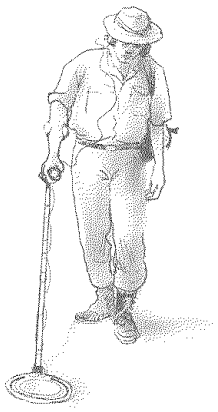
In the best possible case, the progression of such work is therefore as slow as that of an individual on his knees. It is fairly reliable, although it may be defective in treating some specific devices:

- mines with a specific oscillating pressure plate
- mines with a chemical firing system
- mines buried at a particular angle

Probe work is well suited to soft grounds (sand and damp soil) but gets extremely tedious in the case of hard, rocky or frozen grounds. As a matter of fact, the harder the ground, the more dangerous the operation: the U.N. points out that mine-clearance can be safely conducted for months in Cambodia (where the ground is very damp) whereas one week seldom goes by without an accident occurring in Afghanistan (hard barren ground). It is advisable to make sure that the probing operators do not carry any metal object that might trigger a magnetic mine.

MAGNETIC DETECTION

Magnetic detection consists in searching with portable detectors (magnetometers) the metal parts of the mine (casing, parts of the mechanism, etc...) Mine clearance is no faster than human pace. While such systems are efficient in those areas where ancient, metal mines were used, they may fail to detect more modern, non-metal mines (approximately 10% of all).



The Afghan programme chiefly uses manual mine-clearance methods. The basic team is divided into 4 sections. Each section has 3 opening units under the supervision of a section leader. Dogs and flail-equipped vehicles are sometimes used as a complement.

Today we can look back overalmost 10 years and give an approximate evaluation of the progression of mine clearance.

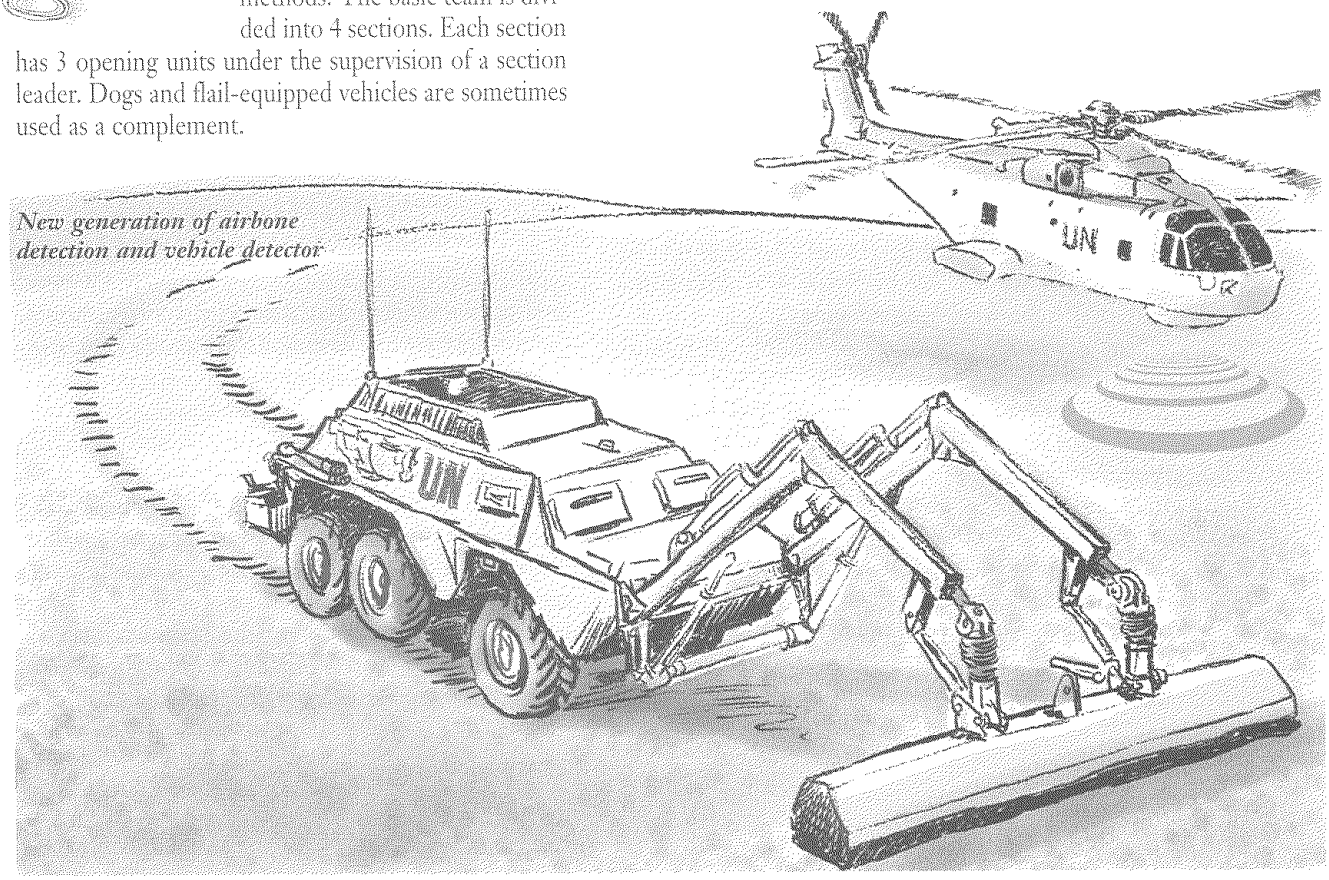
In Afghanistan, it was estimated that a team consisting of thirty experts could clear daily up to:

- 2 500 to 5 000 sq.m in an easy ground
- 1 500 to 2 000 sq.m in an average-difficulty ground
- 800 to 1 200 sq.m in a difficult ground

However, these figures may be greatly modified depending on the density of the metal objects present on the ground (either dangerous or harmless).
Planning is usually based on the estimation that a mine-clearing team will clear between 300 000 and 400 000 sq.m per year. **(See appendix 6, page 77, «The limits of magnetic detection»).**

SEARCHING FOR NEW MODES OF DETECTION

The unsatisfactory results achieved so far (and expected to be achieved), plus the prohibitive cost of the operations put the focus on research and development which will hopefully be able to provide fast substitute methods with high levels of safety, accuracy and profitability. Technology has been progressing so slowly in the area of mine detection since the development of non-metal mines that research today merely consists in exploiting concepts from other scientific areas. Many scientific discoveries formerly tested in other areas should help achieve the following objectives:



New generation of airbone detection and vehicle detector

locate with a 90% success rate and a precision to the meter a mine larger than 4 cm in diameter buried 8 years ago, 7.5 cm below ground surface.

These results should be achieved with a decent false alarm rate. A fairly precise picture of the detected object should therefore be available in order to avoid excavating non-dangerous items.
Bomb-disposal experts tend to recommend the development of cheap, low-maintenance devices more convenient in mined, not well-served areas. They favour portable devices but researchers contend those are not sufficient, as a system moving no faster than man pace could by no means provide an economical and effective solution to the huge problem of mines.

Systems may be classified into categories according to their mode of operation:
- portable (like the metal detector)
- mobile on a vehicle and/or air-transported

Another distinction can be made based on technical characteristics:
- detection of specific elements in the mine: presence of metal (in the case of the detector) or nitro compounds (explosive).
- detection of an abnormality resulting from the presence of the mine within a natural environment: resistance to the probe, as well as a series of magnetic or dielectric disturbances...

DETECTION OF SPECIFIC ELEMENTS

As previously discussed, in many cases, metal is no longer regarded as a specific part of the mine; in fact, very little metal is used.
Detection of the explosive, no matter by which means, would seem to be the most satisfactory since it can not be taken apart from the mine. Most explosives used in the production of mines contain nitro derivatives.

In their natural state, nitro compounds are present in very small amounts in the ground (less than 0.1 %), while they represent between 10 and 40% of the explosive by weight. Moreover, no casing can be hermetic enough to prevent a minimal amount of the explosive used from evaporating therefore the method based on the detection of traces of explosive (the minimum detectable amount was determined to be 10-3 nanograms by the American Army) appears to be one of the most efficient ones.

• Use of mine-clearing dogs

Dogs have been trained to participate in mine-clearing operations for years and in many parts of the world. The dog's sense of smell is well known to outdo the human one, and it enables dogs to detect explosives or other substances even in very small amounts. However, the dog still can not provide a solution in all cases of mine-clearance, due to the fact that their mode of detection is based upon the movement of air conveying exhalations of the explosive. If some misleading current were to divert the smell of the explosive, the dog might end up following it all the way down to the mine itself.

The Soviet troops were said to achieve satisfactory results by using dogs for the detection of mines, especially during pursuit operations, where their opponents would lay mines to delay their hunt.
This is not surprising then, since the mines had been laid just in the few hours, or minutes, before their detection. In such circumstances, there had to be traces of human smells and other ground disturbances at the very place where mines had been laid, as well as recent exhalations from the explosive. Such clues could not escape any trained dog (Unfortunately, those conditions deteriorate over

time, as clues tend to ebb away). The use of dogs is most effective in locating mined zones. In all cases. the dogs should have received extensive training and be attached to one dog-handler specifically; dog-handlers themselves should be highly-trained and motivated.

Dogs should work for fairly short periods of time, usually no longer than 40 minutes depending on the surrounding conditions, with long rest breaks in-between. Those dogs require a veterinary follow-up and a specific diet, as well as unrestricted water Similar to humans, dogs may exhibit depressive symptoms if their motivation happens to decline. In a hostile environment, using dogs is particularly tedious.

Dogs used in mine-clearing operations are psychologically trained to detect some specific substance (nitro compounds in the explosive, see **Appendix 1**). Their sensory detector is located in the mucous membranes of their muzzle which allow them to analyse the aerosols. Their performances are outstanding but they do have a limitation: contrary to humans, dogs do not regulate their central body temperature by perspiration, but instead by panting, which presents the drawback of making their mucous membranes dry and therefore make them less efficient. It is therefore important to restrict the use of dogs in very hot and dusty environments; it is critical to give them great amounts of water and observe their rest time.

• Technologies to enhance the performances of the dogs

Another way of exploiting dogs in the detection of mines is to collect samples of air in areas where the presence of mines is suspected. The air is absorbed by filters where exhalations, including nitrogen fumes, are concentrated.

All samples are tightly sealed, in order to avoid contamination by one another. They are also clearly labelled to determine the location where they were collected. All samples are then presented together to the dog in a central location with highly controlled conditions; the dog will examine all smells in turns. Whenever the dog reacts to a definite sample, the area where it was collected is subjected to further investigation.
This technique, still in the process of development, requires further improvement.

3. TREATMENT OF MINES

CURRENT METHODS

THE MANUAL METHOD

Peace-time mine clearance relies mainly on the **simplest, yet the most dangerous** and **physically challenging techniques**. It comprises at least the following two phases: identification and on-site destruction Neutralization performed in order to allow subsequent destruction requires very delicate handling operations

• Identification of the devices

The identification of the device may be immediate because within a given area, the number of different models used is limited; however, the possibility of a different model being found can not be overruled. The mine-clearance operator will have to interrupt his work for an indefinite period of time. Part of the difficulty is due to the existence, besides the 360 known models manufactured by about 100 firms in 55 different countries, of numerous sub-models generated by adapting different mechanisms The following categories should be distinguished:

- modern mines (ex: non-metal)
- older mines (ex: metal)
- copies of existing mines
- home-made mines
- transformation of ammunition into antipersonnel mines

Some of the mines may be equipped with traps. Some mines, usually having the same general appearance as the others, are equipped with an «anti-discovery» system with the purpose of killing or seriously injuring the mine-clearing agent.
The identification is mainly based upon the experience of the mine-clearing agent, either that he has already run into this kind of device, or he has received a training enabling him to analyse and dismantle any kind of pyrotechnic device. Some military certifications, such as «EOD» (Explosive Ordnance Disposal) or «NEDEX» (French Army), should enable an expert to handle a device he has never seen before, and also to teach the rest of the team how to neutralize it. Therefore, it is advisable that at least one of those experts be present on each worksite.

• Destruction - Neutralization of the devices

On-site destruction

Mines that were located and identified are usually destroyed locally. This operation is usually achieved with the use of specific explosives (demolition charges, as well as explosive foams or even hollow charges) so as to cause the device to **detonate**.
This method is easily applicable, and because it does not involve too much handling operations, it is also fairly safe. It requires the use of explosives (wicks, detonators and explosive cordons. The amount of explosive can range up to several hundred grams per mine, depending on the nature of the casing and the size of the unit package. Obviously, with such items, very strict safety norms must be followed throughout transport and storage. Not only do the norm relate to the risk of accidents occurring, but also to possible robbery or embezzling.

Besides, this kind of destruction may give rise to undesirable side-effects:

- In the case of **particularly dense** minefields (frequent in Cambodia), the mines are so close to one another that the explosion of one could, by a chain reaction (sympathetic explosion), cause the explosion of many