The EOD Robot
Enhancing Capability

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• I have worked at what is now the Defence Academy of The United Kingdom (Formerly known as Royal Military College Of Science) since 1978.
• My base degree is in Applied Nuclear Physics and my Doctorate is in Military Vehicle Vetronics Architectures
• I have worked on explosive ordnance research ranging from nuclear weapons effects to 40mm 40x46 Radar Proximity Fuzes.
• I have been involved in CIED research and training for over 30 years. UK EOD is a small but very close knit family, of which I am a trusted (for a scientist) friend.
• Recently I have been involved in using small low cost robots to investigate future robotics applications.
• It is my privilege to train UK EOD operators in electronics at all levels of competence.

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Plan

• Introduction

• What do the UK users do with current robots?

• Learning from the users and improving the next generation of EOD robots.

• Some systems Engineering

• Low cost alternatives and route proving

• References and Acknowledgements
Introduction

• The UK started using EOD robots of the wheelbarrow family in the mid 1970s as a result of a high attrition rate of EOD operators in NI during the period 1971-1972

• Since then the doctrinal approach has evolved to a point where manual approach is considered the last resort.

• There are now many types of EOD robot in use by the UK including Cutlass, Wheelbarrow, Talon, Dragon Runner, Throw Bot and some complimentary UAV ISTAR systems.

• Robot leaf blowers are used to expose devices and robot GPR is used to locate them.

• Robots are also used to provide ECM cover and locate RF sources.
### Philosophy:
- Preservation of life (Paramount).
- Preservation of property.
- Forensic Evidence.
- **Restore Normality.**

From Scattergood 2012

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UK IEDD Philosophy
Talon

Wheelbarrow MK8

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Throw Bot

Dragon Runner

Cutlass
T-Hawk UAV used for remote observation / sensing and as a downdraught leaf blower to expose an IED.

Cyclone – leaf blower on US vehicle.

Buffalo and Panama Snatch robot GPR system.

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The EOD robot activity cycle

• Assume heavy scales deployment of full size robot and support

• Post arrival drills, such as handover from reporting unit and getting size, history and context information from them the EOD team will set up the ICP. (sometimes with extra cautions depending on scenario)

• After this the Robot will be deployed with the possible exception of VOIED scenarios. (Robot may trigger the device)

• It is here that we need to analyse current non manual procedures to understand current robot tasks.
Robot Deployed

- The robot will be armed with the appropriate tools and disruptor device.
- The operator will guide the robot to the device. He / she may use the approach route used by the detecting persons, to have a proven route if possible.
- After using robot camera the operator will decide upon best placement of disruptor before initiating it (usually cameras will be reversed to protect them).
- Cameras are them placed to view remaining device components and confirm satisfactory disruption.
EOD robot activity light scales

• Smaller robot may not have full set of tools and hence following may occur.
• Robot sent out to get camera view of device.
• Robot places charge or small disruptor near to device and then backs away
• Remote detonation of charge and the robot returns to view results.
• So less likely to be able to disrupt and limits to remote initiation.
Manual Tasks

- Post arrival drills are as described.

- For various reasons including lack of robot access or suspected VOIED devices a manual approach may be taken.

- The activities of the operator need to be studied and understood to determine what capabilities and skills the human has which current robots do not.

- The idea of autonomous EOD robot activity is not under consideration at this point of the study.
Manual Task

• Operator will assess the best access route with preference given to any route proven by previous activity of search or device discovery personnel. Again any information gained by those who found device will be considered.

• As usual a ’soak time’ will be applied before commencing.

• During approach operator will use visual clues and ground signs to avoid any possible VOIED triggers.

• Operator will be trying to assess how the device is placed and whether it has any links to other objects such as PSU or command system.

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Manual cont..

• The operator may use an X ray system to inspect device.

• Once the device has been investigated by non contact measures such as X ray and visual inspection the operator will decide on the best disruptor placement and then withdraw.

• Disruptor is fired and a post disruptor approach along same route is used to confirm device destruction.
Less common manual EOD activities

• A decision may be made to either
  – Disrupt with the aim of removing the PSU.
  – Disrupt with the aim of cutting out the detonator / payload element.
  – Use a heaving charge or manipulator to extract buried charges.
  – To remove the PSU and or detonator manually.
  – Follow any obvious links from the device to other devices or trigger systems. Sometimes to determine the direction of command wires.
  – Deploy remote ECM and other EOD equipment (mule)
Can we automate any of this?

- Robots with 3D visualisation (being studied by Cranfield University) would be able to access some places currently not accessible to robots and hence save a manual task.

- The ability to navigate between waypoints would allow robot to accurately retrace the steps taken by person finding device. (Again saving manual task)

- Flying robots would avoid most VOIED triggers and with good cameras in multiple wavelengths would allow them to spot ground signs and save or support a manual approach.
What do the users really want?

• I spent some time with instructors and very experienced users whilst writing this paper.
• Many of the more advanced technology concepts did not impress them and were considered of limited use in current TTPs and doctrinal concepts.
• The following slides are their wish list but overall …..

• 2 conclusions can be reached.
  – 1. The operators need to be consulted with by someone who is neutral but trusted.
  
  – 2. Are we at a doctrinal watershed? Do we need to decide the doctrine and policy of future EOD robot use before we design the next generation of robots?

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UK operators wish list

• Robot that can autonomously travel via waypoints.

• ECM search for device (semi autonomous).

• Detect and identify explosives and relay data to ICP.

• CBRN detect - all background tasks.

• Take good X ray images without the need to place film behind device (backscatter).
UK EOD Operators Wish List cont.

• Self deploy from vehicle to known good point in ICP.

• Collision avoidance.

• Be aware of incipient rollover, have stability intelligence, have outriggers for high force tasks, obstacle crossing capability.

• Stair climb sequence intelligence (ie climb stairs autonomously).

• If manually driven in to tight space, be able auto extract
More requirements

• Self recover from topple or roll over, or be equipped with recovery attachments to allow a second robot to right it.

• Self test firing circuits including when a cartridge is in the weapon, as per Shrike firing box (ie continuity test of live cartridge).

• Have an ‘ET come home’ function for situations where loss of command control signals occurs.

• Have easily swappable mission packs
Future Robot Capability Studies

HUMAN SKILLS TO ROBOTS
The EOD Operator Skills

• From the previous section it becomes obvious that an EOD operator can do many jobs that a robot cannot currently do, or is unable to do well
  – Cutting PSU or detonator wires
  – Taking X rays
  – Observing signs of VOIED triggers
  – Assessing the threat / technical make up of a device.

• Some are obvious skills but many are performed in a subconscious manner.

• The operator is a walking data-base of IED tactics and technical data.
Learning human best practice

• An experienced EOD operator will have acquired skills over many years of training and operational experience.
• Many will struggle to transfer this to other humans much less robot designers.
• So we could instrument the operator whilst performing manual EOD training tasks, with eye tracking glasses as used in advertising analysis.
• This might be quite useful in training human operators as well. The resulting data would assist in making robots able to search and orientate more like a human operator.
EYE TRACKING GLASSES WITH Samsung mobile phone data capture app. The EOD operator has many difficult to define skills. In order to improve Robots we must capture the retinal scan and imagery of an operator performing a task.

It would then be possible to analyse what makes a good EOD operator able to perform a task and begin algorithms for intelligent EOD robots.

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The HCI

• The interface between the human and the robot will often set the degree to which the robot system is considered successful.

• Current systems are often very 1980s in look and feel with switches and joysticks being the norm.

• Many other industries use robots medical [tele-surgery] and oil industry [underwater ROV]. These have more advanced HCI systems.

• In heavy scales deployment a work station as used by underwater ROV and some medical robots might be appropriate.

• In light scales a Google Glass type visual and audio interface may help.

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The human hand is able to exert great force or exhibit extreme finesse with its sense of touch and neuro-feedback.

Gassert et al 2006 describes how a force feedback robot can perform activities remotely whilst being exposed to an MRI scanner without interfering in the imaging process.

Hu et al 2005 reports on using a tele-presence to perform delicate tasks using a force feedback robot arm and hand.

The idea of a Haptic interface is explored by Carey 2011 and many other research projects since. The work described by Johnston et al 2009 looks at Talon and Pack-Bot and integrates 3 dimensional awareness with autonomous EOD gripper capabilities.
Google Glass

Top left is patent application, top right is 2014 product, and bottom left is functionality diagram. (Google 2014)
Typical contemporary HCI units for EOD robots. [Carey 2011]

•"For our 30lb 310 SUGV, of which we've shipped well over 1,000, we integrated an Xbox controller with a heads-up display," explains Belanger. "We wanted to give our customers and controller that was intuitive, easy to use and had a look and feel of something they may be familiar with in civilian life." Bomb disposal robots - evolution and revolution 13 March 2014 Berenice Baker Army Technology.com
Games Controller with 2.45 Ghz WiFi interface. I think research projects for military robots should seek to exploit the user skills that young soldiers already have from a childhood of gaming.

‘Play Station Generation’ soldiers are the future military robotics users

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Early force feedback Haptic arm experiments (Hu 2005)
Talon and Pack-Bot with 3D vision system as described by Johnston et al 2008.

The 3D visualisation shown on the operators screen is generated in the robot and replaces a camera view. The system feeds a ‘click to go-to’ system for the gripper.
Common architecture AEODRS Increment 1 model from Brezina 2012.

Kozlowski 2010

The vehicular architecture concept of future US AEODRS robots. Systems engineering may be key to common modules and upgradeable systems.
Systems Engineering

• Most armies have a systems engineering plan for manned vehicles such as the UK GVA and Def Stan 23-09
• The USA has been developing the idea for UGVs in the form of the AEDROS and the associate systems architecture. The basic idea is to have capability modules (mobility, power, vision) which function via a set of defined common interfaces (hard and software). This allows easier upgrade when new modules are required but can allow legacy modules to be incorporated.
• This will be important if the availability of EOD robots is to be improved (often this is not good).
• The open systems approach in the UK is led by the LOSA program, the aim being to ensure better connectivity, maintainability, upgradeability and modularity is achieved across all land systems.
Route proving

• Although different to the EOD the task, route proving and hence maintaining manoeuvre is one in which robots are likely to be invaluable. They are close cousins of EOD robots.

• My employer Cranfield University is working on quad copter based route proving robots, UGVs may have much to offer in this role.

• The idea of a robot that can sweep and mark a route autonomously is something we are looking into.
Modified mini diggers for EOD

• We must consider the poorer nations who can’t afford £750,000 EOD robots. They may also be the same nations that have large numbers of post conflict mines and UXOs. I think robot mini diggers are the way forward.

• A fun day spent talking to CAT, Volvo and Husqvarna at the Plantworx 2013 show revealed that this was something they were interested in.

• Subsequently a Dutch company has started to make remote mini excavators.
The above images are of a Dutch remote excavator conversion used for digging and radiographic work. Images by kind permission of Grondwerken van ‘t Veld BV
Robot demolition systems that may be suitable starting points for low cost EOD and de-mining robots.
References


• Brezina 2012, Brezina B., Update presented to: NDIA Robotics Division, Quarterly Meeting, 14 June 2012, www.ndia.org/Divisions/Divisions/.../Mr.%20Byron%20Brezina.pdf

• Carey 2011, Novel EOD Robot Design with a Dexterous Gripper and Intuitive Teleoperation, Bsc Project report Worcester Polytechnic Institute, April 22 2011


References cont..


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• Many people from 11 EOD Regiment.

• Any inaccuracies are mine alone.