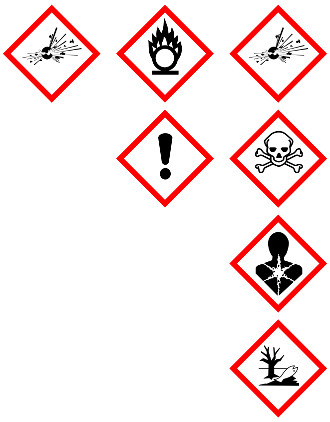


Image 149. Ammonium nitrate–TNT
(source: Bundeswehr CBRN Defence Command ©)

AMMONIUM NITRATE–UREA

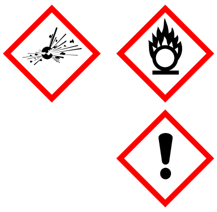


Image 150. Ammonium nitrate–urea
(source: Bundeswehr CBRN Defence Command ©)

5.2.2. CALCIUM AMMONIUM NITRATE (CAN)- BASED HMEs [54]

CALCIUM AMMONIUM NITRATE

Image 151. Calcium ammonium nitrate, processed as prills (source: Bundeswehr CBRN Defence Command ©)

Image 152. Calcium ammonium nitrate, possible appearance (source: Bundeswehr CBRN Defence Command ©)

Calcium ammonium nitrate ($CaCO_3$ & NH_4NO_3) is ammonium nitrate mixed with limestone or dolomite. It is used as a fertiliser, consisting of grey-brown prills with a dirty appearance.

Sometimes, manufacturers will separate calcium and ammonium nitrate. Within certain parameters this fertiliser can be used as an oxidiser for HMEs without any further processing.

Possible fuels are those used with improvised ammonium nitrate HMEs, such as those listed in sub-section 5.2.1 – ammonium nitrate-based HMEs. Due to the calcium additive, these HMEs are less sensitive than comparable ammonium nitrate HMEs and require confinement, a booster and a large critical diameter.

54 The GHS classification represents the hazards after the calcium's reduction / removal.

5.2.3. METHYL NITRATE-BASED HMEs

METHYL NITRATE

Image 153. Methyl nitrate
(source: Bundeswehr CBRN Defence Command ©)

Methyl nitrate (CH_3NO_3) is a colourless, highly volatile liquid, whose vapours are flammable and explode when overheated. In combination with absorbents, methyl nitrate has been encountered as moist improvised dynamite.

Methyl nitrate dissolves in alcohol or ether but not in water. Methyl nitrate easily gelatinises nitrocellulose and evaporates very quickly from the gel.

This explosive liquid reacts by impact or friction, heating or other sources of ignition, with rapid decomposition forming large quantities of gas. Its impact sensitivity is 0.2 J, and the friction sensitivity approx. 353 N. Methyl nitrate brisance is about equal to that of nitroglycerine. Unconfined methyl nitrate coming into contact with flames in an open space may result in burning accompanied by deflagration of the vapours. Confined methyl nitrate above a certain critical diameter may react with an explosion, achieving a detonation velocity of up to 6300 m/s. In general, methyl nitrate is cap sensitive.

This liquid explosive is more often encountered in its 'dynamite' state, obtained by wetting an absorbent such as fine sawdust or charcoal.

WARNING. Liquid explosives should not be touched due to their toxicity and serious effects on the skin. If skin contact occurs, the area should be flushed immediately with large amounts of water. Contamination of liquid explosives with other chemicals should be avoided to prevent any unintended reactions.

5.2.4. UREA NITRATE-BASED HMEs

UREA NITRATE

Image 154. Urea nitrate
(source: Bundeswehr CBRN Defence Command ©)

Pure urea nitrate ($CH_5N_3O_4$ // $NH_2CONH_2*HNO_3$) is a white, flammable, odourless crystalline powder. Mixed with caustic potash and other liquids, it can develop a strong ammonia or urine-like odour. Because of the bonded nitric acid, it turns yellow-brown in sunlight. Urea nitrate has a highly caustic effect (it corrodes most metals) and is thermally unstable. An explosive thermal decomposition is possible if it is heated above its decomposition temperature (152°C).

Urea nitrate is very insensitive to impact and electrostatic discharge, with an impact sensitivity of 50 J and friction sensitivity of 353 N. It is hygroscopic and will dissolve in warm water (190 g/l at 20°C) and ethanol. The storability of urea nitrate is limited due to caking. Urea nitrate manufactured with a high crystallisation rate is more stable in sunlight and less hygroscopic than powder versions. The substance may react dangerously with reducing agents, powdered magnesium or other powdered metals.

Urea nitrate is used as an oxidiser. With a water content of less than 20%, it can act as an explosive on its own. However, there is no modern day commercial or military use for urea nitrate as an explosive, given its poor capacity for ageing. Pure urea nitrate is not cap sensitive. Along with most HME mixtures that contain it, it acts as a tertiary explosive and requires a booster for successful detonation.

Possible fuels used correspond to those already listed in this section. Urea nitrate HMEs will vary in colour, appearance and odour, based on the production process, fuel used, age, environmental impact (sunlight) and impurities. All these factors also affect stability and sensitivity.

OTHER UREA NITRATE–FUEL MIXTURES ENCOUNTERED:

UREA NITRATE–ALUMINIUM

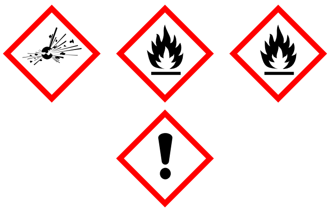


Image 155. Urea nitrate–aluminium
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–CHARCOAL

Image 156. Urea nitrate-charcoal
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–FUEL OIL

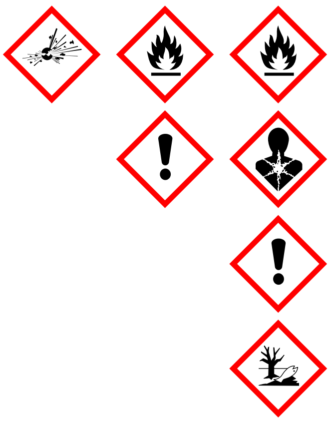


Image 157. Urea nitrate-fuel oil
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–MAGNESIUM

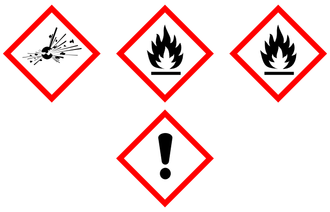


Image 158. Urea nitrate-magnesium
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–NITROBENZENE

Image 159. Urea nitrate-nitrobenzene
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–NITROMETHANE

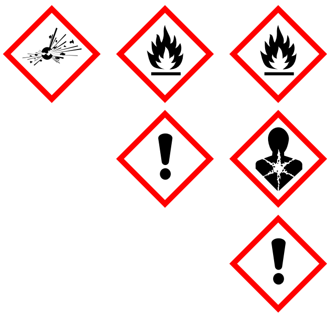


Image 160. Urea nitrate-nitromethane
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–SAWDUST

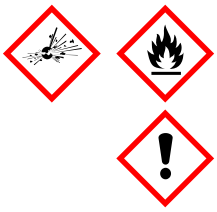


Image 161. Urea nitrate–sawdust
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–SUGAR

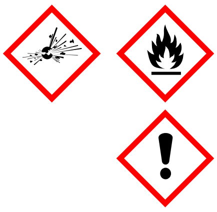


Image 162. Urea nitrate-sugar
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–TNT

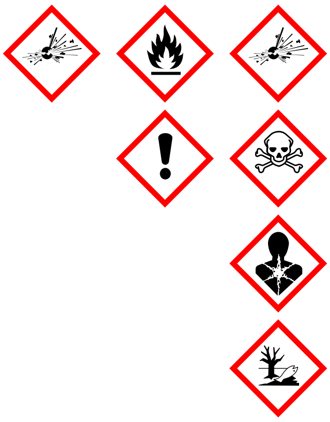


Image 163. Urea nitrate-TNT
(source: Bundeswehr CBRN Defence Command ©)

UREA NITRATE–UREA

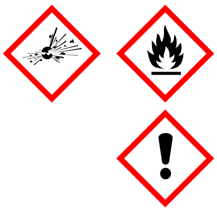


Image 164. Urea nitrate-urea
(source: Bundeswehr CBRN Defence Command ©)

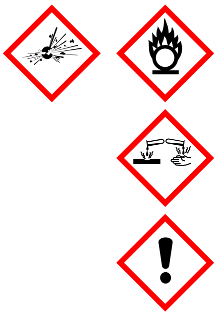
5.3. PEROXIDE-BASED HMEs

The term peroxide refers to a molecule where two oxygen atoms are tied together by a single bond. The peroxide single O-O bond is particularly weak, a characteristic which leads to the thermal instability of peroxide explosives (decomposing between 60°C and 150°C). Whilst these bonds may be weak, not all organic peroxides can be used as explosives.

Image 165. Effects of a small quantity of home-made peroxide explosive on a metal witness plate (source: BCL ©)

Peroxides are considered strong oxidisers, with high brisance, and are an extreme fire hazard when mixed with flammable materials.

5.3.1. CONCENTRATED HYDROGEN PEROXIDE (CHP)



Standard hydrogen peroxide is an aqueous solution; it spontaneously decomposes when mixed with water. Concentrations higher than 86% are hard to sustain and will decompose. Pure liquid hydrogen peroxide is not classified as a high explosive, given that it requires a relatively high input energy to be able to detonate. To form a viable HME, concentrated hydrogen peroxide can be mixed with a fuel and is therefore commonly known as a CHP HME.

The effectiveness of hydrogen peroxide-based HMEs depends on the concentration of the hydrogen peroxide and the ratio of fuel to oxidiser. As such, hydrogen peroxide is the subject of stringent regulation for both private and commercial use.

Common fuels encountered are ground spices (e.g. cumin, black pepper, chilli), flour, coffee, sugar, alcohol, glycerol and fine aluminium powder.

Image 166. Hydrogen peroxide–flour (source: Bundeswehr CBRN Defence Command ©)

Hydrogen peroxide HMEs can have a liquid, semi-liquid or pulpy appearance depending on the source materials. Their colour and odour vary depending on the fuels used. In general terms, the odour of hydrogen peroxide HMEs can be described as slightly pungent.

Image 167. Hydrogen peroxide-pepper (source: Bundeswehr CBRN Defence Command ©)

Hydrogen peroxide HMEs are generally mixed right before use; storage is not common. All these HMEs have a low chemical stability and are sensitive to heat, friction, impact and electrostatic discharge. As the concentration of hydrogen peroxide increases, so does its sensitivity. Large quantities of hydrogen peroxide HMEs may ignite due to internal auto-catalytic (or self-heating) reactions.

EXAMPLE: DISTINCTION BETWEEN ORGANIC PEROXIDE AND EXPLOSIVE MATTER CONTAINING HYDROGEN PEROXIDE

A distinction needs to be made between organic peroxides and explosive mixtures containing hydrogen peroxide. CHPs are not organic peroxides (there are no covalent bonds between the peroxide unit and organic moieties, while organic peroxides contain the organic moieties within their molecular structure) and CHPs are more akin to ANFO in terms of explosive performance. However, CHPs can be initiated without a booster. The most frequently encountered organic peroxide explosives include TATP, HMTD and MEKP.

5.3.2. ACETONE PEROXIDE

Acetone peroxide ($C_9H_{18}O_6$) or triacetone triperoxide (TATP), also known as Mother of Satan.

Image 168. Acetone peroxide
(source: Bundeswehr CBRN Defence Command ©)

TATP is a chemical compound, not a mixture. It has the properties of a primary explosive with a high detonation effect. There is no commercial or military use for TATP due to its instability.

TATP is a colourless-white crystalline or powder solid with a sugar-like appearance. It does not dissolve in water but is soluble in organic solvents. TATP that has dried after being dissolved in organic solvents is extremely hazardous to handle.

Fresh TATP has a soft acetone smell; when aged, it has a pungent, vinegar-like odour. Additives and impurities influence its physical appearance and odour.

TATP's sensitivity and stability (physical and thermal) are strongly and critically dependent on the raw materials used, with the professionalism of the manufacturing process and the HME's moisture content also playing a role. Chemical instability due to gritty impurities or acids used in production must be expected from an improvised production process. As these cannot be identified visibly, relevant HMEs should be treated as extremely unstable.

MA staff will unlikely encounter recently produced TATP. Therefore, the effects of ageing should be borne in mind. By default, TATP must be considered highly sensitive to impact, friction, electrostatic discharge and heat, like all other primary explosives. Ageing will increase its sensitivity to friction dramatically, so that even static electricity from the body or a latex glove could cause detonation. Laboratory numbers for pure, fresh TATP estimate an average impact sensitivity of 0.3 J and a friction sensitivity of 0.1 N.

HINT. It is recommended to earth oneself against electrostatic discharge to increase safety when encountering any improvised primary explosive.

NOTE. Various possible TATP–fuel mixtures exist, such as with grease, black powder or glue. This changes the appearance and colour of the HME.

TATP is highly sensitive to initiation by flame:[55]

- Small amounts of powdered TATP in a thin layer will tend to deflagrate.
- Confined crystallised TATP in thick layers will tend to detonate.

TATP presents unique hazards. It is volatile, potentially thermally unstable, vaporises spontaneously and tends to spontaneously recrystallise. (Large) crystals are more hazardous to handle than powdered TATP. Such crystals can form as TATP ages or through inappropriate synthesis and may decompose when broken.

WARNING. Containers containing TATP should never be opened, to avoid detonation. Detonation can be caused by the rupture of TATP crystals or the friction of crystals caught within the screw threads of the container lid.

55 HMTD will react similarly.

5.3.3. HEXAMETHYLENE TRIPEROXIDE DIAMINE

Image 169. HMTD
(source: Bundeswehr CBRN Defence Command ©)

Hexamethylene triperoxide diamine ($C_6H_{12}N_2O_6$) or HMTD, is a chemical compound, not a mixture. It has the properties of a powerful primary explosive with a high initiation effect. It has no commercial or military use, due to its sensitivity.

HMTD is a colourless and odourless fine white powder. It does not form large crystals. Because of the amines, old HMTD has a fish-like odour. It is slightly hygroscopic but does not dissolve in water or common organic solvents. It does not evaporate or recrystallise.

HMTD is very highly sensitive to heat, shock and especially friction. It is thermally unstable, will decompose in storage and is very reactive with most metals, even when dry. HMTD's impact sensitivity is 0.6 J. Its friction sensitivity is approx. 0.1 N and is considered to be similar to that of Armstrong's mixture.[56] Confined, it will detonate in small quantities. Aged HMTD loses explosive strength but its sensitivity to electrostatic discharge increases.

56 Armstrong's mixture is composed of potassium chlorate and red phosphorus.

5.3.4. METHYL ETHYL KETONE PEROXIDE

Image 170. MEKP
(source: Bundeswehr CBRN Defence Command ©)

Methyl ethyl ketone peroxide ($C_8H_{18}O_6$) or MEKP is a liquid chemical compound, not a mixture. It is produced using butanone / MEK, hydrogen peroxide and a catalyst. MEKP is used as a hardener for different resins. Commercially available, diluted MEKP is sensitised with phlegmatisers. Highly concentrated, it has the properties of a powerful primary explosive with a high initiation effect and its reaction can be compared to that of TATP. Confinement may cause it to explode.

MEKP is a clear, colourless, oily liquid with a pleasant odour. It is flammable and does not dissolve in water. It starts decomposing when exposed to heat between 50°C and 60°C. It is less sensitive to heat, shock and friction than TATP and can be stored. Highly concentrated MEKP is considered very reactive. It may explode upon contact with organic substances, some amines and sulphur compounds. It may react dangerously with strong bases, strong reducing agents and concentrated acids.

MEKP can cause a corrosive effect on mucous membranes and skin as well as severe eye damage (risk of blindness). If ingested, it carries the risk of severe damage to the digestive tract.

Suitable materials for storage of pure MEKP are glass (dark glass for light protection), ceramic, PVC, V2A steel[57] and rubber. Plastics must be tested regarding their resistance before use; unsuitable containers are those made of metals such as aluminium and its alloys, as well as brass, bronze, copper and its alloys, and steel.

Suitable extinguishing agents are water (spray jet), dry extinguishing powder, alcohol-resistant foam and sand.

MEKP is slightly hazardous to water supplies.

WARNING. Liquid explosives should not be touched. They must not come into contact with skin. In case this happens, the area of skin should be flushed immediately with large amounts of water. In addition, any contamination of liquid explosives with other chemicals must be avoided.

WARNING. The distinction between different organic peroxide explosives is difficult to determine with the naked eye, given the similarities in appearance of the crystalline solids. Any unidentified powder in the presence of hydrogen peroxide should be treated as HMTD in terms of extreme sensitivity. Existing render safe techniques such as kinetic disruption carry an undue risk of detonation.

57 V2A steel is stainless steel alloyed with chrome and nickel.

5.4. NITROMETHANE-BASED HMEs

Image 171. Nitromethane (source: BCL ©)

Nitromethane (CH_3NO_2) is the simplest organic nitro compound. It is a colourless, oily, highly flammable, polar liquid, commonly used as a solvent in a variety of industrial applications such as dry cleaning, the manufacture of pharmaceuticals, pesticides, explosives, fibres and coatings. Nitromethane is also used as a fuel additive in various motorsports and hobbies such as drag racing, and in miniature internal combustion engines for model aircraft. Nitromethane-based HMEs are used less commonly than other mixtures but were historically used by the Spanish separatist group Euskadi Ta Askatasuna (ETA). MA staff should be aware that, in general, non-state armed groups with the resources to deploy unmanned vehicles with internal combustion engines have the resources to manufacture this type of HME.

Nitromethane is not normally regarded as an explosive. However, given its oxygen balance, under certain conditions and with a strong initiator, this compound can propagate a detonation. Nitromethane was not considered a high explosive until a railroad tanker car loaded with it exploded in 1958[58] leading to two deaths and estimated damage of USD 1 million. After much testing, it was understood that nitromethane was a more energetic high explosive than TNT, although TNT has a higher brisance. Since nitromethane is oxygen deficient, some benefits have been gained by mixing it with an oxidiser in HME applications. Typical mixtures include ANNM and ANMAL (explosive mixtures of ammonium nitrate nitromethane and aluminium powder). Whilst the explosive performance of these mixtures is higher than that of ammonium nitrate–fuel oil, they are considerably more expensive to produce.

Nitromethane employed as fuel for HME mixtures can be used in a low concentration and needs no additional sensitisation. In general, it is mixed with solid oxidisers.

NOTE. Due to its tendency towards violent thermal decomposition, nitromethane and its mixture with flammable substances must not be heated or ignited in a confined space.

Nitromethane used as an oxidiser requires a concentration close to 100%. Fuels like amines, aqueous ammonia, sodium carbonate or strong acids will increase the sensitivity of a mixture. In general, these mixtures are not cap sensitive.

Used as an explosive, confined nitromethane has reached a detonation velocity of up to 6400 m/s in laboratory trials.

[58] Interstate Commerce Commission. "Accident Near Mt. Pulaski, ILL" (PDF). *Ex Parte No 213*.

Chemical sensitisation to achieve cap sensitivity can be obtained by adding various sorts of amines / derivatives of ammonia.

Physical sensitisation is achieved by enclosing gaseous oxygen in highly concentrated nitromethane. Oxygen is introduced when substances with the physical ability to keep air pockets within their structure are soaked with nitromethane. These substances can be, for instance, fine aluminium powder, fine ground coffee, sawdust or toilet paper. This method does not retain the oxygen for long. Nonetheless, pure nitromethane or nitromethane-based HMEs will detonate when initiated by sufficient external stimuli. Based on the oxidiser to fuel ratio, confinement level and booster explosives used, the required weight of a booster charge can be small – in the range of single-digit gramme numbers.

Commercially available explosives containing nitromethane are KINEPAK® (which uses ammonium nitrate) and the high energy liquid explosive HELIX™, a binary explosive including fine aluminium powder.

Exposure to nitromethane irritates the skin and affects the central nervous system, causing nausea, dizziness and narcosis. This substance is reasonably suspected to have carcinogenic potential.

PICATINNY LIQUID EXPLOSIVE (PLX) OR MYROL

Image 172. Picatinny Liquid Explosive
(source: Bundeswehr CBRN Defence Command ©)

PLX is a high explosive composition of nitromethane 95 and ethylene diamine, with a detonation velocity greater than 6000 m/s. It is a light yellowish liquid that requires a powerful blasting cap or a booster charge. It is not considered to be friction sensitive but has an impact sensitivity above 2 J. PLX has a low chemical stability, its components are both very volatile and corrosive. PLX corrodes brass but not stainless steel.

5.5. NITRATE ESTER-BASED HMEs

Nitrate esters are an important class of explosives for commercial and military applications and are formed from the O-nitration (O-NO2) reaction of alcohols with nitric acid. The five most important nitrate esters in HME manufacture are nitroglycerine, ethylene glycol dinitrate, pentaerythritol tetranitrate, erythritol tetranitrate and nitrocellulose. Nitrate esters are highly sensitive to impact and mechanical stimuli.

NITROGLYCERINE [$C_3H_5N_3O_9$] OR NG

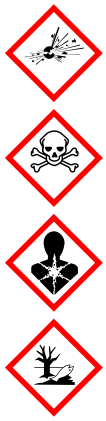


Image 173. Improvised nitroglycerine found in a bomb factory – discoloured from ageing (source: BCL ©)

Nitroglycerine, or glyceryl trinitrate, is probably the best known and most sensitive nitrate ester. It is manufactured on a large scale through the nitration of glycerine and is also used as a vasodilator to relieve angina pain. In its pure state it is a colourless and transparent oily liquid, with a slight sweetish smell and bitter-sweet taste. Auto-catalysation in storage is common (instead of a colourless oily liquid it may have a straw yellow or pale brown colour). This is not a problem in unconfined HME mixtures but in confinement the reaction can lead to detonation.

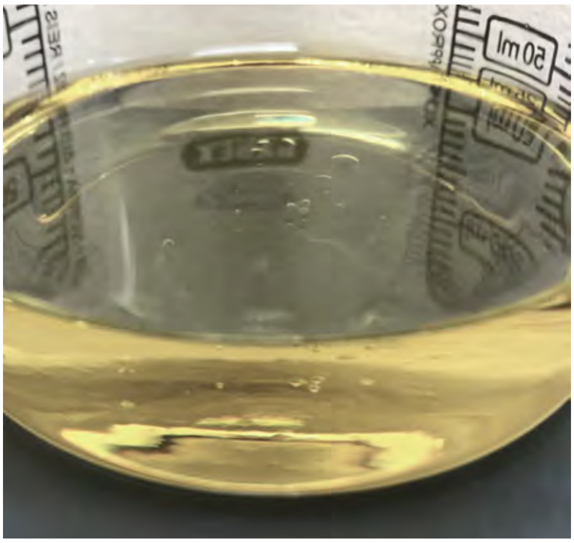
As a liquid explosive (freezing point 13°C), nitroglycerine demonstrates high brisance as well as the ability to provide a source of high energy in single and double base rocket propellants. At a density of 1.59 g/cm-3 its detonation velocity is 7750 m/s. It is only one of very few explosives with a positive oxygen balance, hence its use with oxygen-deficient explosives like nitrocellulose. Due to its oily liquid form, the presence of air bubbles can create hotspots leading to high sensitivity and accidental initiation during manufacture and handling. Nitroglycerine can be desensitised by mixing with absorbents such as wood pulp, flour, starch, chalk, zinc oxide or coal, and then combined with charcoal to form dynamite. Mixed with cellulose nitrate and sodium, potassium or ammonium nitrate gelatine, dynamite can also be produced.

Nitroglycerine is toxic to handle and, being a vasodilator, can lead to headaches during handling and after detonation (because of the NO_2 fumes generated). It is almost insoluble in water but soluble in most organic solvents.

Image 174. Improvised dynamite comprising nitroglycerine, potassium nitrate and charcoal (source: BCL ©)

Nitroglycerine-based dynamite has largely been replaced by ammonium nitrate-based mixtures, which are much safer to use and also less expensive.

ETHYLENE GLYCOL DINITRATE [$C_2H_4N_2O_6$] OR NITROGLYCOL, EGDN



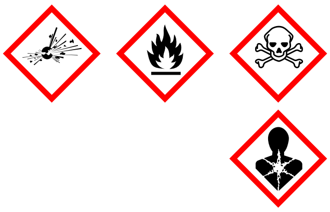


Image 175. EGDN (source: BCL ©)

EGDN or nitroglycol, is a non-hygroscopic, viscous, pale yellow-colourless oil with properties and performance similar to that of nitroglycerine. At a density of 1.49 g/cm^{-3}, its detonation velocity is 8000 m/s. EGDN has an oxygen balance of exactly 0.00 and is considered more stable than nitroglycerine against impact, although more volatile. EGDN was used in explosives manufacture to lower the freezing point of nitroglycerine, in order to produce a type of dynamite useable in colder weather (down to -22.7^{o}C, as opposed to 13.2^{o}C).

Due to its high vapour pressure, which does not favour use in propellant applications, it has been used as a high energetic plasticiser and taggant in plastic explosives to allow for more reliable detection. It is produced through the nitration of ethylene glycol and, like all nitrate esters, it is a vasodilator, strongly affecting blood circulation. EGDN is almost insoluble in water but soluble in most organic solvents.

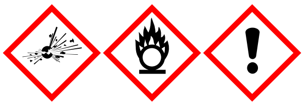
PENTAERYTHRITOL TETRANITE [$C_5H_8N_4O_{12}$] OR NITROPENTA, PETN

Image 176. PETN (source: BCL ©)

PETN is the most stable and least reactive of the explosive nitrate esters. It is an extremely powerful and brisant explosive. With a density of 1.77 g/cm^{-3} its detonation velocity is 8310 m/s. It is a fine ivory-white, crystalline solid produced through the reaction of pentaerythritol (an alcohol used in paints and varnishes) with nitric acid. Given its high detonation velocity, PETN is an easily initiated secondary explosive used in detonators, detonating cords and boosters. When mixed with an appropriate plasticiser, PETN becomes desensitised (phlegmatised) and can be moulded to almost any shape, making it hugely attractive in small improvised explosive devices. Unlike many explosives, PETN shows little trace of decomposition when stored for long periods and in high temperatures, making it a good choice for military applications (performance, reliability, safety). However, when heated above its melting point of approximately 140°C, it explodes violently (decomposition starts at > 150°C, explosion hazard > 205°C). It is insoluble in water, hardly soluble in alcohol, ether and benzene, and soluble in acetone and methyl acetate (a solvent).

The toxic effects of PETN are similar to those of nitroglycerine but less pronounced.

ERYTHRITOL TETRANITRATE [$C_4H_6N_4O_{12}$] OR ETN



ETN is another white crystalline powder, very similar to PETN in appearance and performance. It is manufactured from the nitration of erythritol. In its pure form it is extremely sensitive to shock and friction. In general, ETN is more sensitive to friction than PETN, has a positive oxygen balance and is easier to manufacture, given the wide availability of erythritol as a sweetening agent. As such, its use in improvised detonators significantly increases reliability. Its low melting point of 61.5°C suggests that it may be less adequate for long-term storage. ETN has largely replaced NG in medical applications, since its physiological effects are similar but more prolonged.

NITROCELLULOSE $[C_6H_9(NO_2)_3O_5]N$ OR FLASH PAPER, FLASH COTTON, FLASH STRING, GUN COTTON, COLLODION

Image 177. Improvised nitrocellulose (source: BCL ©)

Nitrocellulose is produced from the reaction of cellulose (obtained from cotton, wood, paper) with a mixture of nitric acid and sulphuric acid. The product normally forms a pulpy, fibrous, white, solid, granules, flakes or powder, which require vigorous washing to remove excess acid. There are different kinds of nitrocellulose, classified based on nitrogen content. Nitrocellulose's nitrogen content for explosive applications, usually (commonly) varies between 10% and 13.4%.

Nitrocellulose is highly flammable (ignites at around 180°C) and can burn even when wet. It is susceptible to initiation by percussion or electrostatic discharge. All nitrocellulose is soluble in acetone. As a projectile driver, simple gun cotton (with a nitrogen content above 13%) generates six times more gas than an equal volume of black powder and produces less smoke and heat.

Whilst nitrocellulose is proven to be a far better propellant explosive than black powder, it is susceptible to degradation in storage. Thermal stability decreases with increasing nitrate content and storage stability depends on the manufacturing process. Improvised manufacture cannot achieve the standards of industrial manufacture, and excess acid catalyses the decomposition of nitrate ester links during storage. If the temperature increases above 200°C, auto-ignition can occur.

NITROSTARCH [($C_6H_7O_2(ONO_2)_3$)N] OR XYLOIDINE

Image 178. Nitrostarch (source: BCL ©)

Nitrostarch was discovered in 1833 by Henri Braconnot and is produced by the nitration of corn starch with mixtures of concentrated nitric acid and sulphuric acid, followed by washing and drying. Similar to nitrocellulose, it varies in nitrogen content and was used extensively in World War I as the main explosive filling for some types of hand grenades.

Nitrostarch is a light yellow to orange-coloured powder, which resembles nitrocellulose in several aspects, other than its poor stability, relatively low strength and hygroscopicity. Unlike other nitrate esters, it is a ‘headache free’ explosive. Nitrostarch can be detonated when not mixed with other substances. When pressed, densities of little more than 0.9 g/cm^{-3} can be achieved.

6. GAS-GENERATING REACTIONS

Gas-generating reactions are chemical processes that produce a large amount of gas. In commercial use, a confined space is created by a pressure-resistant or pressure-responsive container. Within the container, pressure is created by a deflagrating gas-generating compound capable of undergoing self-sustaining decomposition without detonation. For safety reasons, the beginning of the reaction is controlled by means of a deflagrating ignition. Airbags are a common example of such a mechanism.

The contact of two or more specific chemicals can start a gas-generating reaction, without the need for a trigger or ignition element. Forming gas in a confined space increases the pressure to a level where the encasement / container bursts. Resulting hazards are heat, acceleration of container fragments, leakage of toxic gases, liquids or solids, that through reaction with oxygen or chemicals in their vicinity, can result in violent follow-up reactions. These reactions occur quickly and are usually unstoppable in confined spaces. In general, such effects will occur when mixing alkali or acids with metals but are not limited to this. The examples below refer to precursor chemicals commonly used to produce HMEs.

ALKALI / LYE:

Dissolved sodium hydroxide and aluminium, which produces:

- Gaseous hydrogen, an extremely flammable gas that forms explosive mixtures with air; and
- Solid sodium aluminate, a substance which reacts with and is corrosive to metals, and caustic to tissues.

ACID:

Hydrochloride acid and aluminium, which produces:

- Gaseous hydrogen; and
- Aluminium chloride, a yellow powder-like substance with a pungent, caustic odour which causes corrosive effects to mucous membranes and skin and, if inhaled, internal damage, especially to the upper respiratory tract.

Nitric acid and zinc, which produces:

- Water;
- Gaseous nitrogen dioxide,[59] which itself does not burn but increases the fire hazard on contact with flammable substances and can significantly intensify an existing fire; causes lung damage and has an irritant effect on mucous membranes; and
- Zinc nitrate, a white, odourless solid that reacts in a similar manner to nitrogen dioxide, causing localised irritation to mucous membranes and skin, chemical burns to the eyes, impairment of taste, and damage to the digestive tract including gastrointestinal disorders.

59 Nitrogen dioxide can ignite hydrogen / oxygen mixtures. Nitrogen dioxide is heavier than air; contact causes irritant effects and can lead to lung damage and chronic pulmonary dysfunction.

OTHERS

Calcium carbide with water forms gaseous acetylene, an extremely flammable gas that forms explosive mixtures with air.

Wood ash (sodium carbonate and potassium carbonate) dissolved in water, salt (sodium chlorate) and aluminium forms gaseous hydrogen, an extremely flammable gas that forms explosive mixtures with air and other compounds.

WARNING. Containers containing the possible hazard of a gas-generating reaction must not be moved as this will very likely restart the reaction.

7. IMPROVISED INCENDIARIES

This section provides information on several possible combinations, applications and hazards of improvised incendiaries and improvised chemical igniters. The main objective of this section is to raise awareness of possible applications and dangers.

Image 179. Remains of an improvised incendiary (gel-based), which has reignited when exposed to atmospheric oxygen in the disturbed ashes of a commercial property (source: BCL ©)

7.1. BASICS OF IMPROVISED INCENDIARIES

Most improvised incendiary explosives are solids, liquids or mixtures of both. They can be flammable or require chemical stimuli to start a reaction.

Some chemicals used in home-made incendiaries react violently and spontaneously when coming into contact with each other. This effect can occur accidentally or by design. Reactions are very difficult to stop once underway. Military applications of incendiary explosives include the Buck chemical fuze, used in anti-personnel and anti-vehicle mines during World War II or liquid rocket propellants. It must be noted that some of the chemicals reacting after being mixed do not require additional oxygen to combust.

The term ‘hypergolic reaction’ is used to describe the self-igniting effect between mixed liquids such as hypergolic propellants for rocket fuels. In hypergolic fuels, one liquid serves as fuel, one as oxidiser. The reaction starts immediately after mixing. Examples of oxidisers are potassium permanganate and different liquid chlorate compounds; examples of fuels are brake fluid, glycerine, ethylene glycol or propylene glycol.

Substances can even react violently when coming into contact with water, a property that can be used to start reactions deliberately. Ignition with water is used with zinc, ammonium nitrate,or ammonium chloride mixtures. Water drops, even from simple perspiration, can start the decomposition reaction.

7.2. IMPROVISED INCENDIARY COMPOSITIONS

Improvised incendiary compositions have a wide variety of applications. The use of gasoline mixed or thickened with polystyrene foam, sodium palmitate (curd soap) or oil, for example, is very common. Types of incendiary HMEs are described hereafter.

> **NOTE. In general, home-made incendiaries require an external heat source to combust.**

Image 180. Polystyrene foam (source: Bundeswehr CBRN Defence Command ©)

THERMITE

Thermite is a solid mixture of powdered iron (III) oxide and aluminium that, after ignition, generates iron and aluminium slag in a liquid state by achieving very high temperatures, up to 2400°C. It was used commercially to weld railway rails and does not require an external oxygen source to react. Thermite cannot self-ignite and commercially produced thermite mixtures are very stable. Damp thermite may explode after ignition, although it may also not ignite at all. Sometimes the ignition of a dry mixture is delayed whilst the amount of heat to start the reaction is generated. Impurities containing copper, magnesium, sulphur or potassium permanganate can increase the hazard of an explosion or self-ignition. As such, improvised thermite can be unpredictable if exposed to heat or flame.

Image 181. Thermite
(source: Bundeswehr CBRN Defence Command ©)

GELLED FLAME FUELS

Gelled flame or paste-type flame fuels are used for incendiary devices. Gelled flame fuels adhere more readily to an object and can produce a greater heat concentration than burning gasoline. The best-known example for gelled flame fuels is napalm, but several other methods are known to make improvised gelled flame fuels.

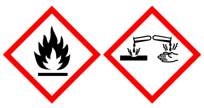
Napalm is a mixture of gasoline and various additives, including salts of naphthenic acid and palmitic acid. Napalm's oxygen source is the air; it requires an external initiation stimulus. Napalm is hard to extinguish with water as it is hydrophobic. After ignition, temperatures up to 2000°C can be reached. The adhesive effect of napalm is improved by using rubber products, soap or ethyl alcohol.

Common to improvised gelled flame fuels is the use of easily obtainable raw materials to gelatinise or plasticise gasoline or another hydrocarbon fuel. Gelled flame fuels are immiscible or hardly soluble in water. They derive the necessary oxygen from the air. The most suitable extinguishing agents are dry powder extinguishers, carbon dioxide or any means to suffocate the fire (for instance sand or fire blanket). Gelled flame fuels will continue to burn once they adhere to an object. Based on the raw chemical materials used, contact with an oxidiser or an acid may ignite gelled fuels. Known mixtures, listed by ingredient, are:

- Latex mixtures – which use gasoline, commercial or natural latex and an acid or an acid salt. Latex mixtures have the appearance of a swollen gel mass.
- Lye mixtures – which use gasoline and resin, or gasoline, tallow and alcohol to produce a flammable gel.
- Lye-alcohol mixtures – which use alcohols, which are then responsible for the gel quality.
- Soap-alcohol mixtures – which use soap (not detergents) in combination with alcohol to gelatinise gasoline.
- Wax mixtures – which use several common waxes to gelatinise gasoline.

WARNING. The presence of open flames in the vicinity of gelled flame fuels represents a serious hazard.

TRIETHYLALUMINIUM [$C_6H_{15}Al$] OR TEA



Triethylaluminium is a colourless-yellowish liquid. When thickened with polyisobutylene (binding agent) for military use, it is termed thickened pyrophoric agent (TPA). TEA / TPA can self-ignite but needs oxygen to combust that can be sourced from air or water. TEA / TPA itself cannot be extinguished with water, as it reacts explosively in contact with it. If other extinguishing agents are used, self-ignition can start again at any time through contact with air. After ignition, very high temperatures of up to 2000°C can occur.

OTHER MIXTURES

Mixtures including potassium perchlorate powdered metals, sulphur or phosphorus can also be used as incendiary explosives. These do not require an additional oxygen source. Potassium chlorate itself does not burn but reacts so violently with flammable substances that it can cause them to ignite, sometimes without a further ignition source and can considerably promote an existing fire. These mixtures require external stimuli. After ignition, temperatures of up to 2500°C can occur.

7.3. IMPROVISED CHEMICAL IGNITERS

Chemical mixtures able to self-ignite are used for igniters and fuses, meaning that they are independent from stimuli such as electricity, heat etc.[60] This offers a clear advantage from the user's point of view. With adequate coating, these igniters / fuses can function for a long time without any deterioration due to ageing. Chemical mixtures with the ability to self-ignite may be encountered as an initiation element in an explosive train as well.

To optimise the reaction, mixtures are usually contained in closed systems. The trapped heat accelerates the heat development and thus the reaction. Improvised applications separate the substances through vessels or separating discs. As a rule, this barrier between the chemicals must be destroyed by mechanical action. More sophisticated designs use acids to disintegrate these barriers. If no effect is observed after accidentally triggering an ignition element, it should not be assumed that it has failed, given that it is impossible to reliably determine the time offset for this kind of device. On the whole, the time offset is affected by age, thickness of the barrier and concentration of the dissolving agent.

WARNING. An intended delay may occur between activation of a chemical igniter and initiation.

WARNING. In general, fuses using chemical igniters do not require an initiator to be triggered. They are metal free and therefore difficult to detect.

EXAMPLE: SELF-IGNITION FUSE

The combination of a potassium–chlorate–sugar mixture with concentrated sulphuric acid is an example of an ignition mixture that is used to cause self-ignition upon impact with a target.

Fragile material containers are filled with a flammable fluid and sulphuric acid. A fabric strip (cotton) impregnated with a potassium chlorate–sugar mixture is attached to the outside of the container. On impact, the container will shatter. The reaction of the sulphuric acid with the impregnated strip will ignite the flammable fluid.

Such devices have been encountered in urban areas, stocked and ready to use. Any contact between the ignition elements must be avoided.

Devices such as these must not be considered safe to transport.

60 Initiation of mixtures by means of pressure, sparks, flame or electrostatic discharge is explained in section 8 *Improvised pyrotechnics*.

8. IMPROVISED PYROTECHNICS

This section provides information on several possible combinations, applications and hazards of improvised pyrotechnic HMEs. The main objective of this section is to raise awareness of possible applications and dangers.

8.1. BASICS OF IMPROVISED PYROTECHNICS

Improvised pyrotechnics are used in a similar way to industrial pyrotechnics to produce coloured lights, smoke or sound effects. Typically, pyrotechnics contain various chemicals.

As improvised pyrotechnics do not appear to have explosive properties, the hazards they pose are often underestimated. Pyrotechnics may even be considered harmless, as some are used in toys for children. However, it is important to be aware that pyrotechnics are energetic mixtures whose behaviour and stability are among the most difficult to assess, as they may be very sensitive and could produce the same effects as high explosives (depending on confinement, mixture components, impurities and the effects of ageing).

Pyrotechnic mixtures suffer greatly from ageing, which can reduce their stability and increase their sensitivity. Improvised pyrotechnics are often flame sensitive. They decompose creating high temperatures with strong gas or smoke emissions. Some mixtures can have explosive properties, especially when confined.

The raw materials used for improvised pyrotechnics correspond to the chemicals used for other HMEs.

Fuels used in improvised pyrotechnics include:

- Light metals and their alloys, such as aluminium and magnesium. Iron, zirconium and titanium can also be found;
- A source of carbon – mostly charcoal or sawdust;
- Sugars such as glucose, sucrose, lactose, mannose or fructose; and
- Various resins, sulphur, rosin, shellac, acetylsalicylic acid (e.g. Aspirin®), ascorbic acid (vitamin C) and acetaminophen (paracetamol).

Oxidisers used in improvised pyrotechnics include:

- Nitrates (potassium, sodium, barium or strontium nitrate);
- Chlorates (potassium, sodium, barium or strontium chlorate);
- Perchlorates (potassium or sodium perchlorate); and
- Manganates such as potassium permanganate.

Image 182. Fructose
(source: Bundeswehr CBRN Defence Command ©)

Image 183. Glucose
(source: Bundeswehr CBRN Defence Command ©)

Image 184. Lactose
(source: Bundeswehr CBRN Defence Command ©)

Image 185. Acetaminophen pressed as a pill
(source: Bundeswehr CBRN Defence Command ©)

Image 186. Ascorbic acid
(source: Bundeswehr CBRN Defence Command ©)

Image 187. Acetylsalicylic acid pressed as a pill
(source: Bundeswehr CBRN Defence Command ©)

8.2. NOISE AND LIGHT EFFECTS

Flash compositions can be used to produce irritating noise and light effects, for instance for stun or shock grenades used for law enforcement (so called flash bangs). Historically, flash compositions called flash powders were used to create flashes for photography. Today, they are used in pyrotechnics for theatres, in firecrackers and military training aids. Flash compositions are mixtures of oxidisers and fuels. They burn very rapidly and may decompose violently when confined. Some compositions are very powerful and can produce a blast effect similar to TNT, depending on quantity and confinement.

Flash compositions are very sensitive to all external stimuli, including static electricity. The (intended) presence of sulphur and a small particle size of constituents increases their sensitivity. Magnesium particles do not need to be as small as aluminium particles to achieve the same negative impact or sensitivity.

Hazards of flash compositions:

- Flash compositions containing magnesium are more sensitive than other mixtures containing aluminium. Magnesium mixtures coming into contact with PTFE will ignite spontaneously.
- Mixtures containing chlorates. One component decomposes faster than those with perchlorates and are more sensitive. In general, chlorates or perchlorates mixed with sulphur / sulphide are sensitive to vibration, friction and sparks.
- Mixtures including potassium permanganate, barium oxide or barium chlorate as they are not stable and tend to decompose spontaneously.

Flash compositions encountered in the past included potassium nitrate, potassium perchlorate, strontium nitrate or barium nitrate as oxidiser, and fine powdered metal aluminium or magnesium, sometimes sulphur and charcoal as fuel. The composition ratio of all these mixtures is different. Based on trials using raw materials with a defined particle size and mixture, the impact sensitivity of nine tested combinations differed from 2.9 J to 17.7 J. Apart from Armstrong's mixture and under laboratory conditions, barium nitrate-based flash compositions were more sensitive to impact and friction than those with potassium nitrate. Potassium perchlorate compositions demonstrated a very high friction sensitivity down to 32 N.

NOTE. Flash compositions must be considered very reactive, sensitive and unstable. Contamination or further mixing with other chemicals must be prevented. Precautions against electrostatic discharge must be taken.

8.3. COLOUR EFFECTS

Pyrotechnics can be used to create colour effects, such as to dazzle the crew of vehicles or to mark positions. The duration and intensity of these effects depend on the chemicals used. In general, the pyrotechnic basic mixture for coloured lights includes potassium perchlorate, a carbon source and sulphur.

Various chemicals combust with a unique colour spectrum.[61] This can be used to identify chemicals in a mixture and may allow for an estimation of its hazards. The list below is not exhaustive.

• Blue:	copper salts	azure
	arsenic, lead, selenium	light blue
	cobalt	deep blue
• Orange:	sodium salts	yellow
• Red:	strontium salts	deep red
	calcium compounds	orange
	lithium	crimson
• Green:	barium salts	light green
	copper	green
	zinc	green
• Violet:	potassium components, potassium perchlorate	violet
	caesium components	violet
• Gold:	iron	gold
	coal	gold

Image 188. Lithium, an alkali metal
(source: Bundeswehr CBRN Defence Command ©)

Coloured effects are brightened by including aluminium, magnesium or zirconium and intensified by adding mercuric chloride. Adding powdered metals increases sensitivity.

61 As a prerequisite for their use in pyrotechnics, the compounds must be volatile at flame temperature.

8.4. SMOKE EFFECTS

Saccharose (sucrose), potassium nitrate, as well as sulphur, carbon tetrachloride and charcoal are the basic components for smoke effects. Iron oxide, metal powders and black powder are encountered in white smoke screen mixtures and black smoke mixtures. Smoke can be coloured by adding a colouring agent.

Smoke effects are created by burning potassium nitrate and magnesium mixtures or via the reaction of oxygen with white phosphorus or with hexachloroethane compositions. Achievable expansion and duration of smoke effects depend on the amount of chemicals used, and weather conditions.

WARNING. It is important to be aware that smoke poses a health hazard. Inhalation can result in severe poisoning and lung damage.

9. IMPROVISED PRIMARY EXPLOSIVES

This section provides information on several possible combinations, applications and hazards of improvised primary explosives. The main objective of this section is to raise awareness of possible applications and dangers.

9.1. BASICS OF IMPROVISED PRIMARY EXPLOSIVES

Primary or initiating explosives are used to commence deflagration or detonation. Initiators include blasting caps, detonators and detonating cord. In general, blasting caps are mechanically or electrically initiated. Improvised igniters are manufactured as well. Their application includes the ignition of propellants or incendiary charges.

Improvised primary explosives encountered are TATP, HMTD and lead azide. Each of these can be initiated by flame or friction. TATP and HMTD can be used as main charge compositions as well. Improvised blasting caps can contain more than one explosive composition, such as potassium chlorate or sugar combined with TATP, PETN and ETN for instance.

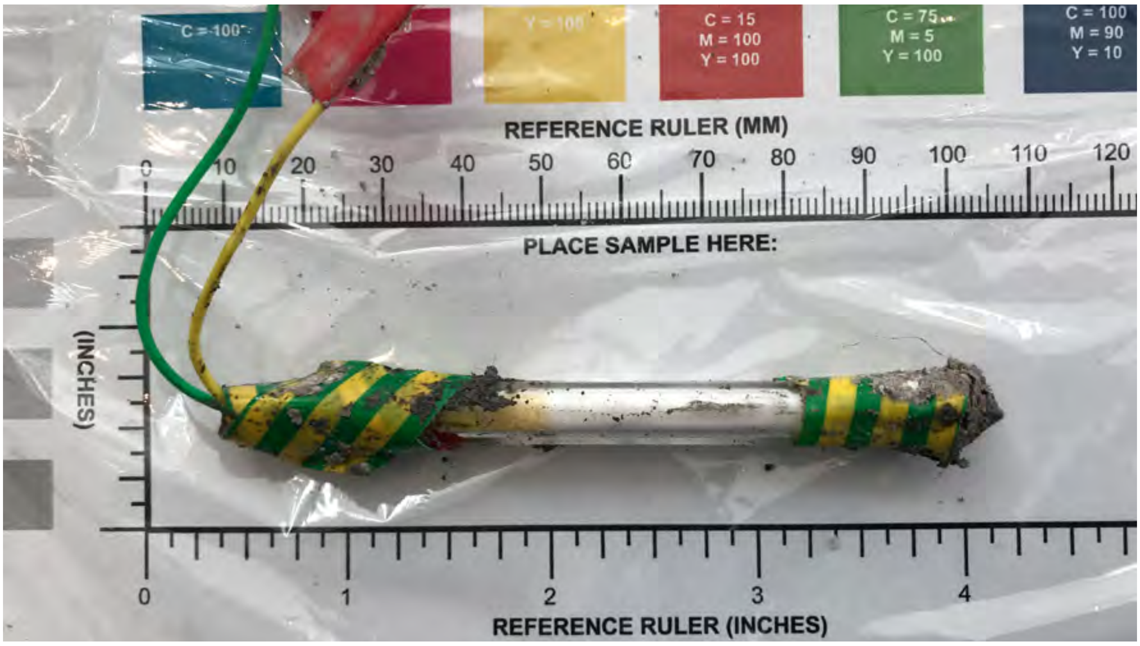


Image 189. Electrically initiated detonator using improvised chlorate and organic peroxide explosives (source: BCL ©)

The design of an improvised detonator very much depends on available resources and the producer's knowledge. Usually, improvised detonators encountered are electrically initiated (e.g. by a blasting machine, a battery or another source of electricity). A second common type is with a mechanically initiated improvised blasting cap (initiated by a safety fuse or by a shock tube system, for instance).

Improvised detonators with no metal content have also been encountered. In these cases, paper or plastic was used for the casing. Furthermore, if the presence of a detonator is not indicated caution should be taken, as various non-metal ignition techniques have been developed. For example, some TATP compositions have been mixed with ground glass to be able to detonate by friction alone.

Image 190. Improvised rocket igniter (source: FSD ©)

Further initiation elements retrieved housed two separated chemical compounds that would violently react when combined. These initiate through the energy released when the components are mixed. Such improvised initiation elements often contain no metal, which complicates detection.

WARNING. In aged, improvised detonators, explosive fillers may react with the metal casing, potentially resulting in the formation of extremely sensitive metal salts. Therefore, improvised detonators should NOT be considered safe to transport under any circumstance.

Image 191. Example of an improvised detonator (source: FSD ©)

WARNING. Improvised detonators are hazardous. Analysis, disassembly or handling of improvised detonators should not be conducted by untrained personnel.

Home-made primary explosives display characteristics that make their handling extremely dangerous, such as their high sensitivity and adverse mechanical properties. Many detonator compositions used in some improvised explosives (such as silver azide) have been discounted from any form of military or industrial use because of their overwhelming negative properties such as lack of stability, for instance.

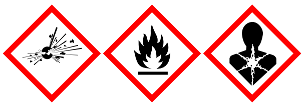
WARNING. Improvised primary explosives and improvised explosive devices containing home-made primary explosives should not be considered safe to transport.

HINT. Improvised detonators, like primary explosives, should be considered very sensitive to heat, flame, impact and electrostatic discharge. When encountering improvised primary explosives, confirmed or suspected, all possible measures (technical and organisational) must be taken to avoid initiation by one of these triggers.

Typical substances encountered in the production of improvised primary explosives include acetone, acetic acid, aminoguanidine carbonate, ammonia, dry fuel, hydrogen peroxide, iodine, mercury, nitric acid, picric acid, potassium chlorate, silver nitrate, sodium azide, sodium hydroxide, sodium nitrate, sulphur or sulphuric acid.

9.2. EXAMPLES OF IMPROVISED PRIMARY EXPLOSIVES

DINITROBENZENEDIAZOXIDE [$C_6H_2N_4O_5$] OR DIAZODINITROPHENOL, DINOL®, DDNP



DDNP is an explosive, yellow, crystalline powder that is neither hygroscopic nor volatile. It was used as a starting material for dyes until its explosive properties were discovered by Wilhelm Will of the Prussian Ministry of War, in 1892. Subsequently, it was used as an initiator for explosives where lead-free priming compositions were required. However, its military use ceased because of its poor physical properties.

When exposed to sun and / or light, it will darken to a dark red-brown colour and have a slightly reduced performance. Industrially produced DDNP is shipped wet with at least 40% water or as a water-denatured alcohol mixture. Confined DDNP can explode under prolonged exposure to heat or fire. It can be initiated by static discharge, which makes handling difficult. Its detonation velocity is approx. 4400-6900 m/s and varies depending on density and confinement. The decomposition temperature of DDNP is between 165°C and 195°C. Its friction sensitivity is considered to be less than that of mercury fulminate, TATP and lead azide. DDNP's impact sensitivity is approx. 1.5 J. Its fumes are toxic and caustic.

LEAD AZIDE [$Pb(N_3)_2$]

Image 192. Lead azide powder (source: BCL ©)

Image 193. Lead azide, produced by a very fast reaction that has caused small crystals to form visible chunks. The pinkish tint is uncommon
(source: Bundeswehr CBRN Defence Command ©)

Lead azide is an explosive, colourless, crystalline solid that appears as light-greyish needles or white powder. It explodes at between 315°C and 360°C and does not dissolve in water. Lead azide is resistant to heat and humidity. Its sensitivity increases with the size of the crystals. Pure lead azide has an impact sensitivity of 2.5–4 J and a friction sensitivity of 0.1–1 N. Depending on its density, the detonation velocity is between 4630 m/s and 5180 m/s. Lead azide reacts by impact or friction, flame or other sources of ignition with rapid decomposition and forms large quantities of gas. Lead azide reacts with copper, zinc, cadmium or alloys containing these metals forming other azides. As such, the choice of storage medium and confinement vessel is important.

Lead azide is less toxic than sodium azide. Its toxicity is due to the azide ion, which can cause lowered blood pressure, vertigo, nausea and collapse. Lead azide can cause damage to the kidneys, spleen and induce fatal convulsions.

Lead azide is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

LEAD STYPHNATE [$C_6HN_3O_8Pb$] OR TRICINAT, KNALLQUECKSILBER

Image 194. Lead styphnate (source: BCL ©)

Lead styphnate is an explosive, crystalline solid that has an orange-yellow to dark brown colour. It is not hygroscopic, is insoluble in water and sparingly soluble in acetone. Lead styphnate (particularly in long thin crystals) is particularly sensitive to flame and electric sparks and does not react with metals. In general, it reacts by impact or friction, heating or other sources of ignition with rapid decomposition, forming large quantities of gas. The impact sensitivity of lead styphnate is 2.5–5 J, the friction sensitivity is approx. 1.5 N. Lead styphnate is very sensitive to electrostatic discharge. It explodes at 260°C. Depending on its density, the detonation velocity can reach up to 5200 m/s.

Lead styphnate is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

MERCURY (II) FULMINATE [$Hg(CNO)_2$] OR MERCURIC CYANATE, MERCURY DIFULMINATE

Image 195. Mercury fulminate (wet)
(source: Bundeswehr CBRN Defence Command ©)

Mercury fulminate is an explosive, pale yellow to white-grey, crystalline solid that is insoluble in water. When dry, it is highly sensitive to shock, impact and friction. It will respond to other external stimuli, for instance sparks and flame, with a rapid decomposition and the formation of large quantities of gas. Mercury fulminate’s impact sensitivity is 1–2 J only, its detonation velocity can reach up to 5000 m/s, depending on the density. It is considered extremely sensitive to friction. Due to its sensitivity (greater than that of lead azide), it is often stored in water and dried prior to use. Its fumes contain toxic mercury. Mercury fulminate is reported to be relatively safe to handle when wet.

An explosion may occur when mercury fulminate comes into contact with sulfuric acid.

Mercury fulminate is highly hazardous to water supplies, even in small quantities. Leakage into water, sewerage systems or soil must be prevented.

NITROGEN TRIIODIDE [NI_3]

Image 196. Nitrogen triiodide (wet)
(source: Bundeswehr CBRN Defence Command ©)

Nitrogen triiodide is an explosive, black, extremely unstable, crystalline powder. It explodes under the slightest touch or warm heating. Dry, it is nearly uncontrollably sensitive. Because of its sensitivity, nitrogen triiodide is not considered to be practical for improvised explosive use.

SILVER ACETYLIDE [Ag_2C_2]

Image 197. Silver acetylide
(source: Bundeswehr CBRN Defence Command ©)

Silver acetylide is an explosive, white, crystalline solid that is insoluble in water. It is very sensitive to impact; its flashpoint is around 77°C. Its impact sensitivity is less than 1 J, its friction sensitivity is 0.1 N. Because of its tendency to decompose during storage and sensitivity, it has no commercial applications.

SILVER AZIDE [AgN_3]

Image 198. Silver azide
(source: Bundeswehr CBRN Defence Command ©)

Silver azide is an explosive, colourless solid in the shape of crystal needles (forming the chunks shown in Image 198). It will darken when exposed to light. It is sensitive to heat, friction and impact and does not dissolve in water. Its detonation velocity is 1000-5000 m/s, depending on its density and charge geometry. It starts to decompose at 270°C and, heated quickly to 300°C, it will detonate. Silver azide is no longer in commercial use because of its high manufacturing cost and very high friction sensitivity.

It is highly unlikely that MA staff will come across silver azide given its tendency for such spontaneous detonation.

SODIUM AZIDE [NaN_3] OR SODIUM AZOIMIDE, SODIUM TRINITRIDE, SMITE


Image 199. Sodium azide
(source: Bundeswehr CBRN Defence Command ©)

Sodium azide has been used in airbags with an oxidiser to create a gas-generating reaction. It is also used in the chemical industry as a reactant. Even though it does not own the properties of a primary explosive, it can be encountered by MA staff as it is used to produce other azides, such as lead azide. Sodium azide is a combustible, crystalline, white, colourless solid. It is highly soluble in water and sensitive to moisture. Its flashpoint is approx. 300°C. It can cause dust explosions.

Sodium azide must not come into contact with non-ferrous metals, as this leads to the formation of metal azides that are sensitive to impact and friction. In case storage containers are required, suitable materials are glass, stainless steel or plastic.

Sodium azide is considered very toxic, causing irritation to mucous membranes and skin, functional disorders of the central nervous system and cardiovascular system, as well as metabolic changes.

Sodium azide poses severe hazards to water supplies. Leakage into water, drainage and sewerage systems or the ground must be avoided.

TETRA AMINE COPPER (II) CHLORATE [$Cu(NH_3)_4(ClO_3)_2$] OR CHERTIER'S COPPER, TACC

TACC is a shock- and flame-sensitive solid, improvised primary explosive. It will decompose on impact.

TETRAZENE [$C_2H_8N_{10}O$] OR 1-TETRACENE

Tetrazene is an explosive, colourless-light yellow, crystalline solid with a downy appearance. It does not dissolve in water, alcohol, ether or benzol. Its effectiveness to initiate is considered low but tetrazene can be used in detonators when initiated by another primary explosive functioning as an intermediate booster. When mixed with another primary explosive, it increases the latter's sensitivity to flame or heat. Tetrazene starts to deflagrate at 140°C and its impact sensitivity is approximately 1 J.

Tetrazene can cause eye irritation and is harmful if inhaled or swallowed. Inhalation of high concentrations may cause difficulty in breathing. Ingestion may cause nausea, vomiting, constipation, cramps and stomach discomfort.

10. GENERAL SAFETY CONSIDERATIONS

This section provides an overview of general safety considerations when encountering HMEs, abandoned chemicals (for example, in former industrially used storage sites), abandoned manufacturing sites or ammunition stockpiles during mine action (MA) operations.

The aim is not to reiterate well-established standards for safeguarding staff from explosive hazards as these are comprehensively covered by International Mine Action Standards (IMAS), International Ammunition Technical Guidelines (IATG), national mine action standards, as well as standing operating procedures (SOPs). Rather, this section focuses on options to counter the health risks that HMEs or chemicals pose to MA staff.

WARNING. For many chemicals and biological hazards (e.g. substances produced by the decay of organic matter), required safety measures to prevent acute or chronic damage to the human body, organic life or the environment are very specific and unique.

Substance databases and safety data sheets are a recommended source for comprehensive information required when encountering chemicals. Safety data sheets include details on personal protective equipment (PPE) required when handling a specific chemical. If the type of chemicals likely to be encountered is known, safety data sheets should be used to define required PPE when preparing a specific task. In general, an organisation's SOPs should cover safety guidelines when encountering unknown chemical, yet non-explosive, threats.

10.1. BASIC SAFETY RULES AND CONSIDERATIONS

This sub-section describes basic safety rules and considerations concerning the non-explosive hazards of HMEs and / or their precursors.

10.1.1. SAFETY CONSIDERATIONS

HMEs or their precursors do not only expose personnel to explosive hazards. Some substances or compounds used in their manufacture are physically sensitive, others are highly corrosive, carcinogenic or toxic. Exposure may cause short-term effects, such as skin irritation, or lead to more serious long-term health issues, such as cancer, as in the case of nitrobenzene, for instance. Furthermore, absorption, inhalation or ingestion of a few milligrammes or less of certain chemicals can be lethal to humans.

WARNING. Absorption can occur via respiration, mucous membranes, skin or the digestive system. Protection measures to counter all (four) ways of absorption must be implemented.

Good practices applied in order to counter hazards posed by HMEs and chemicals are diverse; some may be implemented on a selective basis only. In general, interaction with HMEs and chemicals should only take place when the appropriate safety measures are in place. Personnel should be trained in the appropriate skills to handle hazardous material. These skills must include first aid procedures and using first aid equipment, as required, when addressing anticipated cases of contamination.

Safety considerations should not only cover personnel, but also environmental protection and measures to ensure public safety from non-explosive hazards as well. Disposal techniques and procedures must be tailored to the specific HMEs / chemicals.

GOOD PRACTICE. Environmental response may include clean-ups from hazardous materials and their remnants.

Image 200. Finding of chemicals contaminating the environment. An exposure to dust and / or particles is likely; an absorption can occur via respiration, mucous membranes, skin or digestive system. An assessment of the chemical's hazards aids in selecting appropriate PPE and measures to minimise the impact on the environment (source: FSD ©)

All flame- or spark-producing devices should be kept away from HMEs or their precursor chemicals. Equipment and clothing which does not create static electricity should be used, as electrostatic discharge can trigger improvised explosives. In non-contaminated areas, cotton clothing and shoes with rubber soles are recommended. Equipment must meet explosion-proof standards. The movement of personnel (walking) or remote means (tracks or wheels) should not result in unnecessary pressure being applied to HMEs or their precursors.

WARNING. An HME should always be considered as highly sensitive, energetic matter.

When encountering packages or canisters, additional research as well as technical support may be required before being able to identify hazards. Packaging and casings are sometimes used without markings, are wrongly labelled or reused. It is important to understand the local supply chain and to know names and labels used locally / regionally for common precursors.

NOTE. Explosive trains including a mix of commercial, military and HMEs that cannot be separated should be considered as an HME in its entirety.

Image 201. Green packaging for chemicals reused as main charges, prior to disposal (source: FSD ©)

HMEs and chemicals must not be mixed. Substances may react dangerously or explode when in contact with each other. Chemicals and HMEs must be positively identified prior to further processing. It is recommended to treat unknown bulk explosives / chemicals as if they were HMEs until positive identification has been carried out.

Groups of chemicals that may react when coming into contact with each other, and the possible resulting hazards are listed in Table 12:

CHEMICAL SUBSTANCE		HAZARD
Acids	Metals	Spontaneous combustion
Acids	Alkalis	Exothermic reaction (release of heat)
Oxidiser	Organic substances	Fire, explosion
Sulphides	Acids	Toxic, hydrogen sulphide
Alkali metals	Water	Spontaneous combustion
Carbides	Water	Highly flammable, formation of acetylene gas
Metal powder	Aqueous solutions	Spontaneous combustion
Metal powder	Air / oxygen	Spontaneous combustion
Nitric acid	Organic substances	Toxic, hydrogen sulphide
Nitric acid	Metals	Toxic, hydrogen sulphide

Table 12. Overview of possible dangerous interactions between chemicals

Measures to prevent an accidental release of chemicals as well as to prevent fires must be implemented. These measures may vary based on the source of the hazard or its toxicity. The default, pre-planned minimum measures should include:

- Marking and clearing the endangered area and warning the local population of the area affected;
- Entering a contaminated area only with suitable protective equipment;
- Ensuring that a universal binder (absorbent and neutralising agent for spilled acids) is available. Binding agents and cleaning agents should be disposed of in accordance with environmental protection regulations;
- If a release of chemicals occurs within an enclosed infrastructure, ensuring that rooms are ventilated, and contaminated objects and floors cleaned.

10.1.2. WORK HYGIENE AND SAFETY

To minimise the exposure to toxic elements, the regulations used in industries dealing with chemical agents should be applied when encountering HMEs and / or precursor chemicals. Personal hygiene rules should be followed very strictly.

Regulations used by industries include:

- Items known as contraband (e.g. food and drink, matches or drugs) are not allowed inside contaminated areas and working areas.[62] Suitable areas must be set up for this purpose.
- Avoiding contact of chemicals with skin. Skin cleaning is required in case of contact with a chemical.
- Preventing inhalation of vapours or aerosols.
- Limiting contact with clothing / PPE. Contaminated clothing must be changed and cleaned thoroughly. It is important to be aware that, for some chemicals, cleaning should not be done using water. If PPE is used, PPE should not be oversized or loose, it must fit. For the application of some PPE, training is required.
- Changing work clothing before rest breaks, if contaminated.
- Separate storage facilities must be available for street and work clothing, if there is a risk of contamination of work clothing.
- Cleaning skin with soap and water before breaks and at the end of work.

62 A list of what constitutes contraband can be found in IATG 06.10 clause 5.3, and Annex C.

10.2. PERSONAL PROTECTIVE EQUIPMENT AND INTRINSICALLY SAFE EQUIPMENT

The use of PPE is well described and regulated within the MA sector. This sub-section's objective is to describe basic PPE considerations to counter **non-explosive, toxic** and **caustic hazards** from HMEs or raw materials as well as biological agents, such as those transmitted by corpses.

10.2.1. APPLICATION OF PPE AND INTRINSICALLY SAFE EQUIPMENT

PPE is equipment and clothing that is intended to be worn or kept by employees at work and which protects them against one or more safety and health risk.[63]

PPE designed to counter chemical, biological or other hazards can be quite specific. Masks and respirators might be included in a PPE kit as well. Working in contaminated or confined spaces may increase the level of PPE needed; for instance, to counter absorption via inhalation.

PPE designed to counter non-explosive, toxic or caustic hazards, can be purchased via providers specialised in environmental protection, via suppliers for the chemical industry or via online shops.

Images 202 and 203 demonstrate situations where MA personnel can be exposed to non-explosive, toxic or caustic hazards, in addition to explosive hazards, by chemicals or by containers with unknown content.

Image 202. Substance presenting a possible exposure to ammonium nitrate. Unprotected, the ammonium nitrate may be absorbed via breathing or via the skin. Ammonium nitrate dust stirred up by the wind can irritate eyes, mucous membranes or the respiratory system (source: GICHD ©)

63 IMAS 04.10 Glossary of mine action terms, definitions and abbreviations, Second edition, Amendment 10, February 2019.

Image 203. Finding of various canisters and barrels with unknown content next to a former textile factory in Mosul, Iraq; located by an explosive detection dog (source: GICHD ©)

An assessment of a planned task can support the choice of PPE, for instance regarding the required level of protection against chemicals or the use of disposable or reusable PPE. This assessment may include the following questions:

- What activities are being carried out?
- What work procedures are being used?
- Which hazardous substances / biological agents are expected?
- What quantity of hazardous substances / biological agents is expected?
- In which physical state or in which form does the hazardous substance / biological agent occur?
- To what extent or in what form is there contact with the hazardous substance / biological agent?
- How long and how intensive is the contact with the hazardous substance / biological agent?
- Is the PPE exposed to mechanical stress?
- Are there possibilities for storage and cleaning of used PPE?
- Are there possibilities for decontaminating of used PPE?
- Are there possibilities for proper disposal of used PPE?

PPE must not expose MA staff to additional risks, for instance by blocking their field of vision or by severely hampering mobility when conducting survey, search, clearance or disposal.

NOTE. Use of specific PPE may require additional training.

HINT. PPE should never be more restrictive than necessary.

WARNING. For all elements of PPE, prescribed time limitations of exposure to chemicals (leading to the permeation of PPE) must be observed; if this limitation is reached after contact with the relevant substances, the protective clothing must be replaced immediately.

GOOD PRACTICE.

PPE should be available for first responders to ensure their safety in case of an emergency.

PPE should be cleaned daily, after use. It may be necessary to use specific types of PPE while cleaning contaminated PPE. Only decontaminated equipment and PPE should be used, particularly when working in different areas contaminated with different chemical hazards.

Maintenance work on PPE should only be conducted by certified personnel.

It is recommended that used PPE is kept separate from new unused equipment, even after cleaning and decontamination.

10.2.2. CONSIDERATIONS REGARDING SPECIFIC PPE

Hereafter, explanations of PPE that protects the torso, head and limbs, the respiratory system, the eyes, and the hands from non-explosive, toxic and / or caustic hazards, are provided.

PPE FOR BODY PROTECTION (HAZARDOUS MATERIAL SUITS)

Body protection is necessary to prevent direct exposure of body tissue and external organs to a hazard, such as a toxic hazard, for instance. It supports the prevention of a chemical's absorption through the skin and / or mucous membranes. Body protection, such as chemical protective suits, can be combined with a mask, gloves or boots to achieve the required protection level.

Appropriate body protection with regard to chemical-related hazards covers a wide range of equipment, from an apron up to chemical protection suits, which must be tailored to the hazard and the size of the person using it.

As with all PPE, chemical protective suits are tested according to relevant (national) standards and their respective requirements regarding dust, gas and liquids. Amongst other effects, they are tested for abrasion resistance, puncture resistance, tear resistance, tensile strength and resistance to the permeation of chemicals. A distinction is made between different types, as follows:

- Gas-tight chemical protective suit, including:
    - Gas-tight chemical protective suit with an ambient air independent breathing air supply worn in the suit;
    - Gas-tight chemical protective suit with an ambient air independent breathing air supply worn outside the suit;
    - Gas-tight chemical protective suit with overpressure breathing air supply;
- Non-gas-tight chemical protective suit;
- Protective clothing against liquid chemicals (liquid-tight);
- Protective clothing against liquid chemicals (spray-tight);
- Protective clothing against (fine and / or dispersed) particles of solid chemicals;
- Spray-tight protective clothing (time limited).

Chemical protective suits can combine protection from hazards from liquids and from sprayed and solid chemicals, for instance. Furthermore, PPE with antistatic properties, or protective clothing against infectious agents or biological hazards, is also available.

WARNING. The effectiveness of PPE with antistatic properties depends on air humidity.

HINT. If PPE with antistatic properties is certified according to the European Norm 1149-5, the functionality of the antistatic equipment is only guaranteed for a humidity level greater than 25%.

The maximum time before a hazardous chemical breach a protective garment or liner (time limit of resistance, permeation by the chemical), resulting in the PPE losing its protection, should be known and taken into consideration when carrying out tasks. These data are provided by PPE manufacturers and are based on both the acting chemical and material used.

Even though maintenance and repair of chemical protective clothing is carried out by trained personnel, chemical protective suits should be inspected for defective fasteners, holes or cracks before use. This applies to both disposable and reusable protective clothing. Even new, unused chemical protective clothing may have been damaged by careless opening of packages. Therefore, a visual inspection should be carried out before wearing unused protective clothing for the first time.

The use of flame-retardant underwear / clothing can be appropriate to minimise the heat effects of combustion, deflagration or detonation to the human body.

PPE FOR RESPIRATORY PROTECTION

Respiratory protection aims to prevent absorption via mucous membranes and lungs.

Filters and masks must be tailored to counter specific contaminating substances. To ensure this, the type and characteristics of the contamination must be known. MA staff should be informed about the protective properties of filters and how they are specified (for instance markings and labelling), restrictions of respiratory protection equipment, and the range of use of this equipment.

Gas filters must only be used against contaminants such as gases and vapours, whilst particle filters are used to counter particle contaminants. If contamination with gases and particles is expected, combination filters or combined filter systems should be employed.

It may be necessary to use a rebreather in case of an emergency such as an unintentional substance release or if concentration limits are exceeded. Such equipment may also be needed if the oxygen concentration of inhaled air is below a certain level (17%).

PPE FOR EYE PROTECTION

Different kinds of glasses and eye protection are available. Appropriate eye protection must be worn, one that is resistant to a chemical's corrosive effects, for instance. If the face is also at risk, an additional protective screen must be used.

In case of eye-damaging vapours or aerosols, a full-face mask should be worn.

PPE FOR HAND PROTECTION

In general, protective gloves should be used. The gloves' material must be sufficiently impermeable and resistant to the substance expected to be found. Gloves should be obtained from a certified manufacturer.

Gloves should be checked for leakage before use. If contaminated, they should be pre-cleaned before removing and being disposed of. Reusable gloves should be stored in a well-ventilated location.

The maximum time before a hazardous chemical breach a glove, resulting in the glove losing its protection, should be known and taken into consideration when carrying out any task. For instance, natural rubber gloves are breached by acetone within 10 minutes.

WARNING. In the case of some substances, such as peroxides or acids, fabric or leather gloves are completely unsuitable. For instance, cotton or Nomex® gloves are unsuitable for handling spilled nitric acid or sulphuric acid, leather gloves are unsuitable when handling hydrogen peroxide (of unknown concentration).

For gloves, the time limitations of resistance given by a manufacturer are standard values based on a temperature of 22°C and permanent contact with the hazard. Increased temperatures and wearing time reduce the breakthrough time.

In case of doubt, the manufacturer should be contacted. If a glove's thickness is approx. 1.5 times thicker / smaller than the equivalent model for which the information is given, the respective breakthrough time is doubled / halved respectively. Hazard data only applies to pure substances. When transferred to a mixture of substances, the data should only be considered as a guideline.

10.3. TEMPORARY STORAGE OF HMEs AND CHEMICALS

Storage and transport of ammunition, explosives and energetic materials are well regulated. Robust SOPs and solutions have been developed regarding the storage and transport of hazardous goods. This sub-section illustrates some good practices for the temporary storage of HMEs and chemicals, designed to prevent hazardous accidents due to poor storage conditions.

The International Technical Ammunition Guidelines (IATG) deliver high-quality support for adequate ammunition management. Much of the advice provided by the IATG are of significant use when forced to store HMEs and chemical precursors.

The United Nations 'Recommendations on the Transport of Dangerous Goods' addresses the regulation of the transport of dangerous goods, in relation to governments and international organisations. The recommendations have been developed in the light of technical progress, the advent of new substances and materials, the demands of modern transport systems and, above all, the requirement to ensure the safety of people, property and the environment.

NOTE. For the purposes of this publication, *temporary storage* is defined as the storing of hazardous substances in closed containers or packages in a facility designated for this purpose. *Storage* is considered as the storing of hazardous goods in facilities developed for this purpose, as found in industry or waste management facilities.

HINT. Comprehensive information on the transport of ammunition and hazardous goods can be found in the United Nations 'Recommendations on the Transport of Dangerous Goods', the 'Accord européen relatif au transport international des marchandises dangereuses par route' (ADR), and the European Union's agreement concerning the international carriage of dangerous goods by road. IATG 08.10 Annex D provides a summary of these regulations.

10.3.1. GENERAL CONSIDERATIONS ON TEMPORARY STORAGE OF HMEs AND CHEMICALS

The storage of explosives and chemicals is regulated by domestic law. Similar laws and obligations will regulate temporary storage. Generally, normative frameworks on the storage of hazardous substances (solid, liquid and gaseous) are developed to regulate their storage in their original containers (for instance drums, bottles or bags). Such frameworks can be very complex and cover a wide variety of substances, distinguishing between explosive properties and other hazards. Even though the legal requirements for storing hazardous substances may vary across countries and can be complex, many regulations offer tangible guidelines. MA organisations should assess any hazards as part of their risk assessment and take appropriate protective measures.

Encountering HME and chemicals should be identified as a risk during early planning phases. Priority should be given to their immediate disposal or storage in a waste management facility.

GOOD PRACTICE. Being already mixed as an explosive, an HME's threat is an explosive one. The IATG cover good storage principles and practice. An HME should always be stored using regulations for compatibility group 'L', including when storage conditions have been taken into consideration and the HME is safe to transport. An HME should always be stored separately from all articles belonging to other compatibility groups, as well as from all other articles of different types of compatibility group and hazard division 1.1 (hazard division 1.1 refers to substances and articles which have a mass explosion hazard).

The decision to provide temporary storage very much depends on an organisation's mandate, regional situation and other conditions such as access to waste management facilities. However, short-term storage of HMEs and chemicals requires minimum standards for storage and safety as well. Requirements to be considered when temporarily storing collected chemicals and HMEs should include:

- Preventing further contamination of the environment;
- Protecting stored materials from weather and other external influences;
- Securing against unauthorised access to HMEs and chemicals;
- Securing of the storage site against unauthorised entry; and
- Complying with necessary safety measures when handling hazardous substances.

Some professional waste management facilities (not all of them) are equipped with appropriate means to store and process chemicals; indeed, there may be companies specialised in the management of chemical waste. Depending on the location and available infrastructure, the use of such facilities cannot be guaranteed. The requirement to store HMEs and chemicals can prompt MA organisations to design temporary storage sites with greater degrees of protection and for longer time frames. The design of a temporary storage site must also prevent any harm to the environment and local population.

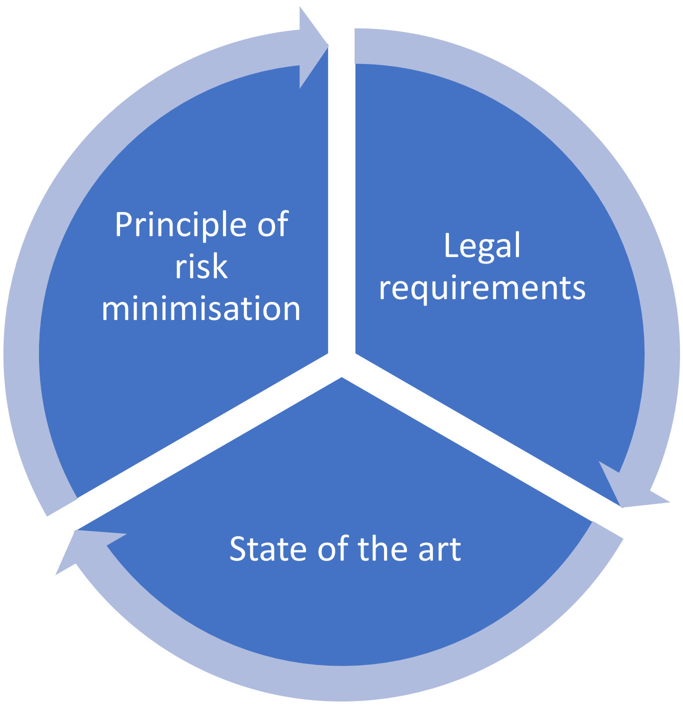


Figure 8. Principles of storing hazardous goods (source: GICHD ©)

Good storage practices for hazardous goods follow the principle of risk minimisation, compliance with legal regulations and the application of state of the art, yet practical, techniques. To ensure this approach is followed / implemented, the development of a comprehensive storage concept in the planning process is advisable.

A comprehensive storage concept should:

- Consider local environmental conditions and adapt storage methods to the hazardous nature of the substances to be stored;
- Identify contradictory measures and procedures early on in the planning process; and
- Comply with legal requirements.

To achieve these goals, the comprehensive storage concept should:

- Include a description of the site conditions;
- Provide details on the type and quantity of HMEs / chemicals to be stored; and
- Outline the constructional, technical and organisational measures to be taken.

NOTE. For appropriate short-term storage (for instance at a search site), analogous protective measures must be taken.

POSSIBLE HAZARDS	IMPACT
fire / explosion	distribution of toxic fumes and vapours, secondary effects of explosions; contamination of soil, surface water and groundwater with firefighting water
flooding	hazard to the environment from contaminated water
leakage or improper disposal	spread of toxic or environmentally hazardous substances

Table 13. Possible impact of improper storage

When hazardous substances need to be stored in containers or in large quantities, the available space in a suitable storage facility often reaches its limit. Hazardous material storage facilities can be used for safe storage. Hazardous material storage facilities offer plenty of space for the safe and versatile storage of water-polluting and flammable substances.

GOOD PRACTICE. Empty chemical packaging can still include hazards. Residual quantities may produce flammable and explosive air-vapour mixtures. Contaminated and uncleaned containers should be treated as full. However, it is advisable to separate them from full packages and mark them as empty.

Organising the storage of chemicals is less of a challenge, as they are commonly stored worldwide for various industrial uses. Commercial providers offer functional and internationally proven solutions to fulfil this task. However, budget constraints and access limitations to operational areas can make it difficult for an MA organisation to resort to support from commercial providers. This may lead to the need to develop ad hoc storage solutions, in order to reduce the risks to as low a level as practically possible. In addition, storage facilities may need to be adapted to specific regional requirements.

NOTE. Standard sea containers (e.g. 40-foot containers) are a good option to generate storage space within a (temporary) storage facility. They offer protection from weather and can be easily air conditioned and ventilated. Containers can be moved and relocated as required. With simple means such as filled sandbags stacked as a wall (traverse), containers can be strengthened to contain the reaction of explosives stored inside or hardened to counter external effects. Alternatively, mechanical handling equipment can be used to create makeshift bunds surrounding a container.

The storage of chemicals without their original packaging, which was designed to mitigate the hazards of storage and transport, will always be challenging. Any non-original packaging that is used must therefore have sufficient mechanical, thermal and chemical resistance to fulfil its task. As a rule, packaging must be approved for transport on public roads. Plastic containers are subject to ageing and thus have a maximum service life; in Europe, this is usually 5 years. Exposure to UV radiation can greatly accelerate ageing.

NOTE. Anyone operating in storage and handling facilities for hazardous substances is responsible for ensuring that measures are taken in accordance with good practice. It is worth noting that some hazards can only occur when chemicals come into contact with other chemicals. To prevent this, necessary attention must be paid to the combined storage of substances at both planning and implementation stages.

10.3.2. CHEMICAL-RELATED STORAGE CONSIDERATIONS

Flammable liquids quickly burn up until they reach explosive decomposition, and accelerate the spread of fire by flowing outwards once a container is breached. Liquids that are less dense than water or immiscible with water, tend to float to the surface of extinguishing water, continuing to burn. Vapours of flammable liquids are generally explosive and can be ignited by sparks or electrostatic discharges. Empty containers that have not been cleaned often contain explosive air-vapour mixtures. Most flammable liquids pose a hazard to soil, subsoil and water.

Solids have a different burning behaviour to liquids. This can range from a glow to a violent burn. The dust of combustible solids can be explosive even if the substance is not dangerous. Solids can smoulder over a long period of time (days to weeks). This can lead to self-heating and a sudden outbreak of fire. Powder must be prevented from trickling onto floors and entering other materials.

Substances liable to spontaneous combustion, including mixtures and solutions (solid or liquid), may ignite very rapidly on contact with air, even in small quantities. Self-heating substances, including mixtures and solutions (solid or liquid), may self-ignite in contact with air when in larger quantities and after a longer period, and without further energy input. Exposing them to high temperatures (sunlight) must be avoided. Furthermore, a rise in temperature due to internal friction during transport and storage must be prevented. Substances liable to spontaneous combustion should be stored separately from other explosives, and oxidising and flammable substances. They should be stored in such a way that they are protected against fire transmission.

Various chemicals react with water to form flammable or explosive gases. Such a reaction generally releases so much heat that the resulting gas ignites itself. These substances should be stored separately from other hazardous substances and preferably not outdoors. Cross-ventilation of the room is advisable. These substances must be stored in tightly closed containers in a dry and cool place. Specific hazards may occur when halogens, acids, water and oxidising agents are stored together.

Oxidising substances, together with combustible substances, form highly flammable or explosive mixtures. These substances are not necessarily classified as hazardous but are sufficient to promote fires in basically flammable substances, such as sugar or wood chips. Special care must be taken with organic peroxides, which combine the properties of oxidising and flammable substances. They generally burn very violently or even explosively. It is advisable to consider storing organic peroxides separately. Oxidising substances should be stored separately from flammable and corrosive substances. Oxidising substances and organic peroxides should not be stored together.

Toxic substances can have a very harmful or even lethal effect on humans, flora and fauna and the environment, even in very small quantities. These chemicals must be stored in such a way that they are inaccessible to unauthorised persons. They must not be stored in the vicinity of human or animal food. When handling toxic substances, the focus must be on self-protection and the protection of others. Employees must be trained regularly in handling, safety and emergency procedures.

Corrosive and caustic substances cause serious damage to health, or even death, when coming into contact with tissue, mucous membranes, eyes or if swallowed. These chemicals can attack and cause metals to decompose. Furthermore, they can form dangerous gases once in contact with the air. Corrosive and caustic substances must be separated from others in combination with which they form dangerous gases, and from substances that promote fire. Containers and collecting trays must be made of medium-resistant material. Acids and alkalis can react with each other, generating a considerable amount of heat and should be stored separately.

Substances that are harmful to health or are irritants can cause damage when ingested or through contact, and / or have environmentally hazardous properties. In the case of liquid substances, leakage into soil, surface water and groundwater must be prevented. In the case of solid substances, rainwater or firefighting water can lead to their infiltration into the surrounding environment. Solids can also be dispersed by wind. During storage, it must be ensured that no substances that are harmful to health or which are irritants can enter the soil, subsoil, surface water or groundwater through their release.

10.3.3. CONSTRUCTIONAL, TECHNICAL AND ORGANISATIONAL MEASURES

Organisational measures have proven to be an effective and inexpensive tool to increase safety and prevent accidents in all kinds of storage.

Organisational measures ensure:

- The permanent surveillance and documentation of the stored HMEs and chemicals;
- That the storage infrastructure and system are fit for the task;
- The prevention of handling errors;
- The application of good working practices;
- The protection of stored goods from environmental influences or external events;
- That the prerequisites are set for an accident investigation; and
- Security against theft.

Risk assessments of the properties of temporarily stored HMEs and chemicals establish the preconditions for safe and well-organised storage. Questions that should be asked during such assessments include:

- What hazards do the stored goods present, because of their chemical and physical properties?
    - Explosion and fire behaviour;
    - Reactivity;
    - Chemical and physical stability;
    - Emission of fumes and vapours;
    - Decomposition effects on containers, packaging, etc; and
    - Toxic threat to humans and the environment.
- What issues need to be considered in the surroundings of the temporary storage site?
    - Safety distances;
    - Neighbouring infrastructure;
    - Floor drains;
    - Access by unauthorised personnel; and
    - Natural hazards.

GOOD PRACTICE. Floor drains in the vicinity must be closed or secured in such a way that neither hazardous substances nor extinguishing water can flow away unchecked.

- Which counter measures can decrease the hazards and increase storage safety? Measures include:
    - Assessable documentation of the stored chemicals;
    - Regulated access;
    - Danger-specific training plan for staff;
    - Incident reaction plan, including fire protection plan and equipment;
    - Phlegmatisation of HMEs and chemicals (e.g. storing phosphorus in water);
    - Separation of goods by their hazardous material classification;
    - Separation of primary and secondary explosives;
    - Separation of flammable substances, propellants and pyrotechnics;
    - Organisation of the spatial separation of stockpiles;
    - Separation of chemicals that must not be stored together, as contact may lead to intense reactions;
    - Determination of the maximum safe quantity of explosives per storage location;
    - Structural protection measures;
    - Creation of fire compartments;
    - Limitation of stored amounts per fire compartment;
    - Provision of appropriate PPE;
    - Provision of threat-adapted first aid materials such as eye showers; and
    - Provision of oil binders, chemical binders and shovels.
- Are there external threats to a storage facility including man-made and natural threats (such as flooding)?
- Which external sources of danger or facilities worthy of protection are in the vicinity?

Hazards to the surrounding area do not only include fragmentation resulting from a detonation. The effects of fragmentation can be minimised by the limitation of amounts of chemicals per stockpile, and structural protection measures. Threats to the surrounding area also include the toxic and caustic properties of chemicals. Fumes and vapours can be a threat to health. Preventing leakage of chemicals into the water supply is as important as fire protection. Depending on the amount and type of a substance, contamination of the environment can negatively affect lives for months or years to come.

GOOD PRACTICE. Building materials should not contribute to the amount of fragmentation in the event of an explosion or fire hazard.

Risk assessment will provide courses of action on how to conduct safe and organised storage, although it should be kept in mind that proper storage will usually be a challenge during MA operations. Storage of hazardous goods will require great improvisational talent, planning skills and good adaptability on behalf of the organisation, especially if a state's support is limited. In post-conflict scenarios, meeting industrial standards for the storage of hazardous substances can be hard to achieve but should be considered as the goal, regardless.

Industrial guidelines[64] propose seven main steps to assessing a planned storage facility:

- Step 1 – stock list.
  A comprehensive stock list should be created. Which substances and chemicals are expected to be stored? It will always be challenging to foresee all types of HME and chemicals.
- Step 2 – classification and hazardous properties.
  Classification and hazardous properties of the stored HMEs and chemicals are added to the list. This includes the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), classes of water hazards, flashpoint,[65] health, environmental and explosion hazards. Depending on the substances, further relevant items may be added.
- Step 3 – maximum storage quantities.
  The expected maximum quantities of substances and products to be stored are added to the list, which must respect applicable legal limits. Due to the nature of the list, many of the items and entries can be based on assumptions.
- Step 4 – determination of the corresponding storage class.
  Determine the corresponding storage classes:[66]
  - Explosive substances;
  - Infectious substances;
  - Radioactive substances;
  - Liquefied and pressurised gases;
  - Oxidising substances / organic peroxides;
  - Spontaneously combustible substances;
  - Gases flammable with water;
  - Flammable solids;
  - Toxic substances;
  - Corrosive and caustic substances;
  - Other liquids;
  - Other solids with hazard labels; and
  - Other solids without hazard labels.

64 Hans-Peter Beutler et al., *Lagerung gefährlicher Stoffe, Leitfaden für die Praxis* (*Storage of Hazardous Substances – Practical Guide*) (Frauenfeld: Environmental Departments of the cantons of Nordschweiz, Thurgau and Zürich, as well as GVZ Gebäudeversicherung Kanton Zürich, 3rd Revised Edition, 2018).

65 If an ambient temperature exceeds the flashpoint of a substance, its flammable vapours form an explosive atmosphere together with the ambient air.

66 In each storage class, substances with hazard characteristics that are of the same type are grouped together and consequently also require the same safety measures. Some storage classes (e.g infectious substances) are listed for the sake of completeness only, as they are not relevant to HMEs or their precursors.

- Step 5 – allocation.
  Available storage quantities are assigned to the corresponding storage classes.
- Step 6 – requirements for storage rooms / facilities.
  Requirements for storage rooms / facilities such as fire compartments, ventilation, leakage containment, extinguishing agents, explosion protection and so on, are determined.
- Step 7 – implementation.
  Implementation of the results of the planning of the storage facility. The relevance of the planning to the current situation is to be checked periodically.

NOTE. A proper assessment of the storage facility will help to define equipment and procedures necessary to counter an emergency such as fire or contamination.

It is appropriate to define specific storage areas within the available space. Doing this can minimise:

- The necessity for and amount of constructive protection measures;
- Efforts needed for fire protection measures;
- The required amount of collecting trays; and
- The required amount of chemical binders.

HINT. A collection tray must be chemically resistant and have the usable volume of at least the largest package stored.

An underrated but effective tool is bookkeeping of stored substances, their amount, location, as well as having a visual overview of possible paths and cross sections of the infrastructure used. This information must be easily accessible for staff and external support, in case of an emergency.

GOOD PRACTICE. Appropriate and well-organised documentation supports the prevention of incidents and can help minimise their impact. It provides information on the type of chemical, associated hazard(s) and location in the storage site. Documentation should include rules establishing when firefighting should be stopped, in case of fire, due to the increased risk of explosion and when evacuation should be carried out. In addition, proper bookkeeping prevents stored chemicals from being forgotten and the potential increased risk of explosion or fire due to ageing.

It is good practice to mark the individual stockpiles (e.g. containers) according to the hazards they contain, for instance explosive, corrosive material, biohazard, etc. Printouts or downloads of the safety data sheet or hazardous material information should be added to the documentation as well.

NOTE. If an organisation has its own storage facilities for the energetic substances required for its operations, it is advised to store HMEs and explosive precursor chemicals separate from these stockpiles.

Temporary storage of HMEs and chemicals should be split with regard to explosive and other hazards. Within enclosed storage spaces, there should be an option to ventilate areas before entering. In enclosed spaces, proactive measures (prevention of dust dispersion, for instance) to counter the threat of dust explosions are also required.

WARNING. It is not appropriate to store HMEs and hazardous chemicals together with flammable materials such as wood, cardboard boxes, paper or plastics.

10.3.4. SPATIAL SEPARATION

Depending on the available space, funding, support and the type of HMEs and chemicals, a combination of different storage solutions may be implemented at a temporary storage site. All solutions are aimed at protection from fire and explosion, as well as minimising the effects of an incident both in the temporary storage site and to the surrounding area.

Spatial separation increases the safety of a temporary storage site. Some separation and protection measures target very specific threats defined by the storage classes. The figure below demonstrates the concept of ad hoc storage, separate storage and selective storage.

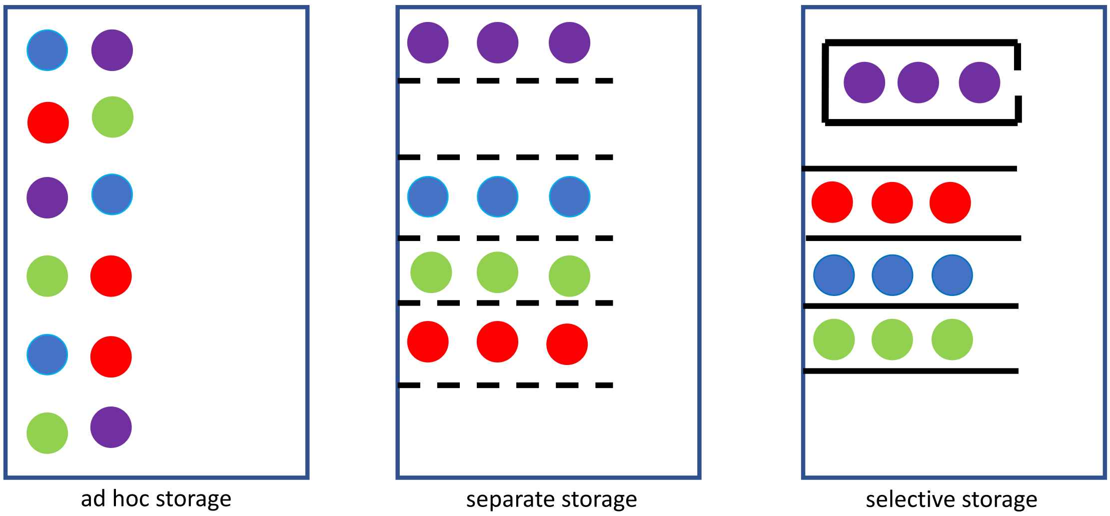


Figure 9. Storage options (source: GICHD ©)

AD HOC STORAGE

HMEs and chemicals can be temporarily stored as they are delivered. This is better applied to chemicals that do not pose specific threats or which have no limitations based on their storage class. This is a very cost-effective approach.

SEPARATE STORAGE

HMEs and chemicals having storage limitations because of their chemical and physical properties should be stored separately. Those having similar characteristics and responses can be stored in the same fire compartment. For each compartment, protective conditions must be implemented, for example minimum distances, separate collecting trays and maximum storage quantities. An increase of space between individual stockpiles improves storage safety, prevents the progress of fire and minimises the chances of a sympathetic detonation (unintended, accidental initiation of an explosive by a nearby detonation, sometimes referred to as flashover) from one stockpile to another. A proven rule for the storage of explosives has always been that increased distance improves safety.

GOOD PRACTICE: Fire protection measures are more effective if substances are stored separately according to their firefighting requirements and storage class. One example is to separate out chemicals which must not be extinguished with water and make the appropriate firefighting equipment available at that location.

SELECTIVE STORAGE

Selective storage divides HMEs and chemicals strictly according to their properties, compatibility and predicted hazard. Specific construction techniques are used to mitigate the effects of an explosion, as are separate fire compartments. If available space becomes compromised and no additional storage is available, separate storage can be implemented in some bays but only with items deemed to pose the lowest risk.

> **NOTE. If disposal is not possible, it is better to store safely, using all available storage techniques, as opposed to leaving HMEs and explosive precursor chemicals open to the elements or at risk of further illicit diversion.**

10.4. FIREFIGHTING

Firefighting involving HMEs or chemical precursors should always be carried out by personnel trained and equipped for the task. The following basic considerations may be of use if an incipient fire is encountered or for the preparation of temporary storage.

10.4.1. SAFETY CONSIDERATIONS

Some chemicals do not burn but have an oxidising effect. This property increases the fire hazard when in contact with flammable substances and can significantly promote an existing fire. In case of the involvement of such chemicals in a surrounding fire it is appropriate (if safe) to:

- Cool surrounding containers and vessels with water spray;
- Move containers out of the danger zone if possible; and
- Eliminate sources of ignition.

> **NOTE. Specific information on the behaviour of a substance when exposed to heat or fire is provided by safety data sheets, including general firefighting methods.**

> **HINT. Vapours arising from a fire can be suppressed with a water spray.**

> **WARNING. Increased pressure caused by fire within containers may cause them to burst open or their contents to deflagrate or detonate.**

Some HMEs, such as ammonium nitrate, can release hazardous gases such as nitrogen oxide and carbon monoxide when exposed to heat. Under such circumstances it may be necessary to wear a self-contained breathing apparatus and chemical protective suits when conducting firefighting.

The effect of a fire on HMEs or precursor chemicals with explosive properties is hard to assess or predict given the many variables, such as melting point, impurities, ignition temperature, particle size, density and confinement. Necessary measures (or safety measures) include taking cover immediately, clearing and cordoning off as large an area as necessary and evacuating as appropriate. The fire should be tackled, if possible, from a safe position.

WARNING. In the event of a sudden release and swirling up of large quantities of dust, there is the risk of a dust explosion. Taking cover immediately is the appropriate response.

WARNING. Some chemicals decompose violently when coming into contact with water.

10.4.2. PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers are an appropriate means of countering emerging fires. It is important that a fire extinguisher contains the appropriate extinguishing agent to fulfil this task and must be selected based on the expected fire load and fire class.

FIRE LOAD	Solid substances (Europe: fire class A)
	Liquid substances (Europe: fire class B)
	Gaseous substances (Europe: fire class C)
	Metal fires (Europe: fire class D)
	Grease fires (Europe: fire class F)

Table 14. Classification of fire loads

Fire extinguishers are divided into rechargeable and continuous pressure fire extinguishers. Compared to continuous pressure, rechargeable extinguishers are much more complex in terms of construction and technical specifications. The advantages of rechargeable fire extinguishers compared to continuous pressure fire extinguishers include:

- Easy and ample dosing of the extinguishing agent, even for inexperienced users;
- Ease of maintenance;
- Reliable handling; and
- A longer legal operating time (typically 25 years, with continuous pressure fire extinguishers lasting only 20 years).

Fire extinguishers are available with regular extinguishing agents like powder, foam, water and carbon dioxide (CO_2). The fire class determines the choice of the appropriate extinguishing agent.

POWDER

ABC extinguishing powder is the most widely used extinguishing agent. It consists mainly of phosphate and ammonium sulphate (approx. 90% in total).

The advantage of ABC extinguishing powder is that it can be used universally for fire classes A, B and C. In principle, extinguishing powder has a high extinguishing capacity. This can vary considerably depending on the type of fire.

The disadvantage of this type of extinguishing agent is the extremely heavy dust formation and its associated contamination. Electrical devices react sensitively to the fine dust produced by ABC extinguishing powder.

Using powder fire extinguishers to address small incipient fires can quickly lead to significant damage in certain contexts because of the contamination with the ABC powder itself.

Special extinguishing powders are also used to extinguish metal fires (fire class D).

FOAM

Foam fire extinguishers are cleaner than powder fire extinguishers, but their performance is comparatively low. At the same time, very good extinguishing results can be achieved depending on the kind of material that is burning.

Foam fire extinguishers are not powerful enough to extinguish fire classes A and B. They therefore have a more limited use, compared to that of powder fire extinguishers. For most commercial, public and private applications, however, a foam extinguisher is an appropriate alternative to a powder fire extinguisher. In outdoor areas, care should be taken that a frost-proof version (via inclusion of additives) is chosen.

WATER

Water fire extinguishers are intended exclusively for extinguishing class A fires. Additives are included that increase the extinguishing performance compared to that of regular water. Extinguishing fire with water is cleaner than with powder but less effective than with foam.

Grease fires (fire class F) are extinguished with specially manufactured water and / or foam fire extinguishers.

CARBON DIOXIDE CO_2

Carbon dioxide fire extinguishers extinguish with non-flammable gas. In the process, the gas displaces the oxygen, thus smothering the fire. This enables the cleanest way of extinguishing, and is completely residue free. Due to its physical properties, this extinguishing agent is only suitable for class B fires. However, carbon dioxide fire extinguishers are also used to protect electrical systems, for example in server rooms and in the computer sector.

11. CONCLUSION

Image 204. Containers with HMEs prior to their disposal (source: CAR ©)

The continued deployment of IEDs around the globe has focused attention on the issue of HMEs. Sadly, the trend of IED use is not abating, instead their on-going presence continues to cause innocent victims in large numbers.[67] As highlighted by the Landmine Monitor 2021, "The majority of casualties in 2020 were reported in countries experiencing armed conflict and which suffered contamination with mines of an improvised nature.[68] Notably, many of the devices defined as "improvised mines" make use of HMEs in their construction, and the risks to personnel operating in these environments and their populations from HMEs, must therefore be addressed.

This chapter has been produced to address the immediate need for basic information related to the proliferation of HMEs in environments affected by IEDs. It aims to support the effort to keep MA practitioners (as well as other humanitarian workers and first responders) safe by allowing them to better plan for and manage the risks associated with HMEs – both explosive and non-explosive. Knowledge of the physical and chemical properties of HMEs and their chemical precursors plays an important role in strengthening safety measures and this information therefore forms the basis of this chapter.

Unfortunately, encountering HMEs, HME-contaminated storage sites, or HME manufacturing sites, will always entail a degree of risk and will require that decisions are made on a case-by-case basis by field personnel. The very nature of "improvised" devices is that they are ever-changing and continuously evolve in terms of their structure. As a result, the knowledge presented in this chapter, targeted to the needs of humanitarian personnel, supports evidence-based decisions to identify and counter those hazards.

Through the review of various safety aspects that are relevant to dealing with HMEs, it is hoped that national programmes and MA operators will also be supported in the development of national standards and standard operating procedures (SOPs) in environments affected by IEDs. For example, suggestions

67 In 2020, at least 7,073 casualties of mines/ERW were recorded, which represents an increase over the 5,853 casualties recorded in 2019, according the Landmine Monitor 2021. The majority of these casualties were as a result of improvised mines. http://www.the-monitor.org/en-gb/reports/2021/landmine-monitor-2021/the-impact.aspx

68 Ibid.

in terms of equipment – in particular PPE – that can shield personnel from the effects of HMEs and allow them to interact more safely with these substances, have been provided. Appropriate PPE will most certainly improve the likelihood that HMEs can be removed and/or destroyed in as safe a manner as possible by appropriately-trained personnel. Ensuring that MA and other humanitarian personnel understand what they should avoid when encountering HMEs, as well as the steps they should take when HMEs are found, is another important objective of this chapter that can inform standards and procedures.

The content on HMEs has been produced with the support and participation of a number of organisations. In particular, the GICHD would like to thank Bundeswehr CBRN Defence Command, Brimstone Consultancy Limited, Conflict Armament Research and the Fondation Suisse de Déminage, for their valuable support in preparing this chapter.

Finally, due to the changing nature of IEDs, this document must continue to evolve and incorporate new information from the field. The GICHD therefore counts on the input of MA stakeholders engaged in IED-affected environments to provide feedback on the content, including where gaps may occur with regards to information provided on HMEs encountered in the field. It is essential that information is shared and that MA personnel are equipped with the most recent and complete information possible to ensure the safety and effectiveness of humanitarian work where IEDs are found. In order to reach this goal, we count on your continued support.

12. LEXICON OF ABBREVIATIONS

ANAL	ammonium nitrate–aluminium
ANFO	ammonium nitrate–fuel oil or ANC
ANIS	ammonium nitrate–icing sugar
ANMAL	ammonium nitrate–nitromethane–aluminium
ANNIE	ammonium nitrate–nitrobenzene
ANNM	ammonium nitrate–nitromethane
ANS	ammonium nitrate–sugar
CHP	concentrated hydrogen peroxide
DDNP	dinitrobenzenediazoxide or diazodinitrophenol, DINOL®
EGDN	ethylene glycol dinitrate or nitroglycol
ETN	erythritol tetranitrate
FOI	figure of insensitivity
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
HME(s)	home-made explosive(s)
HMTD	hexamethylene triperoxide diamine
IATG	International Ammunition Technical Guidelines
IED	improvised explosive device
IMAS	International Mine Action Standard
LEL	lower explosive limit
MA	mine action
MEKP	methyl ethyl ketone peroxide or butanone peroxide
NG	nitroglycerine or glyceryl trinitrate
PE	polyethylene
PETN	pentaerythritol tetranitrate or nitropenta
PLX	Picatinny Liquid Explosive or myrol
PP	polypropylene
PPE	personal protective equipment
PTFE	polytetrafluoroethylene or Teflon™
PVC	polyvinylchloride

RDX	trimethylentrinitramin; or Hexogen
SDS	safety data sheet
SOPs	standing operating procedures
TATP	acetone peroxide or triacetone triperoxide
TEA	triethylaluminium
TNT	trinitrotoluene
TPA	thickened pyrophoric agent
UEL	upper explosive limit

13. GLOSSARY OF TERMS

alkali metals[69]. lithium, sodium, potassium, rubidium, caesium and francium.

black powder. intimate mixture of sodium nitrate or potassium nitrate with charcoal or other carbon, with or without sulphur. (IATG 01.40 Glossary of terms, definitions and abbreviations, 3rd edition, March 2021)

blast. a destructive wave of gases or air produced in the surrounding atmosphere by an explosion. The blast includes a shock front, high pressure behind the shock front and a rarefaction following the high pressure. (IATG 01.40, 3rd edition, March 2021)

booster. explosive device used as a donor charge to amplify the energy to the acceptor charge. (IATG 01.40, 3rd edition, March 2021)

brisance. the shattering effect of an explosive or explosion. (IATG 01.40, 3rd edition, March 2021)

catalyst. in chemistry, any substance that increases the rate of a reaction without itself being consumed. (©2021 Encyclopædia Britannica, Inc.)

charge. a bagged, wrapped or cased quantity of explosives without its own integral means of ignition. Secondary means of ignition may or may not be incorporated. (IATG 01.40, 3rd edition, March 2021)

combustion. rapid chemical combination of a substance with oxygen, involving the production of heat and light. (Oxford English Dictionary, ©2021 Oxford University Press)

confinement. the characteristics of the casing of a charge, which restrict the expansion of the decomposition products when the explosive substance reacts. (IATG 01.40, 3rd edition, March 2021)

contamination. impurity of an HME with a substance(s) other than that intended to be part of the improvised explosive.

critical diameter. the minimum diameter of an explosive charge at which detonation can still take place. (Rudolf Meyer, Josef Köhler and Axel Homburg, Explosives. Sixth Edition. Wiley-VCH Verlag GmbH & Co. KGaA, 2007)

dangerous goods. items classified under the United Nations (UN) system within Classes 1 to 9 in accordance with the UN Transport of Dangerous Goods Regulations (Orange Book). (IATG 01.40, 3rd edition, March 2021)

decomposition. chemical reaction of a substance which is not a detonation or deflagration, resulting in significant change in properties. (IATG 01.40, 3rd edition, March 2021)

deflagration. a reaction of combustion through a substance at sub-sonic velocity in the reacting substance. (IATG 01.40, 3rd edition, March 2021)

deflagration to detonation transition. the transition to detonation from an initial burning reaction. (IATG 01.40, 3rd edition, March 2021)

density. mass of a unit volume of a material substance. (©2021 Encyclopædia Britannica, Inc.)

detonation. reaction which moves through an explosive material at supersonic velocity in the reacting material. (IATG 01.40, 3rd edition, March 2021)

69 If no source is added, the definition is taken from this publication.

detonation velocity. velocity at which the detonation travels through the explosive charge or column in m/s. (IATG 01.40, 3rd edition, March 2021)

detonator. a device containing a sensitive (primary) explosive intended to produce a detonation wave. (IATG 01.40, 3rd edition, March 2021)

diurnal cycling. the exposure of ammunition and explosives to the temperature changes induced by day, night and change of season. (IATG 01.40, 3rd edition, March 2021)

dust explosion. the result of the rapid combustion of fine solid particles, such as organic dusts (sugar or wood), metal dusts (aluminium and magnesium); polymer-based dusts and carbonaceous dusts. (E. Salzano, in Reference Module in Chemistry, Molecular Sciences and Chemical Engineering, 2014)

equivalence (TNT). when explosives having a significantly more or less powerful effect than TNT are being considered, a TNT equivalent may be used to determine the appropriate quantity distance(s). (IATG 01.40, 3rd edition, March 2021)

explosion. sudden release of energy producing a blast effect with the possible projection of fragments. (IATG 01.40, 3rd edition, March 2021)

explosive. a substance or mixture of substances, which, under external influences, is capable of rapidly releasing energy in the form of gases and heat. (IATG 01.40, 3rd edition, March 2021)

flash composition. a pyrotechnic composition (mixture of oxidiser and (metallic) fuel) which burns bright and quickly and, if confined, produces a loud noise.

flashpoint. the lowest temperature at which a volatile substance evaporates to form an ignitable mixture with air in the presence of an igneous source and continues burning after the trigger source is removed. (Joaquín Isac-García et al., Experimental Organic Chemistry, 2015)

fuel. a substance or compound that is electron rich and acts within an explosive as a chemical reducing agent.

fuel-air explosion. occurs when fuel vapour mixes with ambient atmospheric air and when mixing is complete, is initiated by an ignition source.

fuse. a device for protecting an electrical circuit against damage from an excess current by the melting of a fuse element to break the circuit. Also used for burning fuses, i.e. those fuses which do not use detonation to ignite the explosive train. (IATG 01.40, 3rd edition, March 2021)

fuze. a device that initiates an explosive train. (IATG 01.40, 3rd edition, March 2021)

harm. physical injury or damage to the health of people or damage to property or the environment. (IATG 01.40, 3rd edition, March 2021)

hazard. potential source of harm. (IATG 01.40, 3rd edition, March 2021)

hazard class. the UN recommended system of nine classes for identifying dangerous goods. Class 1 identifies explosives. (IATG 01.40, 3rd edition, March 2021)

high explosive (HE). substance or mixture of substances that can undergo a fast internal decomposition reaction leading to a detonation in its normal use. (IATG 01.40, 3rd edition, March 2021).

A substance or mixture of substances which, in their application as primary, booster or main charge in ammunition is required to detonate. (IATG 01.40, 3rd edition, March 2021)

Home made explosive. a combination of commercially available ingredients combined to create an explosive substance (2014). (IMAS 04.10 Glossary of mine action terms, definitions and abbreviations, Second Edition (Amendment 10, February 2019)

homogeneous mixtures. a mixture having the same composition and the same physical and chemical properties in all parts. Heterogeneous mixtures consist of at least two immiscible phases. Their individual components may be present in different aggregate states and / or consist of different substances.

hotspot. spot in an explosive where adiabatic compression of small, occluded gas bubbles generates up to 400°C-500°C heat.

hygroscopic. readily water-attracting.

hypergolic reaction. the self-igniting effect between mixed liquids.

ignition. the initial heating of a deflagrating explosive or pyrotechnic composition, by flame or other source of heat, up to its point of inflammation. (IATG 01.40, 3rd edition, March 2021)

improvised explosive device (IED). a device placed or fabricated in an improvised manner incorporating explosive material, destructive, lethal, noxious, incendiary, pyrotechnic materials or chemicals designed to destroy, disfigure, distract or harass. They may incorporate military stores but are normally devised from non-military components. (IATG 01.40, 3rd edition, March 2021)

incendiary munition. ammunition, containing an incendiary substance and designed to give a primary incendiary effect which may be a solid, liquid or gel including white phosphorus. (IATG 01.40, 3rd edition, March 2021)

initiation. refers to the commencement of a deflagration or detonation reaction.

loading density. ratio between explosive weight and the amount of space in which an explosive is detonated (compactness).

low explosive. deflagrating explosive used for propulsion. *See* propellant (IATG 01.40, 3rd edition, March 2021)

low order detonation. an incomplete and relatively slow detonation, being more nearly a combustion than an explosion. (IATG 01.40, 3rd edition, March 2021)

oxidiser. a substance that is combined with a fuel to produce an energetic material. (IATG 01.40, 3rd edition, March 2021)

phlegmatiser. a substance added to an explosive to enhance its safety in handling and carriage.

porosity. the ratio of void volume to total volume of a substance or mixture of substances.

prill. a pellet or solid globule of a substance formed by the congealing of a liquid during an industrial process.

primary explosive. an explosive substance which is sensitive to spark, friction, impact or flame and is capable of promoting initiation in an unconfined state. (IATG 01.40, 3rd edition, March 2021)

An explosive that is extremely sensitive to stimuli such as heat, friction and/or shock and requires special care in handling. Generally, primary explosives are synonymous with initiating explosives. (IATG 01.40, 3rd edition, March 2021)

propellant. deflagrating explosive used for propulsion. (IATG 01.40, 3rd edition, March 2021)

pyrophoric. a substance capable of spontaneous ignition when exposed to air, such as white phosphorous. (IATG 01.40, 3rd edition, March 2021)

pyrotechnic. a device or material that can be ignited to produce light, smoke or noise. (IATG 01.40, 3rd edition, March 2021)

reactant. substance participating in the chemical reaction.

risk management. the complete risk-based decision-making process. (IATG 01.40, 3rd edition, March 2021)

safe. the absence of risk. Normally the term tolerable risk is more appropriate and accurate. (IATG 01.40, 3rd edition, March 2021)

'safe to move'. a technical assessment, by an appropriately qualified technician or technical officer, of the physical condition and stability of ammunition and explosives prior to any proposed move. (IATG 01.40, 3rd edition, March 2021)

secondary explosive. an explosive substance which requires a large stimulus to detonate.

sensitiser. substance used to increase susceptibility to ignition (initiation). (IATG 01.40, 3rd edition, March 2021)

sensitiveness. a measure of the relative probability of an explosive being ignited or initiated by a prescribed stimulus. It is used in the context of accidental ignition or initiation. (IATG 01.40, 3rd edition, March 2021)

sensitivity. a measure of the stimulus required to cause reliable design mode function of an explosive. (IATG 01.40, 3rd edition, March 2021)

solution. in chemistry, is a homogenous mixture of two or more substances in relative amounts that can be varied continuously up to what is called the limit of solubility. (©2021 Encyclopædia Britannica, Inc.)

stabiliser. a substance which stops or reduces auto-catalytic decomposition of explosives. (IATG 01.40, 3rd edition, March 2021)

stability. the physical and chemical characteristics of ammunition and explosives that impact on their safety in storage, transport and use. (IATG 01.40, 3rd edition, March 2021)

standing operating procedures (SOPs). instructions that define the preferred or currently established method of conducting an operational task or activity. (IATG 01.40, 3rd edition, March 2021)

strength. determined by the gas volume produced and the energy (heat) created by the explosion as well as the detonation velocity.

sympathetic detonation. unintended, accidental initiation of an explosive by a nearby detonation, sometimes referred to as flashover.

tinder. substances that lower the ignition temperature of a low explosive.

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https://pubchem.ncbi.nlm.nih.gov/x

U.S. National Library of Medicine – PubMed:
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ANNEX I

RISK MANAGEMENT - SAFETY DISTANCES IN URBAN ENVIRONMENTS

INTRODUCTION

The management of risk is the responsibility of all staff involved in mine action operations, and details of who is responsible for what should be established in national mine action standards (NMAS) and standard operating procedures (SOPs), clearly identifying roles and expectations at every level. Any risk management plan should be able to be reviewed for suitability, and to do so requires auditable documentation that provides relevant detail without being overburdensome to staff or the programme in general.

Urban environments present mine action with the challenge that a substantial local population can be found within the potential safety distance area of unexploded ordnance (UXO). This includes busy city centres to where families and businesses have returned, and routes are busy with foot and vehicle traffic that can pass through a task site. Explosive ordnance (EO) contamination can be dense and varied, in an environment where it is difficult to assess its presence prior to technical interventions. The implementation of unmitigated safety distances in these contexts can result in very large evacuation zones that may need to be in place for extended periods of time or employed on multiple occasions. This can negatively impact the local economy, quality of life, relationships within communities and general recovery for the area.

Establishing a relevant and reliable cordon and evacuation requires detailed planning and coordination with other agencies, as mine action will often lack the numbers of staff required to inform and ensure evacuation of the local population. There is also a requirement for establishing multiple positions to prevent deliberate or accidental access into the danger area by residents or people passing through. Due to national laws, these requirements and powers are likely to be outside the mandate and beyond the capability of a mine action operator, or even the national mine action authority (NMAA), and a standardised response should be designed with the roles and responsibilities clearly defined.

SCOPE

The purpose of this annex is to highlight the considerations required when working in any urban environment: the risk assessment process and safety aspects when conducting mine action clearance operations regarding the calculation of safety distances, their implementation, and the mitigation of potential consequences. It is intended as a supplement to existing guidance in International Mine Action Standards (IMAS) / International Ammunition Technical Guidelines (IATG), referenced on p. 20.

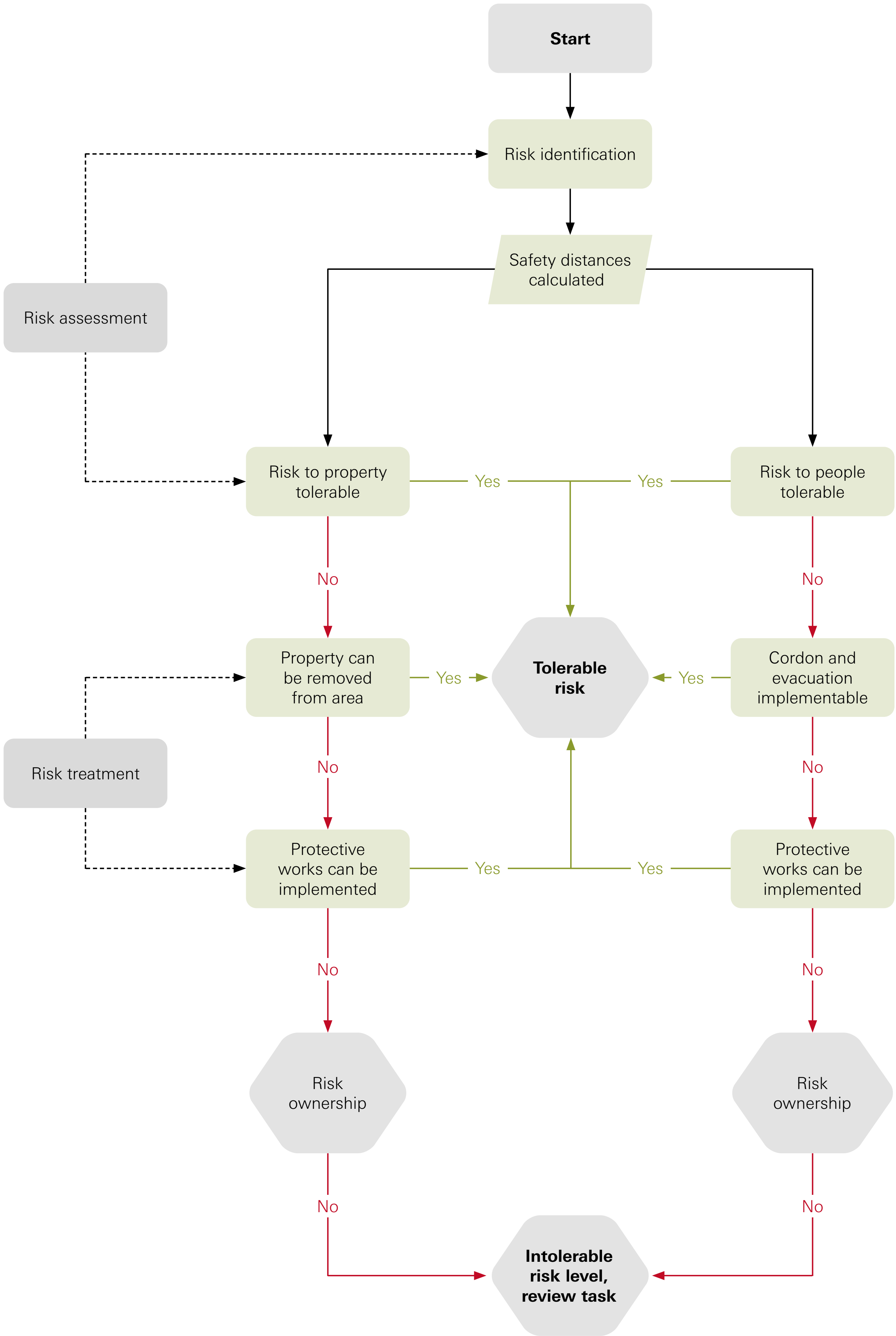
Chapter 2 (Search), Annex 3C (Risk Assessment Form), of this guide provides an example that can be adapted for use in conjunction with this guidance.

RISK ASSESSMENT PROCESS

A risk assessment should follow a rational sequence, gathering all relevant information for consideration that provides outputs to be used for each subsequent phase. Below is an example outline based on IMAS 07.14, Risk Management in Mine Action, and good practice, that creates a framework for mine action staff.

SEQUENCE

1. RISK IDENTIFICATION
    - a. Hazard identification – survey and assessment of potential EO hazards present
    - b. The risk of explosion from the hazards and clearance activities
2. RISK ANALYSIS
    - c. Estimation of explosion danger areas
    - d. Identification of at-risk groups
        - i. People
            - Staff
            - Local population
                - o Resident
                - o Transient
        - ii. Property – including secondary hazards e.g. bulk fuel, chemicals
            - Personal
            - Commercial
            - Government
            - Utilities and infrastructure
    - e. Methods of analysis
        - i. Bow-tie analysis for an overview of all risks and vulnerabilities on a task
        - ii. Severity / likelihood matrix for individual risks
3. RISK EVALUATION
    - f. Is the risk at a tolerable level?
        - i. Requirement for mitigation
4. RISK TREATMENT (MITIGATION)
    - g. Cordon and evacuation
    - h. Protective works


Start
Risk identification
Safety distances calculated
Risk assessment
Risk to property tolerable
Yes
Yes
Risk to people tolerable
No
No
Property can be removed from area
Yes
Tolerable risk
Yes
Cordon and evacuation implementable
Risk treatment
No
No
Protective works can be implemented
Yes
Yes
Protective works can be implemented
No
No
Risk ownership
Risk ownership
No
No
Intolerable risk level, review task

1. RISK IDENTIFICATION

Urban environments that have been involved in conflict can conceal a large quantity and variety of UXO, AXO and IEDs, that may even be present on one small task site. The identification of the potential presence of a threat will be based on survey that should be combined with a threat assessment (IMAS 07.14 Risk Management in Mine Action) and technical note for mine action (TNMA) 10.10/03 Explosive Hazard Risk Assessment in Debris Management (Rubble Removal) Operations.

A variety of contamination, Old City of Mosul 2018
(Courtesy of Optima Defence & Security Ltd.)

Once a hazard is identified, the safety distance it requires for fragmentation, debris and shockwave should be calculated using the relevant guidance in IATG / NMAS. Ground shock is a significant consideration in urban areas where there may be multiple services such as water, power and gas that are subsurface and could be damaged. It also has the potential to affect the stability of surrounding structures that may already be severely damaged from the conflict.

2. RISK ANALYSIS

2.1. ESTIMATION OF EXPLOSIVE DANGER AREAS

The following calculations are taken from TNMA 10.20/01 Estimation of Explosion Danger Areas, and are provided here for ease of reference. There are three main contingencies to consider during the application of these calculations: uncontrolled public access; controlled public access; and those where there is no fragmentation hazard. It should be noted that this includes areas where protective works that mitigate fragmentation becoming a hazard have been carried out. These calculations are primarily intended for open demolition areas where the intent is to destroy the EO, but are also relevant to identifying the maximum distance for consideration. This is especially important where an item of EO may have line of sight to a tall building or other structure.

WARNING. These ranges are those outside of which only one fragment is expected to travel.

Distance = metres

AUW = all-up weight in kg (the all-up weight (AUW) is the total weight of the munition, or munitions, including packaging and palletisation)

PUBLIC ACCESS

This will provide the maximum danger area, where the local population has access to the area.

Distance = 634(AUW)1/6

CONTROLLED PUBLIC ACCESS

This is when the local population can be expected to be evacuated and a suitable cordon enforced to prevent re-entry, and when only trained personnel remain within the danger area in a protected position.

Distance = 444(AUW)1/6

NO FRAGMENTATION (BARE EXPLOSIVES ONLY)

This calculation assumes there is no fragmentation hazard and was originally researched to calculate the distance at which hearing damage may occur from overpressure, so remains relevant in urban areas where a reduced cordon and evacuation may be required.

Distance = 130(AUW)1/3

WARNING. The resulting distance for no fragmentation should be doubled for urban settings where overpressure is channelled.

GROUND SHOCK

Urban environments contain many buildings and infrastructure that may be vulnerable to ground shock. The following estimation is for the distance at which ground shock can be felt and can be expected to cause damage to structures.

The danger areas shown in this table have been pre-calculated for ease of use; at 2000 kg, controlled access and bare explosive range converge:

	PUBLIC ACCESS	CONTROLLED ACCESS	NO FRAGMENTATION HAZARD	GROUND SHOCK
Weight (kg)	R=634x(AUW)1/6 (metres)	R=444x(AUW)1/6 (metres)	R=130x(NEC)1/3 (metres)	R=32x√NEC (metres)
1	634	444	130	32
2	712	498	164	46
3	761	533	187	56
4	799	559	206	64
5	829	581	222	72
10	931	652	280	102
20	1,045	732	353	144
30	1,118	783	404	176
40	1,172	821	445	203
50	1,217	852	479	227
60	1,254	879	509	247
70	1,287	901	536	268
80	1,316	922	560	287
90	1,342	940	583	304
100	1,366	957	603	320
150	1,461	1,023	691	392
200	1,533	1,074	760	452
250	1,591	1,114	819	506
300	1,640	1,149	870	555
350	1,683	1,179	916	599
400	1,721	1,205	958	641
450	1,755	1,229	996	679
500	1,786	1,251	1,032	716
1,000	2,005	1,404	1,300	1012
2,000	2,250	1,576		1432

Range = metres
NEC = net explosive content
R = 32 x √NEC

2.2. IDENTIFICATION OF AT-RISK GROUPS

Once unmitigated safety distances have been calculated, people and property at risk can be identified, and options for mitigation can be explored.

2.2.1. PEOPLE

STAFF

Mine action staff are at obvious risk, but this may differ depending on the phase of the task. The local population should be kept informed at the earliest opportunity, through community liaison, of the possible disruption and given advice on how they can keep themselves safe. Coordination with national actors such as community services and security forces may be required to assist in the dissemination of information and the provision of cordon and evacuation.

LOCAL POPULATION

Residents

Residents within the safety distance. These are the most obvious and will be those most adversely affected by mitigation measures that include cordon and evacuation. Where possible, instances of these requirements should be kept to a reasonable minimum to reduce their impact and in the interests of community acceptance.

Transient

Transient population. This includes foot and vehicle traffic that may be passing through the task site or within the safety distance. These will be the most difficult to reach and inform of possible mitigation measures that may affect them.

2.2.2. PROPERTY

When considering the potential for damage, options for the possibility of its removal from the danger area should be considered prior to the requirements for protective works or other similar mitigation methods. Identification and engagement with owners should take place prior to the start of clearance tasks. This will allow them to remove / prepare / protect their property as appropriate. Mine action actors should also take into account the economic impact of any mitigation measures that could adversely impact the recovery of the business and surrounding population.

WARNING. Secondary hazards such as storage of flammable liquids and chemicals should also be assessed, possibly requiring their own separate risk assessment.

Property is anything of value to a person, business or other body, including but not restricted to:

- Land
- Buildings and other structures
- Vehicles

Property types:

- **Personal**
  Property belonging to an individual for their personal or family use

- **Commercial**
  Property belonging to an individual or business which may require engagement from local authorities to assess the requirements for the prevention of damage

- **Government**
  Property that belongs to local or national government may differ considerably from country to country and may, for example, include that related to transport, health, energy or communications. The NMAA, if one is present, could provide the correct points of contact and level of engagement for coordination

- **Utilities and infrastructure**
  Utilities, such as water, power and gas, may run above or below ground, and will often follow the streets of an urban area. The damage to these supplies can have a severe impact on the population, disrupting their delivery for a significant amount of time, and there is potential for contamination of potable water. Where possible, these supplies should be protected, and the agency responsible for their maintenance engaged with and kept informed. This may require the temporary suspension of the flow / delivery of supplies which may aggravate any damage caused or, at least, help prepare for their repair and reinstatement as soon as possible

2.3. METHODS OF ANALYSIS

There are many methods that can be used for analysis. Both examples below are taken from IMAS 07.14 Risk Management in Mine Action, and are presented here as options. The bow-tie analysis method presents a good model that can be used as an overview for a task site, providing key considerations in planning. The consequence / likelihood matrix, however, provides a method where a risk factor can be produced and expressed clearly. This can serve as the threshold for the requirements of mitigation and the allocation of level of responsibility for acceptance of risk.

The following three phases are those most likely to be distinct enough to warrant individual consideration during a mine action clearance task. In each of these, the location of an unintended or intended explosion has the potential to change the consequence of the event. Considerations for each phase have been provided but are not exhaustive.

2.3.1. ARRIVAL, ACCESS AND SITE SET-UP

Urban environments present a potential challenge for a clearance team with regard to site set-up; this may often include setting up on the task site itself, which may be a suspected hazardous area or confirmed hazardous area. This means there is a requirement for temporary set-up offsite until a suitable area can be cleared for the main phase of clearance. In tightly constrained areas with population return, this may include temporary cordon, evacuation and advice to residents, depending on the expected EO hazards assessed to be present. At this stage the preparation or construction of protective works for this and future phases can begin where applicable. Some of these may be temporary until more suitable measures can be deployed on the site itself, reducing long-term disruption in the area.

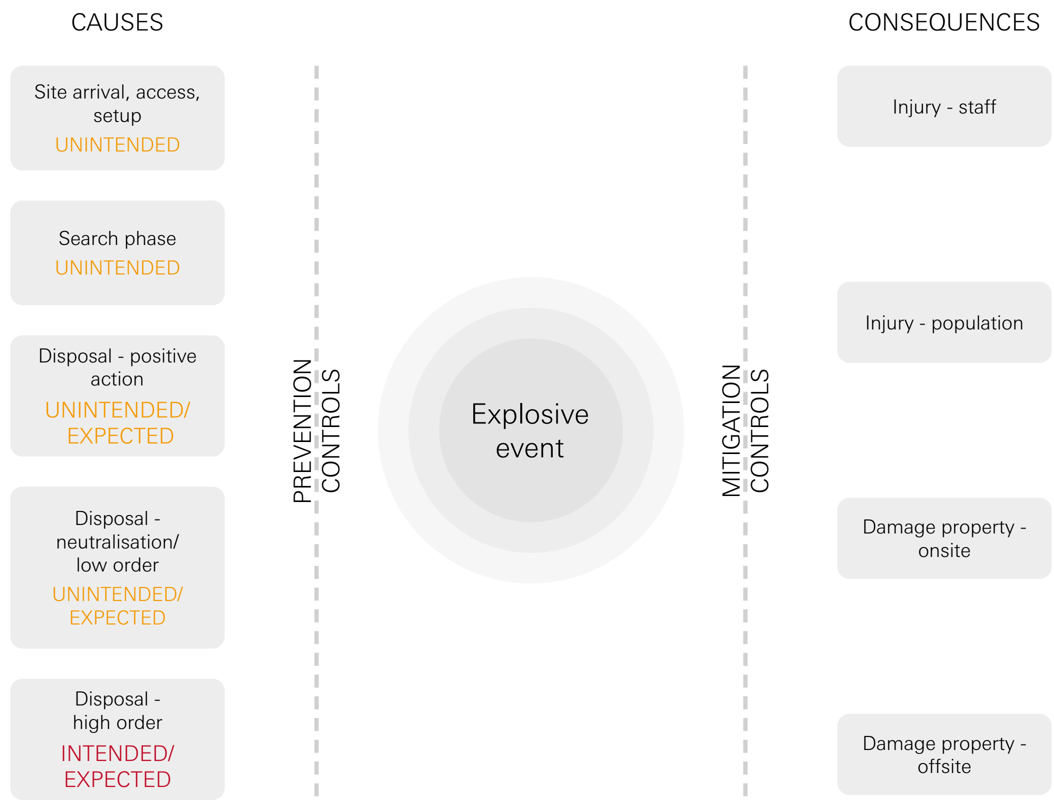
2.3.2. SEARCH PHASE

In this phase it is not expected for there to be an unintended explosion, as the correct use of procedures should not cause interaction with the EO, but mitigation measures should, however, be considered. This may mean that areas where protective works are to be used are given priority for clearance, so that work can begin.

When EO is discovered, the decision on the next course of action should be considered depending on the situation in the surrounding area. If contamination is dense or there is potential for undiscovered EO that may sympathetically detonate, it is worth considering whether those found can be marked and avoided until enough have been found to justify a day, or other specific amount of time, dedicated to disposal. This could reduce the impact of clearance operations on daily life and disruption to redevelopment and rebuilding in the area.

2.3.3. DISPOSAL PHASE

Disposal will require interaction with the EO, and there are three distinct activities where that interaction may intentionally or unintentionally result in an explosion. Prior to any activity that requires interaction with the EO, the current mitigation measures should be reviewed for their suitability, depending on the location, type and explosive hazard present.



Causes are the activities that are being undertaken and that may potentially influence the assessed hazard, causing an explosion.

Prevention controls for mine action include the application of IMAS / NMAS, training, equipment and quality management (QM) controls such as accreditation and supervision.

The explosive event is what we are trying to avoid or reduce the severity of.

Mitigation controls are those that prevent or reduce injury or damage from the event.

Consequences are the potential for injury to personnel and damage to property.

2.4. CONSEQUENCE LIKELIHOOD MATRIX

The examples below show the risk to people. The design of these tables and their contents should be agreed with mine action actors and established in NMAS and SOPs.

	CONSEQUENCE	DESCRIPTION
1	Delays	Damage to equipment, rerouting of site access
2	Minor injury	Scratches and bruises, minor burns, sprains and strains, fractures of digits, dizziness, cuts, abrasions
3	Single major injury	Fractures of hand, wrist, ankle, major burns, unconsciousness, amputation of digits, temporary loss of sight / hearing
4	Multiple major injury	Multiple major injuries to one person or multiple persons, with one or more major injury
5	Fatality	One or a small number of deaths
6	Multiple fatalities	Large number of deaths

	LIKELIHOOD	DESCRIPTION
1	Almost impossible	It is almost impossible to envisage this happening
2	Very unlikely	The event has never happened or is very rare. There is no expectation that this will happen
3	Unlikely	It is known that this event has happened. We recognise this could happen, but we do not expect it to
4	Possible	This event occurs infrequently. This might happen and is feasible
5	Probable	It is fairly likely that this will happen
6	Very likely	This event occurs frequently. We expect this event to happen

From this, a risk table can be produced showing the risk factor by multiplying the numbers together or risk level expressed from very low to very high. The inclusion of colour coding can help identify thresholds for decision making, acceptance of risk and level of responsibility / authorisation required.

		LIKELIHOOD					
		1	2	3	4	5	6
CONSEQUENCE	1	1	2	3	4	5	6
	2	2	4	6	8	10	12
	3	3	6	9	12	15	18
	4	4	8	12	16	20	24
	5	5	10	15	20	25	30
	6	6	12	18	24	30	36

3. RISK EVALUATION

After the analysis of the risk, a decision must be made on whether it is at a tolerable level, and this should happen after each. If this is not the case then further courses of action may include supplementary information gathering and reassessment of the risk, or the requirement for risk treatment to reduce the risk through mitigation controls.

3.1. MITIGATION CONTROLS

To provide suitable mitigation controls for an explosive event, the effects of an explosion should be accounted for. This is especially important in urban settings, compared to situations where full safety distances can't be applied, due to the close proximity of potentially vulnerable objects. An explosion is a sudden release of energy caused by a very rapid chemical reaction that turns a solid or liquid into heat and gas.

The six basic effects are:

- **Thermal radiation**
  Can be considered to be the "fireball" that occurs in the first few milliseconds of an explosion, it is intense but very short lived.
- **Brisance or shattering**
  The shattering effect that happens very close to the explosive event and is particularly dangerous to structural components.
- **Primary fragments**
  Material that is part of the EO and is shattered by the brisance effect and is propelled at high velocity over large distances.
- **Blast wave**
  A very fast-moving pressure wave that can be reflected, magnified and "funnelled" in enclosed spaces such as in buildings or streets.
- **Ground shock**
  The force of the explosion transferred through the ground; this is especially dangerous to buildings and underground utilities such as water mains.
- **Debris / secondary fragments**
  Material in the environment that is damaged and loose items that become propelled by the blast wave. Falling debris is of particular significance in urban environments.

4. RISK MITIGATION

4.1. CORDON AND EVACUATION

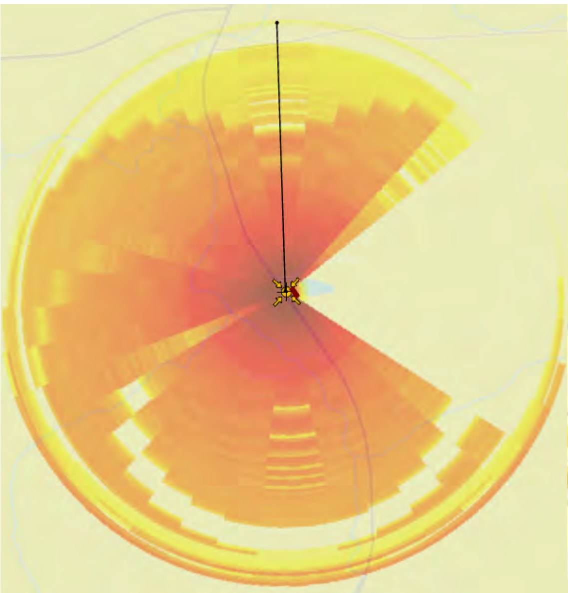
Where the risk assessment and danger area estimation results in an intolerable risk to the local population, there is a requirement to design a suitable cordon and evacuation plan. The previous calculations for danger areas are based on an open ground environment where fragmentation and overpressure are unimpeded. Even without the construction of protective works, the structures found in an urban environment can provide a similar level of protection depending on their construction in extremis.

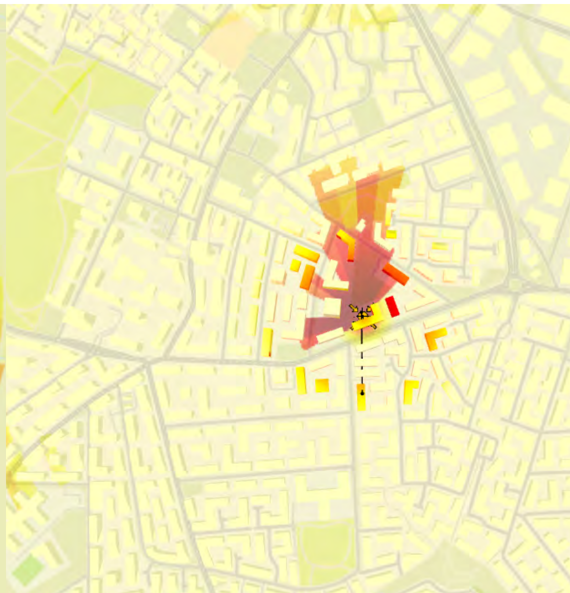
When exactly a cordon and evacuation should be implemented requires consideration, especially when it is likely that there is dense EO contamination in the area, requiring multiple instances for its use. Evacuation can result in a large number of people still needing shelter, food, water and sanitation. The relationship between groups who identify through their religion or ethnicity may also represent multiple sides to a recent or ongoing conflict, and options that prevent them being forced together should be considered.

Cordons may require dozens of roads, paths and other accessible spaces between buildings to be monitored, requiring a large number of personnel to do so, with the authority to enforce them. A pre-prepared plan with local authorities or community bodies should be established to ensure these can be provided for, and that the impact of any disruption is kept to a minimum.

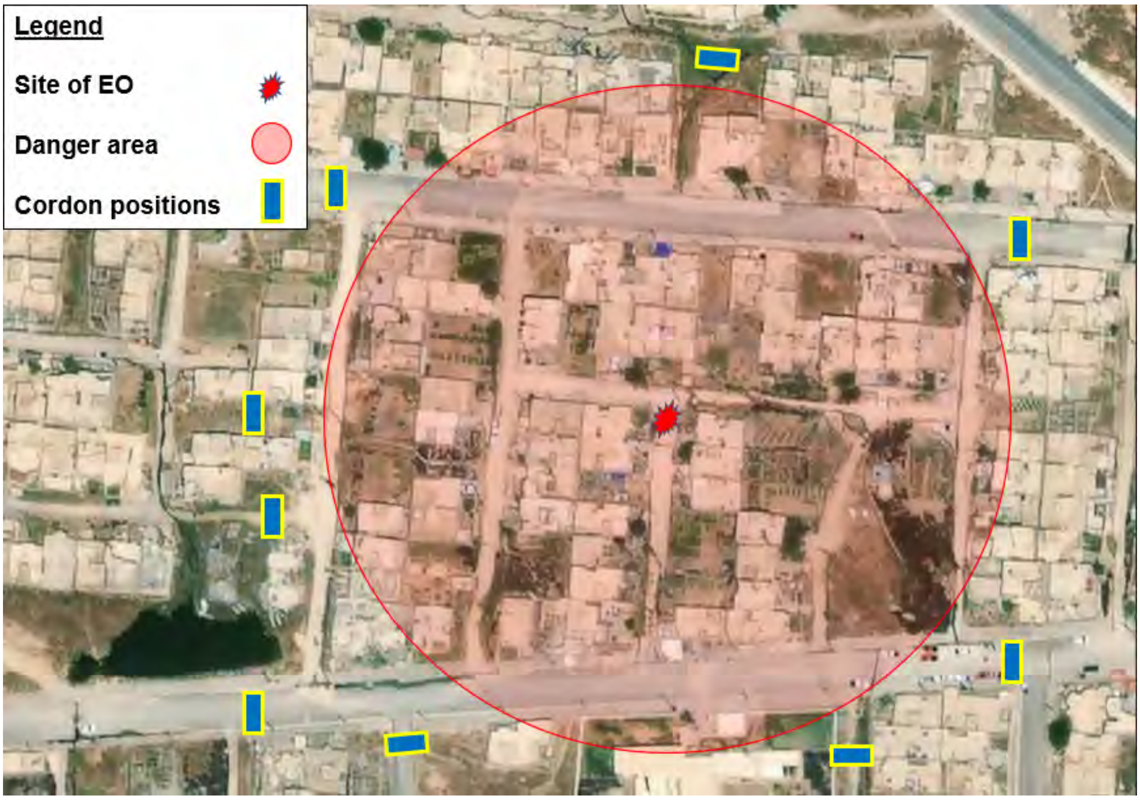
Dangerous areas must be considered in 3D and there may be a requirement to establish control, or at least coordination, with air traffic in the area. Large urban areas often have airports incorporated into the main body of the city or, at least, nearby. Waterways also present challenges for their control, and solutions such as protective works may reduce risks to a tolerable level, reducing requirements for cordon, evacuation and the removal of traffic for safety in these areas.

The following images have been taken from the GICHD's explosive weapons effect simulator, showing the effect of a 500 lb / 227 kg air-dropped high-explosive bomb, demonstrating the protective effect of structures.





The personnel and communication requirements to provide cordon and evacuation should not be underestimated. Below is an example representing a danger area of only 100m. There are 9 positions identified including pathways between buildings that would require personnel to control any foot or vehicle traffic and around 70 residences.



In many countries affected by large items of legacy EO, the protection provided by structures has been used to reduce the requirements for mandatory evacuation based on danger area estimations. This includes large cities where the discovery of large air-dropped EO is not an uncommon occurrence and where the full application of these danger areas would require the evacuation of tens of thousands of people.

Evacuation can also be implemented by degrees based on the distance from the EO without requiring full evacuation. The following evacuation criteria and safety distances have been used, based on research and responses to these types of event.

4.2. DEGREES OF EVACUATION

The following guidance is based on the risk presented by air-dropped bombs in urban contexts with brick-built buildings but does provide alternative distances that have a greater chance for implementation. This will depend on national laws and requires coordination with local government and community bodies. Mine action operators have a responsibility to ensure the safety of local communities, but this is unlikely to extend to powers enabling evacuation or ensuring the integrity of a cordon.

Complete evacuation is where no one is allowed into the area, apart from the demining staff and personnel providing the cordon. If, in the event of members of the population refusing to leave their homes, then it is up to the local authorities to evacuate them or possibly have them sign a disclaimer saying that they are aware of the risk and have chosen to remain in their property of their own free will. This will be dependent on national regulations and the level of acceptance of risk.

Partial evacuation differs slightly, in that all property at risk is removed or protected, but people may still occupy their home in rooms that are on the side furthest from the potential explosion. Access must be protected by means of protected approaches, adequately screened from the EO.

Windows open is a mitigation measure where the potential for flying glass is reduced. Windows within the assessed area are to be opened in order to equalise the pressure inside and outside the building. It is important to remember that during the suction phase, a change in pressure occurs on all sides of the building.

EVACUATION DISTANCES IN BUILT-UP AREAS

BURIED / UNBURIED	HIGH EXPLOSIVE WEAPONS EXCEPT BLAST BOMBS AND ANTI-SHIP MINES (kg)	BLAST BOMBS AND ANTI-SHIP MINES (kg)	RADIUS		
			Complete evacuation (m)	Partial evacuation (m)	Windows open (m)
Unburied	50-250	50-250	50	150	150
Unburied	250-1500	250-500	100	300	300
Unburied	1500-2000	500-1500	200	400	800
Unburied	2000-4000	1500-2000	300	600	800
Unburied	4000-10000	2000-4000	400	800	800
Buried	Up to 2000	Up to 2000	50	100	300
Buried	Above 2000	Above 2000	100	200	600

Note: a bomb is to be considered buried when its depth below ground is at least 2.5 times its length.

4.3. PROTECTIVE WORKS

Protective works are constructed or prefabricated barriers that mitigate the potential damage to property in the event of an intended or unintended explosion. They may also be used to provide protection to the population and reduce the size of evacuation areas. The placement of any protective works should be outside the assessed crater size, except for protective works over the EO to mitigate vertical fragmentation and debris.

EXPECTED CRATER SIZE

SERIAL	TOTAL WEIGHT (kg)	DIAMETER OF CRATER (m)					
		CHARGE WEIGHT RATIO (%)					
		Made-up ground		Clay soil		Chalk, sand or gravel	
		50%	80%	50%	80%	50%	80%
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	50	5.8	8.2	4.6	6.4	3.7	4.9
2	250	9.1	13.1	7.3	10.4	5.5	7.9
3	500	11.9	16.5	9.5	13.1	7.3	10.1
4	1000	16.5	22.9	13.1	18.3	10.1	13.7
5	2000	21	29.6	16.8	23.5	12.8	17.7

Note: these diameters may increase as a result of subsequent collapse of the edges.

4.3.1. TYPES OF PROTECTIVE WORKS

The following guidance is a non-exhaustive list of simple-to-construct protective works that can be adapted for numerous types of EO and contexts.

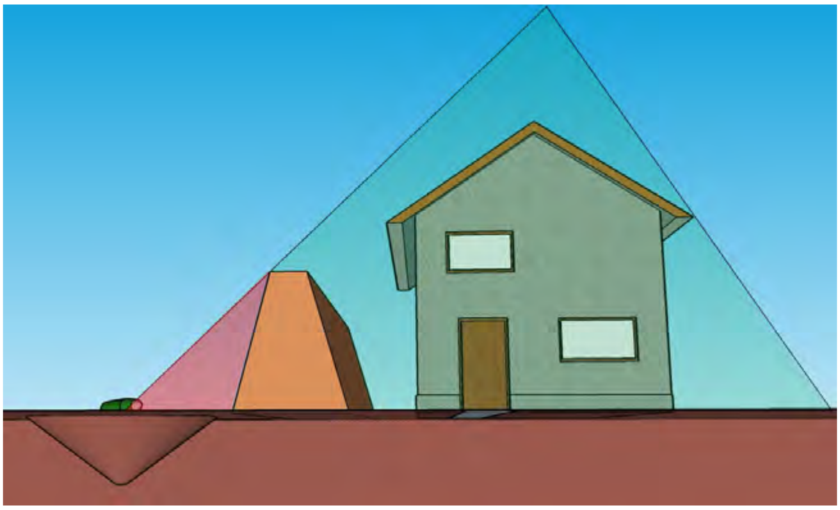
PROTECTIVE WALLS / BARRICADES

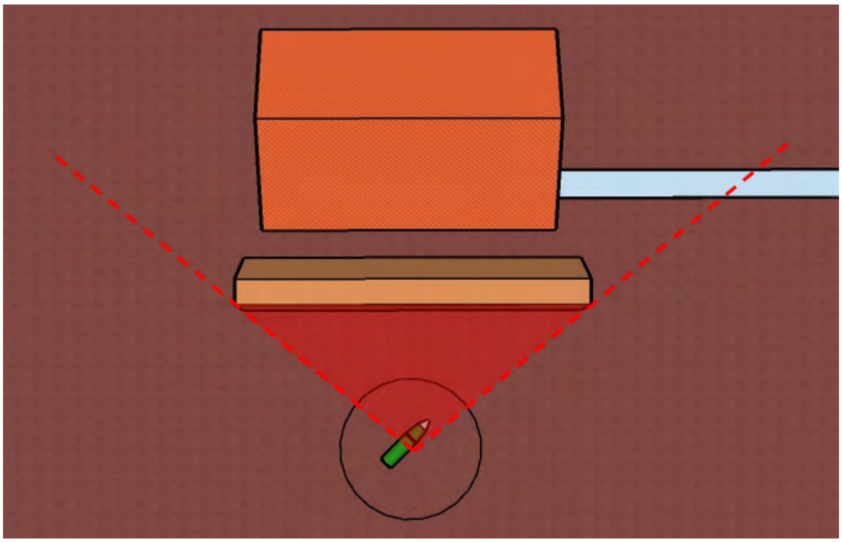
These walls are used to deflect and absorb the shock wave and catch fragmentation from an explosive event usually involving larger EO. They can be employed when either the EO or what is being protected cannot be moved. They should extend beyond the features of the item they are designed to protect, effectively cutting line of sight between the EO and what is being protected. The configuration will depend on the materials available and what you are trying to protect.

SANDBAG WALLS

The following dimensions provide a solid sandbag wall construction; any change in height will require that a sloping face of 1 in 6 is maintained for stability and provision of suitable protection:

- Length is that which overlaps the item being protected
- Base = 1.2 metres wide
- Height = 1 metre
- Should have a sloping face (away from the EO of 1 in 6 (1 metre horizontal to 6 metres vertical) or 80°



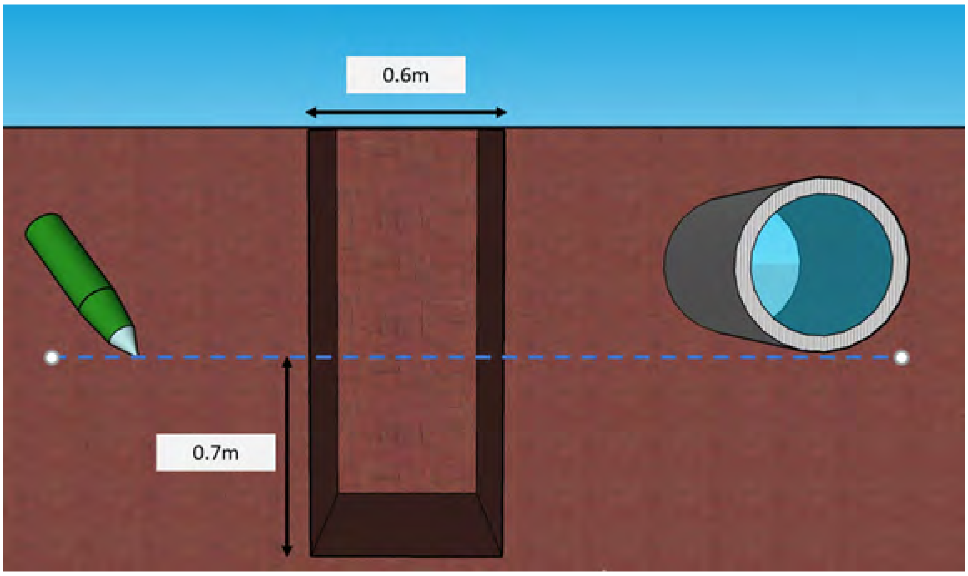


EARTH MOUND

Where the construction of a sandbag wall is unfeasible due to lack of materials or time constraints, an earth mound can be used. The soil will naturally slope as it is mounded providing suitable protection, but a greater amount of material may be required to reach a suitable height and width. Where the sensitivity of EO will allow, mechanical equipment may be used to create these mounds.

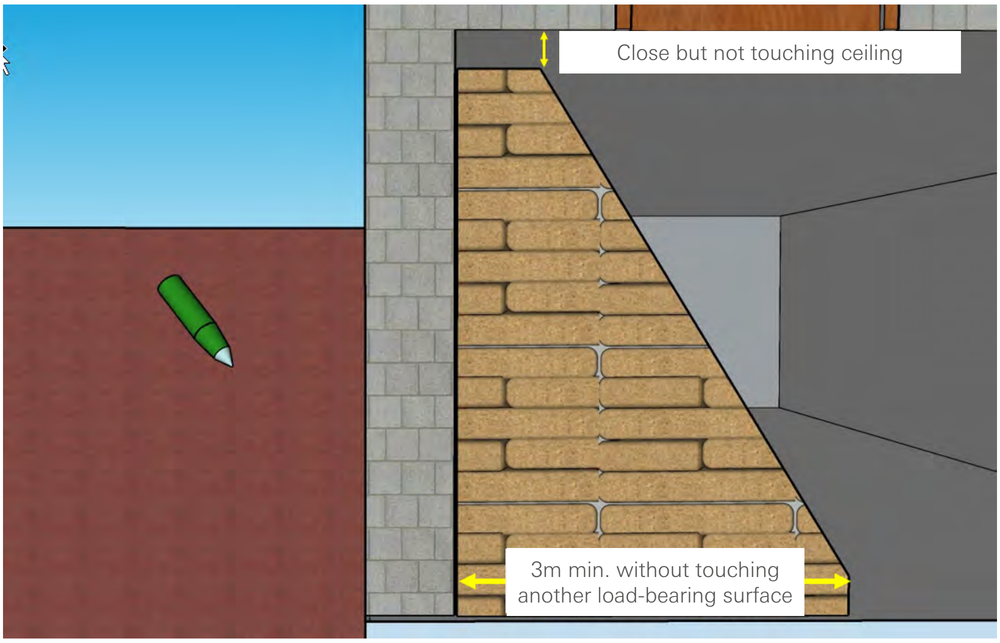
PROTECTIVE TRENCHING

Trenches are used to protect underground services, basements and building foundations that are outside the possible crater area, from damage by ground shock, in a similar way that fire breaks are used to protect woodland. The trench should be placed between the object and the EO, ensuring that the bottom of the trench is extended at least 0.7 m deeper than the object to be protected. The optimum width is 0.6 m and no cross bracing should be used as this will allow the transfer of ground shock.



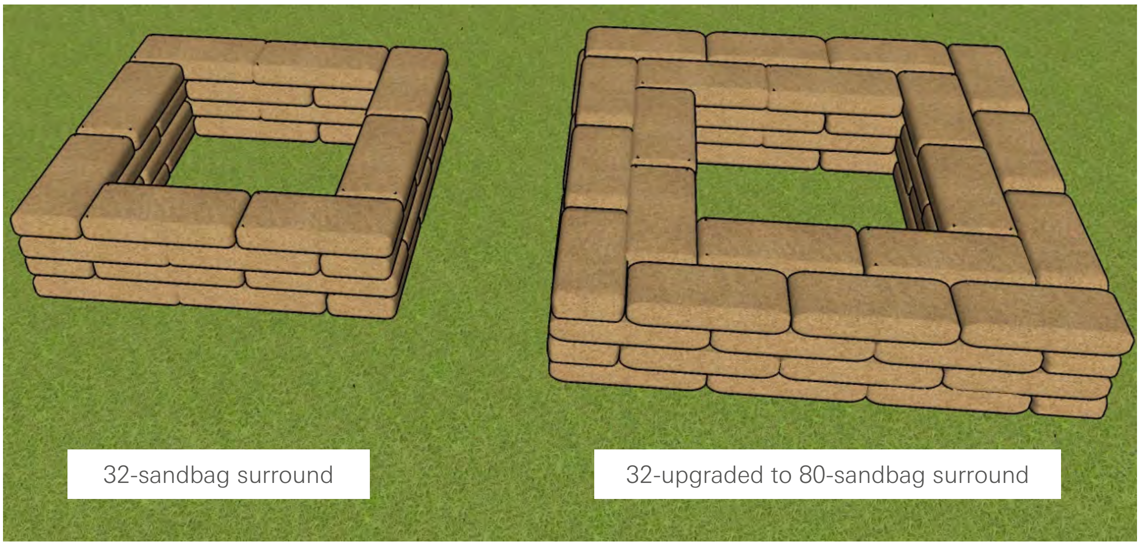
PROTECTIVE ABUTMENTS

Where trenching is problematic, a sandbag wall could be used internally within a basement to protect the walls against ground shock. The sandbag wall should be extensive, with the base extending at least 3 m into the room, but not touching any other internal load-bearing walls, otherwise the ground shock will be transmitted to these walls and extend upwards towards the ceiling.



SANDBAG SURROUNDS

Sandbag surrounds provide protection against blast and fragmentation from anti-personnel types of ordnance weighing up to 2.5 kg. They can be used when conducting any positive action but especially during demolition in situ. A single layer 32-bag surround will provide protection from blast only, and a double layer 80-bag surround will provide both blast and fragmentation protection. In both cases an increase of vertical blast and fragmentation should be expected. If this is also undesirable, boards with a layer of sandbags may be placed on top; in this case the sandbags may be projected out to a distance of 5 m.



VENTING VS MOUNDING

An urban environment may present multiple vulnerable objects, both surface and sub-surface, that require protection, while also requiring that cordon and evacuation is maintained to a minimum. Where a balance between the different requirements for protection must be struck, the risk assessment for both options below should be considered.

Venting is a method used to reduce the strength of ground shock from buried EO by removing as much of the covering material as possible to allow the rapidly expanding gases from a detonation to escape. This will, however, result in a greater distance requirement for blast and fragmentation.

Mounding is the exact opposite, where the intention is to reduce the blast and fragmentation effects of EO by creating a cone of soil or placing sandbags over it. This will, however, increase the distance and severity of ground shock and potential requirements for protective trenching or abutments.

DIMENSIONS FOR PROTECTIVE MOUNDS

SERIAL	TOTAL WEIGHT OF BOMB (kg)	POSITION OF BOMB	TYPE OF SOIL	WEIGHT OF SOIL REQUIRED (t)	NUMBER OF SANDBAGS	DIMENSION OF CONE	
						Dia. (m)	Height (m)
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	5	Buried	Clay	40	1600	6.1	1.8
2	50	Buried	Sand	60	2400	7.3	1.8
3	50	Unburied	Any	40	1600	6.1	1.8
4	250	Buried	Clay	125	5000	12	1.8
5	250	Buried	Sand	180	7200	12	2.7
6	250	Unburied	Any	90	3600	12	1.8
7	500	Buried	Clay	270	Not practicable	14	2.7
8	500	Buried	Sand	400	Not practicable	15	3

5. RISK OWNERSHIP

If after risk treatment, there remains a significant residual risk following reassessment, there may be a requirement for acceptance of that risk. This may include the approval of the next level of management and this should be recorded as such and signed for by that individual. The following tables provide an example of how the risk analysis can be used to identify clear thresholds for responsibility.

RISK ANALYSIS RESULT

		LIKELIHOOD					
		1	2	3	4	5	6
CONSEQUENCE	1	1	2	3	4	5	6
	2	2	4	6	8	10	12
	3	3	6	9	12	15	18
	4	4	8	12	16	20	24
	5	5	10	15	20	25	30
	6	6	12	18	24	30	36

DECISION TO ACCEPT RISK

RECORDED IN PLAN WITH SIGNATURE	
1 – 5 Low	Team leader / Technical field manager
6 – 12 Medium	Operations manager
15 – 36 High	Tasking authority

In cases where EO is found in sensitive infrastructures such as an oil refinery or dam, there may be catastrophic consequences in the event of an explosion. In such situations the possibility of delegating the task to another organisation with the authority to take ownership of the risk, such as state military, should be considered.

6. MONITORING AND REVIEW

Clear roles and responsibilities should be established for all actors involved, with achievable criteria that is recorded formally; Chapter 2, Annex 3C provides a template that can be adapted for use. This will provide an auditable process which can be reviewed by all relevant parties. The management level at which risk can be accepted should be firmly established and the mechanism for doing so clearly identifiable for all team leaders, operations managers and NMAA staff.

The risk assessment and overall plan will be subject to both internal and external influences that will require monitoring and review. Situations where that will trigger review of the plan include:

Any change to the information used in the previous assessment, for example:

- Location of EO not identified during initial planning
- An incident or near miss
- Discovery of secondary hazards or vulnerable property not identified in initial planning

The risk assessment and plan should be reviewed at regular intervals, to be specified under safety and QM requirements.

RESOURCES FOR FURTHER GUIDANCE

IMAS / TNMA

- 07.14 Risk Management in Mine Action
- 07.14/01 Residual Risk Management
- 10.10 Safety and occupational health – General requirements
- 10.10/02 Safety Notes – General
- 10.10/03 Explosive Hazard Risk Assessment in Debris Management (Rubble Removal) Operations
- 10.20 Demining worksite safety
- 10.20/01 Estimation of Explosive Danger Areas
- 10.20-02/09 Field Risk Assessment (FRA)

IATG

- UN Safe*r*Guard website
- 02.10 Introduction to risk management principles and processes
- 04.20 Temporary storage
- 05.20 Types of buildings for explosive facilities
- 05.30 Traverses and barricades

ISO 31000, Risk Management – Guidelines

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