Annex 1

Schematic overview of other systems and technologies

The following table presents a schematic, non-exhaustive overview of other landmine detection and area reduction sensing technologies and systems the editorial team was aware of. These do not appear in full in the main section of this Guidebook either because information was requested but not forthcoming in time or difficult to obtain, or the contacted organisation did not express its interest in having a full entry, or the system did not appear to be mature or representative enough for humanitarian demining applications. Apart from a couple of representative exceptions, systems which seemed to be primarily targeted at defence applications have not been included. In general the proportion of systems for which demining related developments have been terminated or at least put on hold is higher than for the entries in the main section, although applications in other domains, such as non-destructive testing or remote sensing, might again very well be pursued.

The information provided in the following table is meant to be sufficient for an overview and to provide the reader with basic information to start a more in-depth search. The entries are subdivided following the same categories employed in the main section (with the addition of a couple of entries representing enhanced metal detectors), however without any particular ranking inside each category. Where available related *references* (in a short form) and *websites* are reported as well. Bold characters are used to point to the system name, sensor type or contact person which appears to best characterise an entry.

Technology	System name & origin	Basic characteristics & references	Contact person	Additional information
1. Enhanced Metal Detectors	**Meandering Winding Magnetometer** (MWM) Jentek Sensors, Inc., US	Hand-held or vehicle-based. Metal detector relying on shaped magnetic field patterns, and featuring «imaging» capabilities. Quantitative estimates of size and depth for known object shapes are also potentially possible. *References*: N.J. Goldfine, et al., *Proceedings SPIE*, Vol. 5089 (2003), pp. 872-883; *Proceedings. SPIE*, Vol. 4038 (2000), pp. 56-65; *Proceedings SPIE*, Vol. 3710 (1999), pp. 89-100.	Neil Goldfine	Development likely ongoing for other applications (e.g. Non-Destructive Testing).
2. Enhanced Metal Detectors	**DIPS (Digital Induction Pulse Sensor)** EPPRA sas, France	Hand-held. Prototype developed and tested in Namibia/Angola with MgM, within the European MINESEYE project, 1999-2001 (see also www.mgm.org). *Website*: www.eppra.com	Carmen Dumitrescu, Peter Choi	Development possibly on hold for humanitarian demining.
3. Other Low-frequency Electro-magnetic	**Non-metallic Mine Detector (NMD 78, NMD 79)** -, South Africa	Vehicle-based. Currently 30 systems available, as well as technology transfer opportunities. *References*: UNMAS & GICHD, *Mine Action Technology Newsletter*, October 2005, Issue No. 3 (see www.gichd.ch); Peter Stiff, *Taming the Landmine*, Jan. 1986, Galago Publishing Company.	Martin Bird, Eugene Lombard, Boet Joubert	Used in the Rhodesia "bush war" (late 1970s) for the AT detection on roads ("anomaly detector"). Developments likely stopped since then.
4. Ground Penetrating Radar	**Sencion Alpha Pro 4** COS Co. Ltd, Japan	Hand-held. GPR combined with a metal detector. *References*: *Final Report (Summary) for Humanitarian Mine Clearance Equipment in Afghanistan*, Japan International Cooperation System, 31 March 2005, www.mineaction.org/doc.asp?d=452. *Website*: www.cos.co.jp/, www.jics.or.jp/jics_html-e/activities/grantaid/afg2003_01.html	-	Field tested in Afghanistan (2004-2005), and possibly earlier in Cambodia.
5. Ground Penetrating Radar	**Mine Eye** JAHDS and GeoSearch, Japan	Hand-held. Originally based on the LLNL MIR radar module. Developments ongoing since the mid-'90s. *Website*: www.jahds.org/, www.geosearch.co.jp/	Hiroshi Tomita	Likely to have been field tested in Cambodia and Thailand.

Technology	System name & origin	Basic characteristics & references	Contact person	Additional information
6. Ground Penetrating Radar	**HUMUS ATR** platform FOI, Sweden	Hand-held. GPR with classification capabilities. *References*: ITEP Project 2.2.2.5 (report pending). *Website*: www.swedec.mil.se/index.php?c=news&id=17971	Staffan Abrahamsson	Research on GPR at FOI has been ongoing for the past 10-15 years.
7. Ground Penetrating Radar	- **Tricon** Germany	Vehicle-based (**Pookie**). *References*: W. Lawrence, Pookie Rides Again, *MAIC Journal of Mine Action*, Issue 6.2, August 2002 (see maic.jmu.edu). *Website*: www.tricon-online.de	Stefan Schultheiss	Uses a COTS GPR array from Sensors and Software, and has been field tested in Africa.
8. Ground Penetrating Radar	**LANDMARC** LLNL (Lawrence Livermore National Laboratory), US	Hand-held. Based on the LLNL MIR (**Micropower Impulse Radar**). *References*: S. Azevedo, LANDMARC (land mine detection), *IEEE Potentials*, 17(4), Oct-Nov 1998, pp. 19-20. *Website:* www.llnl.gov/str/Azevedo.html	Stephen Azevedo	Looks like developments stopped around 1998.
9. Other Ground Penetrating Radar	**SRI Airborne GPR**, Forward looking GPR, and harmonic GPR, SRI International, US	Vehicle-based and airborne. For airborne system: mostly surface minefield detection. *Website:* www.sri.com/esd/ -> Penetrating Radar.	-	Unlikely to have been tested for humanitarian demining applications.
10. Other electromagnetic	**EDIT-3/RMPA** (Resonant Microstrip Patch Array) Stolar Research Corporation, US	Hand-held "simplified" GPR. *References*: Fully featured in the GICHD *Metal Detectors and PPE Catalogue 2005; NVESD EDIT Fact Sheet* (*www.humanitariandemining.org -> Detection -> Handheld Detectors*). *Website:* www.stolarhorizon.com/	Larry Stolarczyk (Stolar), Joseph Duncan (Stolar), Richard Walls (US Army NVESD)	Tested by US Army. Prototypes available for technical testing. Developments ongoing for other applications.
11. Trace explosive detection	**Portable field detector** FOI, Sweden	Hand-held (battery operated sampling unit) and vehicle based (gas chromatograph and thermoionic analysis unit). *References*: L. Sarholm, Presentation of Mine Clearance research project at FOI, NDRF Summer Conference 2002 (see www.ndrf.dk -> Past Events); A. Kjellström, *Chemical detection of explosives - Analysis of air and soil*, same conference.	Lena Sarholm, Ann Kjellström	Field tests were planned for 2003.

Technology	System name & origin	Basic characteristics & references	Contact person	Additional information
12. Bulk explosive detection: NQR	- King's College London, UK	Hand-held and/or vehicle-based. Noise excitation based device, featuring wide excitation bandwidths and low power consumption. Laboratory demonstrator available. *References*: J.A.S. Smith, et al., *Proceedings EUDEM2-SCOT International Conference*, 2003, pp. 715-721 (see www.eudem.info) *Website:* www.nqrconsultancy.co.uk/	**John Smith**	Research on NQR for the detection of explosives at KCL has been ongoing for the past 10-15 years, at least.
13. Bulk explosive detection: NQR	**NQDR (Nuclear Quadrupole Double Resonance)** J. Stefan Institute, Ljubljana, Slovenia	Possibly man-portable. Use of an external magnetic field to increase NQR resolution and sensitivity (in particular for the detection of TNT). *References*: T. Apih, et al., *Proceedings EUDEM2-SCOT International Conference*, 2003, pp. 722-727 (see www.eudem.info). *Website:* www.ijs.si/ijs/dept/f5-nmr/	Tomaz Apih, Robert Blinc	See also T. Apih, J.A.S. Smith, J. Seliger, NATO Science for Peace project 978007 "Minefield Detection", 2003-2006
14. Bulk explosive detection: NQR	- Kaliningrad State University, Russia	Hand-held and/or vehicle-based. Various systems and techniques developed over the years. *References*: see Websites below. *Website:* www.albertina.ru/, www.ksu.kern.ru/minedet/, http://www.ksu.kern.ru/grechishkin/ww8.htm	**Vadim Grechishkin**	Research on NQR for the detection of explosives at KSU has been ongoing for the past 10-15 years, at least.
15. Bulk explosive detection: NQR	- Darmstadt Technical University & Ruhr University Dortmund, Germany	Possibly man-portable. *References*: J. Altmann, et al., *Proceedings EUDEM2-SCOT International Conference*, 2003, pp. 722-727 (see www.eudem.info); M. Nolte, et al., Journal of Phys. D: Applied. Phys. 35 939-942, 2002.	Franz Fujara (Darmstadt), Jürgen Altmann (Dortmund)	Developments still somewhat far from practical field applications.
16. Bulk explosive detection: NQR (+GPR)	**Advanced Mine Detector (AMD)** GE Security and CyTerra Corporation, US	Hand-held. Combination of GPR, metal detector and NQR, for defence applications. *Website:* www.cyterra.com -> Countermine.	-	Ongoing developments, little public information available.

Technology	System name & origin	Basic characteristics & references	Contact person	Additional information
17. Bulk explosive detection: NQR	- Osaka University, Japan	TBD. *References*: M. Tachiki, et al., *Proceedings of HUDEM 2005 (Robotics and Mechanical Assistance in Humanitarian Demining)*, 2005, pp. 109-111 (see www.hudem2005.org and www.itep.ws). *Website:* www.jst.go.jp/kisoken/jirai/kadai/explosive-e.pdf	Hideo Itozaki	Project probably still in early phases.
18. Bulk detection systems: Neutron based, diverse methods	- Exdet Ltd., US/Russia	Hand-held. Dual portable system: neutron backscattering (hydrogen detection) to be followed by thermal neutron activation (nitrogen detection). *References*: G. Pekarsky, *Proceedings 2nd Intnl. Conf. on the Detection of Abandoned Land Mines*, 1998 (IEE Conf. Publ. No. 458), pp. 147-151; A. Toor, A.A. Marchetti, *Monte Carlo Simulations for Mine Detection*, LLNL Report UCRL-ID-138119, March 2000.	**Gregory Pekarsky**, Vitaly Bystritski	Detectors might have been used by Russian Army. Unclear if developments have been pursued since.
19. Bulk detection systems: TNA	- Kyoto University, Nagoya University, Japan	Likely to be vehicle-based. *References*: K. Yoshikawa, et al., *Proceedings of HUDEM 2005 (Robotics and Mechanical Assistance in Humanitarian Demining)*, 2005, pp. 116-119 (see *www.hudem2005.org* and *www.itep.ws*); T. Iguchi, et al., same *Proceedings*, pp. 112-115; Y. Takahashi, et al., same Proceedings, pp. 120-123. *Website:* www.jst.go.jp/kisoken/jirai/kadai/explosive-e.pdf	Kiyoshi Yoshikawa (Kyoto), Tetsuo Iguchi (Nagoya)	Several sub-projects, in particular on a discharge-type fusion neutron source and on gamma rays detectors, probably still in early phases.
20. Bulk detection systems: Neutron, fast	**PNCAS (Pulse Neutron Chemical Analysis Sensor)** EPPRA sas, France	Man portable or (more likely) vehicle-based. Relies on a very short pulse plasma neutron generator and a large area very fast gamma ray detector. Prototype developed and tested in Namibia/Angola with MgM, within the European MINESEYE project, 1999-2001 (see also *www.mgm.org*). *References*: C. Bruschini, *ExploStudy, Final Report*, p. 33, Feb. 2001 (see *www.eudem.info*). *Website:* www.eppra.com	Carmen Dumitrescu, Peter Choi	Development possibly on hold for humanitarian demining, ongoing in other domains (e.g. security).

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21. Bulk detection systems: Neutron, fast	**SuperSenzor** HiEnergy Technologies, US	Man portable or vehicle-based. Relies on the associated particle technique and high resolution Germanium gamma rays detectors to yield a quantitative empirical determination of the Carbon, Nitrogen and Oxygen ratios, and the chemical formula, of the substance under analysis. *References*: B.C. Maglich, et al., *Proceedings EUDEM2-SCOT International Conference, 2003*, pp. 761-765 (see *www.eudem.info*); *Website:* www.hienergyinc.com/	Bogdan Maglich	Tested as a confirmation sensor for AT mines by NVESD in 2003. Related activities possibly ongoing.
22. Bulk detection systems: Neutron, fast	- **EADS SODERN**, France	Vehicle-based. Associated particle technique based system, mainly for defence applications and as a confirmation sensor for the time being (to be employed in the Franco-German MMSR-SYDERA «Vehicle-Mounted Close-in Mine Detection System» project). *Website:* www.sodern.fr/	Philippe Le Tourneur	Demonstrator successfully field tested in 2004. Developments are ongoing.
23. Bulk detection systems: neutron backscatter	**DIAMINE** INFN (Italian National Institute of Nuclear Physics) Padova, Italy	Hand-held. Integration of a metal detector with a neutron backscatter system, for the detection and imaging of landmines and aimed specifically at humanitarian demining (2000-2002). *References*: G. Nebbia, et al., *Detection of hidden explosive in different scenarios with the use of nuclear probes*, INPC 2004 (see *www.fy.chalmers.se/conferences/inpc2004/*); G. Viesti, et al., *Proceedings EUDEM2-SCOT International Conference, 2003*, pp. 737-742 (see www.eudem.info).	Giancarlo Viesti, Giuseppe Nebbia	Interesting concept and with attention to HD, did however not reach the full development stage. The project included an in-depth Soil Report by the Ruđer Boškovic Institute, Zagreb, Croatia.
24. Other bulk detection systems: X-ray backscatter	- **YXLON** GmbH, Germany	Vehicle-based. Detection has been apparently proven down to 20 cm depth. Prototype featured relatively long detection times. *References*: W. Niemann, et al., *Detection of buried landmines with X-ray backscatter technology*, Proceedings 8th ECNDT, Barcelona, June 2002. Available in Insight Vol 44 No 10, October 2002. *Website:* www.yxlon.com	-	Field tested by German MoD (1997-2000) as a direct imaging technique. Deemed possibly helpful as a confirmation sensor.

Technology	System name & origin	Basic characteristics & references	Contact person	Additional information
25. Acoustic/ seismic: **Impulse acoustics**	- Monash University, Australia	Hand-held. Simple non-contact method employing two stand-off acoustic microphones scanned over the target and used differentially, and an excitation loudspeaker. *References*: C. G. Don, A. J. Rogers, *Location of buried objects by an acoustic impulse technique*, Acoustic Australia, Vol. 22, No. 1, pp. 5-9, 1994; C.G. Don, A. J. Rogers, Journal Acoustic Society of America, 95, 2837-2838, 1994; US Patent No. 5,563,848, 08 October 1996.	Charles Don (retired)	Field testing unlikely to have been taken place. No recent developments known.
26. Acoustic/ seismic: **Non-linear acoustics**	- Stevens Institute of Technology, US	Vehicle based (hand-held variants might be possible). *References*: D. Donskoy, et al., Journal Acoustic Society of America, Vol. 111, No. 6, pp. 2705-2714, June 2002; several US patents. *Website:* www.soe.stevens-tech.edu/News/donskoy.html, www.stevens.edu/engineering/ceoe/People/donskoy.html	**Dimitri Donskoy**	Has pioneered non-linear acoustic landmine detection since the '90s. Systems extensively field tested with US Army.
27. Vehicle-Based Multi-Sensor Systems	**MMSR-SYDERA** Rheinmetall Landsysteme GmbH, Germany, Thales Airborne Systems and MBDA, France	Vehicle-based. Remote controlled mine detection and clearing system (metal detectors, GPR, multi-spectral opto-electronic and neutron based confirmation sensors), primarily for peace-keeping and defence applications. Five vehicles – decoy, detection, confirmation, command & control – to be combined according to the target scenarios. *References*: F. Le Gusquet, et al., Proceedings SPIE Vol. 5804 (2005), pp. 485-495. *Website*: http://www.rheinmetall-detec.de/ index.php?lang=3&fid=950	Hermann Grosch, Axel Kaspari (Rheinmetall)	Franco-German collaborative project. Until 2007: development of prototypes.
28. Remote sensing systems	**Camcopter** using IR or GPR/SAR Schiebel Inc, US, Schiebel Technology, Elektronische Geräte GmbH, Austria	Airborne. Remotely controlled, fully autonomous aerial platform capable of mounting different sensors. *References*: T.R. Gendron, *Mechanically assisted Landmine Clearance and Detection*, MAIC Journal of Mine Action, Issue 3.2, Summer 1999 (see maic.jmu.edu); NVESD Camcopter & Landmine Survey and Detection System Fact Sheets (*www.humanitariandemining.org -> Detection -> Wide Area Detection/Area Reduction*). *Website:* www.schiebel.net	James Rolig (Schiebel Technology, Inc.), Charles Chicester and Karin Breiter (US Army NVESD)	Tested by US Army with Infrared and Synthetic Aperture Radar sensors. Developments might have been halted since these tests.

Technology	System name & origin	Basic characteristics & references	Contact person	Additional information
29. Remote sensing systems	**Mineseeker UWB** Mineseeker Foundation and QinetiQ, UK	Airborne. Airship mounting an Ultra Wideband Synthetic Aperture Radar (UWB SAR) by QinetiQ, in principle capable of high resolution, foliage penetration and buried target detection. Test reports (2000-2001) available from the Website. *Website:* www.mineseeker.com/		Developments might have been halted since the tests in Kosovo.
30. Remote sensing systems: Multi/ Hyperspectral	**CASI (Compact Airborne Spectrographic Imager)** CCMAT & Itres Research, Canada	Airborne or vehicle-based. Possible application to the detection of surface laid mines or of minefield indicators (rather than individual mines), or of mines on roads, in particular recently emplaced ones. Buried mine detection is possible under some circumstances. *References*: J. McFee, et al., Proceedings SPIE Vol. 5794 (2005), pp. 56-67; T. Ivanco, Proceedings SPIE Vol. 4394 (2001), pp. 365-378. *Website:* www.ccmat.gc.ca, www.itres.com	John McFee (CCMAT)	Ongoing developments. Research on multi/ hyperspectral imaging has been ongoing at CCMAT for the past 10-15 years, at least.
31. Remote sensing systems: **Infrared, Polarised**	- FOI, Sweden	TBD. Results seem rather negative («it is very difficult to distinguish man-made objects from the surrounding terrain and it is not possible to detect tripwires»). *References*: ITEP Project Nr. 2.5.2.1 (see www.itep.ws).	Goran Danielsson	See also footnote for the "Polarised camera system for landmine detection" entry (TNO, The Netherlands).
Older systems:				
32. Ground Penetrating Radar	**Zakros (or Zagros)** **CSIR**, South Africa	Vehicle-based GPR array. Developed early 1970s to early 1980s and extensively field tested.		
33. Bulk detection systems: **Neutron backscatter**	- **SAIC**, US	Hand-held neutron backscatter system, probably developed during the 1980s. *References*: G. M. Borgonovi, et al., *Landmines and Unexploded Ordnance Detection, in A Remotely Controlled Multi-Sensor Platform for Humanitarian Demining*, Report of the Advisory Group Meeting held 3-7 April 2000 at the IAEA Headquarters, Vienna, Austria, IAEA publication IAEA/PS/AG-1093.		