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Developing Technology for Humanitarian Landmine Clearing Operations

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DEVELOPING TECHNOLOGY FOR HUMANITARIAN LANDMINE CLEARING OPERATIONS

SUMMARY

The International Committee of the Red Cross estimates that every year approximately 24,000 men, women, and children are killed or injured by anti-personnel landmines. The State Department estimates that between 85 million and 108 million anti-personnel landmines remain in place in 70 countries. The United Nation's estimates that 2 million new mines are laid each year. Even if no new mines are laid, it could take hundreds of years and billions of dollars to clear all affected areas, given current technology and level of effort.

Current technology relies primarily on hand-held metal detectors, probes, and trowels. Clearing proceeds one square meter at a time. It can take all day for a 30-man platoon of trained mine-clearers to clear 1500 square meters (about a third of the size of a football field). Mechanical methods (plows, flails, rollers) have been used militarily for a long time in military operations and have good potential to improve the cost-effectiveness of humanitarian mine-clearing operations. But, mechanical methods are limited by terrain, vegetation and the intended use of the land (some mechanical methods can strip topsoil or destroy dikes or irrigation canals) and need to be made more affordable and transportable. New sensors and sensor suites can improve the cost-effectiveness of metal detectors by helping to distinguish the small amount of metal found in mines and the large amount of harmless metal debris often found in minefields. But, the new sensors, too, are limited by vegetation, soil conditions, etc. Development is needed on hardware and software that can combine data from different sensors (data fusion) and recognize objects (target recognition).

This report identifies a few national programs that have been set up to help develop and test new mine clearing technologies. Most of these programs are off-shoots of military programs. The list is not comprehensive. There are many private efforts being made by individuals and firms around the world who are moved either by humanitarian concerns or by potential profits or both to develop new technologies. Some of these efforts are frustrated by the lack of funds for development and testing. The amount of public funds available is relatively modest. In FY1997, Congress appropriated $14.7 million to test promising new technologies. In addition, the Office of the Secretary of Defense began supporting a five-year, $3 million/year program to do more fundamental research on new sensors.

While the world seeks to develop new mine clearing technologies, there is an international debate about whether to ban the use of anti-personnel landmines altogether. The initial forum for this debate, the United Nations Convention on Conventional Weapons, voted to phase out anti-personnel landmines that do not self-destruct or deactivate within 30 days. Many humanitarian organizations and some countries continue to seek a total ban on all anti-personnel landmines. The United States supports the idea of a total ban but reserves the right to use self-destructing mines until a total ban can be negotiated. The United States also reserves the right to keep its non-self-destructing mines in place along the North and South Korean border.

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INTRODUCTION

This report describes new technologies being developed to help detect and clear anti-personnel landmines, the programs that are developing them, and discusses related issues for congressional consideration.

The International Committee of the Red Cross estimates that every year approximately 24,000 men, women, and children around the world are either killed or injured by anti-personnel mines.[1] The Department of State estimates that anywhere from 85 million to 108 million anti-personnel landmines remain in-place in 70 countries.[2] Millions of square meters (primarily rural) are affected. The United Nations estimates that 2 million new anti-personnel landmines are laid each year as a result of internal and regional conflict.[3] Perhaps over 100 million more reside in national stockpiles.[4] Anti-personnel landmines can remain active for decades. Aside from the personal toll, landmines can also exacerbate refugee relocation programs and can disrupt the economic activity of a community and entire regions.[5] Medical and rehabilitation costs can also drain national resources.[6] The numbers cited above should all be considered as rough estimates. They may or may not overstate the global dimension of the problem. Perhaps they underestimate the

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[1] Anti-personnel Mines: An Overview 1996. International Committee of the Red Cross. Sept. 26, 1997.

[2] U.S. Dept. of State. Hidden Killers: The global problem with uncleared landmines. Executive Summary. July 1993. The estimate of the number of mines is the result of a survey done by the Department of State, carried out by U.S. embassies and consulates around the world, and based on information provided by host governments and non-governmental organizations working in the field.

[3] Clearing the Fields: solutions to the Global Land Mines Crisis. Edited by Kevin Cahill. BasicBooks and the Council on Foreign Relations, 1995. p. 114,167. Source for this estimate was not cited.

[4] Landmines: A Deadly Legacy. Human Rights Watch, 1993. p. 50.

[5] The United Nation's Demining Database describes the impact landmines are having on individual countries and the mine clearing efforts being conducted in those countries. See the U.N.'s URL listing in the back of this report.

[6] See The Worldwide Epidemic of Landmine Injuries. International Committee of the Red Cross, illustrated brochure, Geneva, Sept. 1, 1995. 8 p.

problem. However, reports from the field provide vivid anecdotal evidence that at least in certain areas, landmines are taking a serious toll.

The international community (including non-governmental organizations, international organizations, and national governments) have begun a systematic effort to establish mine awareness programs and mine clearing operations in affected countries. Mine clearing, however, is usually slow, tedious, and dangerous. Most humanitarian mine clearing operations are done by hand with a metal detector, probes (non-metallic rods), and trowel. For every 2,000 mines cleared, a mine-clearer is injured. For every 5,000 mines cleared, a mine-clearer is killed.[7]

A typical mine clearing operation using a 2-person team of trained local personnel can clear between 20 and 50 square meters per day in average terrain.[8] A demining expert can clear 50 to 70 square meters per day.[9] A 30-man platoon can clear between 1500 square meters per day[10] (about one third the size of a football field) and 2300 square meters.[11] Mine clearing operations have been clearing about 100,000 mines per year. However, if millions of new mines are being laid each year, mine clearing operations may never be able to catch up. Even if no new mines are laid, it will take hundreds of years to clear the mines already in-place, *at the current rate of mine clearance.*

An antipersonnel mine costs between $3 and $30 to manufacture and not much more to put in place. Removal costs between $150 and $1000 per mine removed.[12] In 1993, the international community spent $67 million on mine clearing operations. The Department of State estimates that since FY1993, the United States alone has spent $110 million for mine clearing operations (see Appendix B). Various affected nations have set up mine clearing trust funds. In addition, the United Nations (U.N.) has set up a global mine clearing trust fund. As of October 1996, the U.N. trust fund has $32 million in pledges.

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[7] Landmines Must Be Stopped. International Committee of the Red Cross. Feb. 24, 1997. A conversation with a U.N. official (March 17, 1997) indicated that in 1995, out of 6000 deminers working in U.N. demining operations, an average of 1.7 injuries were reported per week.

[8] Craib, J.A. Mine Detection and Demining from an Operator's Perspective. From the Proceedings: Workshop on Anti-personnel Mine Detection and Removal. Lausanne, June 30-July 1, 1995. p. 19.

[9] Clearing the fields, p. 125.

[10] Figure given at Conference on Innovative Techniques for Landmine Neutralization and Removal. December 2-3, 1996. Washington D.C. This is the U.S. standard for demining training. Dept. of State.

[11] Clearing the fields, p. 119.

[12] The high end of the range is associated with the relatively expensive contract negotiated between Kuwait and private demining firms to remove mines after the Gulf War. See Hidden Killers, p. 114. Some view "cost per mine removed" as not being a very useful statistic since the cost of clearing an area of mines is more a function of area cleared than actual number of mines cleared.

Affected countries are hard pressed to come up with this level of support and donor countries must balance mine clearing operations with other foreign aid projects within limited foreign aid budgets.

The international community is addressing the problem of landmines along two parallel fronts: support of mine clearing operations in affected countries and regulate or ban the use of anti-personnel landmines. It is clear that new, more cost-effective mine clearing technologies need to be developed for mine clearance programs to be effective. The international community is appealing to national governments and the private sector to develop such technologies. This report will focus on the efforts to develop these new technologies. Appendix C provides a short discussion of the disputed political effort to ban the use of landmines.

MINE CLEARING TECHNOLOGY

There are 4 basic steps to mine clearing: level 1 survey, level 2 survey, clearing, and quality assurance. Level 1 surveys locate potentially affected areas and classifies them as low or high risk areas. A level 2 survey is a more detailed survey of an area to establish (and refine) the boundaries of an affected area and to locate safe areas within those boundaries. The surveys are used not only to protect local populations and humanitarian workers or troops, but are also used to help a nation prioritize its mine clearing efforts, to plan specific operations and to identify unaffected lands in order to return them to productive use as quickly as possible. Clearing involves the systematic detection and clearing of individual mines within the affected area. Quality assurance is a post-clearing check to verify that an area has been adequately cleared.

A short discussion of the physical context in which mine clearing operations occur will provide a better understanding of the technological problems. There are over 600 types of anti-personnel landmines. They vary in size and shape; in material of construction; in the amount and type of explosive. Some are buried a few inches underground, some lay on top of the ground, some are located above the ground. Some are detonated by pressure, some by tripwire, some by other mechanisms. Some kill or injure by blast, some by fragmentation or both. The type of terrain may be hilly or flat; wooded, jungle, brush, grass, or bare. The terrain may be large open tracts or subdivided by berms or irrigation ditches. Mines may be in or around a town or village, or in individual homes and buildings. They may be on riverbanks, on or along a road or trail. They might be in sandy, muddy, or rocky soil. They may be in shallow water. They may have been placed in one location and dislocated to another by rains, flooding, plowing, or other disturbances.

Current Technology

The standard technique for surveying and mine clearing is to move across a suspected area literally one square meter or less at a time. Starting from a safe boundary line, the immediate area ahead is examined visually for surface or above-surface mines, trip-wires or other triggering devices. If nothing is seen on or above ground, the area must be cleared of any vegetation. This is typically done with hand tools or in some cases by burning. Then the area is scanned with a metal detector. If a signal is received, the area's surface is examined more closely. If nothing is found, a mine clearer begins to delicately probe beneath the surface, trying to identify, by feel, the location, shape and orientation of the object causing the signal. Shape and orientation are important since probing the mine in the wrong location can detonate it. When the object has been located, the mine clearer begins to slowly unearth above and around the object. Not only must the mine clearer be wary of triggering the mine itself, he must also be worried about whether the mine has been booby-trapped. The object located by the metal detector may or may not be a mine. In an area with lots of metal debris, metal detectors can locate hundreds of metallic objects for every mine located. If the object is a mine, once exposed it can be destroyed in place or removed and destroyed elsewhere.

Dogs have been used with some success in locating the presence of mines in support of manual operations. Dogs can detect as little as 10^{-12} grams of explosives. However, a dog can only be trained to detect one specific explosive, and their effectiveness diminishes when they tire and when in unfamiliar surroundings. A South African mine clearing company, the Mechem Division of Denel Ltd., has developed a technique where air samples are taken with a moving vehicle. The location of each sample is accurately determined. The samples are then taken back to the dogs for their assessment. While this does not pinpoint the location of a mine, it has proven helpful in area reduction associated with Level 2 surveys, particularly along roadways.[13]

The international community is hoping that new technologies can improve the productivity and safety of mine clearing, without sacrificing the thoroughness associated with the process described above. For example, large open tracts of land, roads and trails may be amenable to mechanical mine clearing technologies (more on these later). In many cases, however, the standard method discussed above may remain the only effective method. New detection technology (i.e. sensors) may be able to improve the productivity and safety of manual operations by better distinguishing between mines and debris and by providing information on the depth, size, shape and orientation of the object. Other areas of development include robotics for remote operation, new disarming/destruction techniques and new types of personal equipment (body armor, etc.) to improve safety.

As part of its mine clearing program, the United Nations has sponsored two international meetings in the last two years to review the developments in mine clearing operations and technology. Out of these meetings have come some formal and informal standards. The U.N.- mediated standard that perhaps most distinguishes humanitarian demining requirements from those associated with military operations is the requirement that operations achieve a level of 99.96% of a negotiated level of effectiveness. In otherwords, if an operation claims it

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[13] United Nations. Dept. of Humanitarian Affairs. Report of the International Conference on Mine Clearance Technology. Elsinore, Denmark, July 1996. see Chp. II, paragraph 30.

can clear 100% of the mines in a given area, and proceeds to clear 10,000 mines, no more than 4 mines should be found during the subsequent quality assurance check.[14]

Other informal standards are to guide technology development and include the following: mines should be accurately located to within ± 1 cm; detection devices should be able to identify shape, size, depth and orientation down to a depth of 50 centimeters; mechanical devices and sensors should be able to function in a variety of soil, vegetation, and weather; and, equipment should be affordable, maintainable out in the field, and rugged.[15]

Mechanical Mine Clearing Technologies

Open tracts of land, roads, and trails may be amenable to mechanical mine clearing technologies - plows, rollers, flailing machines. Such machines criss-cross a field or move up a road, detonating or unearthing mines as it goes. Large ones typically use military or construction vehicles as platforms. Smaller ones may be remote controlled or pulled by ox. Mechanical devices can handle some vegetation and sloping terrain.

Mechanical mine clearing devices cannot always detonate or unearth every mine it crosses. Nor can they clear near obstacles like trees or walls. In areas where mechanical mine clearing is being used or tested, destruction rates of 80% have been achieved. When followed up with standard manual clearing, operations can achieve the necessary high level of effectiveness in less time than just the standard method alone.

Mechanical mine clearing has its limitations. Large machines (especially plows and flails) may create wholesale disruption of the terrain, even stripping the ground of its topsoil. In some cases, this may not be a problem; for example, if the land is to be used for roadbeds, or construction. In other cases, intended land use may prohibit or limit the use of mechanical machines. For example, rice paddies use berms and channels to allow the paddy to retain water. Plowing through these would require that they be rebuilt. This would be very expensive and time consuming and in some cases traumatic to the population. Many rice fields have been in existence for generations.

Large mechanical machines may also have very high up-front costs, high maintenance costs, and may be difficult to get to location. Many of the machines in use today are designed for military use and suffer from these

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[14] In reality, the number of mines in a given area is usually not known and the level of effectiveness can never be firmly established. The standard is used primarily for contractual purposes. See, Report of the International Conference on Mine Clearance Technology, Chp. III.

[15] Pre-Conference Report of Working Group VIII. Technology for Mine Clearance. International Conference on Mine Clearance Technology. Denmark, July 1996. Also Report on the United Nations International Meeting on Mine Clearance. Geneva, July 1995.

problems. Current capital costs estimates range from $5000 to $3 million (US$).[16] Machines designed for humanitarian demining operations need to be smaller, less costly, and provide better protection to operators (if not remotely operated).

Nevertheless, mechanical mine clearing has the potential to improve cost-effectiveness in areas where the technology can be used. In the report of the second U.N. Conference on Mine Clearance, an analysis of a hypothetical mine clearing operation using mechanical and manual methods showed productivity gains of 3 to 4 times at a savings of $40 million to $50 million (US$) over manual methods alone. This was based on a number of assumptions regarding mechanical methods. For example, it assumed a total capital investment of $9 million for four rolling machines, $2 million per year in operating costs, 85% effective rate of clearance, the ability to clear 50,000 to 80,000 square meters per day, and 2 hours of daily maintenance. These performance levels seem to be within reach of the current technology.[17]

Sensors

Magnetic detectors are actually quite effective at locating anti-personnel mines; even mines with as little as 0.1 gram of metal content. Indeed, that is part of the problem. Sensitive metal detectors will detect all metal within its sensitivity range, whether it is a mine or metal debris. Even soils with a high metallic content will produce a signal. Besides not being able to distinguish between mine and debris, standard metal detectors cannot indicate depth, shape and orientation. The primary goals of new sensor development are to improve productivity by increasing the ability to discriminate and to provide images of the object.

There is a general consensus among mine clearers and technologists that no single sensor will be able to do an adequate job, and that a suite of sensors will have to be employed.[18] Imaging techniques, necessary to distinguish shape and orientation, would have to combine data from the different sensors, reconstruct an image and then be able to compare it with a catalog of mine signatures (target recognition). This will require software development, particularly target recognition software, as well as hardware development.

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[16] Report of the International Conference on Mine Clearance Technology. Denmark, July 1996. Chp. IV, Appendix I.

[17] Pre-conference Report of Working Group VIII. Technology for Mine Clearance. Mechanical Mine Clearance. International Conference on Mine Clearance Technology. Denmark, July 1996.

[18] Gros, Bertrand and C. Bruschini. Sensor Technologies for the Detection of Anti-personnel Mines: A Survey of Current Research and Systems Development. Proceedings of the 6th International Symposium. Measurement and Control in Robotics. Brussels, May 9-11, 1990. p. 564-569. Also Joint Research Centre. European Commission. International Workshop and Study on the State of the Knowledge for the Localization and Identification of Anti-personnel Mines. Dr. Alois J. Sieber, Study Manager. Office of Official Publications of the European Communities. Luxembourg, 1995. p. 31.

Another strategy is to combine sensors that detect objects with sensors that detect the presence of explosives or the vapors given off by explosives.

The types of sensors under development can be divided into physics-based and chemistry/biology-based. Physics-based sensors include adapting metal detectors to create images, ground penetrating radar, infrared sensors, thermal neutron activation, nuclear quadrapole resonance, x-ray backscatter, and acoustic imaging. Chemistry/biology-based techniques include ion gas mass spectrometers, chemiluminescence, and natural occurring or genetically engineered organisms. Chemistry/biology-based techniques are primarily used to detect and analyze vapors. For a more detailed discussion of some of these sensor technologies, see Appendix A.

Robotics

Another area of development is remote controlled vehicles. These vehicles may be mechanical mine clearing machines or they may carry a suite of sensors used primarily for detection. These vehicles must be able to traverse varied terrain, determine its position precisely, communicate with the control operator, and be sturdy and reliable. Much of the development in this area is devoted to adapting relatively mature robot technology to the mine clearing conditions.

Technology for Disarming or Destroying Mines

Destroying mines in place is done for a number of reasons. First, it is dangerous to manually remove mines. Second, in some countries, mines are reused or sold either to combatants, or to civilians that may use mines for anything from blasting, to fishing, to protecting fields or homes. Destroying mines in place removes the possibility of reuse.

A variety of techniques have been tested or are under development for destroying individual mines in place. These include explosives that safely detonate themselves and the mines and chemicals that react with the explosive to either neutralize it or ignite it without detonation. Other technologies include shaped charges and chemicals that can be applied that foul the mine's detonating mechanism. Lasers are also being looked at for destroying mines.

TECHNOLOGY DEVELOPMENT PROGRAMS

Much of the technology currently in use has been developed over the years by military establishments for military missions. The military has focused most of this effort in the past on developing breaching technology (i.e. technology that clears a path through a minefield) to aid in maneuver warfare. The large plows and flails are examples. Breaching does not need to locate and destroy each individual mine as is required for humanitarian operations. In instances when military operations do require the detection and removal of individual mines, the standard technique described above has been used more or less unchanged since World War II. Only in the last few years has the military sought new detection technologies, and only more recently have they sought to apply it to humanitarian missions. Most national programs to develop new mine clearing technologies for humanitarian operations are projects within military countermine programs.[19] As interest grows, however, many individuals and teams are seeking funds, from within their own organizations and/or outside their organizations, to develop new technology. The following discussion focuses primarily on programs supported with public sector funding and is not meant to be comprehensive, but only illustrative.

United States: In FY1995, Congress provided an additional $10 million to one of the Army's Landmine Warfare program elements to test and evaluate technologies that could be used for mine clearing in humanitarian and in "operations other than war" missions.[20] The project was managed by the Army's Communications and Electronics Command, Night Vision and Electronic Sensors Directorate at Ft. Belvoir. The project tested and evaluated over 30 items in four areas -- mine detection, mine clearance, in-situ neutralization, and individual components (i.e. protective gear primarily). Tests were conducted at Ft. A.P. Hill, Virginia, where a suite of test fields recreate the range of real-world conditions.

Among the technologies tested were remote controlled vehicles with sensor suites that would detect and mark the location of mines. One vehicle combined an array of metal detectors and a thermal nuclear activation analyzer. Another used infrared and ultraviolet cameras and ground penetrating radar. Other systems included mechanical mine clearing vehicles such as a remotely controlled mini-flail and a studded roller that could be pulled by a variety of methods. A wide range of in-situ neutralization techniques were tested. Individual components included weed-eaters with extended handles and blast protectors, vehicle armor, and safer probes. While some of the technologies were judged ready for use in the field, the sensor technologies needed further development.[21]

In FY1996, Congress provided another $3 million to further develop some of the more promising technologies.[22] In FY1997, Congress set up a separate account in the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict and appropriated $14.7 million to

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[19] Technical requirements for individual mine removal are comparable for both military and humanitarian operations. However, the degree to which all or most mines must be found and destroyed, and the costs associated with achieving those levels of effectiveness differ; humanitarian operations being more restrictive.

[20] P.L. 103-337. See U.S. House of Representatives. Conference Report 103-747, to accompany H.R. 4650, p. 105. Over the last couple years Congress has appropriated between $50 million and $60 million for the Army's countermine programs.

[21] U.S. Army. Communications and Electronics Command. Night Vision and Electronic Sensors Directorate. Countermine Technologies for Humanitarian Demining, v. II, Test Results. Dec. 19, 1995.

[22] P.L. 104-61. See U.S. Senate. Dept. of Defense Appropriation Bill, 1996. Senate Report 104-124, p. 157. The conference report indicates that $6 million was added. Subsequent deductions reduced that to $3 million.

continue development and testing.[23] The Assistant Secretary of Defense for Special Operations and Low Intensity Conflict sits on the interagency committee in charge of coordinating U.S. humanitarian demining programs. Special Operations units are involved in testing the equipment. They would also be responsible for getting new technology out into the field, through their train and equip programs (see the discussion on US mine clearing programs - Appendix B). For FY1998, the Administration is requesting $7.6 million for humanitarian demining in the Office of the Secretary of Defense account.

In addition to this test and evaluation program, the Office of the Secretary of Defense, through its Multidisciplinary University Research Initiative has begun to support 3 university-led teams to develop new sensor technologies. The three teams are led by Duke, Northeastern, and Missouri-Rolla. The teams include private firms and other government laboratories. The program is a 5-year program and received $3.2 million in FY1997.[24] The program works with the test and evaluation program at Ft. Belvoir.

Canada:[25] Canada, through its Defense Research Establishment (DRE) facility in Suffield, is also supporting a wide range of activities to support humanitarian mine clearing operations. The DRE is spending roughly 2 million to 3 million Canadian dollars (C$) and devoting about 10 person-years each year.

They are spending about 1 million (C$) to improve handheld sensors, including work on ground penetrating radar, multi-spectral stand-off sensors, and smart prodders.

Canada is also supporting, in cooperation with Canadian industry, a 2.5 year project (6.1 million (C$)) to develop a vehicle mounted, tele-operated detection system that would employ infrared sensors, ground penetrating radar, minimum-metal detectors, and a thermal neutron activation detector. The vehicle is being designed primarily for contingency operations of the Canadian military to clear roads and tracks, but could serve a similar mission within a humanitarian mine clearing operation, where terrain permits.

Other developmental work is going on in in-situ neutralization, mechanical mine clearing, and protective gear. The DRE also supports trials and evaluation of technology developed outside the DRE (e.g. a Czech mini-flail, and a Canadian developed bomb-suit adapted for mine clearing).

Technology is funneled into the field through Canadian military missions involved in demining training and operations. These include teams in Cambodia and Bosnia.

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[23] P.L. 104-208. See also U.S. House of Representatives. National Defense Authorization Act for Fiscal Year 1997. House Report 104-724. p. 588-590.

[24] Fact sheet provided Army Research Office, Feb. 5, 1997.

[25] Based on conversation with Major Al Caruthers. Program Manager. Canadian Defense Research Establishment. Suffield, Alberta.

Switzerland:[26] Scientists at the Microprocessors and Interfaces Lab at the Swiss Federal Institute of Technology have set up a Demining Technology Center (DeTeC). The center began work in 1994 with private funds to develop a demining robot. The work has switched to integrating man-transportable sensors (metal detectors and ground penetrating radar) into a system that can effectively discriminate and characterize mines from debris. This involves primarily hardware integration, software development for data fusion and target recognition. DeTeC has 4 scientists and a 2-year (1996/1997) budget of $400,000 (US$). Funds come from the Foundation "Pro Victimis" in Geneva, the Swiss Department of Foreign Affairs, and internal funds of the Institute. Much of the development work is conducted at the Center's lab in a sandbox, but efforts are underway to travel to the field to accumulate more realistic data. The Center hopes to continue beyond its current two year program.

European Union:[27] A study group functioning through the auspices of the European Commission's Joint Research Center in Ispra, Italy, has proposed a 3-year European research and development program that would integrate a sensor suite. The sensors would include a 3-axis induction-gradiometer (metal detector), an imaging polarimetric surface penetrating radar, and an imaging polarization-sensitive infrared sensor. The program would include developing the processing hardware and software needed, field measurements, and integration onto a vehicle and into a comprehensive operational system. The program would end with a demonstration of the total system in the field. The proposed budget would be 50 million ECU (approximately 62.5 million US$).

Sweden:[28] Bofors, a private arms manufacturer in Sweden, began developing a mechanical mine clearing vehicle in 1995. The vehicle is based on a Leopard I Main Battle Tank chassis and uses rollers with teeth that either explode or chew up mines. Bofors has built two test models, the second one is operating in Bosnia. The system weighs 45 tons and must be transported to location. Bofors is redesigning the system to optimize it for humanitarian operations, using all civilian commercial components. Bofors claims their systems can clear mines at a cost of ten cents per square meter, or one-tenth of the average cost for manual mine clearing. They intend to go into production during the first half of 1997. Bofors is part of 4-member consortium that intends to extend research into advanced sensors. The consortium is primarily supported with internal funds. The Swedish government provides some support for the sensor development.

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[26] Based on information from the Demining Technology Center at the Mircroprocessor and Interface Laboratory of the Swiss Federal Institute of Technology (Lausanne, Switzerland) and correspondence with Professor Jean-Daniel Nicoud, the Center's Coordinator.

[27] Based on information provided by the Joint Research Centre and correspondence with Dr. Alois Sieber, Study Manager.

[28] Based on information provided by Bofors.

Germany:[29] The German Government had its own mine clearing problems after reunification. Miles of mine fields defined the former iron curtain. The private firm Vielhaben won a contract with the Ministry of Defense to clear a 28 km perimeter (1,000,000 square meter). Vielhaben, a former East German firm and manufacturer of road milling machines, began adapting its product line for mine clearing in 1993; the equipment was licensed in 1995. Another mechanical system has been developed by W. Krohn GmbH. The German government has contributed funds to test these devices.

CONGRESSIONAL ISSUES

Congress may wish to consider three principle questions regarding the United States' effort to develop new mine clearing technologies. Is the funding adequate, relative to U.S. interests? Is it being spent effectively? And, is new technology getting into the field and being used?

What is an adequate level of funding? If there are many promising proposals submitted in response to DOD's programs that cannot be supported because of limited funds, then Congress may or may not consider additional support. The amount Congress spends within a constrained research and development budget will be determined by balancing all of the demands placed on DOD's technology base programs. What is the importance of humanitarian demining relative to, say, new infrared detectors for missile guidance systems?

Is it being spent effectively? The program must achieve a balance between the effectiveness of the technology in locating and clearing mines (measured in terms of the area that can be surveyed and cleared in a given amount of time and a given level of accuracy), its ultimate affordability and the time it takes to fully develop and field it. The problem is a technologically interesting one. There is a danger of spending resources on seeking an elegant solution at the expense of making less elegant, incremental and nearer term progress.

Another aspect of effectiveness is whether or not efforts in demining are effectively leveraging work being done elsewhere on similar technologies. For example, detection technology is being developed by Department of Energy, Transportation and Justice to address a variety of problems. A 1995 General Accounting Office report noted at the time that more could be done by these various agencies to leverage each other's work.[30] On the international level, the United Nations has sponsored technical meetings on demining the last two years. While not formally coordinating efforts, the meetings bring together developers and deminers from around the world.

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[29] Based on information provided by Vielhaben, Krohn, and LTC Klaus op de Hipt, Director of the EURO NATO Training Center.

[30] U.S. General Accounting Office. Unexploded Ordnance: A Coordinated Approach to Detection and Clearance is Needed. NSIAD-95-197, Sept. 20, 1995. 29p.

It is still a little early to be able to assess whether the technologies being developed will find their way into the field. The U.S. programs are linked to the U.S. train and equip programs (soldiers who participate in these train and equip programs also are involved in testing the new technology), which should help in getting the technology into the field. It remains to be seen whether the technology is accepted by local mine clearing operators and proves effective in practice. Operators appear to be open to new technology, if that technology has adequately proven itself in testing. It should be noted that in many affected areas, local mine clearers make good money and command respect within their communities. Innovation on their part will likely occur within this context.

APPENDIX A

Sensor Development

The types of sensors under development can be divided into physics-based and chemistry/biology-based. A short discussion of some of the technologies being developed follows.

Ground penetrating radar (GPR): GPRs work like typical radar, emitting electromagnetic energy into the ground and receiving reflected signals from objects buried underground. By moving the emitting source so that the radar hits the object from different angles or by emitting radar waves with a broad range of frequencies, the return signals can be reassembled to give 2-D and 3-D images. GPRs have shown good promise in identifying mines with air gaps in them. There is an inherent tradeoff between resolution (which benefits from higher frequency radar emissions) and depth of penetration (which benefits from lower frequency radar emissions). Like metal detectors, radar will locate any object that will return a signal (e.g. rocks). While the imaging capability of radar might allow for discrimination, the image of the mine may be difficult to see among other objects. Also, wet soil and tall grass or bushes can inhibit the usefulness of radar. GPRs are also being considered for airborne applications (a few hundred feet above the ground) as a surveying tools. GPRs have been used commercially, for example, in the oil and gas industry, but more work is needed to adapt them to mine detection. GPRs are considered to be moderately complex and expensive.

Infrared (IR) sensors: IR sensors can detect the differences in thermal radiation between objects. However, the depth to which IR sensors can detect objects underground is somewhat limited. Also, the effectiveness of IR sensors is limited by time of day, weather, and vegetation. Many military establishments are developing airborne IR sensor systems for wide-area surveying (e.g. the U.S. Airborne Standoff Minefield Detection System). Military-derived platforms should be able to meet humanitarian requirements as well.

Thermal neutron activation (TNA): TNA technology can detect the presence of explosives. TNA uses neutrons from a radioactive source to activate the nuclei of nitrogen atoms found in most explosives. The activated nitrogen emits a signature level of gamma radiation that can be detected by a gamma ray detector. TNA used in conjunction with metal detectors or ground penetrating radar can help distinguish mines from debris. The problems with this technology include its limited effectiveness below a certain depth (10 to 20 cm) and the problems associated with handling radioactive materials in the field. The technique is fairly mature but also complex and relatively expensive.

Smart Probes: "Smart probes" is a generic term for equipping probes with sensors to help distinguish between mines and debris. For example, it may be possible to use the probe in a way that acoustic signals unique to the object can be generated and measured.

Ion gas mass spectrometers: Ion gas mass spectrometers ionize gas molecules and then separate the ionized molecules by mass. The technology is mature. However it requires an ionizing source, vacuum chamber, and some sophisticated electronics that may make it difficult to apply and maintain in the field.

Biological agents: A number of ideas have been proposed to use biological agents, either naturally occurring or genetically engineered. One proposal is to coat a piezoelectric crystal with antibodies that react with TNT vapors. The crystal would signal that the vapor was detected if the reaction changed the electrical properties of the crystal. Other ideas include genetically engineering a bug (e.g. a beetle) that would be attracted by the vapors. A conglomeration of beetles would signify the presence of the explosive. Biological sensors of this kind are considered far-term options.

APPENDIX B

U.S. Government Demining Programs[31]

The U.S. currently assists humanitarian demining programs in 14 countries. The program supports: landmine assessment; training in mine awareness; education and training in mine clearance; helping the transition of responsibility to host government or other designated entity; and follow-on assistance. As a matter of policy, no U.S. military personnel are directly involved in mine clearing operations, nor do they go into countries where fighting is still occurring. However, it is U.S. military personnel that essentially implement the program in the field. The program is run by an Interagency Working Group within the National Security Council. The Department of State, Political-Military Bureau chairs the Group. The Office of the Secretary of Defense, Special Operations/Low Intensity Conflict is Vice-chair. Other members include State/Population, Refugees and Migration, State/International Organizations, Joint Chiefs of Staff, US Agency for International Development, and other offices as the Chair and Vice-chair deem appropriate. The United States coordinates its efforts with other national and international efforts, including those of the United Nations.

Since FY1994, the Department of State estimates that the U.S. Government has allocated $18 million in FY1994 and $46 million in FY1995. In FY1996, its estimated the program will have spent $20 million plus another $5 million earmarked for Bosnia. This does not include funding for the technology development and testing programs.

The countries currently being assisted are: Afghanistan, Angola, Bosnia, Cambodia, Eritrea, Ethiopia, Jordan, Laos, Mozambique, Namibia, Honduras, Costa Rica, Nicaragua, and Rwanda.

[31] U.S. Dept. of State. Fact Sheet on U.S. Initiatives on Demining and Landmine Control. Bureau of Public Affairs, July 27, 1995. Also, based on presentation at the Conference on Innovative Techniques for Landmine Neutralization and Removal. Washington, D.C. Dec. 1996.

APPENDIX C

Regulation vs Ban

In the last few years, there has been a major push by humanitarian organizations (including non-governmental organizations, the International Red Cross, and the United Nations) and some national governments to pursue a ban on the manufacture, stockpile, transfer and use of anti-personnel landmines. In 1993, at the request of the French Government, the United Nations' General Assembly voted to review the Land Mines Protocol (Protocol II Relating to Mines, Booby-traps, and Other Devices) of the 1980 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. The 1980 Convention offered some regulation of the use of landmines. The Review Conference was to prepare concrete proposals for amendments to the Protocol that would expand restrictions, especially those relating to the manufacture and use of "dumb" mines (i.e. mines that do not self-neutralize or self-destruct). The Review Conference convened in September 1995. Some countries have publicly committed to support a total ban. Those opposing a total ban were split between some major military powers (including the United States) that have the technology and resources to manufacture self-destructing mines and some developing countries that are major exporters of "dumb" mines. Those major powers opposing the ban argued that anti-personnel mines are not only useful but necessary for military operations[32] and that self-destructing mines, properly used, can significantly lower the risk to civilians. The Review Conference released its final report in May 1996. The Conference endorsed the phasing out of "dumb" mines over 9 years and the regulated use of "smart" mines. Smart mines are to self-destruct in 30 days after emplacement. Among the regulations is that no more than 10% shall fail to self-destruct after 30 days and no more than one in one thousand shall fail to self-destruct after 120 days.[33] Those advocating a total ban are not pleased with this outcome. They argue that as long as landmines are in use, civilians are at risk.

The Clinton Administration announced its latest landmine policy in May 1996. The policy is to immediately ban the manufacture and use (except in the Korean DMZ) of non-self-destructing mines; that the country's entire stock of "dumb" mines will be destroyed by 1999; and the country reserves the right to use self-destructing mines until a total ban is negotiated. Since 1992, Congress has imposed an export moratorium on all U.S. landmines (P.L.102-484, section

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[32] For a short discussion on the military utility of anti-personnel mines, see Clearing the Fields, pp. 24-44. The ICRC commissioned a report that qualifies the military utility of anti-personnel mines, see Anti-personnel mines:not an indispensable weapon of high military value. ICRC Press Release, March 28, 1996.

[33] Review Conference of the States' Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or Have Indiscriminate Effects. Final Report. Technical Annex to Annex B. Protocol on Prohibition or Restrictions on Use of Mines, Booby-traps and Other Devices. (Protocol II) as amended on May 3, 1996.

1365; P.L.103-160, section 1423; P.L.104-106, section 1401). Also, the U.S. is spending some funds on developing non-lethal alternatives to mines that would serve the same military function. The Administration plans on pursuing a worldwide ban through the United Nation's Conference on Disarmament (where it pursued the Comprehensive Test Ban Treaty and the Chemical Weapons Convention). Critics of the Administration's position suggest that this is a slow approach, since the Conference works by consensus. The Canadian government has taken the lead to convene a separate treaty negotiating process that would allow countries to commit earlier to a total ban.

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Report of the international conference on mine clearance technology. Elsinore, Denmark. July 2-4, 1996. (see U.N.'s Demining Database website below).

INTERESTING UNIVERSAL RECORD LOCATORS (URLs)

http://www.dsk.de/mgm/mgmlinks.htm The International Landmine Almanac. Maintained by the Humanitarian Foundation of People Against Landmines.

http://diwww.epfl.ch/w3lami/detec/detec.html Website of the Demining Technology Center at the Microprocessor and Interface Laboratory of the Swiss Federal Institute of Technology.

http://www.demining.brtrc.com/index.html.ssi Humanitarian Demining Website. Communications and Electronics Command. U.S. Army.

http://www.un.org.Depts/Landmine/ United Nation. Humanitarian Agency's Demining Database.

http://www.senate.gov/member/vt/leahy/general/landmine.htm Senator Leahy's website on landmines.