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* Photos and figures used with permission from Saricon of The Netherlands. All other photos and figures by Robby Dehondt.
Executive Summary

The Saricon Company is a leading provider of UXO removal services in the Netherlands. In terms of their clearance techniques, they operate using pure UXO clearance techniques. This includes the use of magnetometers, borehole sensors and when required standard metal detectors. Their emphasis is on locating the UXO and not on clearing ground. The difference being that high investment is made on collecting and analyzing UXO contamination information, then making decisions based on the information obtained. This approach rationalizes the clearance methods used on a case by case basis and is the most economical. The recommendations in this report reflect many principles and methods used by Saricon.

Ground preparation contributes significantly to increasing clearance productivity. Currently UXO LAO uses a mixture of hand tools and mechanical vegetation cutters. Hand tools are too ineffective and UXO LAO will increase its clearance productivity if more mechanical cutters are purchased. Ideally, each lane will have a mechanical cutter. Burning vegetation is also an option but should be restricted to Orange scenario tasks only.

In the later half of 2004, detector testing was conducted to find a suitable replacement for aging detectors currently used by UXO LAO. This testing was exclusive to one type of technology. The project needed to determine if this technology was the most appropriate and conducted a trial in late 2005. As a result, this project can recommend to UXO LAO that detectors with small object discrimination technology, good clearance depth ability and accurate target pinpointing is more appropriate for their line of work than the current technology used. The detector tested that best meets these criteria is the Vallon VMXC1. Additionally, this project recommends the following: That the large loop Upex 740 detector are consolidated in provinces with minimal areas of magnetically susceptible soil so that these detectors can be used on a more regular basis. That the recently purchased large search heads for the F1A4 Minelab detector be used as the standard search head, where available. That the Red cap of the Minelab F3 detector be used, replacing the use of the black cap.

Increasing clearance productivity is not only limited to the use of the most appropriate technology. The way field staff operate their tools and are arranged also effects how much work is completed.

The Deminer works as an individual in a clearance lane. This is not common in Europe and recent observations and trials suggest productivity synergy can be obtained by pairing Deminers in clearance lanes. This approach reduces downtime in task transfer, maintains work momentum and introduces concurrent activity. Proving one system over another can be a difficult thing to prove within the limitations of a trial. However, there is a strong believe in lane synergy and this is a recommendation of this project.

The Enhanced Technical Survey project identified two clearance scenarios that UXO LAO constantly come up against. One is known as the Orange scenario where only land service ammunition is found. This area can be cleared using less sensitive detector settings to hasten clearance and increase productivity. The other is the Red scenario where standard sensitivity settings and methods would be used.
Clearing Orange scenario land requires different procedures. It is recommended that UXO LAO clearance teams use a detector setting of a BLU-26 @ 15cm and clear areas in blocks of 10m x 10m. In the case of finding a Bombie, the clearance team switches to the Red scenario settings. They clear the remainder of the land with this setting, starting from the block where the Bombie was found.

This project recommends to UXO LAO that its principle of using large search head detectors (i.e. detectors that decreases the intensity the magnetic field generated) be used in conjunction with lane teams appropriate for the use of the equipment. This would mean, when using the Upex 740 detector, three persons are allocated to a clearance lane. One person will be at each side of the detector with one of them operating the controls. The third person is following the front pair and conducting investigations. It is recognized that the Upex 740 can not be used everywhere.

In concurrence with the principle of large search heads and lane teams, this project recommends using the Vallon VMXC1 detector with two people in a clearance lane as the standard clearance system. One person would be operating the detector while the other is conducting the investigations. There is no need to have any safety distance separating these two operators.
Main Conclusions and Recommendations

A better clearance system includes three new elements; the use of detection equipment with discrimination technology, the use of clearance lane teams and a stronger link with the technical survey. These three elements represent conclusions made after comprehensive testing, consultation and research. In many ways, including these three elements brings UXO LAO operations more in line with conventional UXO disposal operations as conducted in Europe. The following recommendations represent details that support these three principle aspects.

UXO LAO needs to invest further in mechanical vegetation cutters. The clearance of vegetation is a significant contributor to land clearance productivity. Investment in more vegetation cutters is a necessity. Ideally each clearance teams would have its own mechanical vegetation cutter (weed whackers), otherwise time and effort will be wasted.

UXO LAO needs to employ detection equipment with discrimination technology as the standard UXO clearance tool. Testing has shown the value of discrimination technology. Currently the best available includes technology with the ability to ignore small pieces of scrap metal by determining object size through analyzing the decay times of the secondary magnetic field produced in the object located.

The ability to ignore small pieces of scrap metal will result in a very significant increase in clearance productivity. The detector tested and recommended is the Vallon VXMC1. This detector is still a prototype and further software improvements are still required. Additionally, the size of the search head is considered slightly too small. Therefore, extra time and investment may still be needed to produce the optimal detector for UXO LAO. There is, however, no reason why the Vallon VXMC1 can not be deployed in its current form (if ignoring the subjective requirement for a large search head) as software updates can be loaded onto the detector at a later date.

UXO LAO should adopt a new clearance system which involves a UXO detector being deployed in conjunction with Deminers in “lane teams”. Beyond using the large loop detector involving a 3 person team procedure. UXO LAO needs to adopt the principle of deploying UXO detectors with 2 man lane teams as its standards clearance method.

The benefits of 2 man lane teams are numerous. This includes the ability to employ a rotational system between the two operators, reducing work fatigue. Some activities can be conducted concurrently (e.g. detection and the removal of vegetation or lane making etc.,), Much faster signal investigations are conducted and when the clearance site becomes small, meaning fewer lanes can be deployed, more Deminers are at work. While the feedback from the field was not positive when trialing this approach, the reasoning behind the negative feedback was considered too subjective.

UXO LAO needs to clear land according to recommendations made by the survey team. As a result of the Enhanced Technical Survey project. The survey teams have the means to identify areas in which there is little evidence UXO (specifically Bombies) are present, this is known as the orange scenario. These areas can be cleared.
using hastened techniques as the information does not justify full clearance commitment.

Facilitating this approach is the requirement to recognize two different clearance standards. They are: clearing Orange scenario land with a detector setting of comfortably locating a BLU-26 @ 15cm from the surface of the ground and clearing Red scenario land with a detector setting of comfortably locating a BLU-26 @ 25cm from the surface of the ground.

**UXO LAO needs to adopt the orange scenario procedure as described in this report.** The recommended procedure involves clearing in 10m x 10m blocks and switching detector settings from a BLU-26 @ 15cm to a BLU-26 @ 25cm if and when a Bombie is located. This procedure is required should information about an area be imprecise. This represents an ability to react to new information.

**UXO LAO need to adopt a standard test piece approach.** The use of test pieces to calibrate detectors in the field is a standard method around the world. The test piece should be used to calibrate detectors to the standard of clearance. This study recommends one standard test piece for the Orange scenario and one standard test piece for the Red scenario, as described above.

**Equipping the entire UXO LAO operation with new small object discrimination technology is probably not possible in the short term. Therefore the following is recommended:** UXO LAO needs to consolidate all Upex 740 large loop detectors in the provinces not normally affected by the presence of magnetically susceptible soil. UXO LAO should better organize the equipment they currently have. It is well recognized that this detector is not cable of operating in areas with magnetically susceptible soil. This problem does not occur over the entire country. There are probably enough units in country so that clearance teams in a few provinces can be fully stocked making this unit a full first choice option for every clearance task.

The large loop detector has proved to be effective technology in locating UXO while minimizing the occurrence of false readings/investigations. There needs to be a conscience effort to deploy this technology wherever possible. Clearance teams must first think of using this technology, if not possible, then switching to their conventional detectors. The large loops detectors are here and add value – so use them.
A 3 person clearance practice is recommended. This involves 2 persons carrying and operating the large loop in the 1m x 1m configuration (highest clearance effectiveness) and marking all signals. The third person then follows and investigates all signals marked by the forward pair.

It is important that the third person operates a detector with a small search head so that they can identify the spot of the signal with precision. The Minelab F3 detector fitted with the Red cap is recommended for this role.

**UXO LAO needs to fit the large search heads of the F1A4 as standard.** The large search head option for the F1A4 has a proven ability to ignore small metal pieces far better than the small search head option. This is because large search heads induce a less intensive magnetic field, making smaller pieces of metal more difficult to detect. Ignoring small metal fragments results significant increases in productivity.
Clearance System Study

decisions = efficiency

Introduction

The clearance system study was initiated in August of 2005 in response to recommendations made during the U.S. State Department led technical review conducted in Sept and Oct 2004.

It was strongly believed by NPA that UXO LAO can increase the total amount of land cleared by adopting credible changes in the methods used to clear land of UXO. These changes should better reflect the ERW situation UXO LAO is facing, or in other words, changes that move UXO LAO away from mine clearance techniques to pure UXO clearance techniques.

Aim:

The basic aim of the clearance systems study is to provide UXO LAO with examples of how productivity increases can be obtained through the use of alternative equipment and/or procedures that are easily assimilated into UXO LAO operations.

Concurrently with this project, UXO LAO were undertaking their own internal review of current working methods in order to improve overall operational performance. This included a review of operational structures in the provinces and the first Standard Operating Procedure (SOP) amendments. This report is therefore focused on elements not covered or examined in this internal review.
Foreign Examples:

The Saricon Company of the Netherlands

Introduction
During World War II, The Netherlands was extensively bombed and fought over by both Axis and Allied forces. As a result, countless tones of live ammunition remain in Dutch soil posing a hazard to civil land development.

In recognizing the UXO hazard, the Royal Netherlands Government determined, some years ago, that all land about to be developed shall first undergo a risk assessment regarding the probability of the existence of UXO and, if warranted, further operations are required to remove the potential hazard. As a result of this law, companies specializing in providing explosive remnants of war (ERW) removal services were established. Many of the commercial companies have been offering UXO disposal services for decades, while humanitarian mine action is relatively new by comparison.

Typically, UXO detection and disposal operations in The Netherlands precede a range of land development projects and operations, this includes:

- Earth piling
- Sewage work
- The laying of cables and piping
- Bridge Construction
- Earth drilling
- Tunnel construction
- Railway construction
- Dyke improvement and dredging

During March 06, NPA visited “Saricon” a Dutch company specializing in the detection and disposal of unexploded ordnance. The aim of the visit was to investigate what UXO LAO clearance operations could learn from commercial companies operating in Europe. Saricon is one of the leading UXO detection and disposal companies in the Netherlands.
Concept of Operation

A typical Sacricon operation can be broken down into 6 steps (see illustration above). First there is the preliminary investigation. This involves analysis of historical information including the analysis of aerial photographs, witness reports, on site investigation and archive research.

This phase is used to determine what further physical action will or will not then be required. Hence the inclusion of a team consultation phase as this step requires thorough investigation and general agreement based on information, logical deduction and experience. Importantly, conclusions drawn in this phase are used to support actions in all other phases.

Next is the construction of an operations report which typically includes a map of the risk area, type of munitions expected or suspected to be in the risk area, their condition and any location information which could effect the way the operation could be conducted (e.g. location of vulnerable assets like power lines and residential buildings). A subjective risk analysis incorporating many of the pre-mentioned conditions is also included. This phase is then documented.

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1 Source: Saricon 2005 Copenhagen presentation
A project plan is then drafted. This includes many of the elements previously identified along with logistical, administrative elements added to it.

Once all possible UXO contamination information is gathered, a decision is made as to how the risk area is best approached; considering the client’s requirements and financial restraints. Note that not all UXO operations involves the detection and removal of UXO. Some contracts only involve an historical investigation to confirm that further detection is not warranted.

Normally, detection operations are categorized into either surface detection or bore-hole detection. The former in areas identified as having been fought over and therefore requiring the clearance of land service ammunition. The later in areas identified as potentially being contaminated with air dropped bombs only, which are likely to be deeply buried. The final decision, as mentioned, involves a clear understanding of the client’s requirements.

Notably, Saricon offer an extensive range of detection and clearance options, matching the most efficient means of detection and clearance with the particular risk area’s circumstances is what makes the company as efficient as possible (see Annex C for a basic profile of the detection and clearance options used by Saricon).

As part of the detection/clearance phase, UXO are localized (with search equipment) and identified (by excavation and analysis). They are then secured for removal and then transported to a safe area for disposal.

Finally, all commercial companies are required to submit a final completion report for all tasks conducted.
**Observations of Significance**

During the visit, countless decisions and demonstrations took place regarding clearance procedures and clearance systems. A summary of significant differences in their operations to UXO LAO operations includes:

1. There is a strong link between the Technical Survey and the Detection/Clearance phase. What is determined in the Survey is used to guide the Detection/Clearance actions. This includes extensive use of database and research information.

2. Detection and Clearance are two separate phases. On certain tasks, Saricon conduct a Detection operation, and then conduct a Clearance operation only when items are actually detected or need investigation. The two phases are separated as it is more efficient to confirm areas as UXO free during a detection operation than to expect them and clear these areas.

3. Choice of Detection/Clearance method is based on an assessment of the risk area – no single standard procedure is used. This is so inefficient clearance overkill is avoided where possible.

4. Detection equipment sensitivity is determined by the result of an assessment of the risk area in question. Essentially, Saricon are clearing UXO as opposed to clearing the ground suspected of having it. The difference is not semantics but can be explained by defining clearing UXO as hunting while clearing land is fishing. Hunting UXO would involve using data and information to determine clearance requirements, while fishing is blindly clearing to an acceptable depth and recording whatever was caught.

5. The area to be cleared is not only determined by the requirement of the area under development. It may also be determined by what information is gained from the preliminary investigation and survey (see photo on the left).

6. Saricon primarily use passive (Magnetometer) search equipment. They have recently purchased a dual (passive and active sensors) detection instrument so that the quality of information from one type of sensor can be verified by information from the other. This reduces the over all false alarm rate during the clearance phase.

7. It is more accurate to say that Saricon are in the safety and risk industry and not the UXO removal/disposal industry. They exist to evaluate and weigh the risk of UXO contamination and react accordingly. Not just clear areas of land.
UXO LAO Clearance Operations Analysis

Ground Preparation
Ground preparation is recognized as a key area in the effort to boost productivity. Many mine clearance operations around the world have invested in mechanical systems aimed at preparing the ground for clearance as the investment can result in significant increases in productivity.

While arguably, mechanical systems are more suited to minefields than UXO LAO operations, the principle of investing in vegetation cutting equipment to hasten subsequent clearance is well understood and accepted worldwide.

UXO LAO have invested in hand-held mechanical vegetation cutters or “weed whackers”. A small number of these are available in each province. The issue is that there are too few machines to significantly impact on the clearance productivity of UXO LAO.

Most vegetation clearance is therefore conducted by using large machete knives (see photo). This is time consuming and not as effective as mechanical options.

A Deminer can clear more land per working day if the area is properly prepared with vegetation removed down to ground level. In this environment, the Deminer maintains clearance momentum. Time is not wasted in moving obstacles, re-cutting vegetation and removing and burning the foliage.

It is best if the task of cutting vegetation and preparing the ground is separate from and conducted prior to clearing the ground. Merging these tasks courses a significant loose in work momentum.

Options for Assistance
It is common for UXO LAO clearance teams to elicit the support of local villagers in preparing the ground for clearance. Their preferred method is also to attack the area armed only with machetes. However, unaware of the standards of ground clearance required to maximize speed clearance, the locals tend to leave the field with some vegetation work still required. This opportunity is obviously still beneficial as the work is significantly reduced. One option is for the local villagers to be encouraged to burn the area (if it has been burned in the past). Burning vegetation is an effective means of vegetation removal. While there are concerns regarding the effect of burning on UXO on or near the surface of the ground. The burning of vegetation in some mine action centers (particularly Cambodia) is routine (standard procedure of the last 10 years) with no real ill-effects reported. Furthermore, it is common to slash and burn areas for cultivation in Lao.
Clearance Procedures
It is clear that the clearance procedures used by UXO LAO are recognizable as mine clearance procedures. However, over the years a form of natural evolution has occurred to the extent that the procedures used can still be identified as mine clearance drills but are now wholly inadequate to actually clear mines. The actual clearance procedure conducted in UXO LAO today is more accurately defined as a hybrid of mine clearance and UXO clearance procedures.

A hybrid procedure does not make much sense. For conducting these drills in mined areas it is not safe to say the least. And to conduct such drills in pure UXO areas is inefficient.

An example of this hybrid procedure is the fact that the area being cleared is repeatedly walked over (as mentioned local villagers are even asked to come in to the site to clear the vegetation) and excavations of suspected objects are conducted directly on top of the object. Neither of these two aspects is tolerable for the clearance of mines. However, the positioning of lanes and Deminers (e.g. safety distances and one lane one Deminer operating) plus the extensive marking of the field are hallmarks of a mine clearance operation.

UXO clearance procedures are differentiated by the type of detectors used, the reduction in field marking requirements, the arrangement of Deminers in the field (particularly closer safety distances) and the methods and tools used in investigating detector signals.

Over the course of this project, recommendations regarding the shortening of distances between Deminers were accepted and implemented by UXO LAO. Additionally, UXO LAO decided that they will reduce the requirement for marking. Both decisions reflect a switch to more conventional UXO clearance procedures and were done to increase clearance productivity.

Deminer Drills
Once the Deminer is given the best equipment to conduct their drills, optimizing their performance is a matter of designing processes that maximize productivity.

UXO LAO Clearance teams work one man one lane clearance drills. This requires the Deminer to perform the entire range of clearance processes by themselves. Each switch to a new task/tool represents a delay in conducting clearance and an opportunity to delay further. There are other ways of conducting this process which can result in increased productivity. The one man one lane drill verses the two man one lane drill has recently received much attention in mine action programmes around the world.

In 2004, the Cambodian Mine Action Center (CMAC) conducted a study to investigate which lane structure (one man or two men) was more productive. CMAC trialed a number of different combinations and concluded the following:\(^2\):

\(^2\) Information provided by Mr. Prom Suon Praseth NPA Mine Action Coordinator, Cambodia, by email 9 May 2006.
1. The one man one lane (OMOL) drill is more effective in minefields with low vegetation or supported by mechanical bush cutters.
2. The two man one lane (TMOL) drill worked better in minefields with heavy vegetation, resulting in higher productivity than the OMOL drill in similar conditions.

Scientifically calculating productivity increases when comparing OMOL to TMOL is inaccurate (the Hawthorne effect\(^3\) being just one obstacle) and situation dependent, as evident from the CMAC trials, it can depend on the situation of the minefield.

If UXO LAO adopts the Discretion Model (see Annex B), then the occurrence of working in low vegetated areas (cultivated land) will be few. Also UXO LAO do not employ the same type of mechanical vegetation cutters as used in Cambodia, where large plant machinery is adapted for this purpose.

Arguably, using two men in a clearance lane represents a further shift from mine clearance drills as this is a common approach with UXO disposal companies in Europe.

We believe the two man lane clearance drill provides the greater productivity potentially compared to the current OMOL drill. A form of synergy can come from pairing Deminers in the UXO clearance contest. The main reasons for switching to a TMOL drill include:

1. A rotation system can reduce worker fatigue which could result in reduced downtime periods.
2. Concurrent activity is possible with some aspects of the process (detection and lane marking etc.,)
3. Signal investigations are conducted much faster
4. When the site becomes small, more Deminers can continue work, and
5. Equipment costs are reduced in both the short and long term.

**Standards**

Standards of or for clearance is a critical element. Not only in regards to the quality of final product but also in designing the actual clearance process. According to the UXO LAO Standard Operating Procedures, the standard detector capability is “determined against a standard sized test piece simulating the smallest UXO that poses a danger to staff. This is deemed to be a bombie fuze of 20mm diameter.”

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\(^3\) The "Hawthorne effect" was not named after a researcher, but refers to the factory where the effect was first observed and described. One definition of the Hawthorne effect is:

- An experimental effect in the direction expected but not for the reason expected; i.e. a significant positive effect that turns out to have no causal basis in the theoretical motivation for the intervention, but is apparently due to the effect on the participants of knowing themselves to be studied in connection with the outcomes measured.
Arguably this standard represents an approach of clearing or targeting land and not UXO. This is because the standard is not based on field data and it relates to a UXO item that is not really found by clearance teams. Additionally, it is not found as deep as the detectors are calibrated to for the clearance. There is significant overkill in detector calibration and this is a significant contributor to low productivity rates.

Furthermore, no actual standard detection depth is stated as; the standard is to clear “to the maximum detection capability of the detector used”. This of course is not consistent as UXO LAO use a wide selection of detectors, with different capabilities, some of which can not be calibrated.

The issue is not that the UXO LAO clearance standard is wrong. The approach simply needs to be realigned with the experiences and information gained from over 8 years of clearance operations. A clearance standard of calibrating all shallow clearance detectors to easily locate a BLU-26 bomblet at a depth of 25cm is recommended. This should be further supported by collecting and documenting the clearance depth of all UXO located in clearance operations.

Note that the smaller 20mm HE projectile can also be located at significant depths when calibrating the detector to the BLU standard. In any case, this report goes on to recommend a detector that can discriminate against specific sized metal pieces (length and wide) ignoring anything smaller. The length and width chosen will include the 20mm HE projectile leaving the BLU standard as a matter of setting the detector depth.

**Technology**

In general equipment used in the field is of a standard suitable to the financial, geographical and occupational conditions. A key issue, however, is the choice of technology used to locate UXO. The most common detector used is the Minelab F1A4, which is more appropriate for the detection of minimum metal mines and not UXO.

One of the reasons for initiating this project was a strong belief that the technology represented in detectors like the Minelab was not appropriate for the type of clearance UXO LAO conducts.

**Detector testing**

The Joint Research Centre (JRC) conducted a detector trial for UXO LAO from 27th September to 5th of November 2004. This trial formed part of their systematic test and evaluation of metal detectors project.

The purpose of the trials was to:

- Assess metal detectors which had been previously identified as possibly suitable on the basis of lab tests and on the advice of manufacturers.
- Provide UXO LAO with performance data, which will assist in the selection of future equipment.
- To extend the application of the CEN Workshop Agreement (CWA) to small items of UXO.
The objective of the trial was to:

Carry out the acceptance trial to the following requirements:

- Ability to detect BLU-26B and 20mm cannon shell targets up to 300mm deep and,
- Ability to reject small pieces of scrap metal.

Notable about this trial was that all detectors used were of very similar technology. This is in-line with the CWA and common trial methodology as a comparison trial was being conducted. The data from this trial was helping UXO LAO determine which metal detector was the best for them. Not which type of clearance technology is best for UXO LAO. This question could not be answered in the JRC trial. As part of the systems clearance study, a separate trial was therefore conducted by NPA.

The aim of the testing was to see which technology could effectively locate a target, which reflected the ERW situation in Laos, and did this the fastest as measured over a 50m working lane. Note that the term fastest was defined by identifying the technology that ignored most of scrap metal laid in the test lane.

The following different technologies were tested:

- Ground Penetrating Radar.
- Pulse induction with low intensity magnetic field.
- Pulse induction with high intensity magnetic field.
- Pulse induction with time decay discrimination.
- Sine wave with low intensity magnetic field.
- Magnetic locator with no compensation ability.
- Magnetic locators with compensation ability.
- Magnetic locators with evaluation software.

The test method

A 50m long testing lane was set-up in a school ground recently cleared by UXO LAO.

The targets were BLU-26 Bombies located at depths from 20cm to 15cm. Additionally, 150 metal pieces were laid to represent typical scrap metal found on a clearance site. Scrap metal pieces varied in size from 1 to 5 cm. They were represented by cut pieces of reinforcing rod.

All detectors were applied to the test lane. The operator was required to mark all signals by placing a small plastic marker on the spot indicating the presence of an object. When the operator had completed the lane, the grid frame was fitted to each square meter. As the location of each piece of scrap metal and Bombie was known, the results of each detector were compared to the master sheet to determine how many Bombies had been located as well as how many pieces of scrap metal were also
located. The preferred or quickest detector would then be determined by which could locate the Bombies as well as the least quantity of scrap metal.

The following detectors were tested at the site:

- **Vallon VRM1** dual sensor detector – combining conventional metal detection technology with ground penetrating radar (GPR).
- **Vallon VXCl** magnetic locator - technology that locates UXO by recognizing magnetic anomalies caused by the presence of Ferro-magnetic objects i.e. UXO.
- **Schonstedt GA 72 CD** magnetic locator.
- **Minelab F1A4** – minimal metal mine detector used in the test for comparative purposes. It was tested with and without a UXO search head.
- **Minelab F3** fitted with a black cap – minimal metal mine detector used in the test for comparative purposes (currently used by UXO LAO).
- **Minelab F3** fitted with a red cap – available to UXO LAO but at the time of testing was not in standard use.
- **Ebinger UPEX** large loop detector – conventional metal detector technology but maximizing the advantages of magnetic field dispersion.
- **CEIA UXO** – dual search head technology also with magnetic field dispersion.
- **Vallon VMHS UXO** – conventional metal detector technology.
- **Vallon VMXC1** – conventional metal detector with discrimination technology.
- **Vallon VMH3CS** – conventional UXO detector with magnetic field dispersion.

**Previously tested:**
- **VD1** – Vietnamese detector used by local scrap metal traders (tested by NPA, and considered far too in-sensitive a detector).

**Results and Conclusions:**

![Figure 8: Table of Detector trial results](image)
As stated the idea was to single out the fastest detector as this would represent significant productivity increases for UXO LAO. That was defined by identifying the technology that ignores the most scrap metal pieces while also locating the UXO targets. As a result of this testing, Ground Penetrating Radar (GPR), magnetic locators and sine-wave technology are ruled out as being appropriate for use as standard clearance tools.

Pulse induction with small target discrimination technology is the most appropriate technology for UXO LAO. Of all the detectors that proved to have small target discrimination, the detector considered most appropriate for UXO LAO clearance operations is the Vallon VMXC1. Other UXO detectors have similar ability to ignore scrap metal (e.g. CEIA/D1/DS) but pinpointing targets becomes difficult as their search heads are too large (reflected in their time to complete the test lane). This can be overcome by having one Deminer mark the approximate location of the signal so that a second Deminer, following with a small search head detector, can locate the item and conduct the investigation. This will, however, increase the detector investment required. The Vallon VMXC1 has a small search head. It is essentially a UXO detector in a mine detector’s body. It can both discriminate against small pieces of metal and accurately pinpoint genuine signals of interest. Moreover, it can compensate for the magnetically susceptible soil found in Lao PDR, were as other technologies struggle.

A small explanation of the discrimination principles in pulse induction technology available is necessary to explain our recommendation.

Essentially there are two methods to ignore small metal objects. One method is by decreasing the intensity of the magnetic field on the detector’s search head. The effective range of a detector depends to a large extend on the diameter of the coils used in the search heads\(^4\). UXO Detectors are required to detect objects deeper than mine detectors. Therefore they tend to have larger search heads. The added benefit of this is that the large search head further disperses the magnetic field on the search head making it weaker. It therefore is less able to detect small scraps of metal that would not represent the size of even the smallest UXO (hence it can not be used for mine clearance).

This technology immediately seems more appropriate for UXO LAO who do not clear minimum metal mines but are required to clear larger UXO at much increased depths. The disadvantage of large search heads is that pinpointing targets is more difficult.

![Figure 8: magnetic field intensity](image)

Another method of discriminating is by including algorithms within the unit’s software that can ignore certain sized pieces of scrap metal. When the magnetic field of the search head induces a secondary magnetic field, this secondary magnetic field decays. The rate of decay depends on the size of the object (an analogy would be that

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larger stones in a fire, keep their heat longer than smaller stones would). Software within the electronic unit can be used to recognize the decay time of each object located. The detector can and will ignore decay times considered to quick to represent an object worth investigating (see annex B for an explanation of the Vallon VXMC1’s dual discrimination technology).

The ideal detector, therefore, would be a combination a small UXO search head with discrimination software as specific sized targets can be located at reasonable depths while minimizing the false signal rate. These attributes are reflected in the choice of the Vallon VMXC1 detector.

There are additional recommendations from this testing that UXO LAO can implement now based on current equipment. This includes:

1. The maximum use of the Ebinger UPEX large loops\(^5\) currently available to UXO LAO. These units have been available to UXO LAO for sometime but seldom used. UXO LAO needs to consolidate the use of large loops in provinces not regularly affected by magnetically susceptible soils. The large loop should be the first choice in these areas. However, it is fully understood that this would not always be possible. Therefore, Clearance teams also need the ability to fall back on to their normal detectors and clearance methods in specific cases.

2. A switch from using the black cap of the Minelab F3 to using the red cap as standard. The black cap is designed for detecting minimum metal mines. It is out of place in the UXO LAO contamination environment. The Minelab F3 fitted with a Red cap, however, represents a quick alternative. Testing shows that the Red cap is capable of detecting a BLU-26 @ 25cm and does so without detecting as many pieces of scrap as the black cap. The signal strength is, however, not as strong for a BLU 26 @ 25 cm as it is with a black cap and Deminers need to be aware of this. Decreasing sensitivity always effects effective clearance depth.

3. A switch to maximizing use of the large search heads for the F1A4 Minelabs currently in use. The recent purchase of large search heads for the F1A4 again represents the acquisition of UXO detectors that are not put to daily use. Testing shows that this detector can locate the threat while also minimizing the false signals. Placing all available large search heads on the F1A4 would represent an action UXO LAO can do now to increase productivity. Ultimately, however, this technology needs to be replaced by that recommended.

4. Schonstedt magnetic locators are cheap and effective. They, however, increase the occurrence of false signals as they react to magnetic hot spots which they can not be calibrated to ignore. The Vallon magnetic locator can be calibrated but its sensitivity performance is in question.

\(^5\) The CEIA MIL/D1/DS also performed well (ignoring all scrap metal pieces), however, deploying this detector operationally requires the use of a second small search head detector, extensive marking of lanes and the most changes to standard operating procedures.
Linking with the Technical Survey

Getting information and benefiting from it
The enhanced technical survey project concluded that more efficiency and effectiveness can be gained from acquiring more information. There is no use in acquiring better information if you are not going to use it. Information gained in the survey should be used in decisions on where and how to clear a particular area. In particular, the enhanced technical survey project identified the need to have a checking method as well as a clearance method. This was in response to the analysis which identified three separate clearance situations UXO LAO generally come up against. This includes clearing areas with no UXO, clearing areas with bombies and clearing areas with Land Service Ammunition only.

Orange Scenario

The enhanced technical survey project identified two clearance situations. Known as the Orange and Red scenarios. These situations recognize if bombies are likely to be in the area or not. The Orange scenario situation is where only Land Service Ammunition is probably present. As this situation involves larger UXO that are more easily detected, a different or less sensitive detector setting would be possible. This will result in increased clearance productivity. The recommended detector setting is detecting a BLU-26 @ 15cm below the surface of the ground. The recommended detector setting for the Red scenario is detecting a BLU-26 @ 25cm below the surface of the ground.

Procedure
The difference between the Orange and Red scenario should not be limited to the detector setting. After all what happens if or when the assessment of an area is not accurate. The Orange scenario is specific to sites not containing bombies (as identified by the technical survey team). But what happens if Bombies are found anyway? Will the area cleared have to be re-cleared?

Perhaps the best way of overcoming any potential of the information being faulty is to adopt an adaptive clearance procedure. This means clearance is conducted at the above mentioned standard. If a Bombie is located during clearance of an Orange scenario site, then the standard of clearance switches to that of the Red scenario (see Red scenario). The switch would occur from and including the block where the Bombie was discovered. The blocks already cleared to an Orange scenario standard can remain that way.
To facilitate this adaptive approach, areas are best cleared in blocks with each block being 10m x 10m (see illustration) as Deminers are now 10m apart during clearance operations.

![Diagram showing block layout and Bombie locations](image)

**Figure 9: Orange scenario procedure**

On encountering a Bombie, the block the Bombie was found in is used as the new start line for the new clearance setting (BLU-26 @ 25cm).

In essence, all that is happening is the land is being checked (Orange scenario setting of BLU-26 @ 15cm). But once information determines that checking is not appropriate (the location of a Bombie), clearance then switches from a checking mode to a clearing mode (Red scenario setting of BLU-26 @ 25cm).

The enhanced technical survey techniques are designed so that convincing evidence is first obtained before the decision is made to check or clear an area. The purpose of switching from one standard to another is to appropriately respond to a change in the information that would reclassify the area.

This procedure requires specific test pieces. The test pieces recommended are easily available and manufactured in the provinces.

Both the Orange and Red scenario require their own test pieces when/if a depth stick is also used. These can be easily distinguishable by painting the Red scenario test piece red and the Orange scenario test pieces orange to prevent any mix ups.

![Photo of unpainted detection pieces used in field testing](image)

**Figure 10: Photo; unpainted detection pieces used in field testing (red scenario depths)**

23
Combining Technology with Procedures

This project has identified the requirement to combine the most appropriate technology with the most appropriate procedures. It is clear from our study that UXO detectors with discrimination technology is the most appropriate technology for UXO LAO and working in teams on clearing lanes is believed to be the most appropriate procedure.

Working in teams of pairs is the prominent clearance method used in European UXO clearance companies. It is also implemented in Laos. Mines Advisory Group (MAG) has successfully employed a 2 person lane system using the CEIA MIL/DS detector with the F3 fitted with the Red cap in their Xieng Khouang operations. This has proved successful for them and provides confidence that deploying two Deminers in a lane is not sacrificing productivity.

When testing the viability of the two man, one lane (TMOL) procedure. The UXO LAO staff were not in favor of it. They reasoned it was too slow but did not conduct any comparative testing.

Based on our detector testing, observations and consultation, this study recommends to UXO LAO the following as a standard means of UXO clearance:

Vallon VMXC1 with two person lane team

Advantages:
1. Clearance lane synergy
2. Potentially the best small object discrimination ability.
3. Reduced detector costs.
4. Ability to operate in either 1 man or 2 man drill.

Disadvantages:
1. Search head slightly too small but a larger search head can be arranged.
Note that the software (aka firmware) in this detector needs further refinement. Currently it has shown that it ignores pieces of scrap metal 4cm in length or less. This means it has the ability to locate both the 20mm HE projectile and the smallest Bombie. It is understood that its software can also ignore pieces of scrap metal based also on the width of the target. As the smallest UXO is the 20 mm HE projectile, the software needs further development to also exclude pieces of scrap metal with a width of about 18mm or less.

Field comparison of this detector, as is, was conducted with the F3 Minelab and the Vallon VHM3 CS to ascertain potential productivity increases. Results form annex D of this report and are encouraging.
References


Comparison between VMH3CS and VMXC1

This document gives a comparison between the standard metal detector VMH3 and the new UXO detector VMXC1 from Vallon. Both detectors look very similar. They work both with the same principle of pulse induction for object detection. The difference is mainly the firmware. The VMH3CS is optimized for detection of any small metal pieces, whereas the VMXC1 is optimized for detection of medium to large metal objects. In mineral mode, even a rough classification of the detected object is possible.

Advantages of the VMXC1 for UXO detection

In UXO detection, the VMXC1 has several advantages compared to a standard mine detector like the VMH3CS:

- The VMXC1 detects medium to large metal objects without a significant reduction in sensitivity for deep objects and suppresses small objects like screws, coins or cigarette foil even when this small object are lying on the surface. This leads to a reduced false alarm rate for UXO detection. The VMH3CS detects even very small pieces of metal and therefore has a high false alarm rate in UXO detection.
- Working with the detector in mineral mode, well compensated to the ground, the VMXC1 can classify the found metals. The classification is done optically by using the LED display as an indication of the type of metal found. Each object has a significant LED value that represents type of metal and orientation. For ‘ball’- like objects, the orientation is not significant and the LED value gives directly the type of metal found. E.g. BLU gives an indication on LED 9 or 10, a grenade gives an indication on LED14… As UXOs like e.g. BLUs or grenades mostly consists of iron which is ferromagnetic, the false alarm rate can be further reduced using this information. The VMH3CS does not have this feature of discrimination. Therefore a high false alarm rate is the result.
- Working with the detector in mineral mode, well compensated to the ground, the VMXC1 can classify the found objects as ferromagnetic or non-ferromagnetic metals. The classification is done acoustically by using a continuous alarm signal as an indication of ferromagnetic metal and an interrupted alarm signal as an indication of non-ferromagnetic metal As UXOs like e.g. BLUs, grenades, projectiles or bombs mostly consists of iron which is ferromagnetic, the false alarm rate can be further reduced using this information. The VMH3CS does not have this feature of discrimination. Therefore a high false alarm rate is the result.
**Comparison Summery**

Using the VMXC1 for UXO detection, a reduction in false alarm rate can speed up the clearing process. Small pieces of metallic litter are suppressed by the detector. Additionally, the objects can be classified by using the information given by the alarm tone and the LEDs.
**Technical details on metal discrimination**

In principle, the pulse induction method is described as followed:

1. The electronics unit is sending a pulse current to the search head. The pulsed current is running through the copper wire windings in the search head generating a pulsed magnetic field.
2. The search head acts as both an emitter and a receiver as it now senses the time decay of the pulsed field as it is collapsing.
3. If there is no metal objects within the magnetic field, it will decay rather fast.
4. If there is a metal object in the magnetic field range, the following happens:
   - The primary pulsed magnetic field is inducing a low current into the metal object.
   - This current is producing a "secondary" magnetic field around the metal object.
   - The primary magnetic field is collapsing. The secondary magnetic field decays a short time later.
   - The electronics unit is checking the characteristics of the decay of the secondary field.

**Function Principle - Pulsed Field**
**Small object suppression**
Small, good conductive objects (detonation pins, small springs), have a fast decay of the secondary magnetic field. To detect these types of objects, the signal evaluation of the VMH3CS starts only a short time after the primary pulse has collapsed, every small change in the decay curve can be detected.
The VMXC1 waits a longer time before the evaluation is started. Very fast decays from small, good conductive objects like steel pins or cigarette paper, where gone to zero before the evaluation starts.

**Metal discrimination**
The standard metal detector VMH3CS is only optimized to get as much out of the decay curve as possible to detect all metals with the maximum of sensitivity. Doing metal discrimination with the VMXC1 pulse induction detector, the detector is able to evaluate the shape of the decay curve. The decay curve covers all information of metal type, shape and orientation of the object. For ‘ball’- like objects, shape and orientation are not significant and therefore the type of metal can be directly calculated using special algorithms that take into account a wide range of the decay curve.

**Summary on technical details**
The VMXC1 combines these to techniques of small signal suppression and metal discrimination.
Annex B
Discretion Model

Green Scenario: Cultivated land with no evidence of UXO

Yellow scenario: Cultivated land with land service ammunition present

Orange scenario: Non-cultivated land with no evidence of Bombies present

Red scenario: Non-cultivated land with evidence of bombies present

Coloured scenario: mixing/dividing the land into appropriate situations
This machine sifts the ground and passes it through an inspection room where UXO are removed manually. This machine is most viable when deployed in areas with a high level of metal contamination.

Saricon staff conducting a magnetic survey with a multi-probe sled fitted with DGPS technology

Saricon also have the option of employing conventional metal detector technology on sites where small sized UXO are expected near the ground surface.
This is a multi-sensor deployed on a Survey task. It combines both passive and active sensors to reduce the false signal rate.

Multi-probed Magnetometers are also deployed manually in areas not suited for the use of vehicle platforms.

This machine sifts through piles of UXO contaminated soil.

Saricon drilling boreholes in which magnetometer sensors are lowered to search for deeply buried bombs.

Diver being prepared for visual search of UXO in this canal.

A magnet deployed to collect ordnance at the bed of this canal.
In dredging canals for UXO, Saricon use a method of exposing items by washing the collected mud away with a high pressure water hose.
### Annex D

**Field Comparison Data: VMXC with F3 Minelab and VMH3 CS**

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### Annex D

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