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Report on the Hidden Explosives Workshop, Rovereto June 1999

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Other Features

Report on the Hidden Explosives Workshop, Rovereto June 1999.

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This article gives some personal recollections of the highlights of the Rovereto workshop written in a form intended to be useful to working deminers. The workshop was organised by Mirco Elena of Istituto Trentino di Cultura elena@itc.it who can provide additional information. Funding and subsidies were from the United States Department of Energy and the Italian CARITRO foundation.

The Russian KROT Program

The origins of this workshop go back to the end of the cold war. In what one hopes is a very frequent display of intelligence, the United States Department of Energy decided that free market forces should not be allowed to influence the relationships between Russian nuclear weapon designers and the growing numbers of religious fanatics. Accordingly DOE, through Argonne National Laboratory, set up various non-proliferation deals to keep very intelligent Russians busy on demanding and useful research work. One of the research topics was equipment for sensing mines and unexploded ordnance. The Russian program is named KROT. This is not an acronym, just the Russian name for 'mole' as in garden pest not covert agent.

Russia is unusual in that it is a technically advanced country with very large areas of mined land. Few people in the west realise the intensity of the fighting on the eastern front. If it is measured in terms of the deployment of German divisions, the number is seven times that of all other theatres with a correspondingly greater explosives clean-up problem. It is possible that some nuclear power stations may have been built close to or even over unexploded bombs. Two American observers at the workshop believe that Russian work on explosive detection is ahead of that of competitors in the west.

The KROT programme includes studies of magnetometers, infrared, and gas chromatographs for odour-sensing, both fast and slow neutron activation of gamma rays and ground-penetrating radar. Magnetometers are good for locating large items of deeply buried ferrous material such as bomb casings. Infrared works for surface scattered objects such as mines dropped from the air or munitions thrown from cluster bombs. Passive infrared can be very fast, and is one of the few techniques suitable for use from aircraft. It can also work for shallow buried items if the ambient temperature is changing fairly fast. Odour sensing is already being done superbly by dogs but they have unfortunately relaxed views about the proper length of a working day, (perhaps because they know that they are still far better than any man-made sensor.) Slow neutron activation of gamma rays can indicate the presence, but not much about the shape, of explosives. Fast neutrons may be used to show the spatial distribution of chemical constituents. Ground-penetrating radar, at present, the favoured approach by many workers, is a fast way of measuring changes in the electro-magnetic refractive index, mainly the electrical permittivity, of the soil and its contents. Radar mainly shows that there is some electromagnetic variation not what has caused it. Water has a very high dielectric constant and greatly affects radar propagation.

The Russian equipment will be demonstrated to western visitors in Moscow around 20 September 1999 and then will be brought to a European test site in the spring of 2000. Further information may be obtained from Georgy Ignatiev ign@ript.in.ru at the Research Institute for Pulse Techniques in Moscow or Vladimir Minkov minkov@anl.gov at Argonne National Laboratory. American corporations wishing to join a programme to commercialise KROT technology should contact Chris Baumgart <cbaumgart@kcp.com> who is at Allied Signal, Albuquerque, working for DoE and Argonne.

Maps and Aerial Photography

Maps are an extremely valuable asset for both demining and unexploded ordnance disposal. Unfortunately, they are not always reliable or easily available in mined countries where they may be regarded as military secrets. Chris Going of Cambridge Architectural Research described the collection of Luftwaffe aerial reconnaissance photographs. Although two archives have been lost there is still a very large collection of thoroughly documented evidence for 18,000 targets which were declassified in 1981 and is now stored at Keele University in England. Mine fields laid by disciplined troops will usually be surrounded by wire fencing and this can often be seen from the air as areas of ungrazed or untrodden ground. Pictures taken before and after bombing raids can be used to show positions of about 40% of unexploded bombs. Depending on altitude, the technique may just be able to show positions of individual anti-tank mines but not anti-personnel ones. Aerial photographs should be used to produce correct maps and, in conjunction with tactical information from historical sources, for a first-pass area-reduction method. Chris Going is at atcgoing@carltd.com in Cambridge, England.

Archaeological techniques are more useful if there is a series of photographs taken with different lighting conditions and at different seasons of the year, especially at the onset of a drought.

Pictures from satellites could be very valuable for demining in countries where normal maps are missing or inaccurate. Such photographs now have a high commercial value. The Russians seem to be more willing to provide direct access to the original sources than the Pentagon, which offers only an information interpretation service.

Ground Penetrating Radar

Ralph Benjamin from Bristol described his work on synthetically focussed ground-penetrating radar from moving vehicles. He uses a 2.8-m by 1.4m horizontal antenna array, with its major axis normal to the direction of vehicle movement. Unlike the many in-contact systems, this is placed about 0.6m above the ground, thus avoiding mechanical triggers, as well as making it suitable for use in relatively rough terrain. Short (2ns) pulses are transmitted by all antenna elements in turn, one at a time, and the relevant echoes are picked up by all the other antenna elements. This allows all the paths from any transmit element via a given 3D resolution cell to any receive element to be individually identified and distinctively and optimally processed, to construct a 2D vertical image plane underneath the longitudinal centre-line of the array. This is turned into a continuous 3D image by the forward movement of the vehicle. Rays are refracted at the air-soil boundary and so for the exact measurement of the depth and cross-track position of objects it is necessary to know the refractive index of the soil. Forward velocity can be high with the limit being imposed by the length of the support structure forward of the wheels and the safe braking distance. For additional information, please contact DrBenjamin@aol.com at Bristol University England.

Researchers vs. Practicality and Deminers

Many working deminers are critical of 'arm-chair academic researchers' and their ignorance about real minefield conditions. This may suggest that this ignorance can only be the result of poor transmission of information from the deminers themselves, who should not be too harsh on those seeking to acquire knowledge. Indeed, several very well known charitable demining organisations are extremely reluctant to answer quite innocent questions about productivity and demining costs. It was a refreshing change to hear from Martin Auracher demira1@aol.com of the German demining company Demira. He gave a useful description of the difficulties encountered at the sharp end of demining and circulated copies of a report showing very creditable demining costs.

The lessons that have been learned are that it is difficult, slow and expensive to transport heavy equipment over bad or non-existent roads, especially if containers are shipped to the wrong port. Spare parts are hard to get, so reliability is crucial. Because of this and other variables, there is a strong prejudice against sophisticated designs. Vegetation is a continuous problem for all demining work. Local politicians see maximising the employment of local people as being much more important than getting rid of mines. The well-intentioned insistence by the United Nations on salaries for deminers at several times the local rate has the unforeseen and unfortunate result of distorting the labour market to the point that demining can become the biggest and most lucrative industry. Under these conditions, most of the workers want the project to continue indefinitely.

The European Joint Research Centre

John Dean john.dean@jrc.it described work at the European Joint Research Centre at Ispra, Italy where some workshop delegates were able to visit. The Centre was set up by the European Commission to give advice to commissioners on all scientific matters of interest to the European Community. It controls all European Union funded demining research and has concentrated on the development of mine-sensing techniques. This includes programmes named MINREC, DEMINE, DREAM, INFIELD, HOPE, PICE, GEODE, LOTUS and MINESEYE. Companies include Dassault, Marconi, Thomson, Daimler, Ebinger, and DERA. The nearest of the EU projects to completion is the MINEREC programme aimed at building a radar array with real-time detection and recognition of plastic mines. It was unfortunate that Richard Chignell of Emrad Ltd 73064.226@compuserve.com, working with Thomson Marconi Sonar, was forced to cancel his attendance at the workshop. The Esprit web page http://www.cordis.lu/esprit/src/hphdhome.htm will give updated details of all EC-funded work.

As well as coordinating the work of commercial companies, the Joint Research Centre is also doing its own research at Ispra. There are four experiments. The first uses their existing microwave signature laboratory. This consists of a 20-metre diameter sphere with internal walls that are covered with conductive foam pyramids to make them highly absorbent to electromagnetic waves. Large specimens, up to the size of a car, can be placed at the centre of the sphere and rotated about a vertical axis. Transmitting aerials with any polarisation can be scanned along one circumference while receiving aerials can be moved about a second. The programme will measure the complete, multi-directional radar reflection characteristics of many mines over the band 0.3 to 9.5 Ghz. The mines will be buried in a 2-metre diameter patch of various soils, with various humidities, along with stones and other non-mine objects. The entire data sets of mine radar signatures will be published shortly, perhaps the week of 19 July 1999. They will be essential for everyone involved with ground-penetrating radar. You can download from http://www.tdp.sai.jrc.it/aris.

The second topic does a similar job for the comprehensive measurement of the optical reflectance in the visible and infrared using the JRC 4-metre diameter optical goniometer. Work in the visible range is now complete and is to be extended to 12 microns in the infrared.

Two new facilities have been built specially for mine research. One is an accurate carriage for moving sensors along a path of cleaned earth. This can be sown with a variety of mine surrogates to allow comparisons between different detector systems under controlled and repeatable conditions. The second, known as the Karl Friedrich Gauss laboratory, is a totally non-metal building made from wood joined with wooden dowels and with very carefully screened electrical supplies.

Odour Sensing Robots

Riccardo Cassinis riccardo.cassinis@unibs.it described work at the University of Brescia on swarms of odour-sensing robots. The vehicles are light enough not to fire normal AP mines. They can be directed along straight lines using a laser system. Then they can work in a free-range, cooperative manner, like ants, to home in on odour sources. They carry directionally sensitive air intakes consisting of a bank of nostrils and can find their way to small quantities of ethyl alcohol (unless there is a wind.) Electronic odour sensors are not very fast. The ethyl alcohol recognition takes about one second and the vapour of di-nitro toluene (thought to be the indicator of the tri-nitro molecule) takes about 10 seconds. However, odours are useful to show that no mines are present in the vicinity.

A very sensitive odour detector was reported by Alexey Vasiliev vasiliev@imp.kiae.ru now at IRST in Trento Italy. It uses a deposit of an absorbing layer on the surface of a piezo-electric substrate, which can produce acoustic waves in the 1 Ghz region. The thickness of the absorbing layer is chosen to be three-quarters of the acoustic wave-length but this thickness will change when very small quantities of chemicals are absorbed and alter the frequency of zero reflection. Organic vapours can now be detected at levels below one part in 10^{9} and may eventually be detected down to a few parts in 10^{12}. Vasiliev's reluctance to identify the nature of the absorbing layer is understandable. We may assume that a bank of layers could be tailored for each of the explosives that could be used in mines.

Geophysical Capabilities

Harm Janssen from the Dutch company T&A Radar described their geo-physical services. The western Netherlands has areas of deep clay in which bombs can sink to depths of at least 20 metres, but the high water content prevents the use of ground-penetrating radar from the surface. The company can drill arrays of 30-mm diameter bore holes, insert a transmitter down one and detect bombs along lines to receivers in other holes. The technique has been used to depths of 100 metres and can be used to see bombs under existing buildings. A second large-area detection method uses 20-metre square transmitting loops driven with a sharp bi-polar spike pairs at a 32 Hz repetition rate outside a smaller receiving loop to achieve penetrations up to 10 metres. This is far deeper than any hand-held metal detector.

Giovanni Alli idspisa.signature@tin.it described ground-penetrating radar services offered by the Italian company IDS. They have considerable experience with surveys for pipes and cables before excavation work.

Lorenzo Capineri capineri@ieee.org from the University of Florence, Italy, described a new technique developed in their non-destructive testing laboratory for finding the positions of buried objects by 3D Ground Penetrating Radar scans. The method is based on the automatic search of hyperbolic patterns of reflected signals from the buried object in a set of images acquired over parallel planes. This may be relevant to the analysis of data from mine sensor scans. It has been used in laboratory conditions and also with field data from Cambodia supplied by the DeTeC group at EPFL Lausanne jean-daniel.nicoud@epfl.ch. The technique converts the hyperbolic radar images to easily interpreted, orthographic 'engineering' drawings of buried objects with horizontal position to within 32 mm. The processing time is about 5 seconds on a modern PC.

A conference on detector systems and novel demining methods will be held in Florence from 1 to 3

October 1999. Details are available from mine99@diefi.unifi.it and http://www.diefi.die.unifi.it/~mine99.

The Whirling Dervish

Stephen Salter shs@mech.ed.ac.uk described work at Edinburgh University on the Dervish mine-detonating vehicle, which is financially supported entirely by charitable donations. This destruction method originated from a hopefully erroneous belief that the sensor problem in real ground conditions could never be solved once minelayers began using even the cheapest counter-measures. The only approach was to exploit the inevitable feature that a mine explodes under loading. Work started with explosive tests leading to the development of a three-wheeled explosion-resistant vehicle This vehicle uses a rotation combined with a slow advance to subject every spot of ground to a loading cycle like that of a human foot, but too light to fire normal anti-tank mines. This performs the functions of both detection and neutralisation in a few microseconds. Human steering from safe distances by radio control proved extremely difficult and so a modified high-frequency version of the phase-comparison Decca navigator system has been developed to drive Dervishes (and perhaps-other vehicles) from lines and patterns on a computer map.

Dervishes might also make suitable platforms for carrying mine sensors. There seems to have been little thought about how sensors are to be moved and what a sensing vehicle should do when its sensor encounters a suspect object. The Edinburgh team argues that scanning must not stop and would like to work with any sensor-owner that needs transport.

Also described were ideas for a balloon-based sensor platform controlled by six intelligent winches which would have the ability to move light payloads over obstructed mine fields, allow close-up photography, place markers and squirt paint. With high-modulus carbon-fibre control lines, the correct slope angles and the same Decca navigator technology, it should be possible to move sensors to the precision of a mine diameter in wind speeds up to 20 metres per second. An off-the-shelf Cameron balloon costing $15,000 can lift a 20-kg payload and can be folded up into a pack to fit the trunk of a medium sized car.

While a computer-to-projector connection problem was being solved, Salter gave an impromptu talk about the Dell Explosives water-bag suppression technique. When used with bombs and 155 mm Howitzer shells this can cut over-pressure by a factor of twenty, fragment number by a hundred, and fragment velocity by six. The result is a large reduction in safety distance, perhaps by ten times, and in the number of people who have to be evacuated when unexploded bombs are found in built-up areas. After the workshop was over we learned that the technique had been used for the first time in a military context by a Royal Engineers disposal team in Kosovo. It saved a village from destruction following a high-order detonation of a 2000 LB NATO bomb.

While magnetometers sense ferrous objects, metal detectors sense conductive ones and ground-penetrating radar detects variations in dielectric constant (none of which are specific to explosives), neutrons can get us closer to the chemical nature of objects in the ground. When neutrons hit atoms in their path they can generate gamma rays that have distinct set of energy levels. These can be measured from photons generated when a gamma ray hits a scintillation counter. The peaks in a gamma ray spectrum give precise indication of the element under neutron bombardment.

Alexander De Volpi <adevolpi@anl.gov> showed a fascinating plot of the ratios of oxygen to carbon against oxygen to nitrogen for a variety of substances. Explosives form a distinct cluster with both N/O and C/O always between 0.2 and 1. The nearest other substances are silk, polyurethane and cocaine, all of which have significantly higher C/O ratios. At last we have a specific indicator of explosive substances in the quantities used in mines which can not be dazzled by sprinkling small

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quantities of finely powdered explosives.

A continuous stream of slow neutrons can be generated from a lump of 252californium. G. Viesti, working at the Italian Nuclear Physics Laboratory in Padua Italy, described the work of the Explodet project and, during a visit, showed us the equipment working. Some of the neutrons are absorbed in the soil. Not all will produce a gamma ray in the direction of the scintillator. The scintillator material may have a background count and so about 2×10^7 neutrons are to get statistically significant results for detecting the chemical marker peaks over the background. Both caesium iodide and sodium iodide have been tested with photo-multipliers and semiconductor diodes to count the photons.

It is not wise to carry a lump of ^{252}californium in one's trouser pocket and indeed the package in which you would be allowed to transport even a small source is quite bulky. This means that detection will take minutes not seconds, and should be used as an accurate confirmation of the presence of explosives suspected by a faster sensor.

Alexander De Volpi described work with fast neutrons at Argonne, which may one-day lead to a chemical image of a buried object. Bombarding a target with deuterons accelerated by a high voltage produces the neutrons. Although they move off in a random direction there must also be a photon moving in exactly the opposite direction. This photon can be amplified in a channel photo-multiplier where individual channel outputs will correspond to the directions of the departing neutrons. Meanwhile, the neutrons going into the ground produce gamma rays, some of which produce other photons in a scintillation counter with energy level analysis as before. By comparing the coincidence of the gamma ray detection's with the image from the channel photo-multiplier we can build up spatial information along with chemical element information.

Apparently two other very famous unnamed laboratories attempted but failed to implement the technique. Many engineers believe that something that can only just be done in a top American laboratory may not be suitable as a field instrument. However, every expert on tape recorders, including all except one person in Sony, would have believed something very similar about the Walkman.

The workshop began when NATO was still bombing Serbia. Many of us were thinking of the grim problem of dealing with one or two nuisance mines left at random places in a field of every farm. We also were thinking of how deminers will manage when the people who lay mines begin to use more intelligence to mask their mines or distract deminers with cheaper, non-mine substitutes. It is not a good way to get job security.