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Using the MineBurner System on Cluster Submunitions

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Keeley: Using the MineBurner System on Cluster Submunitions

Using the MineBurner System on Cluster Submunitions

by Dr. Robert Keeley [RK Consulting Ltd.]

This article is a summary of the findings of the mission carried out by RK Consulting Ltd. on behalf of Norwegian People's Aid Lebanon to determine the potential ability of the MineBurner system to destroy cluster submunitions safely.

The M42 target showing the results of a burn. *All graphics courtesy of Bob Keeley*

The MineBurner is a patented system developed to dispose of explosive remnants of war using non-explosive components or subsystems by combining oxygen with liquid petroleum gas to provide a high temperature cutting flame that burns through the case of a landmine and ignites the contents.[1] Oxygen is obtained by pumping atmospheric air through a filter to remove the nitrogen. Liquid petroleum (cooking) gas is locally available, thereby eliminating the requirement to transport hazardous cargo to the minefield.[1] The MineBurner and accessories are all air-transport classified as non-hazardous.[1]

Scope and Methodology

Positioning the MineBurner against a difficult target on a gravel bank. The "memory" in the hose made the nozzle difficult to position.

RK Consulting Ltd. carried out a mission on behalf of Norwegian People's Aid–Lebanon between 13 and 21 October 2006. The objective of this consultancy mission was to conduct an operational trial of the new MineBurner to record the practicality of the MineBurner system in destroying unexploded cluster submunitions. A report covers more detailed results of the technical trials of the prototype MineBurner system.[2]

The methodology for this trial utilised a step-by-step approach intended to test the characteristics and performance of the MineBurner in a safe manner that did not leave target unexploded ordnance in a more hazardous condition than when found or place the user or team member in any additional danger while operating the equipment. The trial plan was designed to move from a known environment to an increasingly "unknown" environment, testing and therefore controlling for variables encountered later in the trial. The first tests were against dummy targets in a sterile environment to ensure there were no gross problems with the MineBurner equipment and confirm the MineBurner, in its current configuration, would have sufficient capability to burn through submunitions. Once basic safety was determined, live trials began using MineBurner against submunitions. The trials followed an incremental approach, with the first attacks being made on targets that were in a comparatively safe condition and position and proceeding to attacks on more complicated targets.

Positioning the MineBurner nozzle against a BLU 63.

Results of the Technical Trials

During initial testing of the MineBurner against dummy targets, NPA personnel were familiarised with the equipment, safe operating procedures were established, and the MineBurner was found to be effective against submunitions based on its ability to cut through metal of similar thickness. Other findings were that the MineBurner looks more complicated than it is, the nozzle of the MineBurner can be awkward to position and that the MineBurner is not yet as rugged as the designer intended but modifications are being planned.

Results of the attack against the last intact BLU63. The two halves of the item of UXO were separated by six metres (6.6 yards) and the explosive burned out.

After the MineBurner was deemed able to destroy an M42[3] submunition safely even when the M42 was on its side,[4] testing progressed to attacks on live M42 targets. Two of the attacks were in safer range conditions, found in partially disassembled states and safe to move. The first test attempted a technique that resulted in a high-order detonation in which the jet[3] functioned and that was judged too risky to attempt further in tests. The second test successfully burned the target and ignited the explosives without detonating the submunition.

The test progressed to the third target in a difficult position—being fully armed, immovable and on gravel—and resulted in a successful low-order explosion that did not function the jet.

One of the final five M42 attacks resulted in a burn.

Further testing occurred on another submunition, the BLU 63, which poses a different set of risks.[5] Results from the tests were mixed, with the initial burn not fully penetrating the case of BLU 63, which contained no explosives or detonator.

The second test successfully burned the explosive fill of half a BLU 63, suggesting the need for a longer soak time. The third test on a fully intact target was inconclusive after difficulty placing the nozzle and an "unsafe to move" status, which prevented picking up the item see if the explosive had burned out.

The last test against another fully intact BLU 63 was successful in burning out the explosives. When the nozzle was more carefully positioned, the two halves of the target were separated and found six metres (6.6 yards) apart and the components of the detonator were also separated, suggesting the MineBurner is suitable against the BLU 63 once an improved nozzle positioning tool is developed.

The testing ended with five more M42 target trials. All five of the targets were destroyed, with a burn achieved on one, deflagration achieved on three and a high-order detonation resulting in a jet forming during the final trial. By this day, the three hours taken to successfully destroy all five targets was similar to the time taken to destroy other targets by conventional (explosive) means by the NPA technicians working on the site. Thus, one could expect productivity of the EOD teams using the MineBurner to improve to the point where the assembly and deployment of the equipment imposes no special delays.

A summary of the results of these MineBurner trials against live targets is found in Table 1.

Ser	Date	Item	Condition	Attitude	Attack	Result	Remarks
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	17 Oct 06	M42	No percussion cap	Flat ground	Attacked cone	High order - jet formed	
2	17 Oct 06	M42	Percussion cap replaced	Flat ground	Attacked 1cm from shoulder	High order - jet formed	
3	17 Oct 06	M42	Complete	Difficult: on stone bank	Attacked 1cm from shoulder	Deflagration: no jet, large frag. remains	
4	19 Oct 06	BLU63	Casing Only	Flat ground	Attacked between vanes	Burn, nearly penetrated casing	
5	19 Oct 06	BLU63	Half casing with explosive but no detonator	Flat ground	Attacked between vanes	Burn, penetrated casing	No explosive left in target.
6	19 Oct 06	BLU63	Complete	Flat ground	Attacked between vanes	*Probable* burn	Burn was off center. Target was intact so not possible to confirm condition.
7	19 Oct 06	BLU63	Complete	Flat ground	Attacked 1cm from shoulder	Deflagration	No explosive left in target.
8	20 Oct 06	M42	No percussion cap	Flat ground	Attacked 1cm from shoulder	Deflagration: no jet, large frag. remains	
9	20 Oct 06	M42	No percussion cap	Flat ground	Attacked 1cm from shoulder	Burn; hole in casing	
10	20 Oct 06	M42	Complete	Flat ground	Attacked 1cm from shoulder	Deflagration: no jet, large frag. remains	
11	20 Oct 06	M42	Complete	Difficult: on stone bank	Attacked 1cm from shoulder	Deflagration: no jet, large frag. remains	
12	20 Oct 06	M42	Complete	Difficult: on stone bank	Attacked 1cm from shoulder	High order - jet formed	Attitude of target may have meant burn was off center.

Table 1: Summary of MineBurner results against live targets.

Limitations

There were a number of limitations to the trial, and the main ones are listed below. These limitations were mainly a result of the short duration of the trial period.

- There were a limited number of targets and hence statistical significance is difficult to infer.
- The team was unable to deploy the MineBurner on other unexploded ordnance, especially thicker-cased items such as mortar rounds.
- The team was unable to fully observe the possibility of training local staff to use the MineBurner, although some on-the-job training was possible.
- The trial did not address the effect of the MineBurner on landmines; this was covered in earlier trials by NPA in Jordan.[2]

Three of the final five M42 attacks resulted in a deflagration, leaving large fragments and no evidence of a jet being formed.

Economic Analysis

Overview. This section of the report deals with the cost-effectiveness of the MineBurner when compared to the alternatives. This economic analysis is done in three parts. First, a quantitative cost-effectiveness analysis[6] is conducted using a previously created budgetary analysis tool, the "Model Mine Action Centre."[7] This tool measures the relative cost against a standard benchmark and identifies the cost of employing the MineBurner compared to the cost of using explosives.


This multi-item demolition, being prepared by Swedish Rescue Services Agency, shows the amount of high explosive required to demolish M42 targets.

The second comparative method used here is a time-and-motion study examining the time costs of an explosive-ordnance-disposal team deploying on two identical sites: the first site is cleared by explosives and the second by using the MineBurner. This analysis is repeated, taking account of the time needed to detour in the morning and afternoon to obtain and then return high explosives.

The third form of economic analysis used here is a qualitative comparison of the MineBurner and its closest competitors to identify which demolition method has the least number of associated logistical burdens. This allows potential users to determine which of the attributes may provide the greatest advantages or least problems in their programme and therefore select the most useful tool for their use. It also allows those wishing to make quantitative comparisons to use any particular programme as a basis by which to identify the issues that must be taken into account, thus ensuring the various alternatives are compared on a "like with like" basis. If the capital costs of purchasing the MineBurner are to be taken into account, for example, the costs of establishing an explosive storage capacity should also be considered, even if the explosives themselves are provided free of charge.[8]

Assumptions and sensitivity analysis. Like any economic analysis, the large number of potential variables means there must be a series of assumptions made in order to concentrate on the key issues. These assumptions are set out below:

1. The estimated prices of the MineBurner are accurate.
2. The MineBurner equipment can be used repeatedly over its working life.
3. The MineBurner and explosives are "perfect substitutes."

Assumptions 1 and 2 are tested using sensitivity analysis.[9] The implication of these assumptions is considered in the full report.[2]

Cost-effectiveness analysis. The forecast prices of the MineBurner and its ancillaries are set out in Table 2. These costs are entered into the Model Mine Action Centre budgetary analysis tool, assuming there will be one MineBurner per demining platoon and one per EOD team. The MMAC model measures the effect, all other things being equal, on the cost per square metre of cleared land.

Ser	item	unit cost (1)	quantity	total cost	max no. of uses	forecast use (2)[1]	forecast cost per burn[2]	remarks
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
MineBurner field set components								
1	Remote firing unit	500.00	1.00	500.00	100,000			includes pair of repeaters
2	Filler unit	400.00	1.00	400.00	100,000			
3	Field module	1,000.00	10.00	10,000.00	100,000			
4	Subtotal			10,900.00	100,000	60,000	0.18	
MineBurner supplied consumables								
5	Bladder assembly	40.00			1,000	60,000	0.04	
6	Wrapping	0.50			30	60,000	0.02	
7	Nozzle set	0.50			1	60,000	0.50	incl. all sacrificial elements: tube, wire, and paper wrapping for air bag
8	Subtotal						0.56	
Total purchase cost for MineBurner								
9	Year one			17,580.00				
10	Subsequent year			6,680.00				
11	**Total over 5 years**			**44,300.00**			0.74	

[1]Forecast use based on:
No. of burns per day: 6 per field module
No. of burns per day: 60 per field set of 10 modules
No. of days per year: 200 working days
Working life: 5 years
Forecast use: 60,000 burns per field set over 5 years

[2]Cost of gas and oxygen insignificant over these scales

Table 2: Estimated MineBurner prices in USD (Source: MineBurner).

First, the comparative cost of using the MineBurner when explosives are provided free of charge are modelled; second, the comparative cost of using the MineBurner when explosives are purchased are modelled; and third, this figure is then modified to model the scenario when the explosives usage rate is 20 percent of its previous figure.

Finally, the MMAC model is adjusted to see the effect of reducing waiting times for explosives by around 30 minutes per day. This is measured by increasing the productivity figure for each demining platoon by 5 percent (which is a conservative estimate of the possible time saved).

Ser	Scenario	Cost US$/m2 using explosives	Cost US$/m2 using MineBurner	Remarks
(a)	(b)	(c)	(d)	(e)
1	Explosives free	$1.22	$1.26	
2	Explosives purchased	$1.42	$1.26	
3	20% explosive usage		$1.31	MineBurner plus some explosive
4	Implications of reduced waiting time		$1.19	As for Ser 3 but with reduced waiting time

Table 3: Results of MineBurner cost-effectiveness analysis.

The MMAC model suggests that, when explosives are free (and readily available), the MineBurner is more expensive to the programme, even though the cost of purchasing the MineBurner is partially recouped by saving the cost of ammunition storage. Where explosives are purchased, the savings realised by using the MineBurner is more evident: the cost of the MineBurner remains constant at US$1.26 per square metre ($0.117 per square foot) cleared, while the cost of using explosives would rise to $1.42 per square metre ($0.132 per square foot). Using some of both would increase the cost to $1.31 ($0.122 per square foot), but taking account of reduced waiting times through a 5-percent increase in productivity would further reduce the cost to the programme to $1.20 per square metre ($0.111 per square foot).

For cost calculations, the working assumption is the MineBurner equipment can be used daily over a 200-day working year for a total of five years, resulting in a total estimated forecast use of 60,000 burns per field unit (refer to Table 2). A lower usage rate would, of course, increase the cost per burn, but a similar reduction in actual usage rate would also drive up the equivalent cost per kilogram stored, which is the main fixed cost in a conventional, explosives-based regime. These cost calculations also assume the introduction of the MineBurner has no significant negative impact on the productivity of the teams using it. The validity of this assumption is measured in the time-and-motion analysis below.

Time-and-motion analysis. There are a number of different scenarios under which the MineBurner might be employed. In this case the first one chosen for detailed analysis is where a mobile EOD team would employ a single MineBurner for use on a piece of UXO that has been discovered and reported by a member of the public (Figure 1). The second scenario is where an area of one hectare (2.5 acres) is searched by a battle-area-clearance team and 10 pieces of UXO have been discovered. In the latter case the team prepares a MineBurner set with 10 modules for simultaneous firing of all 10 (Figure 2). In both cases the time-and-motion study is compared with an identical scenario where the team uses standard explosive charges. The third variation in both cases is where the MineBurner is given a shorter soak time as a result of achieving a deflagration or detonation rather than a burn.

One effect of blowing UXO *in situ* using high explosives is that they re-contaminate the task site with metal fragments. This can be a significant problem when quality-control techniques involve the confirmation of a metal-free area. The deflagrations achieved in most of the 12 MineBurner attacks would mean a significant reduction in this problem.

ID	Task Name	Duration
1	**EOD Mobile Team**	**0.19 days**
2	Team arrives on site	0 days
3	Team Leader questions witness	15 mins
4	Remote reconnaissance of UXO	30 mins
5	Team Leader instructs No 2 to prepare	15 mins
6	Close reconnaissance	30 mins
7	**1.1 HE charge**	**0.11 days**
8	Explosive charge prepared	5 mins
9	Firing cable checked and positioned	15 mins
10	Charge positioned and detonator connected	5 mins
11	Charge initiated	1 min
12	Soak time	5 mins
13	Rewind firing cable	10 mins
14	Recovery	10 mins
15	Task complete	0 days
16	**1.2 MineBurner with 30 mins soak time**	**0.13 days**
17	MineBurner prepared	10 mins
18	MineBurner checked and positioned	10 mins
19	MineBurner initiated	2 mins
20	Soak time	30 mins
21	Recovery	10 mins
22	Task complete	0 days
23	**1.3 MineBurner with 5 mins soak time**	**0.08 days**
24	MineBurner prepared	10 mins
25	MineBurner positioned	10 mins
26	MineBurner initiated	2 mins
27	Soak time	5 mins
28	Recovery	10 mins
29	Task complete	0 days

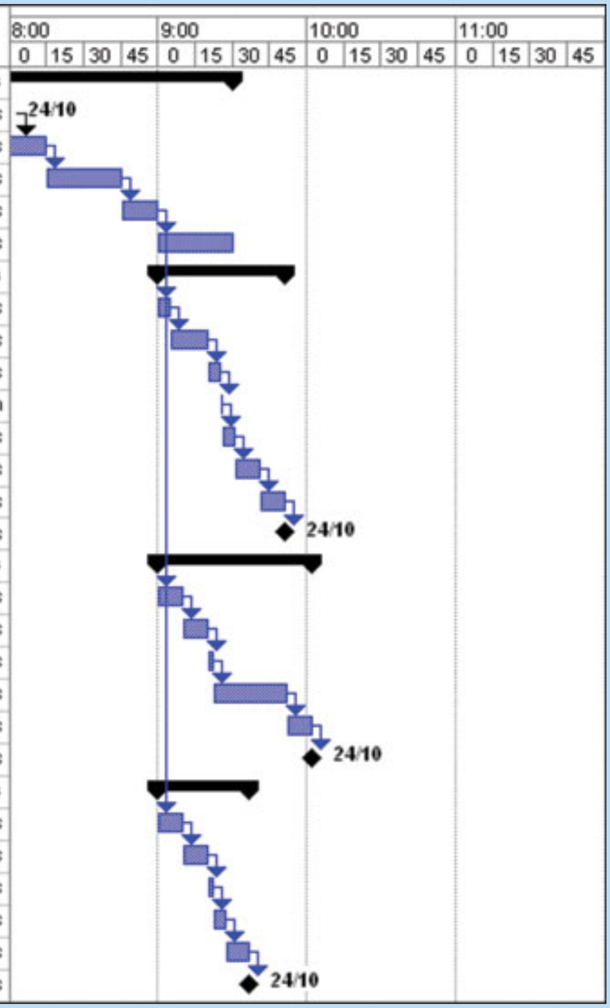

Figure 1: Time and motion study of EOD task using high explosives and the MineBurner with 30- and 5-minute soak times.

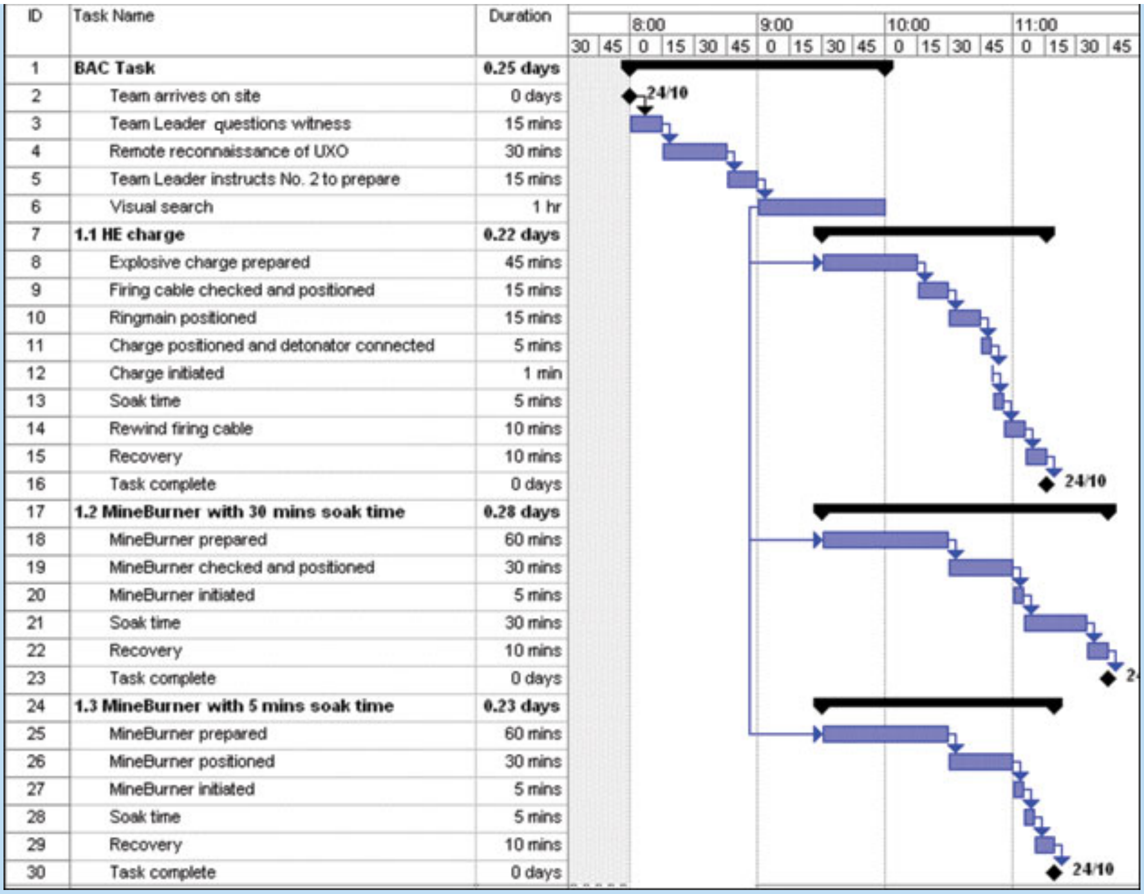

Figure 2: Time and motion study of BAC task using high explosives and the MineBurner with 30- and 5-minute soak times.

Multi-criteria analysis. The final type of economic analysis to be carried out is a qualitative comparison of the MineBurner with high explosive and other close competitors. The multi-criteria analysis lists the four alternatives considered in the columns of Table 4 with the different criteria scored in each. This MCA provides the ability to compare techniques currently considered by the United Nations Mine Action Service to be possible alternatives to high explosives, but which are not yet available in Lebanon and thus not able to be more quantitatively scrutinized there. This MCA was prepared by the author and validated by the NPA technicians in Lebanon for this report.

There are different techniques for laying out an MCA—in the analysis in Table 4, each X represents a positive grading; therefore, the greater the number of Xs, the "better" the alternative. Each user must, however, choose his or her own weighting of the relative importance of the different criteria.

Ser	Criterion	HE	MineBurner	Imported Touch	Fabricated Touch	Recycle	Remarks
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	Local purchase available	XXXXX	XXX				
2	Safe to move by air		XXXXX	XX	N/A		i.e. detonators or similar intiators
3	Ease of import		XXXXX	X	XXX	XXX	Torch and recycle can import tools for fabrication materials
4	Safe storage		XXXXX	XXX	XXX		
5	Ease of fabrication	N/A	XXXXX	XXXXX	XX	XX	
6	Speed to start operations	XXX	XXXXX	XXX			
7	Batching available to monitor quality	XXXX	XXXX	XXXXX	XXX		MineBurner bags can be batched to record name of packer and date
8	Freedom from need for demolition accessories		XXXXX	XXX	XXX		
9	Impact of delays in collecting from storage		XXXXX	XXX	XXX		
10	Potential of increased soak time	XXXXX	XX	XX	XX	XXXX	Providing recycled explosives are able to achieve same quality as purchased explosives
11	Risk of fire	XX	XXX	XXX	XXX	XX	
12	Fragment contamination	X	XXXX	XXXX	XXXX	X	
13	Sustainability	XXX	XXXXX	XX	X	X	

Table 4: Multi-criteria analysis of UXO demolition alternatives.

Conclusions

The MineBurner system trial was limited in scope, but was successful in that it showed the ability of the MineBurner against two different types of submunitions and highlighted some areas for improvement. More experience will generate more significant statistics. Some of the outcomes learned from the MineBurner system trial follow:

- The MineBurner was successful against the M42 and BLU 63 submunitions.
- The MineBurner is not yet rugged enough to withstand sustained use in field conditions; however, the designer already has a number of improvements in hand.
- There are problems positioning the nozzle. The final metre (1.1 yards) of the gas hose has an elastic "memory" that must be eliminated; similarly, the nozzle needs some method to improve the precision of its positioning.
- The MineBurner is not as complicated as it looks—it is merely different. A formal training programme and the production of related instructions and user guidelines will help assure potential end-users who may have reservations about replacing their old system and learning to use this new technology.
- The economic analysis suggests the MineBurner is an economically viable option for mine-action programmes, especially where there are logistical, administrative or political difficulties in obtaining high explosives.

Thus, this study shows the MineBurner is unlikely to **totally** replace high explosives in all situations, but could significantly reduce the problems faced by mine-action agencies obtaining explosives and other demolition ancillaries.

This trial was established on short notice and would not have been possible without the efforts and cooperation of a number of people, including all the staff in the NPA mine-action project in Lebanon and those people in Mines Advisory Group, BACTEC International Ltd. and Swedish Rescue Services Agency whose kindness made this trial possible.

Biography

Dr. Robert Keeley, Director of RK Consulting Ltd., is a former British Army Bomb Disposal Officer who has been working in humanitarian mine action since 1991. He was head of the United Nations Mine Action Centre in Croatia until 1997 and has also worked for Handicap International, Mitsubishi Research International (on behalf of the Japanese Ministry for Economics, Trade and Industry), European Landmine Solutions and as a consultant for the European Commission. Keeley has a Ph.D. in applied environmental economics from Imperial College London.

Endnotes

1. *MineBurner UXO Clearance System*. http://www.MineBurner.com. Accessed 6 February 2007.
2. Contact the author of this article, Dr. Robert Keeley, for details about and information on how to access full reports of the MineBurner test trials in Lebanon and Jordan.
3. Readers with a technical background will be aware that there are a number of submunitions in the M42 family, including the M77 and M85. There are no significant differences for the purpose of this report and so they are all described by the term *M42*, which is in effect a generic term used for the family within the EOD industry.
4. The fact that an M42 is found on its side has implications for its destruction, as it contains a shaped charge that fires a jet of copper in plasma form in the direction in which a copper cone contained in the M42 is pointing. This type of jet will penetrate some 10 centimetres (3.9 inches) and can reach a considerable distance in open air. It is therefore important that, when attacking an M42, either the MineBurner can prevent the jet from forming or the operator employs suitable protective works to prevent the jet from becoming a long-range hazard.
5. The BLU 63 presents different problems from the M42: It is not a directional shaped-charge weapon, but it has a thicker fragmentation jacket and it has its fuse buried in the centre of the weapon. Furthermore, the fragmentation jacket is surrounded by an outer, aluminium alloy case in which a number of vanes are moulded. The outer jacket also increases the stand-off between the MineBurner and the fragmentation jacket, which may be critical to its effective operation.
6. Cost-effectiveness analysis, or CEA, is defined as "a systematic quantitative method for comparing the costs of alternative means of achieving the same stream of benefits or a given objective." From "Definition of Terms." *Economic Analysis Handbook, 2nd Edition*. Published by the Defense Economic Analysis Council and Defense Resources Management Institute. http://www.nps.navy.mil/drmi/definition.htm. Accessed 8 February 2007.
7. The MMAC CEA model was developed in earlier research by the author. This model was also utilised in the Manual Demining Study carried out by the Geneva International Centre for Humanitarian Demining. See "A Study of Manual Mine Clearance: Manual Mine Clearance Costings and Sensitivity Analysis." Geneva International Centre for Humanitarian Demining. August 2005. http://www.reliefweb.int/rw/lib.nsf/db900SID/AMMF-6TDHBQ?OpenDocument. Accessed 8 February 2007.
8. More detail on the cost-capture issue in mine action can be found in Keeley, R. "The Cost Capture Issue in Humanitarian Mine Action." *Journal of Mine Action*, Issue 7.3, December 2003. http://www.jmu.edu/cisr/JOURNAL/7.3/notes/keeley/keeley.htm. Accessed 8 February 2007.
9. *Sensitivity analysis* is "the study of how the variation in the output of a model (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation." From The Free Dictionary by Farlex. http://encyclopedia.thefreedictionary.com/Sensitivity+Analysis. Accessed 6 June 2007.

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