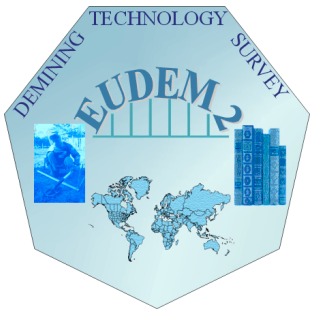

EUDEM2

The EU in Humanitarian Demining-
State of the Art on HD Technologies, Products, Services and Practices in Europe

IST–2000-29220

EUDEM2 Conference Report

Expert Workshop on Explosive Detection Techniques for Use in Mine Clearance and Security Related Requirements

2-4 June 2003, Lake Bled, Slovenia

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1. Introduction

The objectives of this workshop were defined within its agenda as follows:

"The workshop will provide a systematic, multi-disciplinary opportunity for the identification of technologies for explosive detection in general, and which may be useful for demining and security related applications. The workshop is designed to review the current state-of-the-art in explosive detection, and to promote synergistic exchange of ideas to address the technological shortfalls, thus providing a roadmap for research strategies and funding priorities. It is also expected to result in greater cooperation and collaborative international program co-ordination and planning and for the review of research pertaining to explosive detection".

Mr. Sieber, as head of the JRC-IPSC-HSU, underlined during his opening presentation the needs to improve the security of the European citizenship from a global point of view for both, terrorist activities and demining, by using the most advanced technical means of "*Explosive Detection Techniques*" (EDT). This workshop is the first to find out the common points to develop better multilateral arms control and prevent the proliferation of WMD (Weapons of Mass Destruction).

2. Notes on Individual Presentations

The individual talks will be summarised and commented in chronological order of presentation, which is, for several reasons, different from the attached program.

Further details can be found within the attached hand out papers. These are not complete and some are in a low copy quality. No electronic data was handed out during the workshop.

During the final discussion, after several questions came up, it was decided that the contents of this workshop can be handled as **unclassified**.

(Note: The Conference Proceedings have been subsequently put online and are available at http://demining.jrc.it/aris/events/slovenia/PROCEEDINGS.pdf)

***Disclaimer**:* These notes represent the author's personal impressions and point of view only, based for the most part on notes taken during the talks and later discussions with participants; as such they do not pretend to be complete and engage only himself. *The author's comments, his conclusions and summary, are in italics.*

2.1 First Day - 03rd June 2003

2.1.1

Detection of explosives for terrorist-bombs and landmine clearance -- Different applications of similar methods, Professor H. SCHUBERT, ICT, Germany (paper available)

Professor Schubert gave a short overview to find the common points for EDT in between landmine clearing and security applications.
Based on his long experienced expertise in EDT as head of the ICT and other specialised security techniques, he mainly focused on the following issues:

- There are several other improvised explosives compared to the militarily/commercial ones, used by the terrorists scene
- This is extending the number of chemicals to be searched for, not making the job easier
- They all contain oxygen as the only common agent
- Special attention should be given to "powder trains" which act as igniters for fuel and gas to change it into explosive surrogates
- The very distinguished colour and density (most explosives have a density greater than 1.6 g/ml) must be considered

There was no direct relationship to humanitarian demining. The presented table of technology assessment, from the demining point of view, seems to be outdated.

2.1.2

Chemical and physical properties and the detection of home-made explosives
Professor Michel LEFEBVRE, RMA, Belgium, (paper available)

Professor Lefebvre held a detailed scientific presentation about the spectroscopic properties of the whole span of explosives and worked out the differences and problems to detect all of them. Some improvised explosives do not contain nitrogen, the component on which the detection for normal ones is focused.
Also, the temperature dependence of the explosives vapour pressure level and the degradation of explosives over time and under certain circumstances will make the differentiation more complicated; a broad spectrum needs therefore to be used.
To reach a high detection degree (avoiding false alarms) relatively long times are needed for the LC (Liquid Chromatography) and GC (Gas Chromatography) standard techniques (e.g. about 1 minute for TNT at 40°C). RDX and PETN, which are frequently used, are even harder to detect.
He pointed out that some by-products (e.g. DNT) and explosives degradation compounds are easier to detect.

The RMA has shown a very deep expertise for EDT in laboratories. This knowledge is ensuring an excellent scientific backup for the preparation of test substances and the set up of testing routines for field equipment over all phases of development.
To come to reliable hand-held field equipment, based on the chemist's standard techniques, further developments of massively parallel chromatographic systems are needed.
Special focus has to be directed to the gas-sampling procedures, still needing too much time, even under clean laboratory conditions.

The use of fluorescent polymers seems to become a good starting point for sophisticated solutions.

2.1.3
Detection of plastic explosives in explosive devices
Petr MOSTAK, Czech Republic, (paper available)

Dr. Mostak held a very detailed presentation related to EDT to find plastic explosives, focussed on SEMTEX.
He gave a very sharp distinction in between vapour and particle based detection, which are sometimes mixed up.
The differences to other explosives (SEMTEX is a mixture of RDX, PETN and plasticizers) are not as large as often meant. But with the misuse of plastic explosives, not to be sorted out by older X-ray systems for baggage control, the addition of up to 1% of special marking agents (e.g. DNB), agreed with the ICAO (International Civil Aviation Organization) in 1999, represented the solution.

There was no direct relationship to humanitarian demining issues.
He stated that compared to IMS and DETEXII (colour change) dogs are up to 3 orders of magnitude better. The problems of humidity will be a drawback for IMS (Ion Mobility Spectrometry) in field use. His company can deliver calibrated samples, called "AGROSIL", to train dogs or other animals.

2.1.4
Overview of technology development in explosive detection.
Louis WASSERZUG, TSWG, Washington (no paper available)

The presentation of Mr. Wasserzug was only related to security applications of EDT, i.e.:

- People and baggage screening
- Screening of cars and freight containers
- Stand-off and remote detection for suicide bombers and cars

He reported that under the management of the TSWG 40 projects are running.
He gave a short overview to existing EDT. The TSWG favoured stand-off systems are based on lasers.
As new equipment hand-held passive millimetre-wave, non imaging millimetre-waves and terahertz spectroscopic imaging systems are under R&D.
Canine EDT were not on the focus because of some drawbacks.

The information that the TSWG will give the NQR (Nuclear Quadrupole Resonance) technique a better perspective than CT (Computed Tomography) solutions for handheld short range EDT applications, was indicating the same assessment as in my opinion. No useful information for demining purposes was provided.

2.1.5
Detection and Imaging with NQR, THz, and X-ray Techniques
Dr. Garth SHILSTONE, DSTL, UK (paper available)

Dr. Shilstone held a very useful presentation comparing NQR, THz and X-rays principles for EDT.
The DSTL has gathered knowledge in detection of N^{14} by using NQR over a frequency range of 400 kHz to 6 MHz. The best results are for RDX. The detection of TNT needs far more time. The results showed the applicability to AP and AT mines with plastic cases and against all N and Cl containing explosives. The handling of the very weak signals in an EM (Electromagnetic)-wave cluttered environment is representing the hardest problem.
The participants were not optimistic on the use of THz waves for demining purposes, because of the following drawbacks:

- Low penetration
- Moisture depending transmission (through air and soil)
- Radiation sources (e.g. FEL) needed to obtain detectable signals
- No knowledge about health risks

The very high spatial resolution achievable might be useful for tripwire detection.
The use of X-rays in security applications is well known and under steady development. There are applications for both the transmission and the backscatter principle.
The application of the backscatter variant for the detection of mines under field conditions seems far away.

The most advanced NQR systems (some prototypes exist) are preferred for demining purposes. They can also indicate metal, a drawback for EDT but a benefit to ease sensor fusion. The limitations of the THz waves are hard to overcome. Commercially available X-ray applications are also far away, because of the very low field applicability. The DSTL seems to be at the top of the European R&D scene, with already proven practical applications (e.g. TERAVIEW).

2.1.6
THz detection of explosives and biologicals
Professor D. VAN DER WEIDE, University of Wisconsin-Madison, USA, (paper available)

Professor van der Weide held a presentation related to the results of his working group, based on active THz-spectroscopy of the vapour phase. They are using the high wavelengths resolution instead of imaging. The shown results of the discrimination of a variety of explosives are a good starting point to develop security applications under clear using conditions.
For all used instrumentation a THz-radiation source is needed.
Some intentions came out to use lower frequencies (140 GHz and lower) easier to handle and with better penetration.
The use of a fin loaded THz horn antenna is indicating that older antenna principles are still useful. The polarisation and the broadband sensitivity are important features.
For the far future some wide area stand-off and remote screening applications were shown.
The application of a THz system under real mine field conditions seems far away.

2.1.7
Vapour detection and canine/bee olfaction
Dr. John GILBERT, DSTL, UK, (paper available)

Dr. Gilbert discussed in detail the work of DSTL using bees for olfaction purposes. One sponsor of the work is UNILEVER. Bees are used in combination with an electronic readout, attached to special equipment. There was no direct indication to use them for demining purposes.
The theoretical background is well understood and within the ROWANEX study the latest EDT results are available.

Although easy to train, the bees have some drawbacks compared to other animals in the field:

- Short lifetime (days)
- Depending on seasons
- No all weather capability

It might be useful to study the mentioned R&D activities by DARPA (Defense Advanced Research Projects Agency, US) to find out more. The application of bees for collecting samples in presence of explosive contaminated plants on a mine field needs seasons with blossoms.

2.1.8
An Overview of the APOPO Program, rats for landmine detection
Christophe COX, Belgium, (paper available, very short form only)

Mr. Cox started his work on the use of rats as mine sniffers in 1997 at the University of Antwerp. The close co-operation with Mr. Joynt ensured him excellent boosts of knowledge out of the dog's scene.
Later on he founded the APOPO project together with the Sokoine University of Agriculture, Morogoro, Tanzania. APOPO is using scientific training methods and reality related assessments.
He gave a deep inside view how to train and use the rats. The very high sensitivity against odours will lead to marvellous results. With a sampling rate of 150/min the rats are outperforming even dogs. APOPO has trained several hundreds rats.
Their lifetime of up to 8 years and the unlimited availability are advantages. There are other applications such as the medical sniffing of pathogens or finding buried people after earthquakes.
They are very useful for security applications, e.g. to check freight containers in short times, and have some advantages even for personnel screening. They should however be kept out of sight and provided only with the samples.

The recent results of co-operative work with MgM in Mozambique on live minefields will be released next month. It will be highly interesting to receive them.
It is again the nature offering "nearly ready to use" solutions without long lasting R&D and high investments.

2.1.9
Neutron Resonance Radiography for Security Applications
Dr. Richard LANZA, Massachusetts Institute of Technology, USA, (paper available)

Dr. Lanza held a more scientific related presentation, based on a very deep knowledge and practice after having been involved in several projects. His special focus is directed to modelling the targets of security interests by physical laws under application of highly sophisticated mathematical methods and using the whole register of digital image processing.
He was dealing with the "WalMart" syndrome for mass screening of baggage, having one real hit in a million shots.
The imaging and spectroscopy results which were shown are impressive.
As usual for R&D at MIT this work is representing a topic of theoretical sciences.

No direct relationship to the demining activities, running in parallel at the MIT, was found. To find out the importance of his work for the demining issues, further investigation of those programs is needed.

2.1.10
Portable multi-sensor for detection and identification of explosives substances
Dr. Andrey KUZNETSOV, Khlopin Radium Institute, St. Petersburg, CIS, (paper available)

Dr. Kuznetsov (the spelling and address in the ITF papers are wrong) is involved in the development of GPR (Ground Penetrating Radar) systems for both mine detection and EDT for security applications under a scientific NATO program which has been running for several years.
They developed a handheld prototype of a CW (Continuous Wave) GPR working from 2 – 8 GHz that can offer a spatial resolution within the centimetres range (3 to 4) to locate metal bodies or special dielectric targets in the soil. Penetration depth in wet ground (20%) is about 10 cm which increases up to 20 cm under dry conditions.

For the real capability of the device no results were given and also no details about the testing conditions. So the need of evaluation on an approved test area is emerging.

Based on the same knowledge a handheld EDT scanner for personal security check applications, working at 30 GHz, was developed. Within the discussion it came out that this system can be expanded to a freight container inspection system with short reaction times for mass screening applications. The detection time of an amount of 250 g TNT in a 40 ft container was calculated to be about 1 minute.

The second part was related to neutron radiation based EDT.
The institute has developed a special "Nanosecond Neutron Analysis (NNA)" system and established a prototype to be fused with the GPR in a following step, to create a new reliable mine detector.
The radiating source is a Californium 10^6 n/s neutron emitter, using a scintillating crystal and a PMT (Photo Multiplier Tube) as detector element. Within the own created landmine simulator containing 100 g TNT and 100 g of plastic containment, about 5 minutes for detection are needed.
Another prototype using timed neutron radiation will need 10 s.

He reported that the radiation source can be safely operated under field conditions and even in case of accidental destruction by a mine explosion no hazardous exposure will occur.

No further details of efficiency were presented. To follow up the realistic development capability a deeper investigation seems to be very worthwhile.

2.1.11
An emerging analytical technology for military and homeland defence applications
Russel HARMON, U.S. Army Research Office, USA, (paper available)

Mr. Harmon presented a paper dealing with the development of a "Laser Induced Breakdown Spectrometer" (LIBS). This equipment is on a development level close to commercialisation.
The high resolution measurement of laser (20 ns with 10 mJ) induced plasma spectra on the surface of the target will enable the detection of any substance (e. g. explosives, paints, plasticizers).
The received radiation will be checked from 200 nm to 980 nm (UV to near infrared) for the desired spectral lines. Production is foreseen by OCEAN OPTICS Inc.
It was said that a fingerprint for a landmine can be discriminated. With a weight of about 10 kg it can be used in a portable way.
The use of seven single spectrometers to overlap the needed bandwidth is very expensive. They could be replaced by one of the Aphelion type (see next point).
To detect chemical warfare agents, a stand-off version is under development with a range up to 50 m.

No detailed results under realistic mine field conditions were shown. The fact that the surface of the target must be hit by the laser beam led one of the participants to the conclusion: "What a nice very expensive prodder". Hard words but at the end they are near to the truth.

2.1.12
Practical aspects of using explosive detection techniques
Dr. Israel HIRSCH, Aphelion Ltd., Israel, (paper available)

Dr. Hirsch presented a very detailed paper dealing with the development of an unconventional spectrometer having some great advantages. The resolution within the 10 picometer region is highly recommended for a good discrimination between close lines of a spectrum. The design, using two modulated non-linear crystals, forming the laser beam with high linearity and non optical limitations, can be realised as a handheld system. Common spectrometers normally have a resolution of 0.5 nm. Within the FRED-project and around this device a colour spectrometer for EDT was created, to enable a robust instrumentation with a very low false alarm rate. A highly reliable handheld system is close to production. It is the goal of Aphelion to improve the well known ETK system. The only applications are for security purposes.
Additionally some new calculation methods, useful for improvements of the SNR (Signal to noise Ratio) in EDT applications, were presented.
The results of a high resolution imaging X-ray system with mixed transmission and backscatter capability were shown, without any reflections to practice, only as an example of the still unused possibilities.

The important drawback for demining applications is the fact that the sampling of explosives by wiping particles from the targets surface is needed.

Fast and very sensitive spectrometers might be useful to create surface images of mine contaminated land and explosive contaminated plants. It's only a question of rejecting side effects from the atmosphere and cluttering agents. A further future (about 2-3 years) for demining applications seems to be given.

2.2 Second Day – 4th June 2003

2.2.1

Detection of explosives by quadrupole resonance

Dr. Tomaz APIH; Robert BLINC, Institute Jozef Stefan, University of Ljubljana, Slovenia, (paper available)

Dr. Apih held a presentation dealing with NQR for EDT R&D under the NATO SEE program. The IJS was founded in 1998 and started with NMR (Nuclear Magnetic Resonance) and MRT principles. Both are working under strong homogenous magnetic fields only.
He reported recent NQR laboratory results in a region between 500 kHz and 10 MHz. He also stated that TNT is harder to detect than RDX because the spectral discrimination lines are very close together (about 10 picometer). Using the 700 to 900 kHz frequency range the laboratory test system will take 2 to 30 seconds to detect an AP mine.
To improve the SNR, the so called NQDR (D for *double*) principle is under investigation. But to start the required proton coupling a magnetic field is again needed. The better resolution must therefore be paid with higher energy consumption and weight. The latest trick to overcome these problems is the application of a multi-frequency sweep. The results, whilst still insufficient to develop a reliable handheld device, are already useful for the characterisation of the explosives' behaviour under the influence of EM fields.

There are promising results but a lot of further work is needed. The results correspond to those of DSTL.

2.2.2

Improvement of nitrogen NQR detection in explosives by proton polarization.

Professor J. LUZNIK, Institute of Mathematics, Physics and Mechanics, University of Ljubljana, Slovenia, (paper available)

The working group of professor Luznik (together with some international teams) is assisting the NQR R&D work at the University of Ljubljana (see above) under the NATO program SfP (Science for Peace) 978007.
They are studying the theoretical background of polarising the protons by application of magnetic fields. The shown calculated and measured signals are in good agreement.
The application of a magnetic field with a sufficient strength is not feasible in the field. There also problems with the duration of the magnetic field application and with the speed of switching of the reflected signal.
The chosen signal processing by averaging, to improve the SNR, is time consuming.

Further investigations are needed to overcome these disadvantages.

To receive more detailed information and to evaluate this work the study of the NATO research reports is needed.

2.2.3
Explosive detection in mine clearance: chemical behaviour in the field
Dr. Vernon JOYNT, CSIR, South Africa, (paper available)

The presentation of Dr. Joynt was the highlight of the workshop. Because of the conditions set in the historical developments of South Africa he has extensive knowledge and practice of the common factors for both EDT in mine clearing and security applications.
His work is still focussed on dogs without underestimating the problems. In order to illustrate how dogs are trained and work he showed some impressive films.
Based on the well known MEDDS (Mechem Explosive and Drug Detection System) and REST (Remote Explosive Scent Tracing) programs for demining, headed by Dr. Joynt, the importance of his work became clear. Very good results for different clearing operations were shown, and the cost savings in particular are legendary.
The following represent some of the main points of his presentation:

- Dogs are three times cheaper than deminers
- To use dogs safe lines around the minefields are essential
- To establish these is the most complicated and money consuming task
- Dogs are sniffing explosives particles and are weather influenced (e.g. wind, moisture)
- If it is planned to use dogs the cutting of vegetation is forbidden
- For flailed minefields dogs are not applicable for QA (Quality Assurance)
- Dogs have stand-off capabilities, as shown when finding Claymore mines hung on trees in Kashmir
- The dog's nose is acting as a "liquid sensor", so if the air humidity is lower than 40% they can not work. Continuous drinking is also needed.
- There is a place for both dogs and technical systems, e.g. the NOMADICS FIDO detector, for training aids
- Even plasticizers are used as detection agent
- To find out how the degradation of explosives can influence the performance of dogs, one year old samples are used for training
- The dog's nose is a broadband detector
- Rats have better results under higher temperatures and lower air humidity
- To come to a realistic evaluation of the problems the distinction between soil and air parameters is needed

The dog's nose working principles are better and better understood but there are still enough open questions to make it impossible to copy it. First steps have shown that already the doubled arrangement of sensors, similar to the dog's nose structure, will enable better sensitivity.
He pointed to some misinterpretations of statistical data dealing with environmental variations and hitting rates.
During the discussions Dr. Joynt was the counterpart to the more technically oriented participants, even for security applications, and he gave convincing examples for the use of dogs.

It was a great pleasure to follow the presentation of real field results for humanitarian demining using dogs backed up by sophisticated technical means. To follow up the developments at CSIR is highly recommended.

2.2.4
Demands on chemical vapor detection of landmines and explosives for counter-terrorism
Dr. Michael KRAUSA, ICT, Germany, (no paper available)

The presentation of Dr. Krausa dealt with the explosives vapour detection system developed at ICT for several years. It became clear that the sensitivity of a dog's nose is still not realized. ICT`s work is focussed on two ways to overcome this. The use of biological material like SAM to come closer to the dog's nose and the improvement of the already existing sensor by application of cluster analysis, a technique often used to enhance the sensitivity in chemical sensors, are under the focus of the ICT. The results of combining two types of sensors (MOS with electrochemical) are showing for the 8 channel ICT-sensor a sensitivity increase from 100 ppb to 33 ppt. Taking also into consideration the by-products and the degradation products of explosives, which are normally easier to detect, the need to develop sensors with greater bandwidth was agreed.
Based on the collection and evaluation of international data, ICT is setting new goals. The contact to the real field conditions is given.
More details to the modelling of the dog's nose can be found in S. E. Stitzel, *Journal of Am. Chem. Soc.* 125 (2003) 3684.

There was no clear indication how far the ICT is from the introduction of a field deployable mine detector. The shown results are promising and a follow-on contact is recommended.

2.2.5
The IAEA Co-ordinated Research Project on nuclear techniques for anti-personnel landmine identification
Dr. U. ROSENGÅRD, IAEA, Austria, (no paper available)

The presentation of Dr. Rosengard, having extensive experience with neutron based techniques, is dealing with the activities of the IAEA to develop a handheld mine detector based on neutron backscatter principles. The special working group (IAEA Co-ordinated Research Project, or CRP), headed by Dr. Rosengard, is coordinating the international activities. Based on the developments in St. Petersburg (Kuznetsov), University of Cape Town (Brooks) and the University of Delft (Datema), it is its goal to add the knowledge base of the IAEA to the international R&D scene and take over the technical coordination.

Using the SAIC developed "PELAN" device the IAEA has set up its own test bed in Vienna, to measure real background data. In 2002 the areas of interest were widened to the detection of WMD and car bombs, mainly initiated by the "homeland security" activities of the USA.
No clear recent results for demining were shown. Taking into account the problems still to be solved, before this technique can be brought to the field, it was stated that "Further improvements are needed".

It is recommended to follow up the work of the CRP.

2.2.6
Imaging techniques (optical and infrared) in landmine detection
Chris WEICKERT, CCMAT, Canada, (paper available)

The presentation of Mr. Weickert dealt with the electro-optical sensing of mines and UXO (Unexploded Ordnance) mainly for military purposes. The annual budget for humanitarian demining R&D of the CCMAT is about 350,000 US$ for all techniques.
The broad overview of all possible imaging principles, using the visible and infrared spectrum for remote sensing of mines, has shown nothing remarkably new. The drawbacks of those instrumentations to find buried mines are well known. He was not able to answer questions, because the original participant was not available.
Since 1996 the CCMAT is working on optical detection of tripwires. There were no detailed results presented.
For the far future a demining robot to clear roads is under consideration.

To follow up the work of CCMAT, also for other EDT/demining programs, is recommended.

2.2.7
New Developments in Coupling Radar, EMI and NQR for sensing anti-personnel land mines
Professor Lawrence CARIN, Duke University, Durham, NC, USA, (no paper available)

The presentation of professor Carin, who has been involved for a long time in a US demining MURI (Multi-disciplinary University Research Initiative) program, was focussed on further improvements of the well known HSTAMIDS detector.
Additional to the GPR and EMI (Electromagnetic Induction) detectors (200 HSTAMIDS are in field now) the introduction of an NQR sensor is desired.
The design problems to integrate radar antennas into the NQR coil were presented. For further improvements of the GPR it will be changed from the known spiral antennas to horns (Wichmann system). Dielectric rod antennas are also considered. Together with NIITEK a 9 GHz instrumentation is under R&D.
These developments have been found to be necessary to reduce the FAR (False Alarm Rate) and to minimise the influence of soil moisture.
The signature modelling program for mines, to develop a database of fingerprints, came under criticism of Mr. Sieber, because the stability of these over time is not given, even for normal storage.
The working group of professor Carin is developing a moisture model for all techniques.

This presentation was limited to scientific problems only. No HSTAMIDS field results were presented. The successful deployment of the Cyterra HSTAMIDS, based on R&D of Duke University, underlines the need to follow on their activities.

3. **Round-Table Discussion -** Chairman John REINGRUBER

The discussion was started with the remark by Mr. Sieber to exclude the demining issues, because they are already clear. Mr. Reingruber, assisted by Mr. Wasserzug, started then the "homeland security" related discussion asking for technical readiness.

They defined the requirements as:

- People and baggage point screening
- Screening of cars and freight containers
- Stand-off and remote detection for suicide bombers and cars

The results can be found in the "Summary of the technologies" spreadsheet elaborated by Mr. Wasserzug and received on 06.13.2003 (Pages VII-VIII of the online Proceedings, available at http://demining.jrc.it/aris/events/slovenia/PROCEEDINGS.pdf).

Here are some other main points of the discussions:

- Dr. Joynt asked for pilot tests for canines in security applications
- His main focus was on the question: "How to get good samples there?"
- Acoustic techniques were skipped with the advice to consider "time reversed sounds" used for checking turbine blades in France
- For suicide bombers the highly cluttered environment has to be considered and a stand-off capability greater than 10 m is needed
- Mr. Sieber said that the THz-technique is promising
- He also stated that "the process is important, not the technique"
- Professor Schubert told the forum that at Munich airport already special "field tests" for new transmission X-ray equipment for checking persons are running
- One main problem is the point check of vehicles (too much time is needed)
- Mr. Reingruber levelled the workshop documents to unclassified

4. Summary

The following table contains a personal summary of the main techniques presented at this workshop. It provides an overview and indicates the relationships between security and humanitarian demining applications. If it has been mentioned, a type of instrumentation is named as well.

Techniques	System	Application	Maturity
Colorimetric	*EDK, Israel, DETEX, CR*	*Security*	*in use*
TNA	*Prototypes, CIS, ZA, NL*	*Security, Demining*	*near*
NQR	*Laboratory*	*Security, Demining*	*near*
Canines	*Dogs, Rats, Bees*	*Security, Demining*	*in use (bees near)*
GPR	*HSTAMIDS, USA*	*Demining*	*in use*
THz	*Laboratory*	*Security*	*far*
Vapour Detection	*FIDO, USA*	*Security, Demining*	*in use*
MD	*HSTAMIDS, USA*	*Demining*	*In use*
Thermal Imaging	*CCMAT, Canada*	*Demining*	*in use*
X-Ray	*transmission, backscatter*	*Security*	*in use*
Spectroscopic	*LIBS, USA*	*Security*	*close to usage*
Microwave (not GPR)	*Prototype, USA*	*Security*	*close to usage*

5. Acknowledgments

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