Appendix T

CANINE-ASSISTED DETECTION

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HUMANITARIAN LANDMINE DETECTION NEEDS

Buried landmines are difficult to find because they are designed for concealment. These small, low-tech devices appear with a wide variety of designs and materials of construction, and can barely be differentiated from stones, roots, and scrap material in the ground. Yet, they always contain an explosive—most typically, TNT. The simplicity of landmines is thus the greatest challenge for those researchers attempting to develop new or improved methods for detection.

Detection of landmines is, however, only part of the problem. We know that only a small percentage of land typically contains mines. Up to 90 percent of mine-suspected areas could be released and given back to local societies if we knew where the landmines were *not* buried. The humanitarian demining challenge is therefore two-fold:

- Detect the areas that are free from landmines for immediate release (area reduction).
- Determine the exact location of landmines, enabling removal or destruction.

New or improved technology must also satisfy most or all of the following criteria to improve humanitarian demining:

- Help accelerate the demining process.
- Be as safe or safer than existing technology and approaches.

- Be practical to use and easy to repair and maintain.
- Be affordable.
- Enhance overall cost efficiency of demining.
- Not be too complicated for use by deminers.

Demining is a complex multitask process. There are great variations in types of landmines, landscape, terrain, vegetation, soil properties, weather conditions, burial depths, and methods for deploying landmines. Demining further involves many activities: survey, minefield boundary location, removal of vegetation, tripwire detection, ground preparation, and pinpointing and removal/destruction of mines and unexploded ordnance. No single tool can address all these tasks effectively. Thus it is necessary to apply a process with complementary tools and techniques.

The historical approach for landmine detection has been manual mine clearance. While this technique is highly reliable for clearance, it is unfortunately slow and dangerous. Metal detectors used with manual clearance methods are unsuitable for an entire class of low-metal-content mines. Mechanical mine clearance has evolved from the use of military tanks with flails or rollers to commercially produced machines with higher degrees of mobility and reliability. Technology evolution has been slow and mechanical clearance continues to have limited potential in many areas. Trace chemical detection—using dogs—is a versatile tool; yet, much more work is needed to understand optimal applications in the field. Humanitarian demining continues to need improved methods in all activities and research can bring the needed improvements in many areas, especially trace chemical detection.

PHYSICAL PRINCIPLES OF TRACE CHEMICAL DETECTION

The nature of the landmine chemical signature is a complex phenomenon that is now reasonably well understood [1]. First, the landmine must emit an adequate amount of the chemical signature to counter degradation and transport losses in the soil. The properties of the mine case material and method of construction are critical aspects in this most important process.

Once the landmine chemicals reach the soil, the soil acts as a storage media, releasing quantities in proportion to the sorption/desorption equilibria of the soil-water-air system. Transport or movement of the landmine chemicals occurs as a vapor in air, and as a solute in water, where diffusion and convection processes work simultaneously in a complex process. The landmine chemicals are organic molecules, which participate in soil biochemical reactions causing degradation and loss that can be very rapid under certain conditions—and very slow under others. Weather cycles dominate the driving forces that transport the landmine signature chemicals to the ground surface, where dogs identify the odors to make a positive indication.

One must recognize the dynamic variability of the landmine chemical odor, and the conditions that maximize and minimize the expression at the ground surface as a cue for the mine detection dog. Computer simulation tools have been developed that can assess these complex interdependencies and provide insight into optimal conditions for comparison to the vapor sensing thresholds of mine detection dogs.

In addition to odor sensing capability, the dog must follow instructions provided by its handler. The behavioral characteristics of an optimal mine detection dog have been identified [2], and include: nose to ground, consistency of repetitive action, obedience, endurance, focus, and slow-moving. Vapors that emanate from the ground are present in significant amounts only in a very thin air boundary layer. Beyond this layer it is believed that the vapor concentration is diluted to essentially zero. Surface soil residues of landmine chemicals are often discontinuous, which requires that the dog search consistently and slowly in a repetitive fashion over the entire area. This demands that the dog should maintain focus and have endurance to work over long field campaigns. Last, the dog must be obedient—that is, able to follow the handler's commands to start and especially to stop when dangerous conditions appear.

The sensor (the dog) response is established by traditional operant training methods from chemical cues that dog trainers provide. The source of the cue varies from chunks of military-grade TNT, to specially developed vapor sources with pure TNT, and to buried unfused landmines typical of the locale. The objective is to train the dog to lower and lower vapor sensing capabilities, consistent with what is actually found in the field. Only recently has research established the level of soil residues and vapors found in the field that will help define training aides needed to tune the dog to the greatest sensitivity possible.

Dogs indicate the presence of an odor to receive a reward, whether it be food or play. Indoctrination methods vary, reward methods vary, and results vary. This sensor (the dog's nose) and indicator system (dog training) is as varied as there are trainers. The debate among dog trainers for optimal training methods is relentless because there have been few opportunities for performance comparisons.

CURRENT CAPABILITIES OF MINE DETECTION DOGS AND RATS

Dogs use a keen sense of smell to discriminate target odors. This sense of smell originates from ancestral survival needs to hunt for food, determine territorial boundaries, and determine friend or foe. Evolution has given us a highly developed and adaptable sensor; however, users have only begun to understand how to optimally select and field this sensor for humanitarian demining operations.

Dogs can find landmines. Field performance, however, is poorly understood. This is mostly because of the undocumented nature of conflict-based minefields. Most demining operations count the number of mines found but are unable to count the number of *missed* mines. Often, accidents from missed mines are blamed on remining rather than poor performance.

More recently, mine action centers are prequalifying potential mine dog organizations using test minefields. However, these have been few, the data kept proprietary and the subject of controversy. The Geneva International Centre for Humanitarian Demining (GICHD) has initiated a field research effort to define the performance of mine detection dogs, with links to environmental factors that influence the amount of landmine chemical signatures. Projects have been initiated in Sarajevo, Bosnia-Herzegovina, and in Kharga near Kabul, Afghanistan; however, these are long-term efforts that will provide the needed information only after several years of implementation.

It is unfortunate that probability of detection/false alarm rate (PD/FAR) data is not available for the dog. However, that method was developed for electromagnetic technology, where adjustments in sensing thresholds allow one to derive the familiar PD/FAR relationship. This is unlikely to be appropriate for the dog, where biological and training history contributes to variations in sensing thresholds, and environmental factors contribute to diurnal and seasonal variations in scent availability. More work is needed to define appropriate performance indicators for dogs as a group and for individuals.

The greatest advantage of the dog is in its superior ability to discriminate between different scents, making the dog an advanced multisensor. The dog is capable of detecting very low concentrations [3] and only limited work has shown types of compounds dogs use as cues [4]. But, the dog is also able to recognize multiple substances concurrently. Research has not yet defined whether one substance or a bouquet of odors is best used by the dog to discriminate the landmine from background scents. Landmines emanate a variety of substances from the main charge explosive as well as from the casing (paint, plastic, rubber, cardboard, wood, or metal). A dog or rat can be trained to detect all these odors at the same time. If there is no available odor from the main charge but there are some odor traces from the casing, a dog will detect these traces if it has been trained to do so.

ONGOING RESEARCH EFFORTS

Rigorous research to improve deployment of mine detection dogs has been scarce. Mine dog providers and demining service providers use field operations to self-educate and improve for the next contract opportunity. Cross-organizational information sharing has been limited because of concerns over the loss of proprietary knowledge and market share. Recent cooperation sponsored by the GICHD has brought mine dog suppliers, users, mine action centers, and donors together to improve the reliability and utility of mine detection dogs. However, much more work is needed.

Currently, the GICHD study objectives are to

- develop international standards and guidelines for mine dog detection (MDD)
- facilitate/undertake targeted research to improve MDD and make it faster, safer, more reliable and predictable
- create a platform of exchange between researchers, MDD organizations, and other stakeholders.

The study has also established a global focal point for the MDD industry, one that was previously missing. Over two years, the study has evolved into many new activities, one example is the evaluation of the African Giant Pouched rats for trace chemical detection (the APOPO project). Some of the study objectives have already been addressed, including the development of international standards and guidelines for MDD and studies into breeds and tripwire detection. Other objectives in process include a comprehensive analysis of environmental effects on trace chemical detection as well as studies into training methodology, operational concepts, and Remote Explosive Scent Tracing—REST (also known as MEDDS). The latter is given high priority because of its great potential for area reduction—if proven successful.

During the past decade, much has been learned about the chemical odor from landmines, principally from a Defense Advanced Research Projects Agency program (1996–2000) that had goals to mimic the chemical sensing performance of mine detection dogs using advanced technology. This program spawned research that began to quantify the nature of the chemical signature from landmines [5,6], the rate of release of chemicals from landmines [7,8], the phase partitioning of these chemicals in soils [9], field measurements of chemical residues in soils from buried landmines [10], and simulation model estimates of vapor emanations from soils [11]. Field testing, laboratory experimentation, and simulation modeling all have shown that the chemical signature exists as an ultra-trace vapor, which challenges advanced technology applications for this very difficult problem.

FUTURE RESEARCH NEEDS

Only recently has work been completed that has explored the chemical compounds dogs use to recognize landmines [4] and the aerodynamics of how the dog inhales vapors and aerosols [12], and compared the performance of dogs with laboratory instrumentation and detection thresholds for narcotics and other nonenergetic materials [13]. Recent evidence suggests that dogs have explosive odor thresholds a billion times less [3] than the best advanced technology the world has to offer [14].

Fact: Dogs find landmines, dogs miss landmines; *mystery:* What enables the dog to find landmines, what challenges dogs to find landmines? These are critical research needs for a currently functional and operational landmine detector. Past research investments in a multitude of advanced technology applications (i.e., infrared, ground-penetrating radar, electromagnetic induction) have yielded few specific improvements that have transferred to the field and increased the speed of humanitarian demining operations. Now is the time to invest in research to improve the effectiveness of the mine detection dog for humanitarian demining operations.

Training Methodology and Operations Research

Key success factors in the use of mine detection dogs are dog/handler training methods and field operations. It is unfortunately characteristic that dogs and handlers are poorly trained—often a cause of miscommunication between the sensor and the operator. Modern technology relies on automated signal processing and alarm indications, which unfortunately are currently unsuitable for use with the dog and handler.

The training process is as varied as there are training organizations. There are people with significant training experience, but training principles tend to become corporate proprietary knowledge, leaving very little written material available to the global demining community. Lack of documentation contributes to limited institutional memory, resulting in the same mistakes being repeated. Poorly understood principles of training methodology are perhaps the greatest weakness with MDD today. The only systematic attempt to address this problem was through a study launched by the GICHD in 2000. However, more specific research is still required.

When optimal training methods are developed, one can become confident that when a sufficient landmine odor is available, the dog will indicate, the handler will observe, and the mine will be found. This still may not be adequate because field conditions affect whether landmine odors are sufficient. Field operations must take into consideration environmental factors that affect the amount of the odor present for a particular mine type (leakage rate) and diurnal/seasonal weather conditions. Selection of trace chemical detection for a particular scenario must be based in confidence that the field conditions are suitable for MDD work.

If we fully understood how dogs learn and communicate, we could reduce training time and optimize performance to make dogs more reliable detectors. We would further be able to overcome some of the problems caused by environmental factors by changing the way dogs are trained. The fact that we do not fully understand how to train and use the dogs is a great obstacle to successful use of mine dogs. More research is therefore required in the field of operational use of MDD, training methodology, and behavioral aspects for dogs and humans. Key objectives are the following:

- **Basic training methodology—**Develop training methods for dogs in specific demining tasks, such as for dogs in a REST configuration, free-running dogs with professional dog handlers, and free-running dogs to be handled by nationals in demining campaign countries.
- **Research on operational concepts—**Collect and examine data from MDD search procedures, behavior, and other elements of field operations and identify weaknesses or areas with a high potential for improvement. One such study has already been undertaken and the results revealed many surprises. One individual study is insufficient to draw conclusions and further studies should be undertaken.

Performance Measurement and Comparison

The debate among dog trainers regarding optimal training methods has been relentless because there have been few opportunities for performance comparisons. Methods have yet to be developed to calibrate the sensitivity and substance selectivity for the dogs. It is still unknown how vapor-sensing thresholds vary between individual dogs, dog breeds, dog training programs, and for individual dogs on different days.

This further prevents adequate testing of dogs prior to field use (licensing and internal quality control), and it is an obstacle to objective and efficient investigation of missed landmine cases after MDD clearance. If there were benchmarks for acceptable detection performance, international standards could be improved to incorporate a sensitivity test prior to search. It would also be possible to determine whether the dog makes mistakes or whether lack of vapor is the reason for missed mines. Research is therefore needed to

- develop vapor-sensing performance test methods to reliably compare the result of various training methods
- measure the performance of mine detection dogs with field programs in a host country with unfused landmines and weather cycles typical of that location
- develop practical ways of measuring concentrations of target scent from spots where mines have been missed, and develop detection benchmarks for comparison.

Remote Explosive Scent Tracing

Traditional methods with mine detection dogs are based on patterned search methods in mine suspected areas. A less common system is REST. This method relies on the capture of landmine odors on filters for later presentation to specially trained dogs. Each filter represents a sector of road or land area. This method has been successful for area reduction in a very efficient manner. One major issue, however, is that the system is poorly understood, limiting deployment to road verification.

While road verification is indeed important, the global demining process would be significantly improved if REST could be used to eliminate sectors of land (area reduction). Because area reduction is so important in humanitarian demining, REST has one of the greatest potentials for development. The system is promising, but further research is required in the following areas:

- **Training methodology—**Examine ways of training dogs to maximize detection rate and minimize false detection rate, increase search motivation and search endurance, and reduce time of training and dog/handler dependency.
- **Vapor availability—**Determine the extent of the detectable plume of scent from landmines under different circumstances (environment, landmine type, soil, and burial depth).
- **Sampling concept—**Develop a safe and reliable sampling concept where all limitations are clearly defined.
- **Filter technology—**Examine properties of filter material and optimize filters to allow highest possible interception of target scent. Further examine how to present filters to animals and vapor detectors to allow highest possible emission of scent during analysis.

Breed Selection

Not all dogs are alike. Current use of German, Dutch, and Belgian shepherds is based on historic use of these dogs as military working dogs. Whether these breeds are indeed optimal for humanitarian demining tasks has been debated. It is further a problem that very few breeds are used, thus causing a shortage of suitable dogs for MDD. A recent study [2] concludes that there are potentially four routes to producing a mine dog. The advantages and disadvantages for each of these four routes are discussed and an attempt has been made to scale different breeds using categories relevant to the design of a mine detection dog. Eleven different breeds have been examined during this process and their strengths and weaknesses have been scaled using 14 different property indicators. The report proposes alternative breeds for use. One breed—the Swedish Drever—has been identified as particularly suitable; however, no Drevers have been trained for mine detection work to date. Research is therefore needed to experimentally train MDD dogs from alternative breeds and link deployment roles with training requirements to specific dog breeds.

Environmental Factors

The presence or absence of the trace chemical odor from buried landmines is dependent on a complex process of release from the landmine, degradation and sorption in the soil, and volatilization from the soil surface. Many years of research have documented the fundamental properties in these processes and created simulation modeling tools [15] to evaluate the complex interdependencies among these processes. Simulation models appear accurate compared with well-controlled laboratory tests [16,17]; however, comparisons with field situations are needed. With reliable prediction of scent levels above landmines, field programs could determine whether the use of mine dogs, rats, or vapor detectors would be successful in certain areas under certain conditions. Key objectives for the research are

- **Fundamental Properties—**The initial set of data that defined the fundamental properties of trace chemical detection of buried landmines was narrow, principally to establish an initial understanding of the most sensitive processes and measurement methods. This information set needs to be expanded to include more variants for mine leakage rates, soil partitioning (soil-air and soil-water) equilibria, and biological and abiotic degradation rates specific to demining campaign locations.
- **Simulation Modeling—**Simulation modeling can provide great insight into chemical mass transport processes and the complex interdependencies in the buried landmine problem. A robust simulation modeling program is needed to define the key weather cycle, mine flux, and soil environmental conditions that define optimal and detrimental conditions for buried landmine detection. This needs to be aligned with field mine dog and trace chemical detection projects to validate the simulation modeling results.

Landmine Detection Rats

Although dogs are known to be good scent detectors, there may be alternative animals to perform this function as well. A research project in Tanzania (APOPO) trains African Giant Pouched rats to detect landmines. Preliminary results from a comparison test between rats, REST dogs in Angola and South Africa, and free-running dogs in the United States suggest that rats are just as capable of detecting similarly low concentrations as dogs. There may, however, be many additional advantages using rats compared with dogs. Preliminary research suggests that rats are quick and easy to train and have less handler dependency than is typically found with dogs. They are small and easy to accommodate, transport, and feed. They have further proven to accommodate repetitive behavior, which typically results in better endurance and longer search. Rats are currently trained as free-running and REST rats. The latter have shown very good preliminary results, although free-running rats may also be able to compete with dogs in the future. However, much more research and practical experience is needed to determine the full potential of rats for landmine detection.

Research Presentation (Technology Transfer)

Research alone is not enough to make changes: The results from applied research must be absorbed by those who train and use the animals. Scientific publications are likely to fail because it takes a scientist to read a scientific paper. Videos in support of scientific reports are likely to have a positive effect and enhance full understanding about MDD throughout the industry. The target group for MDD research is not necessarily the research community but the people who train and use MDD dogs. These people will better understand the optimum deployment methods, with sufficient background to make adjustments in the field, if the message is visualized through alternative information sources. Production of videos is one such source that should be further explored.

SUMMARY

The mine detection dog is currently a valuable demining resource and has been actively in use over the past decade. Unfortunately, mine detection dogs have been fielded without significant research supporting optimum training, testing, and field conditions for deployment. The fact that the dog has succeeded in actual demining programs is a testament that the sensor is robust and is simple to use. Many of the limiting factors can be overcome with limited basic research and moderate applied research. Research investments will have tremendous impact and make significant improvements in the speed of humanitarian demining for both area reduction and individual mine detection.

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