FOI-R-0424-SE
March 2002
ISSN 1650-1942
User report

Bo Janzon, Matts Gustavsson (Ed.)

Report from the 2nd International Workshop on Demining May 15th, 2001 at Grindsjön, Sweden

Weapons and Protection
SE-147 25 Tumba

SWEDISH DEFENCE RESEARCH AGENCY
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Hosted by The Swedish Defence Research Agency, FOI
Location: Grindsjön Research Centre

Issuing organization	**Report number, ISRN**	**Report type**
FOI – Swedish Defence Research Agency Weapons and Protection SE-147 25 Tumba	FOI-R-0424-SE	User report
	Research area code 5. Combat	
	Month year March 2002	**Project no.** E2003
	Customers code 5. Commissioned Research	
	Sub area code 51 Weapons and Protection	
Author/s (editor/s) Bo Janzon Matts Gustavsson (Ed.)	**Project manager** Lena Sarholm	
	Approved by	
	Sponsoring agency Swedish Armed Forces	
	Scientifically and technically responsible	
Report title Report from the 2nd International Workshop on Demining		

Abstract (not more than 200 words)

The report gives an overview from research and development activities related to demining in the participating countries. The report includes the material presented during the workshop and also the results from the four working groups Close in detection, Detection of explosives, Multisensor and robotics and remote detection.
Participating organisations were Dstl/DERA from UK, CCMAT from Canada, TNO from The Nederlands and FOI from Sweden.

Keywords Demining	
Further bibliographic information	**Language** English
ISSN 1650-1942	**Pages** 70 p.
	Price acc. to pricelist

Utgivare	Rapportnummer, ISRN	Klassificering
Totalförsvarets Forskningsinstitut – FOI Vapen och skydd 147 25 Tumba	FOI-R-0424-SE	Användarrapport
	Forskningsområde 5. Bekämpning	
	Månad, år Mars 2002	**Projektnummer** E2003
	Verksamhetsgren 5. Uppdragsfinansierad verksamhet	
	Delområde 51 VVS med styrda vapen	
Författare/redaktör Bo Janzon Matts Gustavsson (Ed.)	**Projektledare** Lena Sarholm	
	Godkänd av	
	Uppdragsgivare/kundbeteckning FM	
	Tekniskt och/eller vetenskapligt ansvarig	

Rapportens titel (i översättning)

Rapport från den 2:a Internationella Workshop avseende minröjning, 15 Maj, 2001, Grindsjön Sverige.

Sammanfattning (högst 200 ord)

Denna rapport sammanfattar den forsknings och utveckling som pågår inom området minröjning. Rapporten inkluderar det material som presenterades av respektive land och även resultatet från de fyra arbetsgrupperna, Close in detection, Detection of explosives, Multisensor och Robotics and Remote detection
De organisationer som var representerade är Dstl/DERA från Storbritannien, CCMAT från Kanada, TNO från Holland och FOI från Sverige.

Sammanfattning (högst 200 ord)

Minröjning, demining

Övriga bibliografiska uppgifter	**Språk** Engelska
ISSN 1650-1942	**Antal sidor:** 70 s.
Distribution enligt missiv	**Pris: Enligt prislista**

Contents

Management summary

Aim and scope

The aim of the workshop was to be a forum to co-ordinate research and development co-operation on demining between concerned Governmental research organisations of Canada, The Netherlands, United Kingdom and Sweden.

Participants

There were 26 participants at the Workshop from all four Nations. All Nations participated in all Working Groups.

Participation took place by representatives of

- the Canadian Centre for Mine Action Technologies (CCMAT), and the Defence Research Establishment Suffield (DRES), Canada,
- the Ministry of Defence, the Royal Netherlands Army and the Physics Electronics Laboratory TNO (TNO-FEL), The Netherlands,
- the Defence Evaluation and Research Agency (DERA) [hence split into the Defence Science and Technology Laboratory (DSTL) and QinetiQ], United Kingdom, and
- the Swedish Defence Research Agency, FOI [formerly FOA], Sweden.

National Programmes

Introductions to the National R&D programmes were presented in plenary by

United Kingdom	Dr. David Anderson, DERA/QinetiQ
The Netherlands	Mr. Ric Schleijpen, TNO-FEL
Canada	Mr. Robert (Bob) Suart, CCMAT
Sweden	Dr. Bo Janzon, FOI

The following conclusions could be drawn:

- First, there remains a determination and commitment among the organisations and people concerned to provide a substantial contribution to different solutions to the world mine problems, through planning and executing research and development programs.
- The Nations participating have continued to build up a respectable position in the field of demining technologies. This makes it likely that intensified co-operation, through coordination of national programmes, exchange of results, execution of joint programmes and mutual participation in tests and demonstrations will result in a multiplier on the individual results.
- Especially from the technology point of view quite a degree of exchangeability exists between results of humanitarian and military demining programmes, leading to an extra multiplier with regard to applications.
- However, for the working groups established at the first International Workshop on 15-17 May 2000 in the Hague, Netherlands, it was found that only limited exchange had taken place. One reason for this might have been organisational and other changes that had occurred, foremost in the UK and Sweden.
- The scopes and time frames for the various National programmes seemed, in some cases, not to coincide well. Some efforts were aimed at quite near-term results, whereas others

had a much longer time perspective, and some were aimed exclusively at humanitarian demining whereas others focussed on military mine clearance. The future of related programmes was not very clear to some participants.

- Nevertheless, the work of the working groups, found in their respective reports included in this report, demonstrated considerable mutual interest between the participants, making it likely that there will still be much to gain through cooperation and collaboration. Therefore the efforts to seek areas of mutual interest, to create a basis for cooperation through a quadrilateral MoU, and to initialise co-operative and collaborative projects should continue and be intensified.

Members of the Programme Committee:

Dr. Bo Janzon,	Director Weapons and Protection, FOI, Sweden, chairman
Dr. Chris Weickert,	Program Manager, DRES, Canada
Dr. Bob Suart,	Director, CCMAT, Canada
Dr. Cees Eberwijn,	Deputy Director, TNO-FEL, Netherlands
Dr. Ric Schleijpen,	Program Manager, TNO-FEL, Netherlands
Mr. Ian Burch,	DSTL (formerly of DERA), United Kingdom

The committee had two meetings in Sweden before the meeting and one brief meeting during the workshop.

Chairman of the Workshop

As Chairman of the Workshop the Programme Committee had selected Dr. Bo Janzon. FOI, Sweden.

Chairmen and Working Groups at the Workshop

As decided by the Programme Committee the following working groups met:

1) Close-in detection	Chairman: Ian Burch, UK
2) Detection of explosives	Chairman: Robert Deas, UK
3) Multisensors and robotics	Chairman: Ric Schleijpen, NL
4) Remote detection	Chairman: Robert Herring, CAN

This meant that the group “Close-in detection” originally established at the First Workshop was split in two, 1 and 2 above, with the size of the respective areas and the different expertise needed for discussions as the main reasons. To the topic of group 4 the area of “robotics” had been added.

The committee had also decided that the group on “Test facilities” established at the First Workshop had no further purpose and could be deleted, since the work intended for it had now been assumed and a first compilation of existing facilities had already been produced by the ITEP.

The reports of the Working groups will be found at the end of this report.

Organisation

Organisation of the Workshop was done by the FOI Weapons and Protection Division, with Bo Janzon overseeing the process and Ms. Ann Kjellström having the main responsibility and doing most of the practical work. Also Mrs. Lena Sarholm assisted.

In the work of the Programme Committee, also Curt Larsson and Lars Sandström assisted, both of FOI Director General's Staff.

Secretary at the Workshop and Report Editor was Matts Gustavsson, FOI Systems Technology Division. This summary was written by Bo Janzon.

Quadrilateral Memorandum of Understanding

Considerable work on this had taken place, after Canada (Mr. Rick Corrigan, MoD) kindly volunteered to take the lead. Several draft versions had been produced and mutually discussed between the parties, and the MoU was now approaching a final version. The Programme Committee of the Workshop had had some discussions on the MoU, but its contents were not discussed at the workshop.

Other activities

In connection with the Workshop the FOI Weapons and Protection Division also organised, as part of the 60th Anniversary of the Grindsjön Research Centre, two International seminars on 16 May, on the topics of:

Humanitarian Demining – Needs, requirements and possibilities

Needs and requirements,

Mr Geir Bjørsvik, Norwegian People's Aid (NPA)
Mr Conny Åkerblom, Geneva International Centre for Humanitarian Demining (GICHD)

Mine Clearance in International Operations

Maj Ben de Groot, Engineer Training School, Knowledge Centre, Staff officer Mines, Countermine and Demolition, Royal Netherlands Army
Maj Jan-Ole Robertz, Swedish EOD, Demining and Military Engineering Centre (SWEDEC)

Possibilities

Presented by representatives from the National Defence Research Agencies of Canada, The Netherlands, United Kingdom and Sweden,

and

The European Future in Energetic Materials

CEPA 14 – A Mechanism for European Collaboration of Energetic Materials and their Applications, Dr. Adam Cumming, Chairman of WEAG CEPA 14, Technical manager, DSTL/DERA, UK

Some Trends in Energetic Materials. Dr. Alain Davenas, R&T Director of SNPE, France

Energetics Research at ICT Germany on the example of new gun propellants. Dr. Peter Elsner, Director of Institut für Chemische Technologie im Fraunhofer-Gesellschaft, Germany

Energetic Materials Research at TNO Prins Maurits Laboratory. Dr. Paul Korting, Director Prins Maurits Laboratory/TNO, Netherlands

Energetics Research at FOI. Dr. Bo Janzon, Director Weapons and Protection, FOI, Sweden

Most workshop participants remained and participated in the former seminar, or both. In addition there were opportunities at Grindsjön for continued discussions on demining and cooperation during 16 May.

The Way ahead

The established network of experts will be maintained by active stimulation by the WG chairmen.

Mutual invitations to events, like tests or demonstrations, of interest should be circulated between the parties.

MoU discussions will continue through normal channels. Canada will continue to be the lead in this work.

Next Workshop

The next workshop was tentatively agreed to be arranged by Canada, at DRES, Suffield, Alberta, if possible towards the end of May 2002.

Apology

The publication of this report, which was the task of the organiser of the Workshop, FOI, has, regrettably, been much delayed. One important reason for this was that some of the presentations, that were not handed in at the Workshop, but which were promised to be sent in shortly afterwards, arrived at FOI first after some encouragement, and much delayed.

Please accept my sincere apologies for the delay.

FOI 19 February 2002

Bo Janzon

Programme

Tuesday, 15 May 2001

0730	Bus transfer from City Rica Hotel
0750	Bus transfer from Globen Hotel to Grindsjön
0900 – 0915	Coffee / Tea
0915 – 0930	Opening and welcome, Dr Bo Janzon
0930 – 1050	Plenary Session: Overview of Demining Research Activities by Participants

United Kingdom	**Dr. David Anderson**
The Nederlands	Mr. Ric Schleijpen
Canada	Dir Bob Suart
Sweden	Dr Bo Janzon

1100 – 1200	Group Discussions
1200 – 1300	Lunch
1300 – 1400	Group Discussions
1400 – 1430	Coffee break
1430 – 1540	Presentation of the Working Group's Discussions and Plenary Discussions
1540 – 1600	Programme Committee, Summing up meeting
1600 – 1645	Demonstrations of Working Mine Dogs, Swedish Armed Forces Dog Instruction Centre
1645	Summing up and close of Workshop
1715	Drinks and get-together at Skogstorp Mansion
1900	End of day and bus transfer back to Hotels

Wednesday, 16 May 2001

0730	Bus transfer from Central Station / City Terminal
0750	Bus transfer from Globen Hotel to Grindsjön
0840 – 0900	Coffee / Tea
0900 – 1200	International Seminar on Humanitarian Demining
1200 – 1300	Lunch
1300 –	Discussions and follow-up of Workshop, or alternatively
1300 – 1630	International Seminar on The European Future in Energetic Materials
1700	Drinks in exhibition room, basement floor of Mess building
1830	Tent Multi-Course Dinner at Grindsjön Centre Your chef: Sven-Erik (Erkki) Taavo
2100	Transfer to Hotels

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[1] Robin Rutherford has left Dstl/DERA, his replacement is Dan Port, dmport@dstl.gov.uk.

Overview of demining research and development activities in United Kingdom

Presented by Dr David Anderson

Overview of UK Countermine Activities

May 2001

Dr David Anderson

DERA

PRESENTATION OVERVIEW

- Military Applied Research Programmes
  - Mined Area Detection, Technology Demonstrators for
    - Advanced Hand Held Mine Detector, AHHMD
    - Mine detection, Neutralisation and Marking system, MINDER
  - Remote Minefield Detection System Technical Demonstrator Programme, REMIDS
  - Neutralisation
- UK government funded programmes
  - Portable Humanitarian Mine Detector Programme
- Joint ventures
  - MINESEEKER a joint venture between the Lightship Group and DERA

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AHHMD TD

- Combined
  - Metal detection
  - ground penetrating radar
- Confirmation sensor
  - quadrupole resonance

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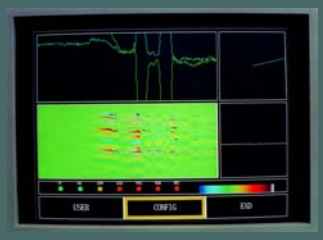
HUMAN COMPUTER INTERFACE, HCI

- Audio signals are used in normal operation.
- HCI is through a lightweight, low power device that does not impinge on the user's line of sight.



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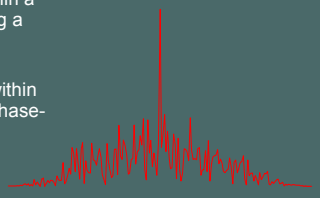
DETECTION OF RDX USING AHHMD DEMONSTRATOR

- NQR detection of 100g within a few seconds at 4-5cm using a basic pulse sequence
- Detection predicted to be within seconds at 13cm using a phase-cycled echo sequence



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AHHMD TD IN PRONE POSITION

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AHHMD TD SUMMARY

- Integrated metal detection, ground penetrating radar and quadrupole resonance detection of RDX explosive is feasible
- TNT explosive detection time is long
- Required electrical power levels are still high
- Technology maturity means system is bulky

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MINDER TD

- Medium range
  - Ultra Wide Band Radar
  - Thermal Imager with polariser
- Close-in
  - Ground Penetrating Radar
  - Metal Detector
- Confirmatory
  - Quadrupole Resonance

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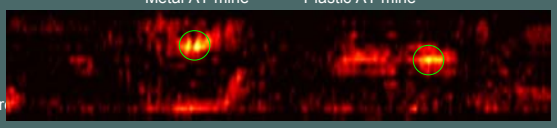
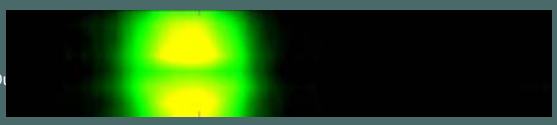
CLOSE-IN SENSOR DATA

Targets at 200mm depth

Metal AT mine Plastic AT mine





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DIFFERENT DATA COLLECTION AREAS

Smooth surface Unmade road Rough track

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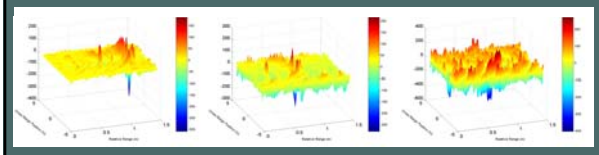
CURRENT UWB RADAR DATA



Smooth surface Unmade road Rough track

The incorporation of an inertial navigation systems will improve performance on rough surfaces.

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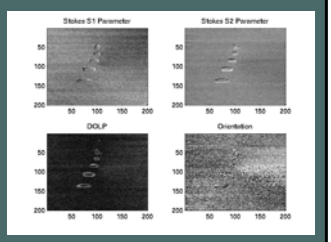
SURFACE LAID TARGETS VIEWED WITH INFRARED POLARISATION SYSTEM



Targets at 20m to 38m

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MINDER TD SUMMARY

- MINDER TD evaluation underway
- Next step integrated data display for close-in sensors
- Further evaluation in Summer 2001

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WATCHKEEPER / REMIDS

- Minefield detection capability included in REMIDS TDP and the WATCHKEEPER URD
- There is a dependency between MINDER and WATCHKEEPER.

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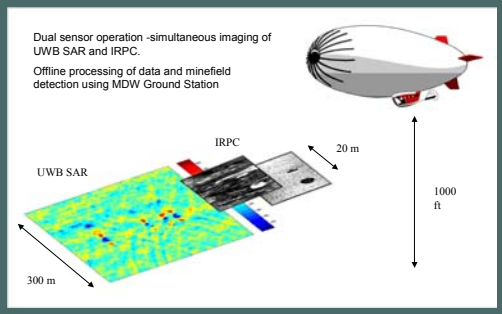
REMIDS TDP: FLIGHT PROFILE



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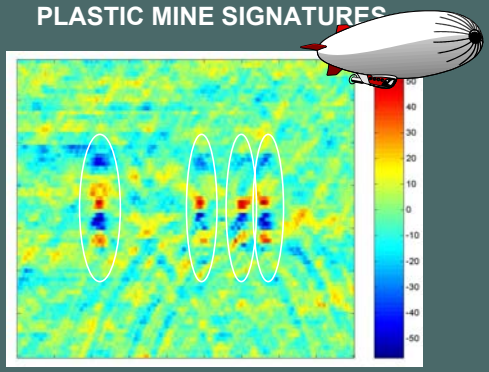
PLASTIC MINE SIGNATURES



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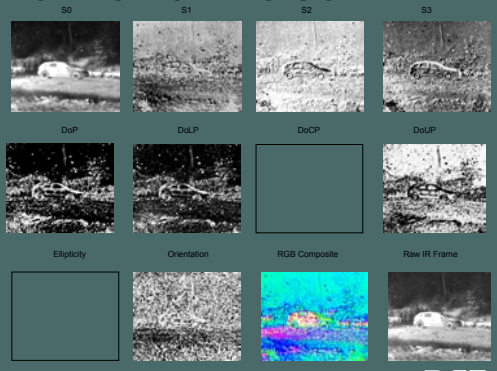
POLARISATION IMAGES OF A CAR



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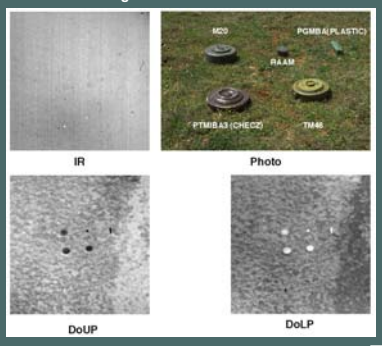
IRPC EXAMPLE IMAGES

Polarisation Images of Mines at 125ft in MW Band



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NEUTRALISATION/CLEARANCE METHODS

- Projectile attack
- Shaped Charge
- Explosively driven spike
- Diode laser/fibre optic
- Explosive harpoon
- RE70 (Richmond Engineering) disrupter
- Megatorch
- Magnetic duplicator

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EXPLOSIVELY DRIVEN SPIKE

- Spike penetrates mine or skewers it so that it can be brought to the surface
- Will detonate anti-handling devices
- Spike array has large area of attack and a means of target confirmation
- Used on buried mines where detonation would be acceptable

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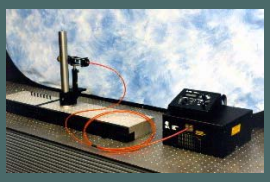
DIODE LASER/FIBRE OPTIC

- Laser light coupled through fibre heats up plastic cased mine and initiates reaction
- Capital expenditure low, only consumable the fibre
- Relatively slow technique
- Used on buried plastic mines where detonation is unacceptable



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EXPLOSIVE HARPOON

- Harpoon fired into ground beside mine, low explosive detonates under mine flipping it out of the ground
- Buried mines where detonation acceptable

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Portable Humanitarian Mine Detector

(Mine photos courtesy of Jane's Publications)

DERA

Project Aims

- Funded by UK Treasury (not a military project)
- Develop & produce a pre-production prototype portable mine detector for use in humanitarian demining.
- 3 Phase project, 2 year timescale
  - Phase 1 - Define threats, select candidate sensors (Year 1)
  - Phase 2 - Develop sensors & test (Year 1)
  - Phase 3 - Integrate & demonstrate (Year 2)

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Candidate Sensors

- **Metal Detection**
- **Ground Penetrating Radar (GPR)**
- **Passive Radiometry**
- **Electro-Impedance Tomography**
  - Limited depth penetration
  - Potentially very cheap sensor
  - Also ground surface measurements (for GPR processing)
- **Acoustic Resonance Detection**
  - Detects “shell-like” objects (i.e. thin walled cavities)
  - Coupling energy into ground is difficult

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MINESEEKER
WWW.MINESEEKER.COM

Contact:

www.MINESEEKER.com

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CONCLUSION

- Military Applied Research Programmes
  - Mined Area Detection, Technology Demonstrators
  - Remote Minefield Detection System Technical Demonstrator Programme
  - Neutralisation
- UK government funded programmes
  - Portable Humanitarian Mine Detector Programme
- Joint ventures
  - MINESEEKER a joint venture between the Lightship Group and DERA

DERA

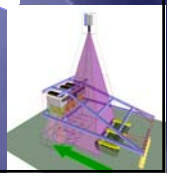
Overview of demining research and development activities in The Nederlands

Presented by Ric Schleijpen

2nd International workshop on Demining, Sweden

Demining R&D at TNO

TNO Defence Research



Ric Schleijpen, Programme manager demining

Contents

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  - Sponsors
  - Projects
- Co-operative efforts
- Selected Projects in detail
- Facilities
- Opportunities

What is new since last year ? Policy

- HOM-2000 came to an end: Results reported and communicated
- Still strong interest in Humanitarian demining
- ITPE signed by the Netherlands (June 2000)
- Royal Netherlands Army study on countermine in MOOTW (2001)
- Royal Netherlands Army general study on countermine (2000-2001)
- Projects related to Humanitarian demining sponsored by MoD in 2001 - 2003 time frame (decision March 2001)
- Spin-off Countermine programme for MoD (2001-2004)

What is new since last year ? Research sponsors

- Sponsors of research programme
  - Ministry of Defence (Direct project funding)
  - Ministry of Defence (Strategic research funding)
  - Royal Netherlands Army
  - Minister of "Development Co-operation"
  - European Union
  - International partners
  - TNO Corporate funding

What is new since last year ? Projects

- Projects for Humanitarian demining
  - Sponsored by MoD in
  - 2001 - 2003 time frame
  - Decision taken in March 2001
  - GPR processing (TNO+University Delft)
  - IR tripwaire detector (TNO)
  - Neutron backscatter (University Delft)
  - Small calibre fire for neutralisation (TNO)
  - Smart prodder evaluation (TNO)
  - ITEP support (to be specified)

Co-operative efforts (examples)

- HPM tests in CA (NL participation)
- TIR test (CA+NL)
  - Test objects supplied to CA
- Polarised IR (NL+ SW)
- Discussions and information exchange
- Invitaitons to attend tests and demo's
  - NQR demo in UK

Projects (selective overview)

- Neutralisation / Protection
  - Aardvark evaluation
  - Bomblet attennuator
- EO polarisation
- EO multi/hyper-spectral
- EO airborne
- Soil effects on Sensor performance
- GPR
- MD
- Sensor fusion
- Semi-autonomous Platforms
- HOM 2000

Neutralisation / Protection(1)

- Vulnerability test Aardvark

  Instrumented Hybrid 3 dummy for measuring crew response

Neutralisation / Protection(2)

- AARDVARK analysis
- Figure: TARVAC simulation of mine detonation underneath Aardvark system

- Figure: MADYMO simulation

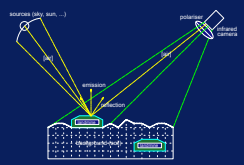
Neutralisation / Protection(3)

- Bomblet/Mine Attenuator

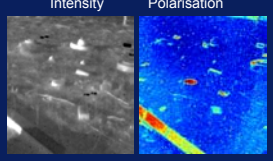
EO Polarised Infrared

- Detection through vegetation
- Tripwire detection

- System Modelling

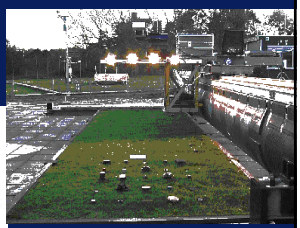


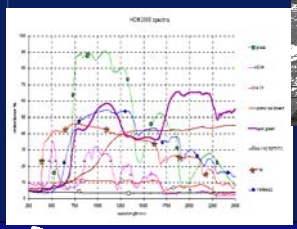
Intensity Polarisation



EO Multi/hyper-spectral (1)

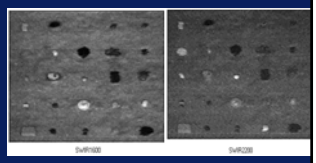
- Visual, NIR 0.4 < λ < 1μm
- SWIR 1< λ < 2 μm



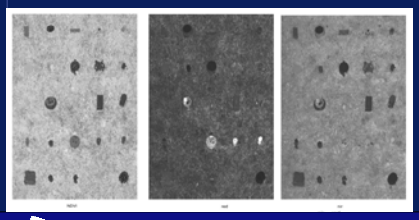


EO Multi/Hyper -spectral (2)

SWIR 1< λ < 2 μm



Visual, NIR 0.4 < λ < 1μm



EO Airborne detection

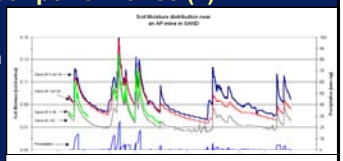
- Detection of minefields by detecting indicators
  EU project ARC: Airborne minefield area reduction

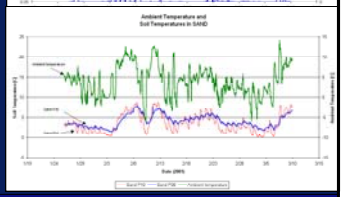
Soil effects on sensor performance (1)

- **Background**
  - Water content affects soil properties
    - dielectric constant, electrical conductivity
    - heat capacity, heat conductivity
  - Water content affects performance of many sensors
    - GPR, TIR, EMI, Passive MW, Vapor detector,..

Soil effects on sensor performance (2)

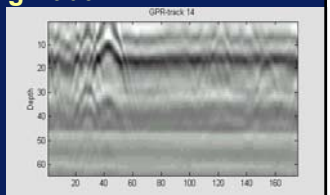
- **Soil water distribution near AP-mine =>**
- **Ambient and soil temperature =>**

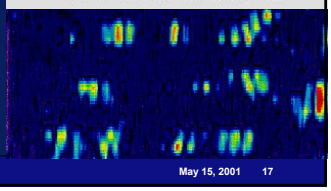




- **Effect on**
  Dielectric constant
  Heat conductivity
  etc ..
- **Effect on sensor performance**

Ground Penetrating Radar

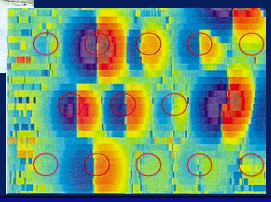




More information than intensity only

- depth
- size
- shape

Metal detection



More information than intensity only

- depth, size, shape
- type and amount of metal

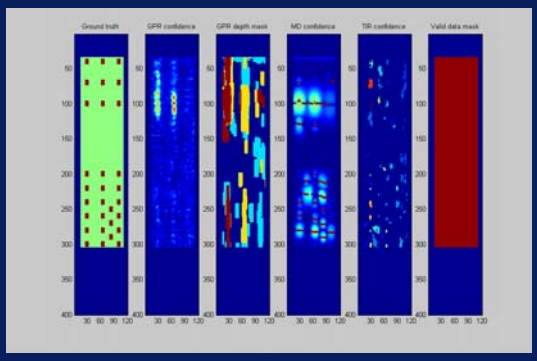
IPPTC: Evaluation of metal detectors for (humanitarian) demining

- Objective: to assist the user in his selection process for the procurement for metal detectors by providing a 'consumer-test' report.
- International cooperation: US, UK, Ca, EU and NL.
- In-soil tests: In controlled conditions at TNO, 70 detectors, 4 soil types
- In-air tests: in Ca at CCMAT, max. detection distance, reproducibility of calibration, influence of moisture on sensor head, influence of sweep speed
- Human factors and ergonomic aspects (UK)
- Field tests: Cambodia and Croatia, involving local deminers, highly magnetic soils
- Reports will be published very soon

Sensor Fusion: Approach

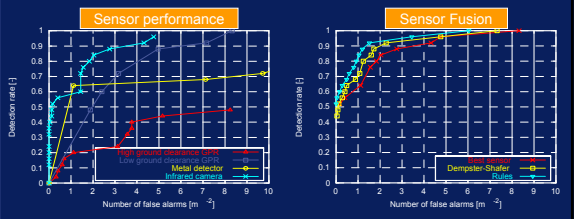
- Model based approach
- Scenario definition
  - expected types and depths of mines
  - soil type and moisture
  - meteorological data
- Sensor pre-processing
  - MD, TIR, GPR each sensor with its own specific pre-processor
  - object data of alarm location with feature information
- Sensor model information
  - threshold and weighing parameters, raw and feature data
  - dynamic simulations, or tabled simulation or real data
- Feature fusion process
  - common spatial grid on surface
  - feature comparison, fusion weight function, match probability

Sensor Fusion : Input Data



Sensor Fusion: ROC curves

- Significant improvement compared to individual sensor



- Further improvement by model based/ feature fusion

Semi-autonomous platforms

- Programme for autonomous platforms and robotics
- Research Testbed
- Positioning sensors

HOM-2000: reported results

- Technology watch
- System concept
  - Scanning strategy
  - Platfrom carried sideways
- Demonstrator design
  - Sensor requirements
  - Requirements for platform stability
- Sensor modelling in demining
- Sensor fusion algorithms
- Testfacilities upgrade
- NQR study

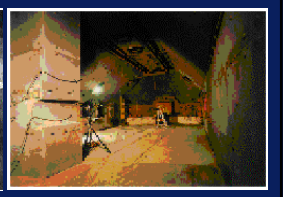
Test facilities: Test lanes

Lanes
- Construction without metal
  10 m x 3 m x 1.5 m
- Different soil types
- Water level control
  (separately per lane)

Platform
- Free of metal
- Different combinations of sensors possible
  (maximum payload 600 kg)
- Position accuracy of 1 cm in all directions
- Sensor height is adjustable
- Computer controlled movement
- Continuous position measurement

Test facilities: Protection / Neutralisation

- TNOs Ballistic Laboratory
  Detonations up to 25 kg
- Large blast simulator of 60 m length
- Small blast simulator of 22 m length



Test facilities: Simulant and Reproduction mines

- Signatures comparable to real mines for TIR, MD and GPR
  - Shape, thermal and electrical properties
- Different AP and AT types
  - Metal casing, medium and low metal content and non-metal

Type	casing material	metal content
AP; type 1	wood	medium
AP; type 2	plastic	high
AP; type 3	PVC	medium
AP; type 4	PVC	medium
AP; type 5	plastic	non
AP; type 6	ABS	low
AP; type 7	PE	medium
AT; type 1	metal	high
AT; type 2	PVC	low
AT; type 3	no casing	non

Opportunities for co-operation

- **Neutralisation / Protection**
- **EO polarisation**
- **EO multi/hyper-spectral**
- **EO airborne**
- **Soil effects on Sensor performance**
- **GPR**
- **MD**
- **Sensor fusion**
- **Semi-autonomous platforms**
- **Explosives detection**
- **NQR**
- **Test and evaluation**
- **Smart Prodder**

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Overview of demining research and development activities in Canada

Presented by Dir Bob Suart

The Canadian Centre For Le Centre canadien des
Mine Action Technologies technologies de´deminage

Presentation Outline

- Humanitarian demining background
- CCMAT Goal / Mandate
- CCMAT Program

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Anti-personnel Landmines - Facts and Figures

- 50-100 million landmines deployed world wide
- $US 3-30 to purchase and $US 300-1000 to remove
- ICRC estimates 2000 victims a month
- 250,000 landmine amputees world wide
- loss of productive land - no estimate

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The Mine Threat

- Blast mines - pressure operated AP and AT
- Stake mines - with trip wires
- Bounding mines
- Directional fragmentation mines (Claymore)
- Shaped charge mines (AT) and booby traps

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Target (Mine) Characteristics

- broad range of types
- significant changes in detailed design and materials within a “type”
- all known mines have detectable amounts of metal
- trip wire activation is relatively common
- functionality is unpredictable

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Background Characteristics

- frequently heavily overgrown
- high levels of metallic clutter

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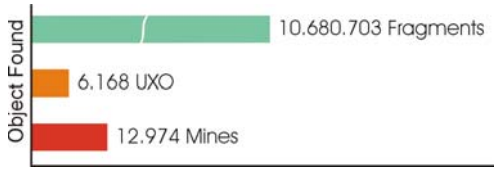
Background Characteristics



Typical Clutter Statistics (Mozambique UN/ADP)

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Military Countermine vs Humanitarian Demining

- Countermine - rapidly clear a path through the minefield leaving most of the mines in place
- Demining - return mine affected land to productive use by systematically removing all of the mines

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The Deminer's Tool Box - Current Status

- Garden tools and machetes for vegetation clearance
- Manual demining - metal detectors and probing by hand
- Mine dogs
- Mechanical mine clearance equipment - flails, rollers, ploughs
- Explosives

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Demining Hand Tools

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Deminer Searches for a Mine (Afghanistan)

(photo - ATC)

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Example of Mechanical Demining Equipment - the Aardvark™

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Explosive Demolition of Mines

(photo - AP)

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Problems with current mine clearance options

- Ground Preparation - complicated by vegetation overgrowth, tripwires and booby traps
- Probing - complicated by hard stony soil, booby traps and heavy vegetation
- Metal detectors - low metal content of AP mines - ground contaminated with shrapnel and metal scrap
- Mechanical clearance equipment - must be affordable, sustainable and transportable

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Transport issues are significant

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CCMAT - Goal

- Established in August 1998 to support the Ottawa process
- Co-located with the Defence Research Establishment Suffield (DRES) in Southern Alberta
- A $17 M (CAD) investment in the development of low cost, sustainable technology for humanitarian demining

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CCMAT - Why DRES?

Improved Landmine Detection Project (ILDP)

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CCMAT - Mandate

- Conduct R&D on demining technologies
- Provide test and evaluation capabilities to demining organizations and equipment developers
- Adapt military technology
- Acquire and disseminate information
- Investigate alternatives to anti-personnel mines

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Research and Development / Test and Evaluation

- Detection
- Protection
- Neutralization
- Enabling technologies

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Detection

- Hyperspectral imaging - VNIR, SWIR, TIR
- Multi-band thermal infrared
- Optical tripwire detection
- Spatially sampled EMI
- Neutron moderation imaging
- X-ray backscatter imaging
- Smart prodder
- Nuclear quadrupole resonance

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Hyperspectral Imaging - An Artists Concept

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The Compact Airborne Spectrographic Imager (CASI)

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Optical tripwire detection

- Need a source of light and a high resolution imager
  - can be broad band or narrow band, active or passive
- Can detect wire if some portions are exposed

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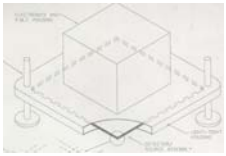
Neutron Moderation Imaging

- Weak neutron source, image returned thermal neutrons
  - potential for AP mines, moisture a problem
- Feasibility study showed that mines can be imaged and proposed a conceptual design
- Follow-on project to build a proof of concept handheld instrument



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Smart Prodder

- Acoustic impedance classification
- Limited production run made to allow user trials
- Trials identified requirement for significant re-design -- currently in progress

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Detector Test and Evaluation Facilities

The Foam Dome and a nonmetallic test rig

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Detector Test and Evaluation Facilities

- Permanent minefields with both A/T and A/P mines
- Several mine lanes with diverse soil types
- Includes paved areas, gravel roads and tracks

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Extensive Detector Testing

- Major joint effort under IPPTC
- Laboratory tests in several facilities
- On-site trials in:
  - Cambodia
  - Croatia
- Tests / Trials in several other countries

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R&D Program - Protection

- Fundamental research in the physics of blast injury and the mechanism of tissue injury
- Apply this knowledge to the development of new protective clothing and equipment

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The Frangible Surrogate Leg

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Instrumented Mannequin Tests with A/P Mines

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"Spider Boot" evaluated against an AP mine (97g)

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Evaluating the Enhanced Demining Ensemble

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Test facilities at the Mine Effects Site

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Neutralization

Effort is focused in two main areas:

- Trials to evaluate mechanical assistance equipment
- Trials to evaluate novel explosives

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Mechanical mine clearance equipment tested at CCMAT

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The Promac Deminer in Operation

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Demonstrating FIXOR™ to Deminers in Kosovo

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FIXOR™ positioned to destroy an AT mine

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Instrumented Surrogate mines for Neutralization Testing

PMA-1: Reproduction Mine on left, actual mine on right

PMA-2: Reproduction Mine on left, actual mine on right

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The Mechanical Equipment Test Site

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R&D Program - Enabling Technologies

- Tele-operated systems for application to:
  - mechanical ground preparation systems
  - area scan or vehicle mounted detectors
  - mechanical neutralization systems
- Affordable, high accuracy, navigation systems for:
  - multiple detector or multiple measurement detection systems
  - target handoff from detection systems to neutralization systems

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Generic On-board Control Systems

- Adapting and simplifying an existing control system (Ancaeus) developed for military applications
- Capable of controlling a broad range of vehicle with minor software customization

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Simplified Control Stations

- Portable control systems
- Inclusion of voice control
- Integration of task requirements into system control

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The Articulated Robotic Scanner

- Robotic scanner for detectors
- Implements automated scan patterns and ground avoidance
- Allows spatially registered detection data -- “detector imaging”

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CCMAT -- Information Availability

- CCMAT Contributes to the Demining Technologies Information Forum (DTIF)
- Founding members of the DTIF are the European Union, Canada and the USA
- The DTIF provides an opportunity for information exchange by:
  - hosting meetings and workshops
  - creating a universally accessible web site
  - publishing an electronic journal of demining technology
  - serving as the publication vehicle for the International Test and Evaluation Program (ITEP)

Canada

Overview of demining research and development activities in Sweden

Presented by Dr. Bo Janzon

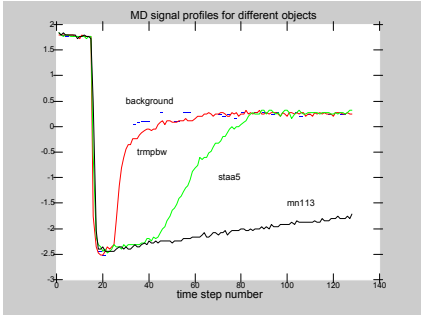
Humus

HUMUS demonstrator platform.

Sensor head with radar antenna (upper) and metal detector antenna (lower).

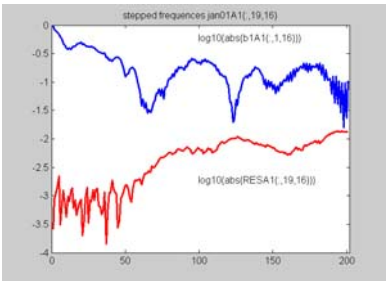
FOI

MD data profiles



FOI

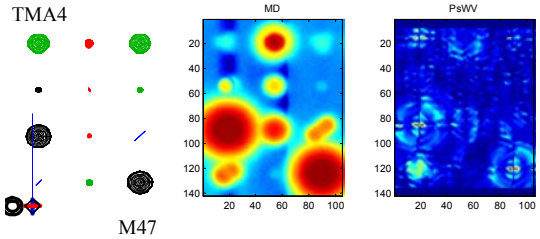
GPR data profiles



FOI

MD and GPR data

TMA4

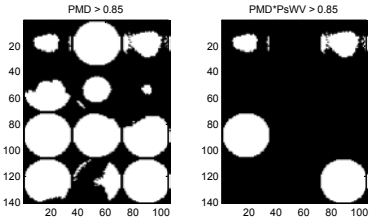


M47

Left: Configuration map of buried objects
Middle: Detected metal using Schiebel metal detector (MD). Log_e scale: blue = 0, red = 5.
Right: Normalised result[3] of matching a Pseudo Wigner-Ville map (PsWV) for one anti-tank mine with PsWV maps at all measured points, using impulse radar with Mpax short antenna.

FOI

Fused MD and GPR

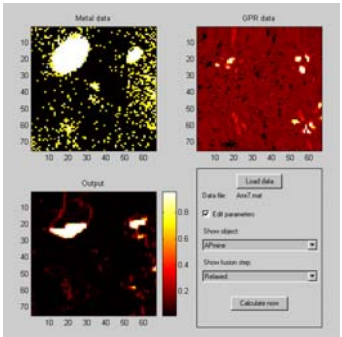


Left: Thresholded PD(MD) > 0.85. Actual anti-tank mines in circular subregions nos. 1, 3, 9 and 12 (counting along columns downwards, from left to right). PD =1, FA = 1.

Right: Surviving subregions of MD detections, consistent with thresholded fused combination, PD(MD)*PsWV > 0.85. All anti-tank mines detected, no false alarms.

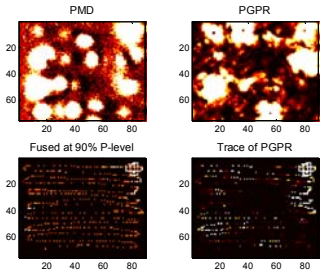
FOI

Gui for fusion of MD & GPR data



FOI

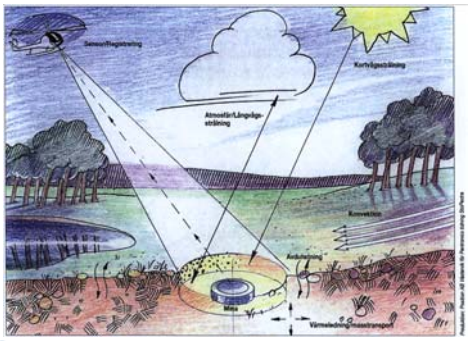
Gui for fusion using cursor



Top: Probability of detection of 16 objects by MD och GPR.
Bottom left: Fused result MD + GPR tracks at 90% probability level.
Max associationdistance 10 pixels
Bottom right: Probability of detection using GPR.

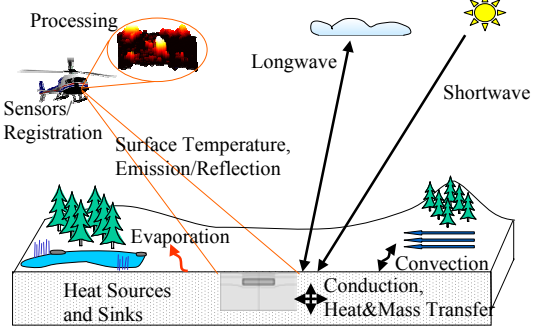
FOI

Optical Detection of Land Mines



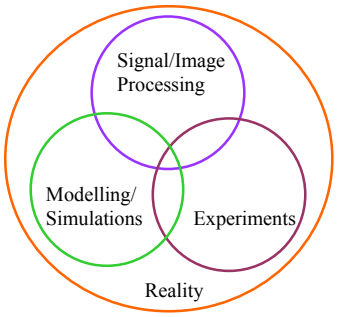
FOI

Optical Detection of Land Mines



FOI

Concept of Optical Detection



FOI

Report of the Close-in Detection Working Group

Participants

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Research goals for :	**Close-in detection**

S/M/L term	Technology	Comment
S	Close-in detection technologies not encompassing explosive detection techniques:	Explosive detection covered by the other group.
M	GPR and Signal processing	Size reduction and classification issues.
S/M	TIR	Polarisation, Signal processing (SP) and signature prediction.
S/M	EO(visible & UV)	Signal processing (SP)
M	Multi & hyper spectral imaging	Signal processing (SP)
S	MD (Advanced or other)	Test and evaluation, FAR reduction.
M	Smart prodder	FAR reduction, field tests.
S/M	HPM/TIR	Frequency dependence, modelling.
S/M	Electrical Imp. Tomography	Prototype, proof of principle (capacitive).

Topics for co-operation:	**Close-in detection**

S/M/L term	Technology	Participants	Result
S	SMART Prodder evaluation	NL/CA	Trial Evaluation report
S	Evaluation of the interaction between metal detectors and magnetic influence fuses: Literature search Threat analysis Trials	NL/CA/UK	Trials Report on findings
S/M	Soil Properties influencing sensor performance	CA/NL/SE/ UK	Data exchange
S/M	Integration issues for Detection sensor arrays: Parametric studies Interference effects tests	CA/NL/UK	Evaluation Report
S	Data exchange on signal processing	CA/NL/SE/ UK	Data exchange

Networks of experts: Close-in detection

Technology	Canadian Expert(s)	Dutch Expert(s)	Swedish Expert(s)	UK Expert(s)
GPR	J McFee jmcfee@dres.dnd.ca DRES	Arnold Wilbers wilbers@fel.tno.nl TNO-FEL Jan Rhebenger Rhenbenger@fel.tno.nl TNO-FEL	Staffan Abrahamson staabr@foi.se FOI Roland Ericsson +46 13 37 8000 FOI	Ian Burch iaburch@dstl.gov.uk DSTL
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EO (visible & UV)	J McFee jmcfee@dres.dnd.ca DRES			Dan Port dmport@dstl.gov.uk DSTL
Multi & hyper spectral imaging	J McFee jmcfee@dres.dnd.ca DRES			Dan Port dmport@dstl.gov.uk DSTL
MD (Advanced or other)	J McFee jmcfee@dres.dnd.ca DRES	Arnold Schoolderman schoolderman@fel.tno.nl TNO-FEL		Ian Burch iaburch@dstl.gov.uk DSTL
Smart prodder	J McFee jmcfee@dres.dnd.ca DRES	-	-	-
HPM/TIR	J McFee jmcfee@dres.dnd.ca DRES			-
Electrical Imp. Tomography	J McFee jmcfee@dres.dnd.ca DRES	-	-	Ian Burch iaburch@dstl.gov.uk

Planned events: Title working group

(trials, demonstrations, briefing)

Event	Date	Location	Organiser	POC			
International Workshop on Demining	May 2001	Sweden					
MINDER TD ARP demo	Sept 01	UK	I Burch	D Ludgate			

Description of co-operation projects

Project Title	Evaluation of the SMART Prodder
Participants	CA and NL
Short description	Evaluation by NL of the Canadian SMART prodder. Output trials evaluation report.
Time schedule	1 to 2 years.
Anticipated Starting	Late 2001 early 2002
Anticipated Completion	2003, 2004
Sponsors	NL predominately, support from CA

Project Title	Effects of metal detectors on magnetic influence fuzes.
Participants	NL, CA and UK
Short description	Evaluation of the interaction between metal detectors and magnetic influence fuses: Literature search, Threat analysis, Trials. Trials report.
Time schedule	2 to 3 years
Anticipated Starting	Once MOU is signed.
Anticipated Completion	2004
Sponsors	NL, CA and UK

Project Title	Soil properties and signal processing GPR data exchange.
Participants	CA, NL, SE and UK
Short description	Data exchange: Soil Properties influencing sensor performance Data exchange on signal processing
Time schedule	On-going through life of MOU.
Anticipated Starting	2001
Anticipated Completion	End of MOU
Sponsors	CA, NL, SE and UK

Project Title	Integration issues for Detection sensor arrays
Participants	CA, NL and UK
Short description	Integration issues for Detection sensor arrays: Parametric studies, Interference effects tests and Report.
Time schedule	4 years
Anticipated Starting	2001
Anticipated Completion	2005
Sponsors	CA, NL and UK

Report of the Explosive Detection Working Group

Participants

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Research goals for :		**Explosive Detection**
S/M/L term	Technology	Comment
S	Vapour sensors	Improve knowledge of vapour transport
M	Vapour sensors	Chemical analysis using dogs or electronics
S/M	NQR	Detection time reduction
M	Nuclear methods	Neutron moderation and X-ray backscatter imaging, proof of concept

Topics for co-operation:	**Explosive Detection**

S/M/L term	Technology	Participants	Result
S	Vapour sensing	NL,UK,SE	Establish ties with respective experts
S/M	Vapour sensing	CA,NL,UK,SE	Shared use of test facilities
S	TNA	NL,UK,SE	Establish ties with respective experts
S	NQR,TNA	CA,UK	Data exchange to facilitate programme definition
M	NQR	CA,UK	CA contribution to NQR development
S/M	NQR	NL,UK	Define NL contribution to NQR development
M	NQR	CA,NL,UK,SE	Shared use of test facilities

Networks of experts:				**Explosive Detection**
Technology	Canadian Expert(s)	Dutch Expert(s)	Swedish Expert(s)	UK Expert(s)
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Planned events: Explosive Detection
(trials, demonstrations, briefing)

Event	Date	Location	Organiser	POC	Comments
Soil sampling in Afghanistan	2001	Afghanistan	SE	L. Sarholm A. Kjellström	For information purposes only
NQR Demonstration	Late 2001	United Kingdom	UK	R.M. Deas	Primarily for vehicle-mounted detection

Description of co-operation projects

Project Title	Close-In TNT detector for landmine detection
Participants	UK and NL with possible co-operation from CA at a later stage
Short description	The development of a landmine detector using NQR technology. A technology demonstrator will be developed to demonstrate buried explosive detection with a prototype to follow from this detection.
Time schedule	Two years development for the technology demonstrator. 1.5 to 2 years development for the prototype.
Anticipated Starting	Late 2001, early 2002.
Anticipated Completion	2005/6.
Sponsors	UK and NL. Possibly CA.

Project Title	Co-ordination of Technical Experts.
Participants	CA, NL, SE and UK.
Short description	Facilitate the contact between technical experts in respective countries.
Time schedule	Ongoing under terms of the MOU.
Anticipated Starting	After MOU signing.
Anticipated Completion	Life of MOU.
Sponsors	CA, NL, SE and UK.

Project Title	Shared Use of Test Facilities.
Participants	CA, NL, SE and UK.
Short description	Shared use of member countries' test facilities for investigation of environmental effects of explosive detection.
Time schedule	Ongoing under terms of the MOU.
Anticipated Starting	After MOU signing.
Anticipated Completion	Life of MOU.
Sponsors	CA, NL, SE and UK.

Project Title	Exchange of NQR and TNA information.
Participants	CA and UK.
Short description	Exchange of Canadian TNA data for UK NQR Data.
Time schedule	Not Applicable.
Anticipated Starting	Late 2001, early 2002.
Anticipated Completion	Ongoing data exchange where relevant.
Sponsors	CA and UK.

Report of the Multi Sensor Systems Group

Participants

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[2] Robin Rutherford has left Dstl/DERA, his replacement is Dan Port, dmport@dstl.gov.uk.
[3] Chairman

Research goals for: (Multi sensor systems)

The group identified the following research areas relevant for Multi sensor systems.

S/M/L term	Technology	Comment
	Sensor fusion algorithms	Detection fusion Feature fusion: Depth, Orientation, …"ID" Signature library/Exchange of data Priority in signals
	System sensor hardware integration	Avoid interference
	Enabling technologies	Positioning, spatial correspondence of data
	Enabling technologies	Robotics
	Presentation of information to operator	Level of processing required
	Performance evaluation	Performance measures, Figures of merit Rate of false alarms Test facilities with representative test objects Dependence on scenario, weather, soil, burial methods and history Prediction models

Topics for co-operation: (Multi sensor systems)

S/M/L term	Technology	Participants	Result
	Performance analysis	All	Information exchange on multi-sensor systems performance
	Sensor fusion concepts	All	Exchange of data and exchange of algorithms
	Sensor positioning Data registration	All	Exchange of information, common evaluation of approaches
	Presentation of information to the operator	SW, UK, CA	Exchange of information
	Robotics/ Teleoperation	All	Explore possible applications of robotics techniques in demining

Experts or POCs: (Multi sensor systems)

Technology		Canadian Expert(s)	Dutch Expert(s)	Swedish Expert(s)	UK Expert(s)
Performance analysis	Name Address e-mail	John McFee Jmcfee@dres.dnd.ca	Piet Schwering Schwering@fel.tno.nl	Andris Lauberts andris@foi.se	Ian Burch iaburch@dstl.gov.uk
Sensor fusion concepts		Kevin Russel	Piet Schwering Schwering@fel.tno.nl Klamer Schutte Schutte@fel.tno.nl	Andris Lauberts andris@foi.se	Dan Port dmport@dstl.gov.uk
Sensor positioning Data registration		Robert Chesney Robert.chesney@dres.dnd.ca	Hans Bol Bol@fel.tno.nl	Dan Axelsson danaxe@foi.se	Dan Port dmport@dstl.gov.uk
Presentation of information to the operator		Robert Chesney Robert.chesney@dres.dnd.ca		Dan Axelsson danaxe@foi.se	Dan Port dmport@dstl.gov.uk
Robotics/ Teleoperation		Robert Chesney Robert.chesney@dres.dnd.ca	Johan van den Heuvel VandenHeuvel@fel.tno.nl	No activity	Ian Burch iaburch@dstl.gov.uk

Planned events: (Multi sensor systems)
(trials, demonstrations, briefings)

Event	Date	Location	Organiser	POC	
International Workshop on Demining	May 2001	Sweden			
ILDP test	August/ Sept 2001	Canada	CCMAT	Robert C	Visitors day
Articulated arm Demo	TBD or ,,	Canada	CCMAT	Robert C	
MINDER TD Demonstration	Sept-Oct 2001	UK	DERA	Ian Burch	Industry +DERA Systems

Description of co-operation projects (Multi sensor systems)

Project Title	Sensor Positioning (working title)
Goal	Provide a suitable solution for sensor positioning and data registration
Participants and POC	Canada: Robert Chesney, Sweden: Staffan Abrahamson UK: Dan Port NE: Hans Bol
Short description	In multi-sensor systems need very accurate correlation between the output of the individual sensors. Depending on the application (AT/AP mines, Vehicle mounted/Handheld) several options to achieve this might be used, involving a set of sensors: Canada: DGPS Driven wheel odometry Downward looking imagery UK DGPS Shaft rotation odometry Downward looking imagery NE Downward looking imagery SW Angular rate meters for handheld Several options are tested in the various nations and information on the results will be exchanged.
Time schedule	Phase 1: Exchange of existing reports Phase 2: Exchange of experimental data Possibly arrange an expert meeting group in conjunction with a planned test or demonstration
Anticipated Starting	Mid 2001
Anticipated Completion	Mid 2002
Deliverable	Matrix in which options for to a suitable solution for sensor positioning and data registration are compared.

Sensor fusion is another promising topic for co-operation but could not be discussed in detail. Exchange of data and exchange of algorithms would be the goals of this project

General remarks: (Multi sensor systems)

- More time should be taken for the plenary session and for the working group discussions
- Interaction between the meetings is essential:
  Use the opportunity of meetings during demonstrations
  Use e-mail

Report of the Remote Detection Technology Elements Working Group

Participants

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[4] Chairperson
[5] Robin Rutherford has left Dstl/DERA, his replacement is Dan Port, dmport@dstl.gov.uk.

Research goals for (CA): (Remote detection technology Elements)

S/M/L term	Technology	Comment
*Short term	Passive IR performance prediction model	Aimed at the buried mine detection problem, starting.
Medium term	Bioluminescence + intensified hyperspectral detection	Aimed at the buried mine detection problem, under evaluation.
Medium term	Vegetation stress monitoring with induced fluorescence and hyperspectral detection	Aimed at the buried mine detection problem, under evaluation.
*Long term	Passive hyperspectral imaging	Begun 1990 (surface-laid, ready as humanitarian tool) and 1995 (buried), SWIR hyperspectral imager available late 2001 and LWIR hyperspectral imager available post 2002?

* Most active program

Research goals for (UK): (Remote detection technology Elements)

S/M/L term	Technology	Comments
Short term	Ultra wide band radar detection	Part of the REMIDS program, aimed at airborne detection of surface-laid and buried minefields, begun 1995, ending 2002, a parallel humanitarian program [mineseeker*] begun 2000. Also part of the MINDER TD
Short term	Polarimetric IR detection	Part of the REMIDS program, aimed at airborne detection of surface-laid and buried minefields, begun 1995, ending 2002. Also part of the MINDER TD.
Short term	Data processing associated with the fusion of the two previous techniques	Part of the REMIDS program, aims at airborne detecting surface-laid and buried minefield, begun 1995, ending 2002. Also part of the MINDER TD.
Medium term	Trip wire detection	To start FY 2001

*medium/long term program.

Research goals for (NL): (Remote detection technology Elements)

S/M/L term	Technology	Comment
Medium term	MWIR and LWIR experimental imaging investigation	Together with modelling of thermal properties
Medium term	MWIR and LWIR processing	will continue with EU project (LOTUS)
Long term	Modelling of thermal properties of mines and background	Heating experiment; temperature database available in different soils.
Medium term	MWIR, LWIR and Visual polarisation imaging	Aims at detecting surface-laid and flush buried mines.
Long term	Acquisition of hyperspectral imager (MWIR or LWIR)	Aims at generic application also in ARC EU project

N.B. The general objective for most of these programs is to detect single mines.

Research goals for (SW): (Remote detection technology Elements)

S/M/L term	Technology	Comments
Long term	IR polarimetry	Currently no funding
Long term	IR modelling	Reduced funding almost sure for another 2 years
Long term	Buried mine detection by soil texture monitoring	Continued partly in ARC, partly in collaboration with Chalmers University of Technology
Long term	Area minefield reduction (ARC) temporal signatures	Collaboration in EU project (AU,BE,NL,E,SP)
Medium term	Modular Airborne Sensor Platform (SIREOS)	First test autumn 2001.

Topics for co-operation: (Remote detection technology Elements)

S/M/L term	Technology	Participants	Result
Medium term	IR Polarimetry and modelling	NL,SW,UK	
Short to medium term	IR performance prediction modelling and validation	NL,CA,SW	Collaboration is already established between CA and NL, in depth discussion is going on. Experiment in CA will start in summer 2001. SW has a model and wants to participate.
	Exchange of hyperspectral data	NL,CA,UK	NL has interest in CA CASI data and NL has Imspector data available. CA to determine if interest is mutual. UK funding not yet available, man power available to work on processing
	Tripwire detection	NL,UK,SE	NL will start a project this year, based on polarimetric techniques.

Experts or POCs: (Remote detection technology Elements)

Technology	Canadian Expert(s)	Dutch Expert(s)	Swedish Expert(s)	UK Expert(s)
IR polarimetry	J-R Simard * Jean-robert.simard@drev.dnd.ca, DREV	W. de Jong * W.deJong@fel.tno.nl TNO-FEL	G. Forssell Gorfor@foi.se FOI	Dan Port dmport@dstl.gov.uk Dstl
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* identified point of contact.

Planned events: (Remote detection technology Elements)
(trials, demonstrations, briefing)

Event	Date	Location	Organiser	POC	Comments
IR performance prediction modelling and validation organization meeting	June 2001	NL,SE	CA,NL, SE	Capt Marc Haché Marc.Hache@dres.dnd.ca	To ensure appropriate experimental design

Description of co-operation projects

Project Title	ARC
Participants	SW (Magnus Uppsäll), NL (Eric den Breejen) plus other EU partners
Short description	Airborne minefield reduction
Time schedule	Jan 2001 till end of June 2003
Anticipated starting	Jan 2001
Anticipated completion	June 2003
Sponsors	50 % EU and 50 % participants

Project Title	Diurnal and seasonal IR, temperature and temperature gradient, and meteorological measurements and modelling
Participants	CA (Marc Haché), NL (Wim de Jong), SW (Stefan Sjökvist), UK (Ian Burch)
Short description	Canada to acquire IR images of instrumented buried mines for at least one year, plus relevant temperature and temperature gradient and meteorological data. Sweden has a very advanced model and wants to validate this model with more measured data. TNO has 6 test lanes equipped with sensors and has a one-dimensional model. The collaboration consists of SE measurements at the TNO facility during a few weeks and exchange of measured data between all three participants and exchange of model results. Interest of UK in data exchange. Some data already available from REMIDS.
Time schedule	Experiment at TNO in August 2001, DRES commencing summer 2001
Anticipated starting	Already started as bilaterals NL-CA and NL-SE
Anticipated completion	Mid 2003
Sponsors	CA: Capt Haché NL: Wim de Jong SE: TBD

Project Title	Comparison IR polarimetry measurement systems
Participants	NL (Wim de Jong), SE (Göran Forssell), UK (Dan Port)
Short description	Joined experiment with the different measurement systems available UK: on chip measurement and rotating filter in the MWIR NL: rotating filter in LWIR (or MWIR) SE: stepping filter in LWIR and MWIR Could be combined with MINDER demonstration in

	September/October 2001 (somewhere in UK). Comparison of measurement results Comparison of detection results after processing
Time schedule	Experiment in late summer 2001, depends on the signing of the MOU.
Anticipated starting	2001
Anticipated completion	End of 2003
Sponsors	NL: running project SE: TBD UK: running MINDER project.