

Pilot Study:

**Technical and non-technical
considerations when developing and
implementing new technology for the
humanitarian mine action community**

- Special focus on close-in detection technology -

Pilot Study:

Technical and non-technical considerations when developing and implementing new technology for the humanitarian mine action community

- Special focus on close-in detection technology -

Developed for the Benetech Initiative

Author: Jennifer Bilec-Sullivan
Researchers: Jennifer Bilec-Sullivan and Leonardo S. Nader
Project Engineer: Parag Mody, The Benetech Initiative
Project Director: Ted Driscoll, The Benetech Initiative
Project Funding: The Lemelson Foundation
Date: 22 October, 2007

This report should be cited as:

Bilec-Sullivan, Jennifer, "Technical and non-technical considerations when developing and implementing new technology for the humanitarian mine action community." A Report developed for The Benetech Initiative. 22 October 2007. Available online at <http://www.benetech.org/??>

Copyright © 2007 by
The Benetech Initiative
480 S. California Ave., Suite 201
Palo Alto, CA 94306-1609 USA

Certain rights are granted under the Creative Commons Attribution-NonCommercial-ShareAlike license, available on the web at: <http://creativecommons.org/licenses/by-nc-sa/1.0/legalcode>

The license terms are summarized here:

Attribution: The licensor permits others to copy, distribute, display, and perform the work. In return, licensees must give the original author credit.

Noncommercial: The licensor permits others to copy, distribute, display, and perform the work. In return, licensees may not use the work for commercial purposes, unless they get the licensor's permission.

Share Alike: The licensor permits others to distribute derivative works only under a license identical to the one that governs the licensor's work.

Contact Information:

The Benetech Initiative
tel: +1 650-475-5440; fax: +1 650-475-1066
Email: info@benetech.org
Web: <http://www.benetech.org>

Disclaimer

This report reflects the views of the author and has been prepared in good faith. It is not an official statement and does not reflect the views of The Benetech Initiative. All information contained herein is based on the stated opinions of individuals who contributed through on-line surveys, interviews and a review of available documentation. Any errors or inaccuracies contained herein are the responsibility of the author and do not reflect upon respondents. For confidentiality reasons, respondents remain anonymous.

Acknowledgments

Many thanks to those who tried to improve the author's knowledge and understanding of this field. Mine action is about reversing the lasting effects of conflict. Anyone involved, from deminers to advocates, have the author's respect for their efforts in attempting to rectify what conflict has destroyed. The author would like to acknowledge the aid of Mr. Colin King, who helped significantly with the loan of several resources, and Ms. Marta Wojcik, for her services in translating the on-line survey from English to French.

Abbreviations

AP: anti-personnel (mine)
AT: anti-tank (mine)
CCW: Convention on Certain Conventional Weapons
CMAC: Cambodian Mine Action Centre
CMC: Cluster Munition Coalition
CROMAC: Croatian Mine Action Centre
DNT: dinitrofluorene
EOD: explosive ordnance disposal
ERW: explosive remnants of war
GC: ground compensating
GICHD: Geneva International Centre for Humanitarian Demining
GPR: ground-penetrating radar
GPS: global positioning system
HALO: Hazardous Area Life-support Organization (UK based demining NGO)
HD: humanitarian demining
HE: high explosive
HMA: humanitarian mine action
ICBL: International Campaign to Ban Landmines
IED: improvised explosive device
IGEOD: Intergalactic EOD and Demining Foundation
IMAS: International Mine Action Standards
IMSMA: Information Management System for Mine Action
ITEP: International Test and Evaluation Programme
LIS: landmine impact survey
MAG: Mines Advisory Group
MDD: mine detection dog
MDV: mine detection vehicle
MgM: Menschen gegen Minen (People Against Mines, German mine action NGO)
NMAA: National Mine Action Authority
NGO: non-governmental organization
NPA: Norwegian People's Aid
PPE: personal protective equipment
QA: quality assurance
R&D: research and development
RDX: research department explosive (cyclonite)
SOP: standard operating procedures
SoR: statement of requirement
TFM: technical field manager
TNT: trinitrotoluene
UN: United Nations
UNMAS: United Nations Mine Action Service
UXO: unexploded ordnance

Common Terminology

Abbreviations and definitions commonly used in the industry have been defined throughout the report. In addition, the following terms are defined for the purposes of this report. Definitions defined herein are not to be considered legally definitive and have only been used for the purposes of this report.

Clearance Toolbox is defined as the set of generic processes and associated equipment used in a mine action operation.

End user is the individual who operates mine action technologies in the field.

Equipment refers to all hardware and software used in mine action that **does not** contain a biological component. For instance, metal detectors are referred to as close-in detection equipment.

Mine action operations is the set of processes, decisions, administration and technologies used by a humanitarian demining (HD) organization for the purpose of mine clearance. It includes the actions, strategies and decisions undertaken by all personnel in the HD organization, from the head of the organization to the deminer.

Technology can either function through a biological or non-biological component. For instance, both mine detection dogs and metal detectors are referred to as close-in detection technologies.

Table of Contents

Acknowledgments	3
Abbreviations.....	4
Common Terminology.....	5
Table of Contents.....	6
Executive Summary of Report	8
Part I - Purpose of the Study.....	10
Part II - Methodology.....	11
Section II-1: Framework and Research Methods for Data Collection.....	11
Section II-2: Defining the Target Respondent.....	12
Section II-3: Limitations of Research and Research Methods.....	13
Part III – Non-Technical Factors: Defining the International Humanitarian Mine Action (HMA) Community.....	14
Section III-1: Historical Overview of HMA.....	14
Section III-2: Overview of Stakeholders in Humanitarian Mine Action.....	15
Section III-2.1 Deminers and Technical Field Managers	15
Section III-2.2 International Demining Non-Governmental Organizations	16
Section III-2.3 Commercial Companies.....	16
Section III-2.4 Military	16
Section III-3: Current Trends in Humanitarian Mine Action	17
Section III- 4: Impact of Current Trends for Mine Action Funding	18
Section III-5: Social, Political, Cultural and Other Economic Influences on Mine Action Operations.....	19
Section III-6: Cost.....	24
Section III-7: Measuring Cost-Effectiveness.....	26
Section III-8: Current Mine Action Tasks and Related Technology	27
Section III-9: The Gap Between Scientific and Operational Humanitarian Mine Action Communities.....	28
Part IV – Technical Factors Affecting Close-in Detection and Other Mine Clearance Technology	31
Section IV-1: Defining the Physical Scenario	32
Section IV-2: Understanding the Impact of the Physical Scenario.....	34
Section IV-3: The Climate.....	37
Section IV-4: The Soil.....	38
Section IV-5: The Vegetation	41
Section IV-6: Anticipated Threat: Landmines and other Explosive Remnants of War	44
Section IV-7: Rating Impact of Obstacles and Technical Factors	45
Part V – Performance Indicators.....	46
Section V-1: Clearance Rates	46
Section V-2: False Alarm Rates.....	48
Section V-3: Additional Performance Indicators.....	49
Part VI - Additional Considerations When Contemplating the Development of New Technology .	50
Section VI-1: End-Users Need for Hand-Held, Close-In Detection Technology.....	50
Section VI-2: Additional Factors to Consider When Developing New Technology.....	52
Section VI-3: Final Analysis.....	54
Part VII - Additional Capability Areas for Technology Development.....	55
Part VIII Conclusion.....	57

Bibliography	62
Appendix A: On-line Structured Survey.....	65
Appendix B: Semi-Structured Interview Protocol.....	76

Executive Summary of Report

When developing new technology for the humanitarian mine action¹ (HMA) community, any research and development (R&D) organization should understand the social, economic, political, cultural and operational factors that impact technology and its usage. A plethora of studies contribute to understanding the HMA community and existing mine action technology. However, in order to develop a clearer understanding, Benetech needed a study that went beyond the usual rhetoric of end-users' needs and defined technical and non-technical factors that could affect technology development and implementation. After a comprehensive documentation review, researchers discovered that a gap still existed between available knowledge and the specific guidelines an R&D organization needed in order to understand current trends, characteristics of the HMA community and mine action operations. Therefore, the primary objective of this report was to validate existing factors and to uncover new factors that could potentially affect the design, functionality, performance and implementation of close-in detection technology.

The factors were divided into two categories: technical and non-technical. Technical factors were defined as characteristics of the mine action operation that may have an operational impact on technology. Non-technical factors were defined as cultural, economic, social and political influences that may directly or indirectly impact the operation of mine action technology, but generally impact the context of implementation. The final analysis resulted in a reference point for the development and implementation of new technology.

Part III served to broadly define the international HMA community in order to highlight social, political, cultural and economic factors which impact technology involved in mine and explosive remnants of war (ERW) clearance. Part IV served to validate and identify new operational factors that impact the performance and functionality of close-in detection technology in the operational HMA field.

The report was written and primarily intended for Benetech personnel. The number of available technologies used in mine action is extremely large. As the scope of the project to be undertaken became clearer, the Benetech target audience narrowed the scope of the research to be undertaken. Since Benetech has been exclusively engaged in understanding close-in detection technology, the primary objective of this research was narrowed to factors that could affect the development and implementation of close-in detection technology.

The research undertaken to provide Benetech with factors to consider was devised to triangulate data from a variety of primary and secondary sources. Primary sources, such as structured, semi-structured and unstructured interviews were used in addition to secondary sources, such as reports. Through documentation reviews, researchers were able to identify a number of factors and criteria that R&D organizations should properly consider when devising new technology. Through the online structured survey, target respondents were asked to comment on and validate factors identified by the documentation review. They were also asked

¹ Mine action is the entire set of activities, processes and tasks that reduces the social and economic impact of landmines and other explosive remnants of war on the indigenous population and the environment.

to provide data regarding functionality of current close-in detection technology and to identify any new factors that an R&D organization should consider.

Although a comprehensive needs analysis was not undertaken, the author found that by closely examining existing information, it became possible to identify specific end user criteria that any new mine action technology should adhere to in order to better satisfy the needs of the HMA community. Also highlighted in this report are additional capability areas beyond close-in detection that were identified as needing improvement. As a result, Benetech will be better able to evaluate which technology might best suit individual participants of the HMA community and direct its research dollars accordingly.

This study had to be classified as a pilot due to resource limitations. All primary and secondary research sources were obtained through telecommunications. Internet searches were conducted to identify relevant reports and potential contact information for target respondents. Email and phone were used to contact target respondents. A comprehensive study would necessarily include field research. Resource limitations also contributed to a small sample size of respondents. As contact information for target respondents was located through the Internet, and not through institutional partnerships, the researchers discovered that contact information was frequently out of date.

The study revealed specifics regarding technical and non-technical factors an R&D organization should be aware of prior to devising new mine action technology. For specifics, the author recommends consulting each section. However, an overall analysis revealed:

- a dearth of standardization for reporting and defining performance indicators that had been identified as of interest from an R&D perspective by Benetech;
- the lack of a comprehensive database specifying permutations of mine action operational scenarios is currently hampering innovations in technology;
- the impact of non-technical factors on a mine action operation's productivity level, clearance rates, false alarms and other performance indicators is not comprehensively understood; and
- the gap between scientific and operational HMA communities is a major obstacle in determining specific end-users' needs and technology gaps to be addressed.

It was concluded that to overcome obstacles, an R&D organization should consider their R&D methodology, and it is suggested that a participatory research method be pursued.

Part I - Purpose of the Study

Through commissioning this report, Benetech identified an information gap between HMA end users and humanitarian R&D organizations. Further, that information gap is responsible for newly developed technology not always meeting the expectations of the HMA community. Therefore, to date, new detection technology has not significantly increased the clearance² rate of ERW³ and landmines⁴. Benetech sought to close that information gap in order to ensure new technology developed would better serve the needs of the HMA community. Since Benetech has worked almost exclusively on understanding close-in detection equipment, the focus of the research was narrowed to technical and non-technical factors that would affect close-in detection technologies. Otherwise, the scope of the project was too large to complete in the designated time frame and with resources allocated for research.

What criteria will an R&D organization use to develop new technology? Benetech was interested in understanding how the characteristics of mine action operations affect the close-in detection technologies used in the field. Benetech was also interested in uncovering factors beyond those illustrated in relevant documentation and specifically requested primary research be conducted in the form of interviews. Therefore, the primary focus of this report will be to validate and elaborate on technical and non-technical factors that affect the development and implementation of new technology for the HMA community; thereby ensuring that a final product developed by Benetech would add value to the HMA community. By pursuing this research objective, a corollary result was to further illuminate specifics beyond the usual rhetoric of end users' needs⁵. As such, the secondary objective to understand end users' needs is included in the report but is not as extensively covered.

² Clearance is defined by the IMAS 04.10 Guidelines as the “tasks or action to reduce or eliminate the Explosive Ordnance hazards from a specified area”

³ Explosive Remnants of War is defined by Protocol V of the CCW. ERW encompasses both unexploded ordnance (UXO) and abandoned explosive ordnance (AXO).

⁴ A landmine is “an explosive or other material, normally encased, designed to destroy or damage vehicles, boats or aircraft, or designed to wound, kill, or otherwise incapacitate personnel. It may be detonated by the action of its target, by the passage of time or by controlled means. [NATO definition]” (King, 2002:10)

⁵ The usual rhetoric of end users' needs is for mine action technology to be lower in cost, robust and low-tech.

Part II - Methodology

Section II-1: Framework and Research Methods for Data Collection

Factors that affect the accuracy of detection technology directly relate to the physical surroundings in which detection and demining occurs. This conclusion is supported by evidence from *Systematic Test & Evaluation of Metal Detectors: Interim Report Field Trials Mozambique* where "the main factor influencing metal-detector performance...[is] the ground." (Guelle and Lewis, 2006). This result for metal detectors was extrapolated to include all forms of close-in detection technologies. By making the independent variable the physical surroundings, a comparative analysis of data collected can be made. Characteristics of the physical surroundings that affect ground conditions have been identified as: physical scenario, climate, soil, vegetation and anticipated threat. The *Mine Action Equipment: Study of Global Operational Needs* (2002) by the Geneva International Centre for Humanitarian Demining (GICHD) established 12 different sub-divisions of physical scenarios that affect mine clearance and under which mine clearance⁶ technologies need to operate. Sub-divisions of each additional category (climate, soil, vegetation, anticipated threat) were devised through direct consultation with experts in the HMA field and through extensive documentation review.

The level of sub-division present was also deemed to have an impact. For the physical scenario, the scale range included Dominant Scenario, Scenario Frequently Found, Scenario Occasionally found or Scenario Not Found. For other sub-divisions, the scale options were High, Medium, Low and None, and were applied as appropriate. The scale options were selected from GICHD's study (2002) in order to provide a basis for consistent analysis.

Since data collection and analysis can be influenced by poorly defined terminology, considerable care was taken with the phrasing of the questions. Recognizing the importance of collecting accurate and unbiased data, this research study used *IMAS' 04.10, Glossary of mine action terms and abbreviations* (2003) as its central source of definitions.

Researchers used multiple research methods in order to triangulate data collected, thus gaining insight into field perspectives and acquiring anecdotal information. Primary research was conducted through the use of structured⁸ online surveys,⁹ semi-structured¹⁰ phone interviews

⁶ Mine clearance is clearing mines and other ERW from a specific region to a required clearance depth as established by the national mine action authority.

⁷ International Mine Action Standards (IMAS) have been developed by the UN to establish requirements and standards for mine action.

⁸ A structured interview is a quantitative research method used to present each interviewee with the exact same questions to ensure that answers can be compared and contrasted. Open and close-ended questions were included in the online survey.

⁹ Online survey software used was www.surveymonkey.com.

¹⁰ Semi-structured interviews are a research method used when specific topics must be covered in an interview and a degree of flexibility is needed to explore new topics as they emerge throughout the conversation. This method allowed the researcher to ask target respondents about pre-determined topics while at the same time permitting exploration of previously unidentified topics that might conceivably provide information relevant to the research study.

and unstructured¹¹ email interviews. Members of the mine action community were consulted on phrasing and types of questions being asked. Clearly, it is as important to ask the right questions as it is to find accurate answers.

By using a structured interview format, data was collected regarding the impact of the physical surroundings on functionality of detection technologies. For quality control purposes, background information on each respondent's technical expertise and length of experience was also collected by using the on-line survey. The target respondent's expertise was then evaluated by researchers and Benetech personnel through consultation with respected HMA consultants. The online survey can be found in Appendix A.

In terms of the semi-structured interview, a series of potential questions were formulated for the researchers to use at their discretion during the course of the interview. It was not anticipated that all questions would be asked of each respondent because of time constraints. The objective of the interviewers was to initiate a dialog with the respondent and incorporate questions as appropriate. The questions were formulated to collect the respondent's opinions on political, social, cultural and economic factors relating to the demining process. All interviews were conducted by telephone. The semi-structured interview can be found in Appendix B.

Unstructured interviews were conducted either by telephone or email generally with respondents who had not completed the on-line survey. In some instances, respondents who answered the on-line survey were too busy due to mine action obligations. In these situations, follow-up interviews were conducted through unstructured email discussions. By using this methodology, the author was able to collect a significant amount of qualitative data about the nature of the HMA community and current trends.

Relevant documents provided by the International Test and Evaluation Programme (ITEP), GICHD and the larger HMA field were reviewed in order to ensure that sufficient background knowledge was acquired to provide a context for the final analysis. Documentation resources were located by using the Internet. Respondents were also asked for references to reports and documents.

Section II-2: Defining the Target Respondent

Researchers used a snowball sampling technique¹² in order to locate and interview relevant specialists. Due to time constraints and the limited financial resources at the researcher's disposal, it was unrealistic to consider an alternative sampling method to locate potential target respondents. Researchers located potential target respondents through contact information in E-Mine, reports available online and by using the e-forums of Menschen gegen Minen (MgM), Intergalactic EOD and Demining Foundation (IGEOD) and Franco-mines.

¹¹ The unstructured interview is a free-flowing dialog between respondent and interviewer.

¹² Snowball sampling is a sampling technique achieved through networking. A target respondent identified will refer the researcher to another potential target respondent. It is acknowledged that the snowball sampling technique results in an inherent bias of collecting a sample size of like-minded individuals.

Clearly, the quality of the respondent is crucial to obtain data that befits the level of technical detail, managerial decision and field experience required to aid the development of new technology. The author would have liked to include indigenous deminers or field supervisors, but this was unrealistic without field visits. However, researchers were able to locate target respondents from nine different countries to obtain anecdotal information. As a pilot study, this small sample size was deemed adequate for analysis. However all conclusions based upon the anecdotal information should be taken with caution, as the sampling method does not reflect a good cross section of the population, and resource limitations did not allow a fair sample size to be achieved.

The primary target respondent was the technical field manager (TFM). The TFM generally works in the operational HMA field, is usually an expatriate with military background and possesses technical expertise relevant for mine action. TFMs integrate their expertise with other colleagues on the team to make decisions regarding the mine action operation. Additional respondents identified include high-level managers and scientific personnel.

Section II-3: Limitations of Research and Research Methods

Data collection for this project was distinctly limited due to the use of telecommunications and primarily depended upon the cooperation and generosity of the target respondents in conducting the research. Insufficient financial resources prevented researchers from conducting field research, thus limiting the number of target respondents identified during the time allocated. To be considered a comprehensive study, two target respondents would be needed for each sub-division identified in each category (i.e. soil, vegetation). Since two target respondents were not identified for all subdivisions, information could not be cross-verified.

Further, identifying the physical surroundings in any country was necessarily based upon the target respondent's perception. Even though all target respondents were very well informed, there was a degree of discrepancy in the data collected and as such, any conclusions made herein should be treated with caution. If a larger study is to be conducted, it is strongly suggested that future researchers use an alternative method of sampling that produces less biased data. To increase the sample size, additional resources are needed, more time should be allocated to achieve objectives and field research needs to be conducted within the context of strategic partnerships.

Part III – Non-Technical Factors: Defining the International Humanitarian Mine Action (HMA) Community

Section III-1: Historical Overview of HMA

Demining has occurred since the first landmine, but modern HD historically defines its origin with the mine clearance operations of Afghanistan and Cambodia in the 1980s (Guelle et al., 2003: 15). In the first decade of HD, mine action operations were large, complex, occurred in post-conflict countries and prioritized clearing areas with the largest absolute number of landmines and ERW. It soon became apparent that prioritizing mine clearance in this manner was not having the intended effect of alleviating the socio-economic impact on the indigenous population. Hence, the HMA community changed strategies and prioritized areas that were deemed to have a greater socio-economic benefit for indigenous communities.

The campaign to ban landmines commenced in the early 1990s and has had well-known advocates such as the late Princess Diana and the International Campaign to Ban Landmines (ICBL). The Mine Ban Treaty¹³ prohibited the production and development of anti-personnel (AP) landmines, except for training and testing purposes. The Mine Ban Treaty also required states to clear all landmines within 10 years of becoming a treaty member. Treaty members who are not mine affected states are obliged to support clearance through financial aid.

According to the ICBL website consulted on April 14, 2007, 153 states are party to the treaty; notable exceptions include United States, Russia and China. However, the campaign to end the use of indiscriminate weapons did not end with the adoption of the Mine Ban Treaty, but rather commenced. According to the Cluster Munition Coalition (CMC) website, Protocol V of the Convention on Certain Conventional Weapons (CCW)¹⁴ was adopted in 2003 and entered into force in 2006. Protocol V requires unexploded ordnance (UXO),¹⁵ such as cluster bombs, to be cleared in conjunction with landmines. The CMC represents a new movement to prohibit and ban the use of cluster munitions.¹⁶

In 2006, the Landmine Monitor reported 78 countries remain affected by landmines. However, progress has been made. Guatemala and Suriname declared their countries cleared of mines in 2005. Also in 2005, 740 square kilometers were demined; “the highest demining rate since the beginning of HD” (ICBL, 2006). Current warfare practice is that predominantly non-

¹³ The original full title is the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction. The Mine Ban Treaty also goes by the name of the Ottawa Convention or Ottawa Treaty as it was opened for signature in Ottawa, Canada.

¹⁴ CCW is the abbreviation for Convention on Certain Conventional Weapons. The formal title of the CCW is the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects.

¹⁵ Unexploded ordnance is "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." (GICHD, 2002:92)

¹⁶ A cluster munition is “A number of submunitions in one container that is aurally delivered.” (King, 2005:9)

state actors¹⁷ use landmines, as opposed to state governments (ICBL, 2006). This is a promising trend, indicating that customary practice on a state government level does not support landmine usage¹⁸. Unfortunately, this trend does not extend to other ERW such as cluster bombs. The Landmine Monitor (2006) reported an increase in landmine and ERW casualties, highlighting civilian casualties that were caused solely by the usage and presence of ERW in post-conflict settings.

Section III-2: Overview of Stakeholders in Humanitarian Mine Action

The following quote demonstrates how stakeholders and actors in the HMA community are intrinsically connected. Regardless of differing agendas, constraints and objectives, all in the HMA community are operating towards the same goal; to create a world free from the detrimental effects of landmines and other ERW. The following section will highlight a few of the key actors within the HMA community.

"At present, humanitarian demining in most affected areas begins with a UN-led emergency response, which is controlled by ex-pats, who usually have a military background and who are largely paid for by "ear-marked" donations from UN countries. Those donations sometimes take the form of staff and goods. At the same time, as the UN arrives (and sometimes before), the specialist charitably funded [NGOs], which are funded by an individual government's aid budget or by trusts and donor charities, tend to move into the area. Following the charitable groups come the commercial companies."

- Andy Smith, Journal of Humanitarian Demining, (1998a)

Section III-2.1 Deminers and Technical Field Managers

Among the most important end users of current mine action technologies is the deminer.¹⁹ A deminer is defined by his job. He will prepare the ground²⁰ through flails,²¹ detect by using metal detectors or dogs, and prod the ground to determine the exact location of the landmine. Essentially, he will use every possible tool or piece of equipment at his disposal to

¹⁷ Non-state actors could be guerrilla groups, resistance fighters, terrorists or insurgents.

¹⁸ A notable exception is the demilitarized zone between North and South Korea.

¹⁹ Women are also involved in demining and the HMA community, but to a much lesser extent. Therefore, this report will generally refer to personnel operating in the HMA community with the pronoun "he."

²⁰ The IMAS 04.10 Glossary of mine action terms, definitions and abbreviations defines ground preparation as "preparing of ground in a minefield or hazardous area by mechanical means by reducing or removing obstacles to clearance e.g. tripwires, vegetation, metal contamination and hard soil to make subsequent clearance operations more efficient. Ground preparation may or may not involve the detonation, destruction or removal of landmines."

²¹ A flail is "an arrangement of flexible arms (normally made from steel chain) mounted on a rapidly rotating shaft, that can be driven across a piece of ground to clear vegetation and/or mines". (King, 2005:9)

ensure the ground and immediate area is cleared of hazardous threat. In the process, the deminer is exposed to significant risk. Deminers are generally from the indigenous community and may or may not have gained relevant knowledge through the recently ended conflict. A deminer's salary is usually around \$5 per day (Smith, 1998b).

A TFM also generally has previous experience through serving in a military role. Alternatively, the TFM may have gained relevant experience through other activities, but is hired because of the specific technical expertise he brings to the mine action operation. A TFM may have a position title such as Operational Officer, Technical Adviser or Operational Manager and is generally an expatriate who is paid at a higher salary than a deminer. The TFM may or may not engage directly in demining. TFM's are generally more accessible to the international community and therefore often act as a focal point between deminers/operations and personnel external to the specific mine action operation.

Section III-2.2 International Demining Non-Governmental Organizations

Some examples of the most prominent demining non-governmental organizations (NGOs) include Hazardous Area Life-support Organization (HALO Trust), Mines Advisory Group (MAG) and Norwegian People's Aid (NPA). They are often engaged in clearance activities that offer social benefits to the indigenous community, such as clearing landmines around a school or water source. Their mandates differ as some NGOs are solely engaged in demining, while others are more involved in post-conflict reconstruction activities. As a result of their primarily social and community oriented mandates, funding is derived from and depends upon the generosity of donors. This is not a continual or stable source. The limited sources of funding results in continual demands for "safer, cheaper, faster incremental improvements to existing equipment" (GPC International, 2002:7).

Section III-2.3 Commercial Companies

Commercial companies involved in HMA have access to the same technologies, processes and advancements as NGOs. Therefore, commercial companies generally have the exact same clearance toolbox as demining NGOs. The primary difference is that commercial companies are engaged in humanitarian mine clearance for profit and thus have a larger operational budget. This translates into a greater ability to purchase new technologies, use technologies deemed to be effective for a specific region or try new techniques without having to account to donors about possible costly mistakes. The commercial company profit agenda allows a degree of flexibility and their larger operational budgets result in increased purchasing power in the demining technology market. The consequence is that commercial companies are strong stakeholders in determining the technology needs of the HD community (GPC International, 2002:8)

Section III-2.4 Military

Demining originated with the military and, not surprisingly, militaries are a primary stakeholder in HMA. It is often militaries who have previously laid landmines and distributed area weapons. Expatriates with military backgrounds often lead mine action operations in the

field. In some regions, such as Latin America, it is the military that dominates the HMA scene. It is this historic linkage between military and HD that could prove to be a challenge for R&D organizations attempting to develop new technology for HMA purposes. The main problem is the military often has a large operational budget to conduct R&D. The result is a strong purchasing power within the demining technology market and the ability to demand that R&D be conducted for military purposes. Typically, military objectives include finding the fastest path through mines from point A to point B. Locations targeted for demining are chosen for strategic military purposes and military deminers are inevitably under pressure to work quickly. Generally, they only clear the immediate path (Guelle et al., 2003:15). The military is often reluctant to report expenditures or share R&D for HMA purposes because it is often tied to military objectives and hence considered to be a security issue.

Section III-3: Current Trends in Humanitarian Mine Action

"The United States aims to greatly accelerate global humanitarian demining operations and assistance efforts to end the plague of landmines posing threats to civilians through a U.S.-led initiative to develop, marshal and commit the resources necessary to accomplish this goal in cooperation with other nations by the year 2010."

***- US Department of State,
US Demining 2010 Initiative
Nov. 13, 1997***

The Mine Ban Treaty requires state parties to clear all landmines within 10 years of becoming a signatory. For many mine-affected state parties, this obligation translates into either a 2009 or 2010 deadline. In conjunction with state parties' obligations, the US Clinton administration formed a Presidential Demining 2010 Initiative. The Initiative committed resources, staff and funds and encouraged international coordination towards the goal of a world safe from mines by 2010 (US Department of State, 1997).

Although the deadline varies from country to country, there is a consensus from the HMA community that 2010 marks the end of the second decade of HD. As the US is the largest financial contributor to HMA (ICBL, 2006), the US Demining Initiative indicates that donor countries do not expect to fund large scale, HD operations after the 2010 deadline. The 2010 budgetary deadline will force a re-evaluation of the current landmine "crisis." Potential reforms within the HMA community will be considered; from technology to governance. For example, one respondent believed that all future mine clearance will primarily occur for commercial benefit, rather than focusing on clearing land for social and community benefit.

The 2010 deadline is the real issue for most of the HMA community. All respondents stated their countries would not be cleared by their respective deadlines. An extreme example is the respondent from Afghanistan reporting "it took 17 years to clear 67% of the problem area with an additional 20 years needed to declare the country mine free."²² Overall, reports from field respondents indicated their inability to meet their countries' target deadlines. This evidence directly contradicts donors' expectations. The US Demining Initiative implies that increased levels of funding until 2010 will have resolved the world's landmine crisis and correspondingly

²² The IMAS 04.10 defines mine free as "a term applied to an area that has been certified as clear of mines to a specified depth. Also applied to a country or an area that has not had a mine contamination problem."

have not made any new pledges of funds for after 2010. Perhaps the growing trend in the HMA community towards accepting a certain level of risk from landmines is therefore a direct and realistic response to countries' inability to meet the mine free 2010 deadlines. Authorities and stakeholders, such as personnel in the UN, reported considering a risk management approach that would set mine clearance priorities to achieving an impact free situation. An impact free area is defined as having removed enough landmines and other ERW to eliminate the socio-economic impact on the indigenous population. "The benefit to the HMA community would be fewer resources, money and time would be spent on removing relatively small threats which have no direct impact on the indigenous community. Instead, the HMA community would be able to move on and provide assistance to groups or projects that still experience a high level of impact from hazardous areas."²³

In contrast to the decreasing focus and waning interest in funding mine clearance, there has been increasing international attention on cluster munitions and other indiscriminate area weapons. The CMC is campaigning for an additional Protocol to be added to the CCW to prohibit or limit the use of cluster munitions. The rationale behind prohibiting the use of cluster munitions is similar to prohibiting the use of landmines. The CMC website reports a cluster munition is able to impact an area of one square mile and project shrapnel to a 50 meter radius. Because of the large radius, cluster munitions affect civilian areas located near military targets. The cluster munitions' inability to solely aim for military targets has forced the international community to reconsider using indiscriminate area weapons. A recent example of impact is the Israel-Lebanon crisis in 2006 that littered Lebanese land with cluster munitions and placed civilians directly in danger.

At the present time, it is difficult to predict the final effect of mine-affected countries' inability to meet the 2009/2010 deadlines, the re-evaluation of HMA and the potential decrease in funding. Whereas it seems improbable that the international community will completely abandon the idea of removing mines from the ground, there is the general sense of waning international interest and donor fatigue for funding mine clearance. Regardless, it is very clear the HMA community will see drastic changes when the 2010 deadline arrives.

Section III- 4: Impact of Current Trends for Mine Action Funding

As the 2010 deadline approaches, the issue of funding becomes a crucial concern for mine action operations. Several mine clearance operations have already reported funding shortfalls in 2006 resulting in personnel laid off and operations stopping. Notable examples include United Nations Mine Action Centre for Afghanistan (UNMACA) laying off 1,130 deminers and operations shutting down for the entire 2005 year in Mauritania. Guinea-Bissau, Croatia and Tajikistan all reported an inability to meet target deadlines if long term funding was not secured (ICBL, 2006). The decrease in funding is not limited to specific countries, but is a global trend.

What is the result? It seems funders may instead be interested in investing in other priority areas for developing and post-conflict nations; priorities that have the potential to directly improve economic development and support the stabilization of the country. One can

²³ Quote from anonymous respondent.

argue that removing obstacles such as landmines to improve access to water, land and buildings does provide a socio-economic benefit. However, a combination of donor fatigue, the 2010 deadlines and a simultaneous increasing trend to accept a level of risk, has resulted in a major change in level and strategic direction for HMA funding.

In the face of this funding trend, and with no new initiatives for funding post 2010, it is suggested that the window of opportunity for funding new HMA technology may be slowly closing with the approach of the 2010 deadline. The HMA market size is directly determined by the level of funding available. A decrease in funds available to HMA directly reduces the size of the market. Even the new international focus on cluster munitions does not require any new R&D funding to create new processes or technology. Cluster munitions and other ERW are generally found through visual means, have a high metal content that is easy to detect and are cleared by the same teams and clearance toolbox used to conduct mine clearance.

As indicated by the opposite quote, some mine action personnel have found the need to change industries because of funding decreases. Other respondents believed they would continue in the mine action field, but the HMA community would extend to clearing cluster munitions and other ERW. Thus, funding and jobs would be ensured. While higher level officials are cautious of the possibility of mission creep it seems likely that mine action operations will receive some funding if cluster munitions are banned; hence requiring their immediate clearance. However, the increase in funding to clear all ERW may or may not compensate for the potential decrease in HMA funding.

"Personal evidence funding is drying up? UK, Canada and Sweden have all dramatically reduced their HMA, R&D and T&E budgets and I am now working in the oil industry."

- Anonymous Respondent

Section III-5: Social, Political, Cultural and Other Economic Influences on Mine Action Operations

The socio-economic impact of landmines has been well researched and documented. The impact of ERW such as cluster munitions is documented and understood to a lesser extent, but it is clear that it also has a negative impact and dangerously affects the indigenous population (ICBL, 2006). Even less understood is how political, social, cultural and economic realities (otherwise referred to as non-technical factors and/or influences) within a country can influence the productivity and implementation of mine action operations. For an R&D organization attempting to develop new technology, non-technical factors can influence how technology is implemented and thus affect the utility of a new innovation or technique.

The following points do not produce a comprehensive picture, but attempt to suggest several potential influences that could directly or indirectly impact an R&D organization's successful introduction of new technology to the HMA community. Additional field research is needed to provide a comprehensive picture and to evaluate the impact of non-technical factors on the productivity of mine action operations.

Political, Social, Economic and Cultural Influences within a Country Conducting Mine Action:

- A national government's interference or support will impact productivity and clearance rates of operations.

Most respondents listed their national government's interference or support of HMA as one of the primary factors that affected the productivity and clearance rate of operations. A national government can hamper productivity through corrupted use of donor funds or by prioritizing land that benefits one specific person rather than the community. However, the opposite also proves true. The respondent from Tajikistan reported the government's strong support of HMA was a key factor that ensured smooth and productive operations.

- Education levels affect productivity and ability to use high-tech equipment.

Respondents often commented on the necessity for data output, signals and equipment panels to be user-friendly, thus enabling them to be used by deminers with low to no formal education. The indigenous population provides the manpower to conduct manual demining. Therefore, the educational level of the indigenous population is a general indication of the indigenous deminer's education level. Sri Lanka's indigenous deminer has an average of 10 years of education in school (Cepolina et al., 2005a:29) versus indigenous deminers in Angola who have an average of three to four years of school education (Cepolina et al., 2005a:22). A higher level of education generally results in a higher aptitude to use high-tech equipment.

- Culture affects choices available to the clearance toolbox.

If it has a biological component, the country's culture may prevent use of certain technologies. For example, mine detection dogs²⁴ (MDDs) are not easily used in predominantly Islamic countries as dogs are considered unclean. Cultural influences also may exclude the use of effective bio-technologies such as honeybees, rats or plants. An indigenous deminer may or may not feel comfortable cultivating bees or rats in his backyard, even if the bio-technology could increase productivity.

- Bio-technologies introduced for the purposes of mine action could disrupt the indigenous environmental balance.

Technology with a biological component has been experimented with, but with very little implementation success. It is possible that a biological component could provide a quicker and more cost-effective way to clear mines, but introducing different biological components to a non-native habitat could be disastrous. For instance, one respondent was convinced that it would be possible to increase productivity by using honeybees to detect explosives, thereby providing a quick way to conduct area reduction²⁵ and pinpoint potential threats. However, when a TFM was asked about the possibility of using honeybees, the respondent replied it was completely impractical because the possible disruption to the indigenous eco-system was extremely high, with potentially disastrous

²⁴ Dogs are used as a form of close-in detection technology. They are trained to detect the scent of explosives in landmines and other ERW. Hence, they are often referred to as an explosive sensor.

²⁵ "The act of narrowing down the suspect area, often by proving the surrounding area to be clear to a reasonable level of confidence." (King, 2005:8). The task is generally accomplished as part of a Landmine Impact Survey. The term Landmine Impact Survey was previously referred to as a Level Two Survey.

results. National governments will not be receptive to technologies that could be productive for mine action but cause long-term environmental damage.

- Mine-affected countries and NGOs want to provide economic benefit to the community through mine action operations.

Ensuring national ownership and building national capacity is a priority for mine action operations. New technology that increases productivity but decreases the need for indigenous manpower puts people out of jobs. Some respondents reported an interest in new, cheap technologies but reported an even greater interest in ensuring their operations provided an economic benefit to the community. This influences the decision-making process of both mine clearing operations and mine-affected countries in selecting technology for the clearance toolbox.

"A humanitarian deminer in Chad receives approximately \$300/month, a salary that allows him to feed his family and resolve many of the social ills he would otherwise be facing. In an interview, a representative from Chad's mine action program indicated that the benefits of gainful employment for locally engaged deminers are a high priority for the program. In fact, this is why they do not invite NGOs to perform mine clearance, rather they ask the NGOs to train and supervise local deminers."

- Assessment of the International Market for Humanitarian Equipment and Technologies, (2002:15).

- Technologies need to be supported by the national capacity and infrastructure where mine clearance operations are occurring. Mine clearance operations generally occur in a post-conflict environment.

R&D organizations need to consider the country's infrastructure and capacity to support high or low tech equipment. Mine clearance operations generally occur in a post-conflict environment and are part of reconstruction activities. Standard characteristics of a post-conflict country are a collapsed economy, a population accustomed to fire arms/munitions/landmines and very few economic opportunities for internally displaced people or refugees. The government has either collapsed or is very weak and therefore does not have the capability to support complex mine clearance operations with personnel or funds. Infrastructure, such as roads, buildings, houses and schools, in a post-conflict country has generally been destroyed. In addition, the rule of law system has generally collapsed. Police and lawyers that implement the rule of law are also rare. Thus, the issue of land ownership in a post-conflict environment becomes an extremely contentious issue and a potential reason to renew the conflict. The clearing of landmines, which releases new land to be used for agriculture or other community purposes, can generate controversy as to who owns and is entitled to the newly released land. While the characteristics of a post-conflict country do not directly impact implementation of technology, a post-conflict country does not have the same capacity as a high income country to support mine clearance activities or high-tech equipment.

Political, Social, Economic and Cultural Influences on an International Level:

- There can be intense competition for mine clearance contracts.

Strong competition for contracts exists between organizations conducting HMA. Competing organizations are less likely to cooperate with one another and exchange best

practices information. Nor are they likely to pool limited resources to fund R&D for HMA technology.

- Mine action personnel may mistrust the intentions of outsiders if interaction does not occur within a strategic partnership.

Following in a similar vein, personnel in mine action understandably may mistrust the intentions of outsiders.²⁶ One of the most difficult aspects of conducting primary research for this report was not only locating research subjects, but convincing respondents that information was collected anonymously and would not be misused, thus potentially jeopardizing their jobs. When attempting to evaluate technological needs, one is essentially asking "What is wrong with your current equipment/technology?" and "What functions inadequately in your mine-affected country?" It forces respondents to comment negatively (or positively) on the conduct of current benefactors, national governments, or the technology in their clearance toolbox; perhaps jeopardizing their organization's relationship with donors, mine-affected countries, R&D partnerships and their jobs. R&D organizations seeking the cooperation of an NGO may need to consider forming a strategic partnership at the outset of a project, thus ensuring confidentiality through a Memorandum of Understanding (MOU).

- Mine action personnel are extremely busy, working long hours towards unrealistic deadlines, with very sparse resources allocated.

One respondent reported he observed an organization cut their budget to the bare bones to gain a contract. The operation should have had at least three or more TFMs for the scale of the project, but only had two full time staff. Well-funded NGOs are able to operate at an appropriate level, but ill-funded NGOs cut in order to be competitive. The competition and/or limited funding sources contribute to a tight budget, which in turn encourages staff to work long hours on limited resources.

- All work conducted by mine action personnel must be beneficial and justify the cost.

Because mine action personnel are so busy and work under tight budgets, personnel are generally not able to allocate time to respond to R&D organizations' queries unless there is a strategic partnership in place that directly benefits their organization. In essence, any work conducted by mine action personnel has to have a direct cost-benefit for their organization or mine clearance operation; otherwise their actions can not be justified. This observation does not apply to all mine action personnel, as quite a few were very cooperative and friendly. However, it does partially explain the lower than anticipated sample size. Without a strategic partnership in place, the same constraint will apply to any R&D organization attempting to gain data or identify technology gaps.

- Security concerns: Will equipment fall into the wrong hands?

Mine clearance and mine clearance technology began with the military; for both defensive and offensive purposes. If an R&D organization is developing technology for the HMA community, it needs to understand that it is equally possible to convert

²⁶ The term 'Outsiders' is defined as individuals who are not directly involved in or engaged by the same demining organization.

humanitarian mine clearance technology to military purposes. Existing guerrilla groups, national armies or new resistance groups can convert technology designed for the humanitarian community into military technology. Conversion of technology can be achieved by any individual who finds himself in the midst of a renewal of conflict or a new conflict. Thus, R&D organizations need to concern themselves with supporting the humanitarian community, while being aware that their new technology could fall into the wrong hands, to the detriment of all and thus, could contribute to the renewal of a conflict.

- The Mine Ban Treaty has reduced the availability and appropriateness of landmines. It has changed how warfare is conducted.

The Mine Ban Treaty only applies to state signatories and does not really have any effect on prohibiting guerrilla, insurgent or resistant groups from misusing mine technology. In contrast, the international community has now realized that the use of cluster munitions and indiscriminate area weapons also has a lasting, negative impact on the indigenous population. The potential addition to the CCW to include prohibitions on cluster munitions may again change the way warfare is conducted, and thus alter mine action operations. When evaluating criteria and technology needs, R&D organizations have to also take into consideration changes made in the way warfare is conducted.

- Secrecy and competition exists between R&D organizations.

The R&D organization that can provide a technological solution that improves demining or greatly increases the rate of productivity in a cost-effective manner will gain a large portion of the international demining market. The result is that there is not a strong incentive for R&D organizations to collaborate and it is most likely that each R&D organization holds a piece of the puzzle.

- Introducing new technologies creates competition for existing technologies. In addition, certain donors may place conditions on technologies to be used

An R&D organization introducing new technology is not doing so in a vacuum. It is creating competition for existing humanitarian and military mine action technologies. The international HD market is extremely small, and introduction of new technologies will increase the competition. The consequence is mine action personnel may only consider new technologies when it has been developed by a benefactor or a partner organization of a benefactor. For example, if a mine action operation is funded by a specific donor, the donor may require the use of a specific close-in detection technology developed by a partner organization. The potential result could be that technologies are sometimes adapted by demining organizations²⁷ as a result of political or strategic partnerships versus increase in productivity or cost-effectiveness.

²⁷ A demining organization is any commercial, non-profit, military or governmental organization that conducts mine action.

In summary, a responsible R&D organization should not blindly develop technology which may increase productivity in test and evaluation trials (T&E),²⁸ but fail in implementation due to non-technical constraints.

Section III-6: Cost

Different organizations calculate and report costs of technology in extremely different ways. Some organizations include maintenance in the total cost of a piece of technology, others simply list the one-off purchase price (Cepolina et al., 2005a). Thus, cost comparisons between organizations are extremely difficult to achieve. Respondents were asked what would be the purchase cost at which they would consider new technology. The answers ranged from \$5,000-\$10,000 USD. However, the response range does not provide a conclusion, as one respondent reported a preference to spend money on employing more deminers to increase productivity rather than buying another piece of equipment. To gain an indication of how much a new close-in detection technology should cost in order to be competitive in the HD market, anecdotal data was collected on costs of currently used close-in detection technologies for each mine action operation.

Table 1: Cost of current close-in detection technology as reported by Respondents

In general, costs reported in Table 1 reflect a one time purchase and not costs associated with required maintenance. The exception to this generalization are the different costs reported for MDDs. When asked, a respondent clarified the variable costs of MDDs reported. In general, MDDs cost \$10,000 USD for a one time purchase. The reported \$25,000 is the monthly cost for maintenance and operation of two dog handlers and four dogs.

²⁸ Testing and evaluation occurs on all software and hardware to be implemented in mine action operations. It is conducted in order to understand each piece of technology's capability, functionality and performance levels.

The variance in calculating costs becomes a potential concern for any R&D organization. While costs are generally reported as one-off purchases, required maintenance, renewal of power supplies and spare parts also contribute to the overall cost of mine action technologies. One could even consider the necessity to constantly buy new batteries or gas for a car to go get spare parts as hidden costs associated with a technology. An R&D organization may be able to provide a very cheap metal detector, but associated hidden costs may contribute to a certain piece of technology not adding value to mine clearance operations.

Unlike the military, most HD organizations have very limited budgets and are not able to support costly equipment. If a piece of technology or equipment's associated hidden costs cannot be supported by the organization, they are useless to the HMA community, regardless of purchase price. "The Schiebel AN-19/2 mine detectors provide an excellent example of this situation. Defunct units of this model, which is uneconomic to repair, litter the African countryside" (Smith, 1998b).

Close-in detection technology is not the only technology present in the clearance toolbox. Therefore, the following price list of all equipment is included to give an indication of costs for equipment used in mine clearance operations.

*Table 2: Cost of some equipment as reported by
Handicap International*

Source: *Equipment for Post-Conflict Demining, Working Paper No. 48* ²⁹

Neither table reports on other equipment used in the clearance toolbox such as flails, vegetation cutters, etc. However, both tables taken together give an overall range of one-time purchase costs for different equipment. For any R&D organization developing HMA

²⁹ "Handicap International use "indigenously made" trowel, shears, sharpening stone, brush, tripwire feeler and mine markers." (Smith, 1996).

technology, the one-time purchase costs and additional hidden costs must be competitively priced.

Section III-7: Measuring Cost-Effectiveness

In order for a close-in detection or any new technology to be adapted, it must be competitively priced, or inexpensive, and thus accessible to demining organizations operating on a limited budget. It must also prove it can increase productivity, improve safety for deminers or satisfy another end-user need. In essence, any new technology must prove to be cost-effective. Cost-effectiveness is defined as the calculated cost (i.e. one-time purchase price, maintenance, etc.) in comparison to improved effectiveness or benefit gained.

If reporting costs vary among organizations and are difficult to assess, calculations assessing benefits gained from technology vary even more widely (Cepolina et al., 2005b:14). How does one define cost-effectiveness for the HMA community? A potential cost-effectiveness ratio could be to measure calculated cost against the rate of mine/ERW clearance.

Calculated Cost : Clearance Rate

However, as discussed earlier in Section III-5, clearance rates are affected by political, social, economic and cultural factors. Furthermore, and as discussed in Part IV, clearance rates are operationally affected by the physical surroundings.

An excellent example of the difficulty in calculating cost-effectiveness based upon the cost:clearance rate ratio is the rake. The rake was reported by a respondent as the most effective and least costly piece of equipment used in Jordan. The rake is as productive as other equipment such as metal detectors in clearing landmines and is produced much more cheaply than metal detectors. Therefore, the rake could be rated as the most cost-effective piece of mine action technology. The respondent did not indicate that national political will or other non-technical factors hampered mine clearance. However, the rake can only be utilized in mine action operations with physical surroundings and non-technical factors similar to Jordan. Therefore, the rake may not be as cost-effective in a mine action operation with technical and non-technical factors similar to Tajikistan's. The national political will in Tajikistan is strong, and therefore influences clearance rates to a degree that a more costly piece of equipment produces the exact same or higher clearance rate as the rake in Jordan. Thus, declaring the rake as cost-effective is a legitimate statement for Jordan, but may not be legitimate for Tajikistan. Cost-effectiveness of the rake for alternative mine action operations is brought into question. Further complicating cost-effectiveness calculations is the need to not only evaluate in terms of land cleared, but also in terms of beneficial change to the indigenous community.

The challenge to an R&D organization introducing or developing new technology becomes immediately apparent. Demining organizations that have had to severely cut budgets in order to gain contracts have very little room for error and little ability to try new equipment that does not immediately prove to be cost-effective. At the same time, accurately evaluating cost or cost-effectiveness is an extremely challenging activity. Nonetheless, any R&D organization

introducing new technology must prove its cost-effectiveness to the end user, regardless of the difficulties in assessing cost or effectiveness. Otherwise, a new technology that may add value and ultimately increase productivity will not be adapted.

Section III-8: Current Mine Action Tasks and Related Technology

According to GICHD's study *Mine Action Equipment: Study of Global Operational Needs*, the process of HD is generally defined by the following tasks: visually checking for mines/UXO, checking for tripwires, vegetation clearance, marking hazardous areas, investigating false alarms/mines, excavating and exposing mines, and ensuring the area is mine/UXO safe. Table 3 below was also taken from GICHD's study. The table highlights the different mine action tasks performed by a demining organization and the associated equipment employed. The table also highlights equipment that is presently being considered for inclusion in the clearance toolbox and its level of development.

Unfortunately, Table 3 provides a good indication of current equipment in use, but does not highlight other technologies employed such as MDDs, the use of Personal Protective equipment³⁰ or information and communication equipment. Mine action operations need access to mobile phones, the Internet and other communication technologies. But, the most important tools in the clearance toolbox are not technologically based. They are visual identification and common sense. Equipment or technology can increase productivity or safety, but to date no equipment can replace the common sense and eyes of the deminer.

Interestingly, regardless of the interaction between factors that make each mine clearance operation unique, there is a global clearance toolbox currently in use. As such, the Table 3 does provide a fairly comprehensive picture of the global clearance toolbox and mine action tasks currently employed.

³⁰ Personal protective equipment (PPE) is body armor and shielding to be worn by the deminer. Items such as visors, armor panels, helmets and boots are all classified as PPE. Of primary concern is the issue of flexibility and mobility for the deminer. PPE should provide protection but allow free movement.

<i>Generic Area</i>	Category 'A' Equipment systems and sub-systems that have been fully developed and can be procured off-the-shelf without significant modifications or changes.	Category 'B' Technologies that have been prove in concept demonstrator programmes, but require further development prior to production.	Category 'C' Technologies that may have an application to mine action, but have yet to mature and have not yet been formally demonstrated.
1. Mine Detection (close in)	Mine prodders Metal detectors Hand tools Video camera	Vibrating prodders GPR (Ground penetrating radar) Minimum-metal detectors FLIR (Forward looking infrared) Sensor-processing software Multi-sensor system	NQR (nuclear quadrupole resonance)
2. Mine neutralization	Plastic explosive Shaped charges Chemical foam Thermitic attack Signature duplicators Explosively Formed Projectile (EFP) Ballistic disk attack	Metal projectile disruption Liquid projectile disruption Laser initiated burning Freezing Techniques Local Mechanical aggression Seismic vibration	Non nuclear EMP Electric arc High power micro-waves Biological degradation Chemical degradation Charged particle beam Ultrasonics Sonic shock waves
3. Mechanical ground 'processing' systems	Deep-cutting heavy flails Light flail systems Rollers Ploughs Harrows Excavators with various buckets	Horizontal flails Ground sifters Ground milling systems Modified turf cutters Modified Peat harvesters Open-cast mining technology	Robotic farming technology Robotic open cast mining technology
4. Vegetation clearance	Defoliant spray Hand tools Mini flails MPV mounted mowers Heavy duty line trimmer excavator (with flail)	Automated defoliant sprayer	
5. Mined area marking systems	Global Positioning Geometric information systems Locally available materials pickets	Soil paints Soil pigments "irremovable" pickets/poles	Intruder warning systems and alarms
6. Minefield survey		GIS IMS MAs (Information Management System for Mine Action)	Air- and space-borne system for identification of mine fields and provision of precise boundaries

Table 3: Mine Action tasks and respective equipment used – Part of the Global Clearance Toolbox

Source: Mine Action Equipment: A Study of Global Operational Needs (2002)

Section III-9: The Gap Between Scientific and Operational Humanitarian Mine Action Communities

An R&D organization seeking to identify and address technology gaps in the clearance toolbox faces an enormous challenge. If any innovation in mine action technology is to occur, the disconnect between HMA operational and scientific communities must be aligned. Frequently commented upon, the gap between scientific and operational HMA communities is blamed for the lack of improvements in HMA technology.

At the core of the gap is the concept that information equals power (Lokey, 2000). NGOs are not required to share the results of field T&E. Similarly, R&D organizations do not share information gained from T&E trials because they do not want a competitor to capitalize on their own investment in T&E and R&D. In fact, free-flowing information sharing regarding functionality or performance of technology rarely occurs between the different R&D, NGO and commercial or military organizations involved in mine action. "It appears that there is a great amount of potentially useful information being generated, but it is treated as proprietary and not open for dissemination" (Carruthers and Littmann, 2001:15).

Other constraints and considerations hamper information sharing. A respondent recently attempted to host a meeting between field based technical staff and commercial R&D organizations with the purpose of identifying technology gaps and encouraging collaboration. He reported observing the commercial staff wishing to only listen because they feared revealing a commercial R&D secret. The NGOs and national staff were also quiet. The respondent believed it was because new technology that increases productivity is seen as a threat to the future of demining. With the approaching 2010 deadline and the future of demining undetermined, this appears to be a valid concern.

Given the lack of information sharing and resistance to collaboration, it is difficult to identify specific technology gaps in HMA operations. A respondent involved in the scientific community reported frustration because a cohesive picture of end user needs and technology gaps has not emerged. GICHD's study of Global Operational Needs (2002) provided an excellent reference point in identifying potential capability areas³¹ needing improvement. But specific design features needed or operational constraints are not provided. In conducting our research study, respondents were asked to describe their operational scenario, identify end-user needs or identify capability areas needing improvement. One respondent reported a desire for better area reduction strategies; another wanted to distinguish between metal and explosive material. Respondents were extremely qualified to provide perspectives in relation to their operational areas, and therefore requested certain features that had potential to provide added value to their operations. But value added for one unique mine action operation does not necessarily translate into value added for another mine action operation. Further, from a scientific perspective, a respondent reported that a cohesive picture of the many permutations of the physical surroundings of mine action operations has not emerged. These realities make it very difficult to develop technology for a specific mine action operation or mine action operations in general.

Another factor contributing to the gap is logistical. One respondent provided a concise summary of the issue.

"...[V]ery few scientists and engineers have the time, resources and aptitude to gain the day to day experience of a demining Technical Field Manager (TFM), and even less TFM's have the time, resources and ability to get to grips with the complex and abstract concepts involved in creating demining equipment." - Anonymous Respondent

³¹ The study defines capability areas as the "[t]asks, activities and procedures that form part of mine action." (2002:87).

Mine-affected countries are generally located in the developing world or less economically developed countries (LEDCs). As mine-affected countries are emerging from conflicts, they generally do not have the infrastructure to support R&D activities. Therefore, R&D innovations are developed far away from the location of their intended implementation, generally in westernized or developed countries. The result is experts who may be able to provide implementation or operational feedback are not easily accessible to R&D scientists.

An unavoidable issue is the presence of certain stakeholders that dominate the international demining market. For example, the US government considers military R&D an essential aspect of the military budget. The US military R&D department designs equipment for offensive and defensive purposes with a large operational budget at its disposal. In contrast, the HMA community and its purchasing power is defined by donors. As cost is an issue, the HMA community does not have sufficient purchasing power to control a portion of the international demining market and therefore cannot demand designs for their purposes. The indirect result is the scientific R&D community can meet the needs of military or commercial demining as it is economically beneficial, but is unable to design for HMA needs. In fact, very few R&D organizations specifically design and market for HMA. This reality contributes to the gap between the scientific and operational HMA communities.

As dire as the situation seems, there have been significant improvements to close the gap in the last five years, and these should not be overlooked. Organizations such as the ITEP have attempted to provide a neutral, information-sharing arena. The scientific community³² acknowledges that technology must be designed for multiple and differing physical terrains instead of assuming one piece of equipment will increase productivity for all mine action operations. Also acknowledged is that mine action equipment designed for the military is not necessarily beneficial or cost-effective for HMA.

³² Caution as there were very few respondents from the scientific community.

Part IV – Technical Factors Affecting Close-in Detection and Other Mine Clearance Technology

The technical factors highlighted in the following sections were identified as affecting the operation of close-in detection and other mine clearance technology. The technical factors discussed in this report include: the physical scenario, the climate, the soil composition, the vegetation composition and the anticipated threats expected. The pilot study was constructed to delve into the specifics of how technical and operational factors impact the functionality and performance of close-in detection technologies used by respondents. Contrary to the original intent of the questions, it soon became apparent that respondents tended to report the impact of each factor on their entire clearance toolbox; only occasionally specifying when close-in detection technologies were impacted. Therefore, the report was forced to consider the impact on all mine clearance technology in the clearance toolbox with a special focus on close-in detection technologies. The terminology used throughout Part IV reflects this decision and often refers to the impact on mine action technologies in general, discussing close-in detection technologies when appropriate.

Table 4 below identifies close-in detection technologies and additional technologies used by each respondent.

Country	Close-in detection technology in use	Other Equipment and Generic processes used	Other Equipment and processes in Clearance Toolbox
Afghanistan - Respondent 1	CEIA ML-D1	Schonsted Bomb locator FEREX 4.032	
Afghanistan – Respondent 2	CEIAML-D1, Ebinger EBEX420 GC, EBEX-420 H, Schiebel AN-19/2, and mine detection dogs	Backhoes, Rotary cutter,	
Balkans region	CEIA ML-D1	Manual prodding	
Cambodia	MineLab	armored vegetation cutters, MDDs are used in area reduction role, normally in areas where bush and high vegetation have been cut by the machines beforehand. Manual deminers with detectors are primarily deployed in the suspected high-risk part of the suspected mine area. Also use mechanical clearance machines.	
Cyprus	Minelab F3	Manual tool kit, prodder, trowel, Large loop ebinger	
Iraq, Kurdistan Region	Minelab, Schiebel and dogs	Technical survey teams gather information and reading terrain, visual search, flails,	Burning vegetation, locally made flails, vegetation removal, ground preparation, softening soil by watering hoses, manual deminers conducting technical survey in support of flails and mine detection dogs, saws, pruning shears, magnets to remove iron fragments from surface to deduce disturbance, bayonets, tripwire feelers
Jordan	MineLab F1A4, Vallon, CEIA ML-D1	Rake method is used in Jordan, mine lines are known so unless there is a lot of erosion, mines are simply excavated	Machines: aardvark, mine cat, minewolf
Sri Lanka	Minelab F3	Rakes, brush rake	Handtools, blast resistant and gardening tools, mine flail for area preparation, machine and running costs gifted by Japanese govt so purchase cost uncertain.
Tajikistan	Ebinger 421 GC		
Vietnam	Ebinger 420 PBD		

Table 4: Close-in detection technologies and other technologies as reported by Respondents

Section IV-1: Defining the Physical Scenario

The most challenging aspect undertaken by this study was attempting to categorize and identify the environmental conditions and terrain present at each unique mine clearance operation. It is commonly understood in the mine action community that the local physical environment and terrain, herein defined as the physical scenario, has the greatest impact on mine clearance operations and functionality of technology. In order for R&D organizations to evaluate and understand the impact of the physical scenario on the functionality of technology, it becomes essential to categorize the local environment for comparison purposes. However, mine clearance operations occur worldwide and each location has a unique physical scenario. It is precisely this categorization of global physical environments into distinct and comparable physical scenarios that proved to be a daunting task.

As a preliminary attempt, this research study took as its point of reference GICHD's *Mine Action Equipment: Study of Global Operational Needs*. The GICHD study classifies the global environmental characteristics into 12 distinct categories: Mountain, Hillside, Grassland, Woodland, Urban, Village, Routes, Infrastructure, Desert, Paddy Field, Semi-Arid Savannah and Bush. In order to compare functionality of technology vis a vis the physical scenario and for continuity purposes, respondents were first asked to identify their operation's physical scenario according to the GICHD's 12 categories for demining scenarios. Further, respondents were asked to identify the level present of each physical scenario also using the terminology of the GICHD study. As such, respondents had to identify each of the 12 physical scenarios on a scale of: Dominant Scenario Found, Scenario Frequently Found, Scenario Occasionally found and Scenario not found. Table 5 below records their responses.

Country	Dominant scenario found	Scenario frequently found	Scenario occasionally found	Scenario not found	Physical Scenario as defined by GICHD	Additional description of Physical Terrain by Respondent
Afghanistan – Respondent 1	Village	Mountain, Hillside, Urban, Routes, Infrastructure, Desert	Grassland, Paddy field, Semi-arid Savannah, Bush	Woodland	Not Applicable.	Afghanistan has a number of different climates. The hard and rocky mountains and hillsides dominate the centre of the country. The South and West are dry and desert-like and includes some grassland. The East is less dry and more fertile for agricultural use. The north of the country is hilly and desert-like. The average temperatures vary from province to province quite significantly.
Afghanistan – Respondent 2		Mountain, Hillside, Village, Routes, Infrastructure, Desert	Grassland, Woodland, Urban, Bush	Paddy field, Semi-arid Savannah	Not Applicable.	To clear the country from mines, need to apply the whole clearance toolbox: manual, dogs, machines. Minimum metal mines in Afghanistan is a major issue. The available detector is only able to detect if buried less than 13 cm. If the mine is deeper, then it can not be located. In order to find the mines, the detector has to be set to a very high sensitivity which results in receiving a higher level of false alarms.
Balkans region			Hillside, Grassland, Woodland, Urban, Routes, Infrastructure, Bush	Mountain, Urban, Village, Desert, Paddy field, Semi-arid Savannah	South Eastern Europe, Dominant: Hillside, Grasslands, Village	The presence of scattered metal pieces of various sizes causes a great deal of problems.
Cambodia	Paddy field, Bush	Grassland, Woodland, Village, Routes	Mountain, Hillside, Infrastructure	Urban, Desert, Semi-arid Savannah	South East Asia, Dominant: Grassland, Woodland, Paddy Field, Bush	The amount of heavy vegetation is a challenge to most demining methods. Some concept of pre-cutting by either manual deminers or machines is a massive time-saving element.
Cyprus		Grassland, Urban,	Mountain, Hillside, Woodland, Village, Routes, Infrastructure	Desert, Paddy field, Semi-arid Savannah, Bush	Middle East, Dominant: Desert	No.
Iraq, Kurdistan Region		Mountain, Hillside, Grassland, Paddy field	Woodland, Urban, Village, Routes, Infrastructure, Desert, Semi-arid Savannah, Bush		Middle East, Dominant: Desert	The areas which respondent answered on concerns three governorates in the North of Iraq. The terrain close to the border is mountainous with neighboring countries that have fertile valleys. In the southern parts, the terrain is more flat, semi-desert type of land with grass growth period 1-2 months/year. The rest of the year it is dry. Most of the border minefields are also battle fields with high metal contamination as well as UXO contamination. The vegetation is not a major obstacle but some grass or bush with thorns causes problems for the dogs.
Jordan	Desert	Mountain, Hillside, Semi-arid Savannah	Grassland	Woodland, Urban, Village, Routes, Infrastructure, Paddy field, Bush	Middle East, Dominant: Desert	It is semi-arid most of the year but prone to flash floods and levels of erosion in certain areas.
Sri Lanka		Grassland, Woodland, Village, Paddy field, Bush		Mountain, Hillside, Urban, Routes, Infrastructure, Desert, Semi-arid Savannah	Not Applicable.	Not unique, but unusual. The mines are largely decayed and most are non-functional. Mines are laid in disciplined and predictable manner, often with a detectable centre line (stakes and sometimes a length of wire). The minefields often accompanied by a defensive boundary, making their position highly predictable. No functional tripwire mines are found. Anti-tank mines are rare, and their position usually predictable. In other parts of Sri Lanka, none of the above is true.
Tajikistan	Mountain, Hillside,		Grassland, Village, Routes, Infrastructure,	Woodland, Urban, Desert, Paddy field, Semi-arid Savannah, Bush	Not Applicable.	Frequent landslides partially cover minefields. Minefields often located at bottom of ravines or cliffs, making access difficult.
Vietnam	Village, Bush	Urban, Paddy field	Mountain, Hillside, Grassland, Woodland,	Routes, Infrastructure, Desert, Semi-arid Savannah	South East Asia, Dominant: Grassland, Woodland, Paddy Field, Bush	Vietnam is largely a UXO/Cluster Bomb problem as opposed to landmines; so searches have better mobility but must go deeper.

Table 5: Defining the level and type of physical scenario as reported by Respondents

It was anticipated that many physical scenarios would be identified as our 10 respondents operated in nine different countries. However, the physical scenarios for each country as identified by our respondents did not strongly correlate with the physical scenarios indicated by the GICHD study as present in each geographical region. For example, the GICHD study identified the Dominant Scenario found in the Middle East as the Desert. However, the respondent from Iraq's Kurdistan region did not report Desert as the Dominant Scenario Found; nor was Desert a Scenario Frequently Found. In fact, out of 10 respondents, only the four respondents from the Balkans region, Cambodia, Jordan and Vietnam agreed or partially agreed with the physical scenarios identified as present by the GICHD study. Data collected reveals the difficulties in identifying the physical scenario where mine clearance operations occur.

Furthermore, two respondents from the same country did not even report the same physical scenario. Afghanistan Respondent 1 reported Woodland as a Scenario Not Found and Afghanistan Respondent 2 reported Paddy Field and Semi-Arid Savannah as Scenarios Not Found. As respondents were with different mine clearance organizations, there is a strong likelihood they were working in different regions. However, discrepancy between answers reveals how the physical scenario can vary within one country.

The data collected reveals the difficulty in attempting to identify and classify the physical scenarios where mine clearance operations occur. Respondents were also asked to identify alternative physical scenarios to the 12 GICHD's categories identified. Out of 10 respondents, no respondent provided an alternative physical scenario, tentatively suggesting that the 12 GICHD physical scenarios adequately describe the environment of each mine clearance operation. However, there is not any current database known to the author that correlates physical scenarios present with specific countries; thus potentially identifying physical scenarios in addition to the 12 utilized within this study. R&D organizations need a cohesive picture of physical scenarios where mine action occurs in order to properly design, develop and implement new technology that has the potential to add value to the HMA community.

Section IV-2: Understanding the Impact of the Physical Scenario

Once the physical scenario and level present was determined by the respondent, he was asked to report on its impact on the functionality of technology. Unfortunately, not all respondents provided answers. However, data collected reveals commonalities of impact for each physical scenario, regardless of country of operation. The respondent was asked to specifically evaluate the impact of the physical scenario in relation to close-in detection technology. However, responses generally took the form of responding on the impact for the entire clearance toolbox, only highlighting if and when close-in detection technologies were impacted in particular.

Country	Close-in detection technology	Mountain	Hillside	Grassland	Woodland	Urban	Village	Routes	Infra-structure	Desert	Paddy field	Semi-arid Savannah	Bush
Afghanistan - Respondent 1	CBA MIL-D1	Practical use according to standard procedures difficult, hence slows down overall performance	Practical use according to standard procedures difficult, hence slows down overall performance	No affect	No affect	High metal content, thus slows down overall performance	High metal content, thus slows down overall performance	Minor affect in sensitivity	Minor affect in sensitivity, occasionally high metal content, thus slows down overall performance	No affect	No affect	No affect	No affect
Afghanistan - Respondent 2	CBA MIL-D1, Ebinger EBEX 420 GC, EBEX-420 H, Schiebel AN-19/2, and dogs	Machine and dogs can not operate.		Dogs can not operate in dense vegetation		Dogs can not work inside the buildings			Metal detectors are not effective due to the presence of minimum metal mines				Affecting both dogs and manual techniques.
Balkans region	CBA MIL-D1	No response.	No response.	No response.	No response.	No response.	No response.	No response.	No response.	No response.	No response.	No response.	No response.
Cam bodia	MineLab	Challenging, but possible. Detectors do not have major problems working in mountain, except where there has been heavy fighting and metal clutter disturbs the detector.	Very often in conjunction with military positions, and therefore also a high density of metal clutter. Here dogs often prove much more efficient than metal detectors and machines	Easy with most tools, provided that the grass is not too high. If so, cutting is required during demining	Challenging to access with machines. Detectors OK, but normally only after mechanical or manual vegetation cutting.		Relatively easy, but challenging for detectors as there is very often a lot of disturbing metal clutter that causes frequent false alarms	If hard surface and much metal clutter (close to civilization) dogs are more efficient than metal detectors	Not so common in Cambodia.		Mines may be very deep. Low metal mines are seldom identified deeper than 10 cm by metal detectors in laterite soil. Here dogs are very efficient		Very challenging. Requires mechanical vegetation cutting beforehand. Flail machines are even more efficient, but CMA C do not have this in Cambodia
Cyprus	MineLab F3	None	None	None	None	None	None	None	None				
Iraq, Kurdistan Region	MineLab, Schiebel and dogs	Limits the choice of methods. Weather disturbs dog operations.	Depends on the incline, but could limit the choice of tools.	If the grass covered land does not contain any thorns and it is possible to burn there are no major effects on the operation. If there is thorny grass/plants, dogs might not be able to operate.	Depends on the distance between trees and size. In general, as Iraq is a country with very limited areas with trees, demining operations try to leave the trees if possible. Normally only dogs and manual.	The proximity to people and possible sensitive installations will have an effect on the demolitions which can mean that protective work might be necessary which leads to more efforts are needed.	The proximity to people and possible sensitive installations will have an effect on the demolitions which can mean that protective work might be necessary which leads to more efforts are needed.	Likely to have metal contamination from garbage which will increase the effort to detect mines.	Likely to have metal contamination from garbage which will increase the effort to detect mines.	Might have very hard soil during dry season and limited access to water. Higher cost to transport water.	Normally, if it is dry no major obstacles.	Might have very hard soil during dry season and limited access to water. Higher cost to transport water.	Depends on the distance between trees and size. In general as Iraq is a country with very limited areas with trees demining operations try to leave the trees if possible. Normally only dogs and manual
Jordan	MineLab F1A4, Vallon, CEA MIL-D1	Soil movement, accompanied by flash floods in rainy season	Erosion							Shifting sands make detection difficult			
Sri Lanka	MineLab F3			None (after veg cutting)	None (after veg cutting)		Lot of metal scrap sometimes means we excavate topsoil by hand				Waterlogged ground can mean areas are left until dry		None (after veg cutting)
Tajikistan	Ebinger 421 GC	Limited accessibility due to Relief	Limited accessibility due to broken ground	Vegetation needs to be cleared			Rural metal contamination, slows work	Metal debris contamination from vehicles.					
Vietnam	PBD	Mobility	Minimal	Minimal	Mobility	Moderate Scrap	High Scrap				Mobility		Mobility

Table 6: Impact of physical scenario on functionality of technology, as reported by Respondents

The following identify the specific impact of the physical scenario on functionality of the clearance toolbox:

- Mountain: The physical scenario limits mobility. The impact is to slow down operations and overall performance. The degree to which this happens varies; Afghanistan reported operations cannot be conducted effectively in their mountains. In contrast, the Cambodia respondent reported Mountains slow down operations, but it is still possible to conduct mine clearance operations. Erosion and soil shifting occurs due to the incline.
- Hillside: Impact depends upon the degree of incline, however similar to mountains, erosion and soil shifting occurs due to incline. Often hillsides have a higher degree of battle debris as hills are used in military strategy as look-out points, etc. Incline affects the choice of tools available for the clearance toolbox.
- Grassland: Where this physical scenario was present, all respondents reported vegetation must be cleared prior to close-in detection being carried out, as there are no alternatives. MDDs do not operate well in dense vegetation.
- Woodland: Trees are reported as being cleared if they obstruct manual demining. Trees are allowed to remain if distance between trees allows manual demining to occur.
- Urban, Village, Routes, Infrastructure: In each physical scenario, there is present a high metal content that is not necessarily a result of battle debris. The metal scrap present is most likely because of the local population. The impact is a high incidence of false alarms as a result of metal debris. The high metal content has a minor impact on the sensitivity of metal detectors, and therefore MDDs are used. In fact, MDDs are generally more efficient in situations with a high metal debris to anticipated threat ratio.³³
- Desert: If Desert is the physical scenario, it has no noticeable impact on functionality of close-in detection. The primary impact noted was if the soil is very hard, excavation was difficult to conduct once a threat was detected.
- Paddy Field: This physical scenario has a very high impact on close-in detection and other technologies in the clearance toolbox, as most paddy fields are left until dried out. The Paddy Field limits mobility and mines may be located very deep.
- Semi-Arid Savannah: Insufficient data was collected to provide a conclusive analysis.
- Bush: Similar to the Grassland and Woodland scenarios, generally vegetation is cleared, either through cutting or flail machines (if terrain is flat enough for their operation), prior to close-in detection and the use of other technology in the clearance toolbox. However, in Iraq, because vegetation is limited, mine clearance operations try to leave it, if possible. However, vegetation can only be left in place if there is enough distance between vegetation to carry out manual demining.

Unfortunately, the pilot study had to rely on the willingness of respondents to provide comprehensive answers for evaluation. As not all respondents answered comprehensively and a large sample size was not obtained, definitive conclusions regarding the impact of the physical scenario on the functionality of technology was not established. Insufficient data collected can be

³³ MDDs are reported as unusable inside buildings. However, data comes from respondent in the predominately Islamic country of Afghanistan. It may be that dogs are effective inside buildings, but are not allowed inside because of cultural reasons.

attributed to a lack of time for respondents to devote to surveys and to a lack of field research conducted. However, the pilot study did reveal that a possibility to evaluate each physical scenario's impact on functionality exists if a large enough sample size was obtained.

Collecting data on the basis of the physical scenario presents a departure from standard data collection that is categorized based upon country of operation. For instance, E-Mine data and the Landmine Monitor present very comprehensive data sets; but extensive data is collected on a country by country basis. This provides unusable datasets for R&D organizations to use to determine a complete, concise and detailed picture of the scope of HMA operations. This conclusion has strong ramifications for an R&D organization attempting to identify technology gaps and areas for improvement. Due to the variety of global regions and corresponding physical scenarios, the ability of an R&D organization to develop new technology on the basis of country data is very limited. However, if the data collection process was altered to reflect the physical scenario of each mine clearance operation, R&D organizations might be able to design and implement technology adaptable to each physical scenario and therefore would have an increased ability to develop new technology which could add value to the HMA community.

Section IV-3: The Climate³⁴

In general, mine action operations do not occur in extremes of hot or cold temperatures. The reasons are twofold. Because of the dangerous nature of mine action, it is essential that operators and dogs function at their peak level of performance. Humans and dogs are not able to function well in extreme temperatures. Therefore, operators and dogs generally take mid-day

"When the detection equipment is well maintained and regularly serviced, a common observation can be stated: the ability of people carrying out the clearance work fails prior to the equipment. This applies to the Afghan climate, which varies a lot but as an average is very hot and dry, occasionally windy for 6 months a year and cold and snowy for 2 months a year."

- *Anonymous respondent*

breaks or stop working when the temperature is either too hot in summer or too cold in winter. The factor of temperature is not limited to close-in detection equipment, as machines such as flails also do not operate effectively in extreme temperature conditions. Therefore, it can be concluded that R&D organizations developing technology for humanitarian purposes do not need to develop equipment that functions in extreme temperatures. However, mine action technologies do need to be robust in order to withstand non-operational extreme temperatures, and later perform with a high degree of functionality.

Nor do mine action operations occur when there is any level of precipitation. Similar to extreme temperatures, deminers and MDDs are uncomfortable and lose their concentration in the rain, thus compromising operator safety. However, in certain physical environments where the soil is very hard, rain can be beneficial to operations. One respondent reported rain as beneficial because it softens the hardened ground, therefore facilitating manual demining. However rain can also be a hazard as significant precipitation can increase groundwater, creating unsafe conditions in which to conduct mine action operations.

Temperature and precipitation also have an impact on the texture and composition of the ground. In turn, the texture and composition of the ground will affect the close-in detection signal.

³⁴ For the purposes of this study, climate is loosely defined to include the temperature, the seasonal weather and level of precipitation.

For instance, one respondent reported a less than 11°C soil temperature makes using MDDs impossible. Another respondent reported dogs could not operate below 8°C or above 35°C degrees. In summary, temperature changes the properties of the soil and ground (Guelle et al., 2006:91). While the exact temperature range for MDDs is beyond the scope of this study, it is clear that soil composition and texture, as well as climatic conditions, impact the functionality and performance of technology. For instance, freezing temperatures makes the soil too hard for any mine action operations, as prodding becomes too difficult and dangerous. The result is operations are suspended until weather and temperature conditions improve.

Climate also impacts the length of the work day. For instance, some respondents reported operations commencing at dawn and concluding in the middle of the day. The average climate in the Balkans limits the work day to five hours. Obviously, a shorter work day will impact the clearance rate of operations and the overall length of time necessary to declare the area mine-free.

Finally, strong winds also intervene and impact the functionality of close-in detection technology. MDDs are unable to operate in strong winds as they become confused as to the exact location of the explosive. Furthermore, deminers are unable to safely hear the audio signals from close-in detection technologies such as metal detectors.

In conclusion, as operators and MDDs generally cannot conduct mine clearance operations under extreme climatic conditions, R&D organizations should not specifically focus on designing HMA technologies that can be operated during extreme weather, temperature or precipitation conditions. It is necessary to make technology robust to withstand climatic variations when not in use and to continue to function when extreme climate variations abate.

Section IV-4: The Soil

In a further attempt to define the environmental characteristics that impact functionality and performance of close-in technologies, (as well as other mine clearance technologies), the respondents were asked to comment on the type, level and impact of the soil present in their physical surroundings.

It would be expected that soil type and level reported would have a direct correlation to the physical scenario previously reported. In eight out of nine responses where the Mountain physical scenario was identified, the corresponding soil type Rocky was also identified. The Balkans provided the one exception, in which a respondent identified Rocky soil without the presence of the physical scenario of Mountain. Strong correlations also occurred between the physical scenario of Desert and the presence of the soil type Dry and Dusty. However, the remaining soil categories did not strongly correlate to the physical scenario reported.

This result is not particularly surprising given the variety and levels of different soil categories present throughout the world. Although eight categories were identified prior to implementing the study, it was soon discovered that a plethora of soil categories are present in mine clearance operations. The Cambodian respondent reported the presence of 27 different soil types. Throughout the course of the pilot study, four additional categories were identified: Red-laterite, Yellow-laterite, Loam and Sand/Loam/Clay mix.

Unfortunately for an R&D organization, not only does the physical scenario strongly impact the functionality of close-in detection and other technologies, each soil type has its own unique impact on functionality. Each tool, piece of equipment and technology must be individually calibrated and has different pre-sets prior to operation, all of which are determined by soil conditions. Furthermore, soil composition may have a strong or weak impact on close-in detection, but soil texture will always interfere with removing the identified threat. Respondents were asked to identify soil type and level present in their physical surroundings. Similar to responses in *Section 2: Understanding the impact of the physical scenario on functionality of technology*, the respondents generally described the impact on technologies in reference to the clearance toolbox. The respondents then highlighted any impact on close-in detection technologies when appropriate. Once soil type and level were established, respondents were asked to evaluate impact.

Country	Close-in detection technology in use	High level of Soil category	Medium level of Soil category	Low level of Soil category	Soil category not present
Afghanistan – Respondent 1	CEIA MIL-D1	Rocky, Dry and hard, Dry and dusty	Sandy, Electromagnetic, Clay,	Muddy/Wet	Saline
Afghanistan – Respondent 2	CEIA MIL-D1, Ebinger EBEX 420 GC, EBEX-420 H, Schiebel AN-19/2, and dogs	Clay, Dry and hard, Dry and dusty	Rocky	Sandy, Electromagnetic, Muddy/Wet	Saline
Balkans region	CEIA MIL-D1	Muddy/Wet	Electromagnetic, Rocky	Clay, Dry and hard, Dry and dusty	Saline, Sandy
Cambodia	MineLab	Electromagnetic, Muddy/Wet, Clay	Dry and hard, Dry and dusty	Saline, Sandy, Rocky	
Cyprus	Minelab F3	Rocky, Dry and hard, Dry and dusty	Clay	Saline, Sandy, Electromagnetic, Muddy/Wet	
Iraq, Kurdistan Region	Minelab, Schiebel and dogs	Dry and hard, Dry and dusty	Electromagnetic, Clay, Rocky	Saline, Sandy, Muddy/Wet	
Jordan	MineLab F1A4, Vallon, CEIA MIL-D1	Saline, Sandy, Dry and hard, Dry and dusty	Electromagnetic, Muddy/Wet	Clay	
Sri Lanka	Minelab F3	Dry and hard	Saline, Electromagnetic, Muddy/Wet	Sandy, Clay, Dry and dusty	Rocky
Tajikistan	Ebinger 421 GC	Rocky, Dry and hard	Sandy, Muddy/Wet, Clay	Electromagnetic	Saline
Vietnam	Ebinger 420 PBD	Electromagnetic, Muddy/Wet, Dry and hard	Sandy, Rocky	Saline, Clay, Dry and dusty	

Table 7: Level and type of soil present in mine action operation as reported by Respondent

Country	Close-in detection technology in use	Saline	Sandy	Electromagnetic	Muddy/Wet	Clay	Rocky	Dry and hard	Dry and dusty
Afghanistan - Respondent 1	CEIA MIL-D1	Not present.	No affect	High density of signals with low sensitivity settings, thus requiring a lot of unnecessary excavation of land and hence slowing down the overall performance	Changing sensitivity regardless of set sensitivity setting gives mixed signals and hence slows down the overall performance	Occasionally electromagnetic. Changing sensitivity regardless of set sensitivity setting gives mixed signals and hence slows down the overall performance	Difficulties with correct application of sweeping the metal detector search head and upon signal and hence slowing down the excavation progress	No affect other than to excavation progress	No affect
Afghanistan – Respondent 2	CEIA MIL-D1, Ebinger EBEX 420 GC, EBEX-420 H, Schiebel AN-19/2, and dogs	Not present.	Sometimes the mines are buried deep and can cause a device to be missed.	It makes difficult to do ground compensation by ML-D1 metal detectors	It affects the dogs ability	Makes the prodding function dangerous	It affects the dogs ability to operate	Difficult to do prodding	It affects the flails machines
Balkans region	CEIA MIL-D1	Not present.	Not present	Respondent did not answer.	Respondent did not answer.	Respondent did not answer.	Respondent did not answer.	Respondent did not answer.	Respondent did not answer.
Cambodia	MineLab	Respondent did not answer	Not a big problem	Detectors may have problems in discriminating between soil and low-metal mines, such as the Chinese T72A	Not a major problem except from potential access problems with machines and vehicles	Not a major problem except from potential access problems with machines and vehicles	Detectors may have problems if the ground is very uneven.	OK, but prodding and excavation is challenging. Soil then needs to be softened by the use of water	OK. Prodding and excavation may require watering of the soil to soften it
Cyprus	Minelab F3	None	Dust	None	Water ingress	None	None	None	Dust
Iraq, Kurdistan Region	Minelab, Schiebel and dogs	Saline does not affect the operations	No major impact on the operations	Only MineLab can be used as Schiebel gets disturbed	Mechanical prep/clearance limited.	During the dry season the clay gets hard as concrete. Some of the flails do not soften the ground making soaking the soil necessary.	Mechanical processing limited	Normally soaking soil will address the problem.	Mechanical operations affected as filters might need to be cleaned/changed more often and the dust penetrates in the mechanical structure which will require more maintenance or higher spare part consumption
Jordan	MineLab F 1A4, Vallon, CEIA MIL-D1	No scientific data, however accuracy of readings drops	Reduction in accuracy	Reduction in accuracy	Reduction in accuracy	Reduction in accuracy	Reduction in accuracy	Reduction in accuracy	Reduction in accuracy
Sri Lanka	Minelab F3	None, detectors cope	None (easy excavation of signals)	None, detectors cope	Cannot work safely: wait until dry	None (hard excavation of signals)	Not present	None (hard excavation of signals)	None (water sometimes used to damp dust)
Tajikistan	Ebinger 421 GC	Not present	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer	Sometimes mineralized - have to turn down sensitivity	Respondent did not answer	Respondent did not answer
Vietnam	Ebinger 420 PBD	Moderate background readings	None	High background readings	Mobility	Moderate background readings	Difficult excavation	Difficult excavation	None

Table 8: Impact of soil type present on technology as reported by Respondents

Summary of impact of level and soil types on close-in detection and mine clearance technologies:

- Saline: Data collected not conclusive because insufficient respondents reported saline present.
- Sandy: Anticipated threats could be buried deep because sandy soil is very supple and compromising. Beyond a potential reduction in accuracy, detection and excavation of threat can occur without significant difficulties.
- Electromagnetic: Causes high background readings for metal detectors. For instance, a Minelab in Cambodia cannot distinguish between the soil and minimum metal mines such as the Chinese T72A.
- Muddy/Wet: Causes difficulties for MDD, MD, mechanical preparation or clearance. It is primarily the water content that impacts technologies, therefore areas are generally left to dry prior to mine action.
- Clay: According to respondents, the primary impact is in terms of excavation and mobility. There may be some reduction in accuracy.
- Rocky: Decreased mobility of operator with close-in detection; mechanical processing and excavation difficult due to uneven and hard nature of soil.
- Dry and hard: Respondents generally reported problems with excavation, but not necessarily in terms of close-in detection.
- Dry and dusty: Respondents generally reported problems with excavation. Also potential for dust to penetrate technology thus interfering with functionality and performance level.

Section IV-5: The Vegetation

Another physical characteristic that impacts functionality and performance of mine action technologies is the presence of vegetation. Respondents were asked to report the type, level and impact of different categories of vegetation. In contrast to other operational factors, three general conclusions can be reached regarding the type and level of vegetation and its impact on technology:

- Generally, the type and level of vegetation depends upon the physical scenario and climate. In hot and dry areas such as deserts, vegetation was reported as sparse. In hot and humid physical scenarios, vegetation was reported as dense.
- Impact on functionality, ease of detection and performance of technology relates to the question of vegetation clearance. If vegetation can be and is cleared, it has no impact beyond slowing down operations so clearing can occur. In physical scenarios where vegetation is sparse, mine action operations try not to clear vegetation except when it is particularly dense.
- In operations where MDDs are part of the clearance toolbox, vegetation must be cleared. If vegetation is not cleared, dogs are unable to operate effectively and operations must resort to manual demining.

Country	Close-in detection technology in use	High level of Vegetation category	Medium level of Vegetation category	Low level of vegetation category	Vegetation category not present
Afghanistan – Respondent 1	CEIA MIL-D1	Barren with little or no undergrowth		Grasses with scattered Bush/Trees; Light Forest; Light Bush	Dense, jungle-type undergrowth, less than 2 m tall; Heavy Forest; Dense, jungle-type undergrowth, greater than 2 m tall
Afghanistan – Respondent 2	CEIA MIL-D1, Ebinger EBEX 420 GC, EBEX-420 H, Schiebel AN-19/2, and dogs	Light Bush	Barren with little or no undergrowth	Grasses with scattered Bush/Trees; Dense, jungle-type undergrowth, less than 2 m tall; Heavy Forest; Light Forest;	Dense, jungle-type undergrowth, greater than 2 m tall
Balkans region	CEIA MIL-D1		Grasses with scattered Bush/Trees; Heavy Forest; Light Forest	Light Bush	Dense, jungle-type undergrowth, less than 2 m tall; Barren with little or no undergrowth; Dense, jungle-type undergrowth, greater than 2 m tall
Cambodia	MineLab	Grasses with scattered Bush/Trees; Light Bush	Dense, jungle-type undergrowth, less than 2 m tall; Light Forest; Dense, jungle-type undergrowth, greater than 2 m tall	Heavy Forest; Barren with little or no undergrowth	
Cyprus	Minelab F3	Grasses with scattered Bush/Trees; Light Forest; Light Bush; Barren with little or no undergrowth	Heavy Forest		Dense, jungle-type undergrowth, less than 2 m tall; Dense, jungle-type undergrowth, greater than 2 m tall
Iraq, Kurdistan Region	Minelab, Schiebel and dogs			Grasses with scattered Bush/Trees; Dense, jungle-type undergrowth, less than 2 m tall; Heavy Forest; Light Forest; Light Bush; Barren with little or no undergrowth	Dense, jungle-type undergrowth, greater than 2 m tall
Jordan	MineLab F1A4, Vallon, CEIA MIL-D1	Barren with little or no undergrowth	Light Bush	Grasses with scattered Bush/Trees; Light Forest	Dense, jungle-type undergrowth, less than 2 m tall; Heavy Forest; Dense, jungle-type undergrowth, greater than 2 m tall
Sri Lanka	Minelab F3	Dense, jungle-type undergrowth, greater than 2 m tall	Grasses with scattered Bush/Trees; Heavy Forest; Light Bush	Dense, jungle-type undergrowth, less than 2 m tall; Light Forest	Barren with little or no undergrowth
Tajikistan	Ebinger 421 GC	Barren with little or no undergrowth	Grasses with scattered Bush/Trees;	Light Bush;	Dense, jungle-type undergrowth, less than 2 m tall; Heavy Forest; Light Forest; Dense, jungle-type undergrowth, greater than 2 m tall;
Vietnam	Ebinger 420 PBD	Grasses with scattered Bush/Trees; Dense, jungle-type undergrowth, less than 2 m tall	Light Forest; Light Bush	Heavy Forest; Barren with little or no undergrowth; Dense, jungle-type undergrowth greater than 2 m tall	

Table 9: Level and type of vegetation as reported by Respondents

Country	Close-in detection technology in use	Grasses with scattered Bush/Trees	Dense, jungle-type undergrowth, less than 2 m tall	Heavy Forest	Light Forest	Light Bush	Barren with little or no undergrowth	Dense, jungle-type undergrowth, greater than 2 m tall
Afghanistan - Respondent 1	CEIA MIL-D1	Vegetation needs to be removed prior to detection. It slows down the overall performance. Upon excavation of an ERW, the root system occasionally poses a safety threat.	Not present	Not present	Some of the vegetation needs to be removed prior to detection. It slows down the overall performance. Upon excavation of an ERW, the root system occasionally poses a safety threat.	Some of the vegetation needs to be removed prior to detection. It slows down the overall performance.	No affect unless the soil is wet	Not present
Afghanistan – Respondent 2	CEIA MIL-D1, Ebinger EBEX 420 GC, EBEX-420 H, Schiebel AN-19/2, and dogs	None	Not present	Respondent did not answer	Respondent did not answer	Can affect the dogs search slightly	Respondent did not answer	
Balkans region	CEIA MIL-D1	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer
Cambodia	MineLab	Needs pre-cutting if possible	Pre-cutting required	Manual deminers or dogs are the only option. Manual cutting of grass and bush between the tree trunks	Cutting of bush/grass between tree trunks prior to deployment of manual deminers and/or dogs	Mechanical vegetation cutting prior to deployment of other methods	Respondent did not answer	Respondent did not answer
Cyprus	Minelab F3	None	Not present	None	None	None	None	Not present
Iraq, Kurdistan Region	Minelab, Schiebel and dogs	Limited possibility to use large mechanical tools. Grass needs to be removed if dogs are to be used. Manual demining possible.	The jungle type in the Northern parts of Iraq can be found close to water sources. Not very common but normally only manual demining possible and it is very time consuming	Dogs possible if ground vegetation can be removed by burning. Manual Deminers always. No machines because it is important to preserve the trees.	Dogs possible if ground vegetation can be removed by burning. Manual Deminers always.	Dogs possible if ground vegetation can be removed by burning. Manual Deminers as it is important to preserve the bush.	Normally good conditions for all tools	Not present
Jordan	MineLab F1A4, Vallon, CEIA MIL-D1	N/A	Not present	Not present	N/A	N/A	N/A	Not present
Sri Lanka	Minelab F3	Slows down the process in order to cut the vegetation. Generally use breaches to locate mine lines, then clear the lines to 5m either side leaving any significant growth	Slows down process, sometimes cut all trees using flail	Advantage of shade. Leave trees.	We leave trees, no adverse affects	Slows down process as vegetation needs to be cut	Not present	Slows down process as vegetation needs to be cut. Leave all trees over 10cm girth but cut branches, sometimes using flail
Tajikistan	Ebinger 421 GC	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer	Respondent did not answer
Vietnam	Ebinger 420 PBD	Mobility	Mobility	Minimal	Minimal	Minimal	Respondent did not answer	Respondent did not answer

Table 10: Impact of vegetation present as reported by Respondents

Section IV-6: Anticipated Threat: Landmines and other Explosive Remnants of War

Questions such as what type of conflict occurred (interstate vs. intrastate)? who were the participants? what weapons were used? how long was the conflict? are asked by TFMs, deminers and operational field staff to establish the anticipated threat type and level. In turn, the anticipated threat type and level will help determine the tools, processes, expertise and technologies needed in the clearance toolbox in order to declare an area mine free.

In terms of landmines and mine action operations, the following characteristics need to be taken into consideration:

- Age and type (AP vs. AT)
- Shape, size and orientation in soil
- Volume and mass
- Casing material (i.e. minimum metal mines are more difficult to detect)
- Anti-lift protection devices and detonation devices (primarily affects EOD)
- Type of explosive: TNT, RDX, RDX/TNT mix, tetryl, picric acid, plastic explosive, xemtex (Guelle et al., 2006:151)
- Laying pattern and method of laying
- Booby trap and tripwire threat

In addition, manufactured landmines are not the only threat. Improvised landmines can easily be constructed and used by non-state signatories. R&D organizations must devise technology that can cope with improvised landmines as well as known, manufactured landmines.

If the mine action operation is using metal detectors, the primary characteristic that directly impacts performance is the level and presence of metal. An R&D organization should be aware that when metal corrodes on either the landmine or ERW, it begins to behave as though it were a minimum metal mine. Further, rust does "not support eddy currents but do[es] generate secondary magnetic fields and can make a metal detector signal. This is important because iron oxide and other magnetic minerals occur naturally in some soils and rocks, and can affect metal detectors even when there is no man-made metal debris present" (Guelle et al., 2006:80).

"In some cases, clearance operations can be disrupted when demining teams lack suitably cross-trained, qualified personnel to remove or disarm UXO and ERW in conjunction with any mines encountered within the clearance area."

- Bob Kudyba, *Journal of Mine Action*, 2006

In addition to landmines, mine clearance operations also need to clear other ERW. In reality, "[a]ll clearance groups are supposed to clear at least 99.6% of all explosive ordnance from bullets, through anti-personal and ant-vehicle mines, to shells" (Smith, 1996). However, mine action in relation to ERW is significantly different than that for landmines. ERW can usually be detected visually, as they often lay on the surface. ERW can be buried deep if their delivery method was aerial. But, their high metal content makes ERW very easy to find. While clearing ERW is significantly easier than clearing landmines, R&D

organizations should realize that the threats to civilians do not only occur in the form of landmines. It has been theorized that the socio-economic impact from ERW is actually far greater than from landmines. The difference between ERW and landmines is in absolute numbers. Munitions fail to

explode at a rate of 10 percent and therefore can be present in post-conflict areas in numbers greater than landmines (King, 1998).

Section IV-7: Rating Impact of Obstacles and Technical Factors

Respondents were asked to rate the impact of the following obstacles on ease of detection, accuracy and functionality: slopes, trenches and ditches, wire defenses, fences, walls and watercourses. While all respondents agreed that identified obstacles did impact ease of detection, no obstacle was rated as having a higher or lower impact in comparison to another. In addition, respondents identified the following obstacles as also impacting ease of detection:

- Tripwires
- Root structures
- Power lines that affect electromagnetic field

One respondent did make a distinction on impact between metal detectors and MDDs. As reported, wire defenses and fences strongly impact the use of metal detectors, whereas all obstacles affect the ease of detection for dogs. In real terms, it is wire defenses and fences that limit the mobility of the manual deminer, and not the metal detector. Therefore, it can be concluded that obstacles that impact the ease of detection primarily affect mobility and access. While the data collected is not conclusive respondents' answers provided further information on the issue of accessibility to the site. R&D organizations need to create equipment and technology that is flexible and versatile in order to deal with all different types of obstacles in addition to coping with the physical surroundings.

Respondents were also asked to rate in comparison to one another the impact of the following factors on the ease of detection, accuracy and functionality: physical scenario, vegetation, soil composition, age of landmines, type of landmines, depth of landmines, skill of deminers, obstacles, metal scrap, area of operations, age of ERW, type of ERW, climate and precipitation. General conclusions are to be accepted with caution because of the small sample size.

However, factors that respondents indicated strongly impact ease of detection are:

- depth of the landmine
- skill of deminers
- all obstacles: slopes, trenches and ditches, wire defenses, fences, walls and watercourses
- metal scrap contamination

Secondary factors that impact ease of detection are the type of landmine and the type of ERW. The remaining factors did not statistically rank higher or lower than each other.

Part V – Performance Indicators

Section V discusses performance indicators use to measure functionality, productivity and effectiveness of equipment. These performance indicators were specified by Benetech prior to research implementation as of interest for R&D purposes.

Section V-1: Clearance Rates

A clearance rate is defined as the rate in which land is subjected to all processes, tools, equipment and technologies in the clearance toolbox in order to declare the land mine free. Therefore, clearance rates not only reflect the performance of close-in detection technologies, but also the functionality and performance of the entire clearance toolbox. Respondents were asked to provide both quantitative and qualitative assessments of clearance rates for their respective mine action operation. The following are observations based upon respondents' answers:

1. In general, it is the physical act of having to thoroughly check each square meter that has a greater effect on clearance rates, rather than the number of landmines and ERW present. Thus, mine density does not greatly affect clearance rates.
2. In general, clearance rates are reported in square meters per work day. Clearance rates do not generally reflect the clearance depth, but included in the definition of mine free is the assumption that a pre-determined clearance depth has been achieved. Depths are primarily determined by the expected end-use of the land. A clearance depth of approximately 10 cm is required if the land is intended for grazing. If construction will occur on the land, a clearance depth of up to one meter could be required. In the future, it is anticipated that the IMAS will be more flexible in terms of required clearance depths. One respondent reported a greater flexibility in terms of clearance depths that will allow "the operators to follow a pre-set risk management process rather [than] uselessly searching for an anticipated threat. This clearance depth will vary from country to country. In this way, massive resources do not need to be wasted where there is no threat" (quote from an anonymous respondent). Thus, future detection technologies developed may be required to function up to a potential depth of one meter.
3. In practical terms, it appears that there is debate in the HMA community as to the validity of clearance rates to be used as a performance indicator. Some respondents felt that clearance rates should reflect the required clearance depth. Other respondents answered that clearance rates varied greatly depending upon the physical surroundings. Still others identified non-technical factors, such as the skill of the deminer, that would lead to a higher clearance rate. As previously discussed, clearance rates are also affected by political and economic factors such as available manpower, funding for the operation or the support of the national government. It appears clearance rates are discussed, debated and used in the HMA community, but prove to be unreliable as a performance indicator.
4. The only possible conclusion gained from data collected is that there appears to be an increased clearance rate with the presence of MDDs in the clearance toolbox, but that conclusion must be approached with caution. MDDs are efficient in areas with a high ERW to landmine ratio, sparse vegetation and where the impact of obstacles on accessibility to the site is low. While it is possible that MDDs provide an increase in clearance rate because they are detecting the explosive vs. the metal content, it is also possible that under these same conditions, clearances rates would be high without dogs. Predictably, clearance rates are higher in mine action operations that have fewer obstacles and less vegetation to be cleared.

Country	Clearance depth to declare area mine-free (cm)	Mountain	Hillside	Grassland	Woodland	Urban	Village	Routes	Infrastructure	Desert	Paddy field	Semi-arid Savannah	Bush
Afghanistan - Respondent 1	13 cm for National standards. Clears at 15 cm especially in urban and village scenarios	10-15 sqm per 8 hour work day	10-15 sqm per 8 hour work day	20-50 sqm per 8 hour work day		15-30 sq m per 8 hour work day	15-30 sq m per 8 hour work day	20-50 sq m per 8 hour work day	20-50 sq m per 8 hour work day	30-50 sq m per 8 hour work day	20-50 sq m per 8 hour work day	20-50 sq m per 8 hour work day	10-15 sq m per 8 hour work day
Afghanistan – Respondent 2	13 cm. Ideal depth is 20 cm.						600 sq m per day	900 sq m per day					
Balkans region	15	Respondent did not answer											
Cambodia	20 cm.			Up to 100 sq m per day							Up to 100 sq m per day. Less than 25 is soil is laterite		
Cyprus	20	Respondent did not answer											
Iraq, Kurdistan Region	No such thing as mine free. Mines and UXOs located below specified depth of standards.	5-25 SQM/day/de miner	5-25 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner	5 to 75 SQM/day/de miner
Jordan	15			15 sq m per deminer						30 sq m per deminer		20 sq m per deminer	
Sri Lanka	10			5-10 sq m per hour	5-10 sq m per hour		1 – 3 sq m per hour				5-10 sq m per hour when dry		5-10 sq m per hour
Tajikistan	13	This is ALL dependent on local conditions.											
Vietnam	Depends on end-land use. 10 cm grazing land. 10-30 cm construction. 1 m excavation depth.	Varies	Varies	Varies		Varies	Varies				Varies		Varies

Table 11: Clearance rates for each mine action operation as reported by Respondents

Section V-2: False Alarm Rates

While there is debate concerning clearance rates, there is an even larger debate and disagreement regarding false alarm rates. Respondents were asked to provide quantitative and qualitative assessments of false alarm rates for their mine action operation.

A quick glance at collected data demonstrates the inherent problem with false alarm rates: definition. The data collected suggests that a clarification on the definition of false alarm is needed by the HMA operational community. For purposes of data collection, the false alarm rate was defined as # false alarms : detected threats. An alternative measure of false alarm rates is # of false alarms per square meter. From the responses, one can easily see that there is a lack of standardized reporting format, definition of false alarms and the exact factors which contribute to false alarms. In some instances, false alarm rates were reported as dependent upon the skill level of the operator. In others, false alarm rates were reported as varying depending upon the physical surroundings. All respondents reported the cause of false alarms as metal scrap. But, there was an equally strong response that metal scrap also had to be cleared and therefore should not really be considered as a "false" alarm. In fact, the industry standard is 99.6 percent of all explosive ordnance and hazardous material must be cleared in order to declare an area impact-free. This suggests that scrap metal should not be classified as a "false" alarm.

Although the data collected casts some doubt on the authenticity and reliability of false alarm rates as a performance indicator, an interesting trend emerged. All "false alarms" occurred within the top five cm of the soil. This trend occurs regardless of physical scenario, type and level of soil and vegetation, climate (temperature or precipitation), impact of obstacles or anticipated threat.

Country	Close-in detection Technology in use	Average false alarm rate (# of false alarms: ERW item detected)	Depth of false alarm	Causes of false alarms
Afghanistan - Respondent 1	CEIA ML-D1	Depends on terrain and climate	Top 5 cm of soil	Metal fragments from battle zones. Rubbish at urban areas, villages, routes. Generally, 2cm layer of top soil is removed prior to use of detector to detect landmines and other ERW.
Afghanistan – Respondent 2	CEIA ML-D1, Ebinger EBEX 420 GC, EBEX-420 H, Schiebel AN-19/2, and dogs	340,000 mines : 98.2 million metal fragments	Surface or just below surface.	Metal fragments due to wide spread use of weapons in Afghanistan.
Balkans region	CEIA ML-D1	N/A	N/A	Metal fragments. But they are not considered false alarms as they have to be disposed off according to national SOPs.
Cambodia	MineLab	Varies within same minefield.	On top soil	Metal fragments. National mine action authorities require all metal to be cleared. Hence, detectors are tuned to very high sensitivity levels. Dogs rarely give false alarms because trained to recognize whole "cocktail" of explosives in mines.
Cyprus	MineLab F3	All signals have metal content. No false alarms	Surface	Metal.
Iraq, Kurdistan Region	MineLab, Schiebel and dogs	Depends on the area.	Surface or just below surface.	Metal fragments such as shrapnel or rubbish.
Jordan	MineLab F1A4, Vallon, CEIA ML-D1	Rare	Less than 20 cm.	Metal contamination.
Sri Lanka	MineLab F3	No average. Approx. 25:1 in minebelts.	5cm of top soil.	No false alarms as most metal is battle debris, etc. which need to be removed as well.
Tajikistan	Ebinger 421 GC	Not applicable	Not applicable	Detector can not differentiate between metal contamination and ERW.
Vietnam	Ebinger 420 PBD	Over 95%	0-5 cm	Scrap metal. Fragments. Rubbish.

Table 12: False alarm rates and causes as reported by Respondents

Section V-3: Additional Performance Indicators

In an attempt to further understand the impact of physical scenarios, climate, soil, vegetation and other obstacles on current mine action technologies, certain performance indicators were identified by Benetech as of interest for R&D purposes. Respondents were asked to report on the following performance indicators: functional depth to detect landmines, functional depth to detect other ERW, approximate sweep rate, area to explore after detection occurred and duration of exploration to locate object. Although the same general close-in detection technology was used by respondents, a comparison revealed answers too varied to be comparable. For instance, one response to “area to explore after detection occurred” was 400 cm² while another response was 20 cm². Both respondents had identified a Desert physical scenario present. Similar to false alarm rates and clearance rates, performance indicators not only depended upon the physical surroundings, but also on non-technical factors such as the skill level of the deminer. Based upon the data collected, the author was forced to conclude that standardization for these performance indicators does not exist within the HMA operational field.³⁵

Country	Close-in detection Technology in use	Functional depth to detect landmines (cm)	Functional depth to detect other ERW (cm)	Approximate Sweep Rate	Area to explore after detection occurred (cm ²)	Minutes to explore indication to locate object	Satisfaction Level to detect landmines (5 High to 1)	Satisfaction Level to detect other ERW (5 High to 1)
Afghanistan – Respondent 1	CEIA MIL-D1	15	250	2 x sideway sweep 120 cm wide. Followed by moving search head 15 cm forward.	400	30 sec – 2 min	4	3
Afghanistan – Respondent 2	CEIA MIL-D1, Ebinger EBEX 420 GC, EBEX-420 H, Schiebel AN-19/2, and dogs	13 cm for min. metal mines. 20 cm for normal metal mines. Dogs detect deeper	40	Answer was not applicable.	800-900	10-30 minutes	3	5
Balkans region	CEIA MIL-D1	15	15	1 minute	400	10 minutes	No response.	No response.
Cambodia	MineLab	10 cm for MD. Dogs can seek deeper.	20 cm with large loop detectors. Dogs can seek deeper. (i.e. UXO at 1 metre)	2 x 3 sec per sweep across 1 metre search lane. Including overlap of one search-head width on each side	1600 for MD. 4 m ² for Dogs.	To locate target is 1 minutes. To find micro-piece of metal in soil 2-10 minutes.	4	4
Cyprus	Minelab F3	30	30	0.6 m per sec.	Pin point available.	2 minutes	5	5
Iraq, Kurdistan Region	Minelab, Schiebel and dogs	13 cm for min. metal mines. Dogs detect deeper.	Up to 1 metre. Bomb locators are used when needed.	Answer was not applicable.	450	Depends on soil type. 15 secs – 5 min.	3	5
Jordan	MineLab F1A4, Vallon, CEIA MIL-D1	20	20	1 metre	20	1-5 minutes.	3	1
Sri Lanka	Minelab F3	25	30	1m per second	25	1-15 minutes. Depends on object.	5	5
Tajikistan	Ebinger 421 GC	13	50 with a large loop head.	120 cm at 10 secs.	All objects located and identified.	Depends on local conditions and the operator	4	4
Vietnam	Ebinger 420 PBD	10	30	50 m ² per man per day	30	15 minutes	No response.	No response.

Table 13: Additional Performance Indicators as reported by Respondents

³⁵ The author acknowledges that performance indicators similar to those listed are discussed and collected during T&E and provided in training manuals for mine action technologies. However, it would appear performance indicators collected in the field vary significantly in reporting format and reliability.

Part VI - Additional Considerations When Contemplating the Development of New Technology

Section VI-1: End-Users Need for Hand-Held, Close-In Detection Technology

The standard rhetorical reply received in answer to the question “What new technology or capability is needed by end-users?” is a “strong, general desire for new, small, light and cheap machines”(Cepolina et al., 2005b:12). There is also the need for technology to be robust in order to withstand the harsh physical conditions of demining operations and the mistreatment technology receives by end-users (i.e. dropped, step on, not stored properly, tossed around in the back of a truck). Although not a specific focus of this report, an overall picture of specific end-user needs beyond the standard rhetorical reply emerged through extensive documentation reviews and interviews with respondents.

First, the reader must understand the fundamental difference between wants, needs and requirements with respect to developing new technology. An end-user may want a high-tech, super computer, but such is not necessarily needed to accomplish the task of mine clearance. In contrast, a requirement of close-in detection functionality is the ability to detect at least to the minimum clearance depth set by the National Mine Action Authority (NMAA). As previously discussed, any close-in detection technology implemented in the field is required to detect a potential threat at the minimum clearance depth; regardless of the effect of soil properties on detection accuracy. A need however, is defined as a potential capability that would either improve safety for the operator or cost-effectiveness of mine clearance without compromising current requirements of technology.

The following is a broad list of additional end-user needs that could be addressed within the field of close-in detection technologies. It should be noted that some end-user needs identified also apply to the development of other mine action technologies. Again, as no field study was conducted, this needs³⁶ list is not comprehensive. In addition, the author is aware that some current close-in detection technologies do take into consideration the following needs.

- Cheap, light, small
- Robust coverings and hinges: Respondent reported hinges and plastic coverings breaking easily due to equipment scrapped on the ground, improper storage, dropped, etc.
- Easy to service, easy to strip and replace parts, readily available replacement parts: In an ideal world, respondents reported a need for close to zero maintenance and no complicated parts.

³⁶ One could rigorously debate if the items on this list identify a need or a want of the end-user. The reality is defining an end-user criteria as a need or a want depends upon the reader's definition and assessment of cost-effectiveness in the field of HMA. As previously examined, cost-effectiveness is a difficult concept to accurately assess within the HMA field. Therefore, the author acknowledges the list could be rigorously debated and leaves it to the reader to decide. However, the author offers the list in an attempt to proceed beyond the standard, rhetorical answers currently given.

- Long-life power supply: Respondents reported equipment is used for extended periods of time and the power supply needs to last up to six hours at one time with a battery life of three to four days.
- Reusable, cheap power supply: Respondents reported batteries are not always available while in the field and were very expensive to replace.
- Handle-Length: Respondents reported that R&D organizations must consider handle length in ergonomic design, while not compromising detection or agility of technology.
- Deminer stands or lies on the ground: Respondents reported end-users use close-in detection technology while standing or lying on the ground. Ergonomic design should take into consideration the standing or lying position of the deminer and design to ease operator's discomfort and prevent onset of muscle fatigue.
- Cope with narrow environments: Respondents reported technology used in narrow, potentially low-visibility, difficult environments (i.e. vegetation obstacle). Ergonomic design of technology needs to be flexible, agile and supple to cope with narrow environments.
- Cope with obstacles: A strong need was reported by respondents that in order to improve the clearance rate, they need detection technology with the ability to cope with obstacles. In other words, obstacles impact the functionality and ease of detection.
- Cope with non-flat terrain: Relating to narrow environments, respondents report ergonomic design of technology needs to cope with terrain that is not flat.
- User-friendly: A user-friendly, integrated, output panel is needed that can be operated by end-users with little to no formal education. Respondents reported signal output needs to be interpreted quickly, easily and intuitively by operator.
- Non-repetitive audio/visual output signal: Respondents reported the output signaling the existence of a potential threat is extremely repetitive and therefore leads to boredom of deminer and unsafe practices. There is a general need for the output signal to not be boring.
- Versatility of technology to function in multiple environments: Respondents reported many technologies only function in specific physical environments and fail in other environments. This reality increases the need for re-training staff and thus increases overall cost. Also, multiple versions of the same technology increase the potential for human error. There is a general need to standardize one technology to work in multiple locations and environments.
- Detect small and deep threats: Ability to detect the smallest mines at sensible depths.
- Linear threats: Ability to detect linear threat targets (Guelle et al., 2006:66).
- Multiple threats: Ability to detect and distinguish between multiple threats that may be located next to one another or in close proximity (Guelle et al., 2006:66).
- Real-time detection: For operator safety and to ensure an adequate clearance rate, detection needs to occur in real-time without delays. If a time-delay occurs with

signal output in order to confirm or deny a potential threat, it places the operator in danger and slows down clearance rate.

- Distinction between Explosive and Metal: "The most desired piece of equipment in humanitarian demining [is] a hand held mine detector that actually detects mines, not just their metal content."(GPC International, 2002:12). In order to increase operator safety and productivity, respondents reported a need to distinguish between metal and explosives with no time delay in detection. Respondents also reported value added if technology could detect the range of high explosives present.

Section VI-2: Additional Factors to Consider When Developing New Technology

In addition to the needs list in Section VI-1, R&D organizations should take into consideration the following factors and issues which apply to close-in detection technologies and other technologies in mine action:

- Cost-effectiveness of technology with dual or multiple sensors: Is it really beneficial?
There is significant debate as to the benefit and cost-effectiveness of sensor fusion. More sensors generally mean an increase in cost. If an R&D organization wishes to pursue a sensor fusion option, it would have to prove an increase in productivity that justified the increased cost. This factor applies to any new technology in mine action. Measuring cost-effectiveness is difficult, and if there is an associated increase in cost for a new technology, an R&D organization needs to seriously consider if the new technology is a *perceived* improvement in functionality or would actually add value to the HMA clearance toolbox.
- In developing new technology, it is essential to not compromise operator safety: Detection technology needs to be stand-off.
One respondent reported observing a T&E of a vehicle mounted GPR. It functioned by first detecting the presence of metal and then using a GPR sensor for confirmation. However, the respondent observed the vehicle had to be directly above the threat in order to detect metal and the shape. This increased the danger to the operator, and the vehicle had to reverse in order to allow manual deminers to re-detect the exact location of the potential threat for excavation. Since the vehicle did not have GPS, the manual deminers had to proceed as if no threat had been detected. Thus, productivity and clearance rate was not significantly improved. In addition, there is an increase in potential danger to the operator when the dual or multiple sensor system relies on one sensor to signal. For instance, one respondent reported his unease with dual sensors as they rely on the first sensor, the metal detector, to signal before the secondary GPR sensor is activated.
- The reality of detecting metal: Is dual sensor beneficial to productivity?
A secondary sensor may reduce the area to prod, or may detect the presence of explosives, which is valuable information for the safety of the deminer. However, there is a debate about the potential increase in productivity with dual sensors as each

piece of metal detected still has to be investigated for the safety of the deminer and to declare the area mine-free. If metal is detected, a deminer will most likely investigate regardless of the information gained from a secondary sensor. The reality is no deminer will not investigate, as to not investigate puts the deminer in direct jeopardy.

- An R&D organization's work is not completed with the development of new technology.

"Responsible manufacturers usually provide a package of training, maintenance and spares"(Guelle et al., 2006:100). R&D organizations are not expected to simply develop new technology and then disappear. They must continuously provide spare parts, technological support for maintenance and training manuals in multiple languages.

- Indigenous manufacturing of equipment is desired by HD organizations.

Many respondents commented that a high priority is hiring indigenous people and incorporating the mine action operation into the indigenous economy. A natural conclusion is the need for indigenous manufacturing of mine clearance technology. The benefits are immediately recognizable. Indigenous manufacturing provides readily available spare parts and maintenance, remains within the national capacity and therefore remains within the nation's ability to support. It also contributes to the post-conflict economic development of the region.

- Village Demining does occur.

Within the context of a post-conflict country, there is a pressing need for cleared land so economic activity can recommence and sustain livelihoods. However, resources dedicated to demining often fall short of clearing all land needing immediate attention, and hence village demining occurs. Village demining is conducted by individuals who frequently have a military background due to the recent conflict and for the purpose of clearing land to sustain their livelihoods. Cleared land can be used for agriculture, houses or to ensure access to necessary resources such as water. The HMA community has rigorously debated training or not training village deminers. The debate centers on the concept of risk. From a western perspective, it can be too risky to provide village deminers with limited training, very few resources and almost no additional support. From a village deminer's perspective, it is either demine or face the risk of not surviving. In certain situations, laws have been put in place banning village demining. However, the consequence of banning village demining is to create obstacles for indigenous level coping strategies and effectively negates the agency of indigenous actors to deal with their own lives, to manage their own risk and increases their vulnerability to factors such as starvation and survival (Bottomley, 2003:832). In post-conflict countries, cleared land becomes a high priority. However, village deminers will not sell their services because of their inability to declare an area mine-free and thus could potentially be held accountable for any accidents on the cleared land. In the case of an accident, they may be required to provide financial compensation (Bottomley, 2003: 830). These circumstances could also result in a renewal of conflict.

Section VI-3: Final Analysis

When considering criteria or factors that impact the future development and implementation of new technology, one needs to remain aware of the inter-connected nature of constraints. Cultural, social, economic, political and operational conditions are unique to each mine action operation thereby creating extremely varied conditions that make designing new technology for the HMA field complicated and difficult.

There are many mine clearance capability areas that new technology could improve or fill. However, current methodology to identify technology gaps and to identify end-users' needs generally follows a top-down approach: starting by interfacing with high level managers/directors and eventually reaching deminers. Perhaps in many ways this cannot be avoided. Most R&D organizations are based in the West and Europe whereas deminers often are based in remote locations with limited communication access. But, in order to gain a true appreciation of the needs of the end-users, to create innovative solutions and to add value to the HMA community, an R&D organization should consider their methodology in development and design.

Part VII - Additional Capability Areas for Technology Development

Due to Benetech's project focus, this report has primarily focused on the concept that improvements in close-in detection technology would translate into decreased false alarm rates, increased productivity and would add value to the HMA community. Identified by GICHD's Study of Global Operational Needs, close-in detection to locate mines and ERW is a capability area that needs improvement. However, it is not the only capability area that needs improved technology or strategies.

GICHD's study of Global Operational Needs, Chapter 2, identified the following capability areas that could benefit from improved technology:

- Area reduction: to determine the outer edge of mined areas (Technical Survey³⁷)
- Locate hazardous areas
- Determine impact of hazardous areas
- Personal protective equipment
- Vegetation clearance
- Clearance verification in the form of quality assurance³⁸ and quality control³⁹
- Information Management
- Render safe mines and UXO
- Hazardous area marking
- Project management tools

GICHD's study further models and evaluates the direct benefits achieved through improvements in each identified capability area. Significantly, GICHD's study concludes that improvements in technology for close-in detection and area reduction would provide the greatest value and benefit for the HMA community. Anecdotal evidence from field personnel leads the author to also conclude the two primary areas of concern are area reduction and close-in detection.

Increased focus on area reduction follows the current trend of the HMA community to accept a degree of risk in mine action operations. Initially, surveys of mine-affected countries over-estimated suspected hazardous areas to ensure the safety of the population. However, as detailed technical surveys are conducted, suspected areas are significantly reduced thereby releasing land for use. Currently in Tajikistan, exploratory lanes, dogs and machines are used in the impact and technical surveys. However, detailed technical surveys mainly rely on the common sense and expertise of the person conducting the technical survey.

³⁷ The IMAS 04.10 defines the Technical Survey as "the detailed topographical and technical investigation of known or suspected hazardous areas identified during the planning phase." Often, a technical survey will simultaneously perform area reduction by reducing the suspect area and determining the exact outer edge of a mined area.

³⁸ Quality assurance in humanitarian mine action refers to the activity of verification after a demining organization has cleared all mines from a region. It is defined by IMAS 04.10 as "providing confidence that quality requirements will be fulfilled."

³⁹ Essentially, quality control is conducted after mine clearance. It ensures that mine action organizations have completed their tasks to the requirements as stated in the terms of contract.

In addition to area reduction and close-in detection, designing technology to cope with obstacles such as vegetation would enable the deminer to detect mines and ERW without having to clear vegetation (Habib, 2002). Respondents did not report any technologies or equipment which are able to provide this design feature.

Part VIII Conclusion

Throughout this report, it is important to remember that the primary research for this pilot study was conducted through telecommunications. Therefore, conclusions should be taken with a note of caution and an understanding that field research is needed in order to verify results. However, some important lessons and analysis can be gained from the pilot study.

The stakeholders and actors operating in the HMA field are many, but they are bound by a common set of goals. Similar goals allow for a global clearance toolbox. Clearance toolboxes for each individual mine action operation are derived from the global clearance toolbox. The global clearance toolbox available is essentially the same regardless of the stakeholder but technology is selected depending upon financial resources and agendas. Decisions made regarding selection for a clearance toolbox for each mine action operation is determined by the intersection of technical and non-technical factors for a specific site. Parts III and IV highlight and discuss in detail the impact of political, social, cultural, economic and operational factors that intersect to form a unique mine action operation.

Non-technical factors (Part III) ultimately affect the productivity and performance levels of mine clearance operations; but do not necessarily affect the direct performance level of a piece of equipment or technology. For social and capacity building reasons, certain demining organizations may consider hiring more deminers rather than investing in new equipment and technologies. National political concerns impact the context in which the HMA community functions and thus indirectly impact a mine action operation's performance level. Cultural influences also limit the ability of mine action operations to use more efficient technologies. For instance, MDDs can clear at an increased rate in certain mine action scenarios. However, predominately Islamic countries do not always respond positively to the use of dogs.

Current international political trends such as donors' waning interest, the approaching 2009/2010 deadlines as set by international law and the potential decrease in available funding for HD, all create pressing economic constraints. A funding decline will directly result in a decreased HD market, a decrease in purchasing power of the HD organization and a decrease in the current scale of mine action operations; all combining to affect HMA's ability to demand technology developed for HMA purposes. Even the increased focus on cluster munitions and other ERW will not necessarily translate into a renewal of funds for HMA, as most ERW can be located visually or detected easily. In conjunction, it is reported that demining will most likely continue after 2010, but the focus of most demining activities could turn towards clearing land for commercial purposes and not for socio-economic benefit such as access to water. From an R&D perspective, any new technology developed must consider the HD market size after the 2010 deadline. The scale of HMA operations may decrease, but it is possible commercial or military mine action operations may remain at current levels. In essence, while non-technical factors may not directly affect functionality or performance of mine action technology, they do affect implementation of mine action technology.

The concept of cost-effectiveness in HMA prominently affects the introduction of new technology. Since cost-effectiveness for the HMA community is very difficult to calculate, it becomes even more difficult to convince decision-makers and operators of the cost-effectiveness of new technology. Interestingly, the evaluation of cost or cost-effectiveness is directly

calculated in contrast to technical performance indicators of mine action technologies and hence highlights the interconnectedness between technical and non-technical factors in developing and implementing mine action technologies. Of further interest, based upon data collected, the author is forced to conclude that indicators attempting to measure productivity such as clearance rates, false alarm rates, cost, cost-effectiveness and other performance indicators identified by Benetech are not defined or standardized within the HMA community. This reality could also contribute to the fact that new technologies have not significantly increased productivity of mine action operations.

In contrast to non-technical factors as discussed in Part III, technical and operational constraints, as considered in Part IV, directly impact the functionality and performance of technologies. Examples include, but are not limited to, the general physical scenario, soil composition, grain size, water intrusion, precipitation, vegetation level and anticipated threat (types, ages, depth, laying pattern, quantity, density, etc.). Similar to non-technical factors, technical factors also affect the decision-making process for selecting mine action technologies. For instance, according to respondents a high ratio of ERW to landmines in a sparsely covered region is an ideal situation to employ MDDs.

On the technical side, the challenge for R&D organizations is the unlimited permutations of physical characteristics leading to endlessly unique mine action operational scenarios. Research undertaken concludes that any R&D organization needs to consider operational categories beyond the physical scenario. Instead, an R&D organization must design for the mine action operational scenario. The following general physical characteristics have been identified: physical scenario, soil, vegetation, climate and anticipated threat. Each category has a set of sub-divisions. For instance, the physical scenario can be described using the GICHD's 12 descriptive and distinct sub-divisions. Furthermore, for each sub-division, the level present must be defined. For instance, each soil type corresponds to a specific level: High, Medium, Low or None. Thus, a mine action operational scenario is the specific permutation of type and level of sub-divisions present. The challenge in R&D development is that each mine action operational scenario's type and level of sub-divisions impacts the functionality of technologies differently. Anecdotal information highlights the many potential divisions and sub-divisions that should be included to correctly describe a mine action operational scenario. Further research, especially field research, is recommended in order to validate the definition of mine action operational scenario proposed, to increase the number of classifications currently in use and to develop a quantitative versus qualitative description measuring the level of each sub-division present.

A corollary conclusion is that the operational and scientific communities could derive greater benefit from T&E field trials if the mine action operational scenario was specifically identified in field trials. In many respects, T&E field trials already evaluate impact from sub-division types and levels present. Anecdotal data collected for impact of each sub-division revealed similarities on functionality or ease of detection. For instance, respondents from different physical scenarios and locations who reported hard and dry soil type present all answered that it was difficult to excavate the potential threat. If greater standardization could occur in defining divisions, sub-divisions and measuring levels present, an R&D organization could more easily compare impact evaluations and potentially identify technology and functionality gaps to address.

From an R&D perspective, identifying technology gaps or the needs of the end-users is the first step towards innovation. A comprehensive review of general capability areas that need improvement is provided in GICHD's study (2002). However, the study does not provide general design criteria or specific functional needs of end-users for each capability area identified.

When asked directly, respondents did not indicate a specific technology or equipment that did not work satisfactorily. In fact, respondents reported a general satisfaction with the functionality and performance level of available equipment/technologies for mine clearance. Contradictorily, they reported a general dissatisfaction with the entire clearance toolbox's inability to quickly and safely demine. Respondents highlighted potential technological gaps such as distinguishing between explosives and ERW or the ability to quickly and precisely determine the outer edge of a mined area. However, additional research is needed to determine the value added to productivity of each identified end-users' need.

In attempting to identify end-user needs or technology gaps, an R&D organization should take a lesson from the decision-making process used to determine a specific clearance toolbox. Final selections and inclusion of mine action technologies reflects the intersection of technical and non-technical constraints for a mine action operational scenario. Importantly, a clearance toolbox is used as an integrated system. A single piece of equipment is not solely used for a specific task. Instead, mine action tasks are achieved by using the entire clearance toolbox. Final decisions as to when to use a specific piece of equipment or technology are made by the deminers using common sense and experience. Therefore, the introduction of new technology must be properly integrated into the current global toolbox in order to add value for the HMA community and to potentially increase productivity.

Identifying end-users' needs or technology gaps to address is extremely difficult as a result of the gap between scientific and operational communities. The gap occurs because there isn't a strong incentive to collaborate or share information between stakeholders and/or competing organizations. Increased collaboration has occurred in the last five years through various initiatives such as the ITEP. The gap highlights the importance for an R&D organization to enter into partnerships with operational stakeholders as the first step in developing new technologies. Working in conjunction with operational stakeholders, an R&D organization can close the feedback loop, identify technology gaps and specify end-users' needs.

The obstacles the gap presents and the need to first identify end-users' needs forces an R&D organization to consider its design methodology. A participatory design methodology (Cepolina et al., 2005b:13) is needed in order to gain the necessary insight. A participatory design approach advocates starting with the end-user, engaging the end-user in R&D, conducting R&D in the field, and testing with the end-user as the operator to gain realistic feedback. Many research studies have attempted to identify technology gaps and end-users' needs with little more result than concluding the standard "light, cheap, small and robust" answer. A change in methodology means putting scientists, engineers, TFMs, and deminers on the same R&D team from the outset of any initiative to develop new technology.

A participatory design approach advocates starting at the grassroots level, perhaps partnering with one organization in one mine action operational scenario, designing for the

challenges and constraints of one scenario and then building upwards to a versatile, multi-functional, multi-scenario piece of technology. There is an inherent logic in pursuing a participatory design methodology. Humanitarian R&D would occur in the area where the solution is needed. At the same time, it provides the additional benefit of supporting the indigenous community. By underscoring the importance of closing the gap between scientific and operational communities as a first step, the methodology may be able to provide the context to see innovative technology solutions that add value to the HMA community.

Conclusion Summary

In developing and implementing a new technology for HMA, an R&D organization must take into consideration:

- The mine action operational scenario that directly impacts the functionality and performance level of a new technology.
- Non-technical factors such as political, social, economic and cultural that directly impact how technology is implemented and thus affects the productivity level of a mine action operation.
- Mine action is achieved by using the integrative system called the clearance toolbox, including a deminer's common sense and expertise.

An R&D organization must overcome the following obstacles in order to develop new innovative technologies that would add value to the HMA community:

- The multiple permutations for a mine action operational scenario are not comprehensively formed or agreed upon by the HMA community and this hampers humanitarian R&D efforts.
- The impact of non-technical factors on a mine action's operation and influence on the regional clearance toolbox selected is not comprehensively understood.
- Performance indicators, as highlighted as of interest to Benetech, are not consistently defined or reported.
- The gap between scientific and operational HMA communities hampers the ability to properly and conclusively identify specific end-users' needs and technology gaps that need to be addressed.

Bibliography

Buse, Margaret S. (April 2002). The European Commission: The Future of Mine Action From a Donor's Perspective. *Journal of Mine Action*, Issue 6.1. Accessed database: <<http://maic.jmu.edu>>

Bottomley, R. (2003). Balancing Risk: Village De-mining in Cambodia. *Third World Quarterly*, Vol 24, 5:823-837.

Carruthers, A. and Littmann, F. (30 November 2001). *Test and Evaluation Inventory in South Eastern Europe, ITEP Project No 1*. International Test and Evaluation Program for Humanitarian Demining. Available at: <<http://www.itep.ws/testresults/project-1/itep-1.html>>

Cepolina, E.E., Bruschini, C. and De Bruyn, K. (2005a). "Field Survey Results", *EUDEM2 Technology Survey publication*. The EU in Humanitarian Demining - State of the Art on HD Technologies, Products, Services and Practices in Europe. IST-2000-29220. Available at: <http://www.eudem.vub.ac.be/files/FieldSurvey_Results_V1.0.0.pdf>

Cepolina, E.E., Bruschini, C. and De Bruyn, K. (2005b). *Providing demining technology end-users need*. Conference proceedings of the International workshop on Robotics and Mechanical Assistance in Humanitarian Demining held in Tokyo, Japan 21-23 June 2005. Available at <<http://www.dimec.unige.it/PMAR/demining/papers/HUDEM05CepolinaDeBruynBruschini.pdf>>

Cluster Munitions Coalition (CMC). Legal Issues. Available at <<http://www.stopclustermunitions.org/dokumenti/dokument.asp?id=37>>

Cluster Munitions Coalition (CMC). Technical Analysis. Available at <<http://www.stopclustermunitions.org/dokumenti/dokument.asp?id=24>>

Filippino, E. and Paterson, T. (August 2005). Mine Action Lessons and Challenges: Is Mine Action Making a Difference...or Avoiding the Question? *Journal of Mine Action*, Issue 9.1. Accessed database: <<http://maic.jmu.edu>>

Geneva International Centre for Humanitarian Demining (GICHD). (June 2002). *Mine Action Equipment: Study of Global Operational Needs*. ISBN 2-88487-004-0. Geneva:GICHD. Available at <<http://www.gichd.org/photogallery/mine-action-equipment-study-of-global-operational-needs>>

Goose, S. (June 2000). The 1997 Mine Ban Treaty. *The Acronym Institute. Disarmament Diplomacy*, No. 47. Accessed from: <<http://www.acronym.org.uk/47mine.htm>>.

GPC International. (January 2002). *Assessment of The International Market for Humanitarian Equipment and Technologies*. Prepared for the Government of Canada: GPC International.

Guelle, D. and Lewis, A. (August 2006). Systematic Test and Evaluation of Metal Detectors: Interim Report Field Trials Mozambique. *Journal of Mine Action*, Issue 10.1. Accessed database: <<http://maic.jmu.edu>>

Guelle, D., Smith, A., Lewis, A., and Bloodworth, T. (2003) *Metal Detector Handbook for Humanitarian Demining*. (ISBN 92-894-6236-1). Italy: Joint Research Center, European Commission.

Habib, M. (April 2002). Mine Clearance Techniques and Technologies for Effective Humanitarian Demining. *Journal of Mine Action*, Issue 6.1. Accessed database: <<http://maic.jmu.edu>>

International Campaign to Ban Landmines (ICBL).(2006). Landmine Monitor Report 2006: Toward a Mine-Free World. Available at <<http://www.icbl.org/lm/2006>>

King, C. (Ed). (2005). *Jane's Mines and Mine Clearance 2005-2006*. Tenth Edition. Cambridge: Cambridge University Press.

King, C. (June 1998). Demining: Enhancing the Process. *Journal of Humanitarian Demining*, Issues 2.2. Available at: <<http://maic.jmu.edu/journal/2.2/features/king.htm>>

Kudyba, B. (August 2006). Mines and ERW. *Journal of Mine Action*, Issue 10.1. Accessed database: <<http://maic.jmu.edu>>

Lokey, J. (June 2000). It's Mine and You Can't Have It! Feeding the Information Appetite or Starving the Data Hungry? *Journal of Mine Action*, Issue 4.2. Accessed database: <<http://maic.jmu.edu>>

Marsh, D. (February 2006). How Can Economists Contribute to Mine Action?. *Journal of Mine Action*, Issue 9.2. Accessed database: <<http://maic.jmu.edu>>

Smith, A. V. (January 1996). *Equipment for Post-Conflict Demining. A Study of Requirements in Mozambique. Working Paper No. 48*. Humanitarian Demining Research Program, Development Technology Workshop. Available at <<http://www.eng.warwick.ac.uk/DTU/pubs/wp/wp48/10industry.html>>

Smith, A. (October 1998a). The Future of Humanitarian Demining. *Journal of Humanitarian Demining*, Issue 2.3. Accessed database: <<http://maic.jmu.edu>>

Smith, A. (October 1998). Myths, Mines and Ground Clearance. *Journal of Humanitarian Demining*, Issue 2.3. Accessed from: <<http://maic.jmu.edu/Journal/2.3/features/myths.htm>>

U.S. Department of State (1997). *U.S. Demining Initiative. Fact Sheet*. (13 November 1997). Bureau of Political-Military Affairs. Washington DC: U.S. Department of State. Available at <http://www.state.gov/www/global/arms/971031_demining2010.html>

United Nations Mine Action Service (UNMAS). (2003). *IMAS 04.10 Glossary of mine action terms, definitions and abbreviations, Second Edition*. New York City:UNMAS. Accessed database: <<http://www.mineactionstandards.org>>

Appendix A: On-line Structured Survey

The follow survey was placed on-line by using the service at www.surveymonkey.com. Once respondents agreed to be interviewed, they were sent the link to the on-line survey. Please contact the author or the translator for a French version of the on-line survey. For a French version of the online survey, please contact Marta Wojcik at email: marta.wojcik@yahoo.fr.

Benetech Survey - Close-in Detection Technology

1. Purpose of Survey

Benetech has embarked on the research and development of close-in detection technology for use by the Humanitarian Mine Action (HMA) field.

Through this experience, Benetech has identified an information gap which exists between HMA users and humanitarian Research and Development (R&D) organizations.

It is this information gap that is responsible for newly developed technology not always meeting the expectations of the HMA community.

In order to develop technology that would benefit the HMA field, Benetech has commissioned a research study whose primary purpose is to understand the operational context, constraints and factors affecting close-in detection technology. There is space at the end of the survey to add any additional comments, concerns, or suggestions for Benetech to consider in our efforts to develop better technology.

This study could not be accomplished without your input and we thank you in advance for participating. Please inform your Benetech contact if you are interested in a final copy of the report.

2. Attention

For the purposes of this study, the "Clearance Toolbox" is defined as the set of generic processes and associated equipment used in a mine clearance operation. This on-line survey has been constructed assuming you use a process or piece of equipment for close-in detection. Examples of close-in detection technology include metal detectors, mine detection dogs, etc. If you do not use close-in detection technology in your "Clearance Toolbox", or if you have any questions, please contact your Benetech representative.

3. Confidentiality Agreement

In order to ensure quality data collection and to prevent duplication, Benetech will ask for your contact information and identity. However, Benetech respects and protects the privacy of survey respondents. Contact and information sources will not be made public or published in any format without prior permission.

1. I understand all contact information provided to Benetech for the purposes of this study will remain confidential. In addition, I understand any answers I provide during the course of this study will remain anonymous.

Yes

No

2. Please enter your contact information. Full contact information is not required, but is helpful to ensure quality and prevent duplication.

Name of Respondent:

Organization:

Position in Organization:

Location and Country of Operation:

Contact Number (with international codes):

Contact Email:

Contact SKYPE:

Years of Experience in HMA:

Previous Countries of Work Experience in HMA:

4. Identifying your Physical Scenario and the Functionality of your Close-In Detection Technology

The physical characteristics of the terrain surrounding landmines and other ERW is one of the primary determinants in demining operations and determining the "Clearance Toolbox". Therefore, Benetech asks that you respond to survey questions in relation to the characteristics of the terrain for your physical scenario.

1. Please specify the country and region on which you have chosen to respond.

2. Most questions throughout the survey will relate to close-in detection technology (metal detector, mine detection dogs, etc.). Please specify the type, brand, cost and how many years you expect your close-in detection technology to endure for your physical scenario. In addition, what is the available power supply for your close-in detection equipment or process?

Type

Brand

Cost (Indicate currency, i.e. USD, CAD, Reais)

Expected Duration

Power Supply

3. Please list any additional process or equipment used in your Clearance Toolbox for close-in detection. How is this additional process or equipment used? Do you use it in combination with the close-in detection technology listed in the previous question?

4. Please list any additional associated equipment or generic process in your "Clearance Toolbox". Indicate the expected duration of each piece of associated equipment and approximate costs {Indicate currency, i.e. USD, CAD, Reais, etc.}.

5. Please specify if each of the following 12 possible physical scenarios is a Dominant scenario found, Scenario frequently found, Scenario occasionally found or is a Scenario not found in your operational region.

- Mountain
- Hillside
- Grassland
- Woodland
- Urban
- Village
- Routes
- Infrastructure (primary routes)
- Desert
- Paddy field
- Semi-arid Savannah
- Bush

5. Functionality

1. What affect does each identified physical scenario have on the functionality, (i.e. performance and ability), of your close-in detection technology? If the physical scenario is not present, please leave the space blank.

Mountain
Hillside
Grassland
Woodland
Urban
Village
Routes
Infrastructure (primary routes)
Desert
Paddy field
Semi-arid Savannah
Bush

6. Contaminated Terrain

Contaminated Terrain refers to land which contains landmines or other ERW.

1. Of the contaminated terrain, what is the level (High, Medium, Low, None) of each soil category present in your physical scenario?

Saline (i.e. salty)
Sandy
Electromagnetic (i.e. soil with electric and magnetic properties)
Muddy/Wet
Clay
Rocky
Dry and hard
Dry and dusty

2. What affect does each identified soil category have on the functionality, or performance ability, of your close-in detection technology? If the soil category is not present, please leave the space blank.

Saline (ie. salty)
Sandy
Electromagnetic (i.e. soil with electric and magnetic properties)
Muddy/Wet
Clay
Rocky
Dry and hard
Dry and dusty

3. Of the contaminated terrain, what is the level (High, Medium, Low or None) of vegetation/undergrowth category present in your physical scenario?

Grasses with scattered Bush/Trees
Dense, jungle-type undergrowth, less than 2 metres tall
Heavy Forest
Light Forest
Light Bush
Barren with little or no undergrowth
Dense, jungle-type undergrowth, greater than 2 metres tall

4. What affect does each vegetation category have on the functionality of your close-in detection technology? If the vegetation category is not present, please leave the space blank.

Grasses with scattered Bush/Trees
Dense, jungle-type undergrowth, less than 2 metres tall
Heavy Forest
Light Forest
Light Bush
Barren with little or no undergrowth
Dense, jungle-type undergrowth, greater than 2 metres tall

7. Climate

Climate refers to the average weather you experience at the location of your mine clearance operations.

1. How does climate affect your ability to detect and demine in your physical scenario?

8. Additional Description of Physical Terrain

1. Is there anything about your physical scenario that makes your context unique?

9. Indicators for Functionality of Close-In Detection Technology

The following series of questions relate directly to the close-in detection equipment or process that you have indicated at the commencement of the survey.

1. Up to what depth (meters) is your close-in detection technology effective at locating the landmine threat you have identified in your physical scenario?

2. Up to what depth (meters) is your close-in detection technology effective at locating the ERW threat (other than landmines) that you have identified in your physical scenario?

*** 3. What is the average false alarm ratio (number of false alarms: ERW item detected) for the detection technology that you use?**

*** 4. What is the depth at which most false alarms occur?**

*** 5. What causes the false alarms in your physical scenario? And why?**

6. What is the approximate sweep rate with your close-in detection technology?

7. What is the clearance rate with your close-in detection technology for each identified physical scenario? If the physical scenario is not present, please leave the space blank.

Mountain	<input type="text"/>
Hillside	<input type="text"/>
Grassland	<input type="text"/>
Woodland	<input type="text"/>
Urban	<input type="text"/>

Village	<input type="text"/>
Routes	<input type="text"/>
Infrastructure (primary routes)	<input type="text"/>
Desert	<input type="text"/>
Paddy field	<input type="text"/>
Semi-arid Savannah	<input type="text"/>
Bush	<input type="text"/>

*** 8. What is the clearance depth for your physical scenario in order to determine the area mine-free? Has this depth, or do you anticipate this clearance depth changing in the future? And if so, why?**

9. How large (square centimeters) is the area which needs to be explored once a detection has occurred?

*** 10. How many minutes does it take to explore the indication in order to determine if it is a false alarm or a Landmine/ERW?**

10. Impact

1. Please rank in descending order (7 = High to 1 = Low) the impact of the following obstacles on the accuracy of close-in detection for your physical scenario. If factors hold equal weighting, give each factor the same number.

Slope
Trenches and Ditches
Wire Defenses
Fences
Walls
Watercourses

2. Are there any additional obstacles which impact the detection ability of your close-in detection technology that was not mentioned in the previous question? And if yes, what impact does it have?

11. Impact

1. Please rank in descending order (15 = High to 1 = Low) the impact of the following factors on the accuracy of close-in detection for your physical scenario. If factors hold equal weighting, give each factor the same number.

Physical Characteristics of Terrain
 Vegetation
 Soil Composition
 Age of Landmines
 Type of Landmines
 Depth of Landmines
 Skill of Deminer
Obstacles (Slope, Trenches, Watercourses, Walls, etc.)
 Metal contamination in the ground
 Total area of operations
 Age of ERW
 Type of ERW
 Climate
Precipitation (rain, snow, hail, etc) Level

2. Are there any other factors which affect the accuracy and functionality of close-in detection technology?

12. ERW other than Landmines (Optional)

This section has been deemed to be optional information to be completed in order to respect your time constraints.

1. What, if any, difference is there in detection and demining of landmines in comparison to other ERW?

2. What ability does your close-in detection technology have to detect both landmines and other ERW?

3. What type of diagnostic capabilities are necessary for detection of ERW other than landmines?

13. Rating your Satisfaction Level

1. What is your satisfaction, on a scale of 5 to 1 (5 is Extremely Satisfied) with your close-in detection technology's ability to detect the landmine threat in your scenario?

2. What is your satisfaction, on a scale of 5 to 1 (5 is Extremely Satisfied) with your close-in detection technology's ability to detect the other ERW in your scenario?

Any additional comments.....????

1. What additional factors (technical, political, social, and/or economical) does a Research and Development organization need to consider when developing new close-in detection technology for the HMA field?

Appendix B: Semi-Structured Interview Protocol

The following are a series of questions that have been constructed to be used at the discretion of the interviewer during the course of the interview. It is not anticipated that all questions will be asked of the target respondent due to time constraints. The objective of the interviewer will be to initiate a dialog with the respondent and incorporate questions as appropriate. As respondents are often under tight deadlines, the following protocol will be observed due to time constraints. Semi-structured interviews only occurred as a follow-up to the on-line structured survey.

Interview Protocol:

1. Divide target respondents into two sample groups - Group A and Group B.
2. All target respondents will be asked the 4 primary questions.
3. Interviewer will ask target respondents in Sample Group A questions from Group A: Political, Social and Economic Factors affecting Humanitarian Demining Operations. Target respondents in Sample Group B will be asked questions from Group B – The Future.
4. All target respondents will be asked the concluding question.

Primary Questions: The Clearance Toolbox

What technology or feature not currently available in the humanitarian mine-action community would you most like to see introduced?

Of the technologies in your Clearance Toolbox, what has proven to be most effective in your physical scenario?

Of the technologies in your Clearance Toolbox, what has proven to be most problematic in your physical scenario?

Have you adapted any equipment for detection and demining purposes? Why?

Group A: Political, Social and Economic Factors affecting Humanitarian Demining Operations

If cost or donor conditionalities were not a barrier, what demining equipment would you use, and why?

How is your mine action program integrated with the post-conflict reconstruction of the country?

What major obstacles are there in management and implementation of a demining project?

In general terms, what is the socio-economic impact of ERW ?

Beside the physical scenario, what factors are considered when preparing and selecting an operation's Clearance Toolbox?

What sources of information and/or indicators do you use to make decisions regarding technology selection?

Group B – The Future

- If you were to create a new close-in detection technology, what criteria or alterations would you make sure happened?
- What would cause your organization to consider new technology deployment in your context?
- What do you see as the future trends in HMA? (i.e. site remediation? ERW other than mines?)
- How many years will it be until your country of operation is declared mine-free? Your opinion, the opinion of the National Authority?
- What major political, financial or technical changes need to occur for the country to fulfill its MBT obligations?
- What is the funding trend for HMA in the next 10 years?

Concluding question:

Do you have any Statement of Requirement documents available that you could share?