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Signal Processing Challenges in the Contested Electromagnetic Environment

Dr Chris Swinerd CEng FIET

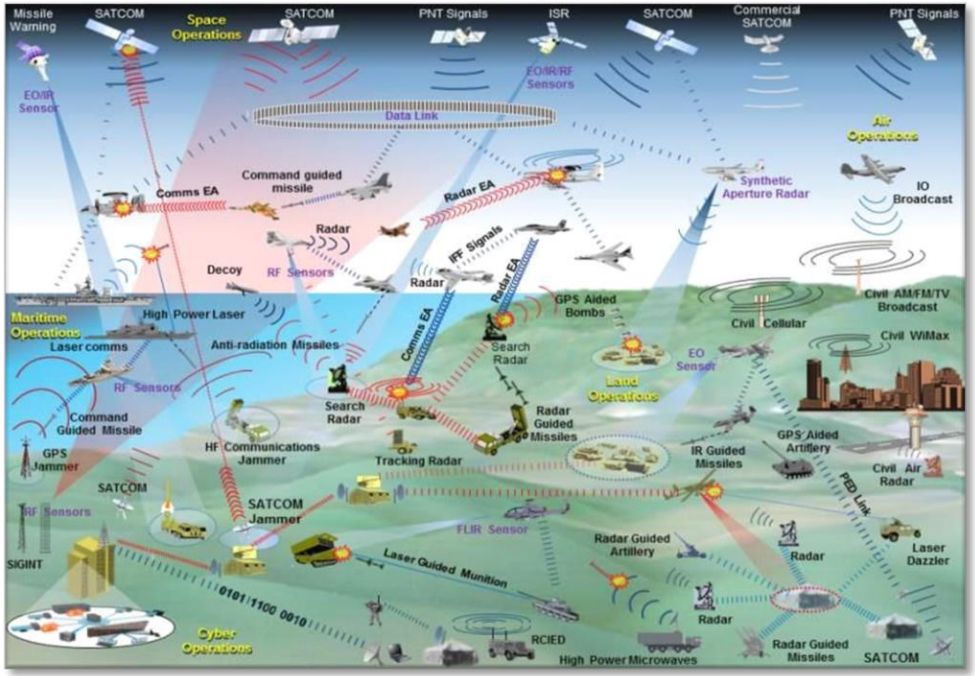
Dstl Fellow

DSTL/PUB127188

Ministry of Defence

The EM Environment in a Defence Context

- Dependency on Access to the Electromagnetic (EM) Spectrum
- UK Defence Vision:
  - Coordination and Synchronisation of EM Activities
- Resilience and Agility



NATO View (2019) of the Electromagentic Environment 2

The Contested EM Environment (CEME) Programme

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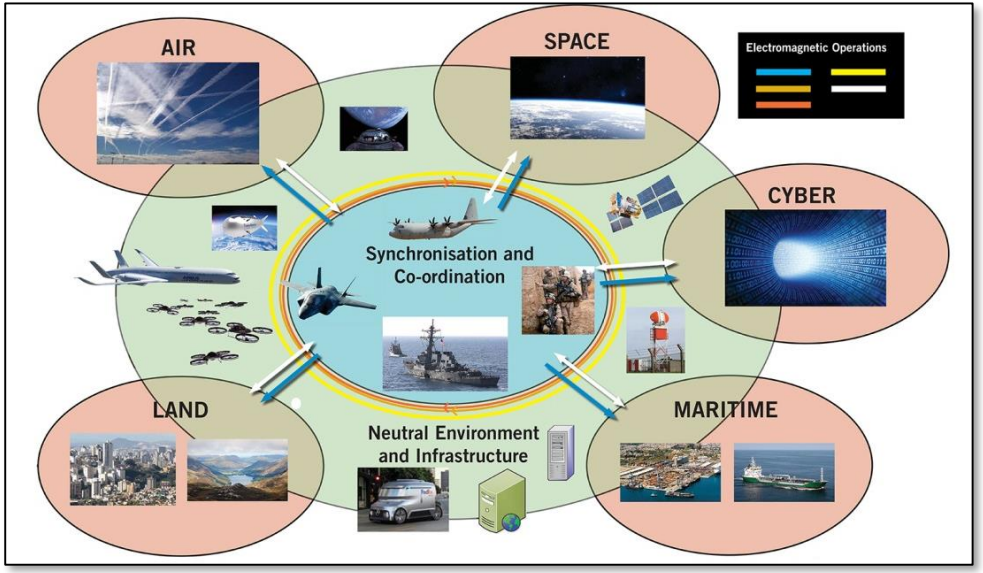
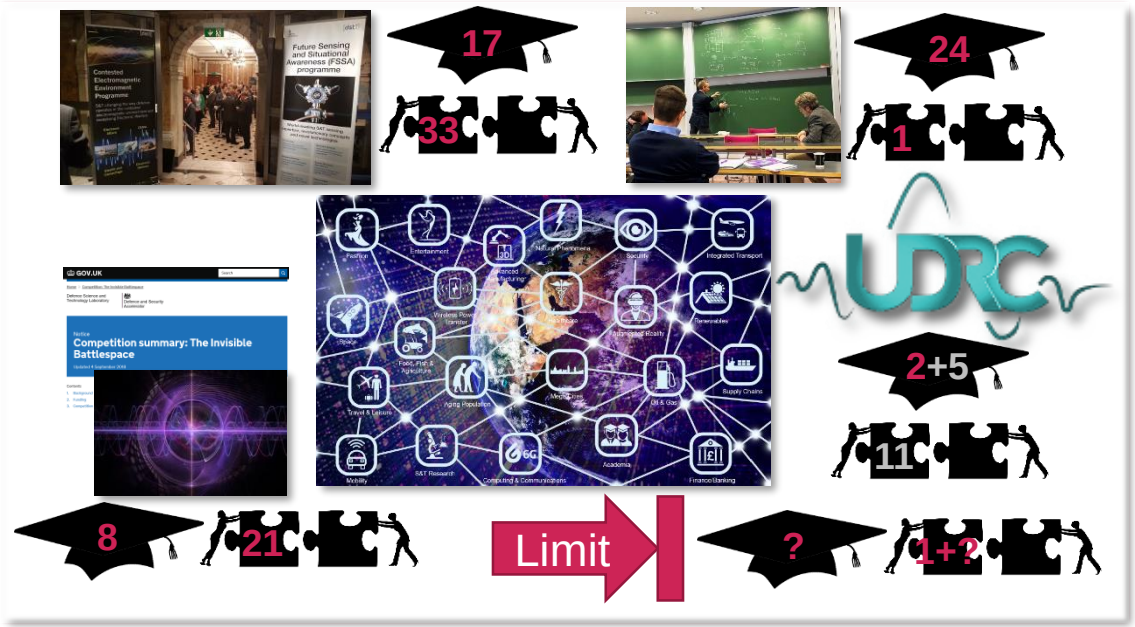
- New to the MOD Research Portfolio 2017
- To change the way Defence operates in the EM Environment and to revitalise Electronic Warfare
- Across Operating Domains



CEME Programme Operating Environment

The Science of Electronic Warfare Project

- CEME Project from 2018
- Drive new thinking and initiate new concepts
- Ideas, Limits, Outreach
  - ~50% of ideas exploited to other Dstl projects and programmes



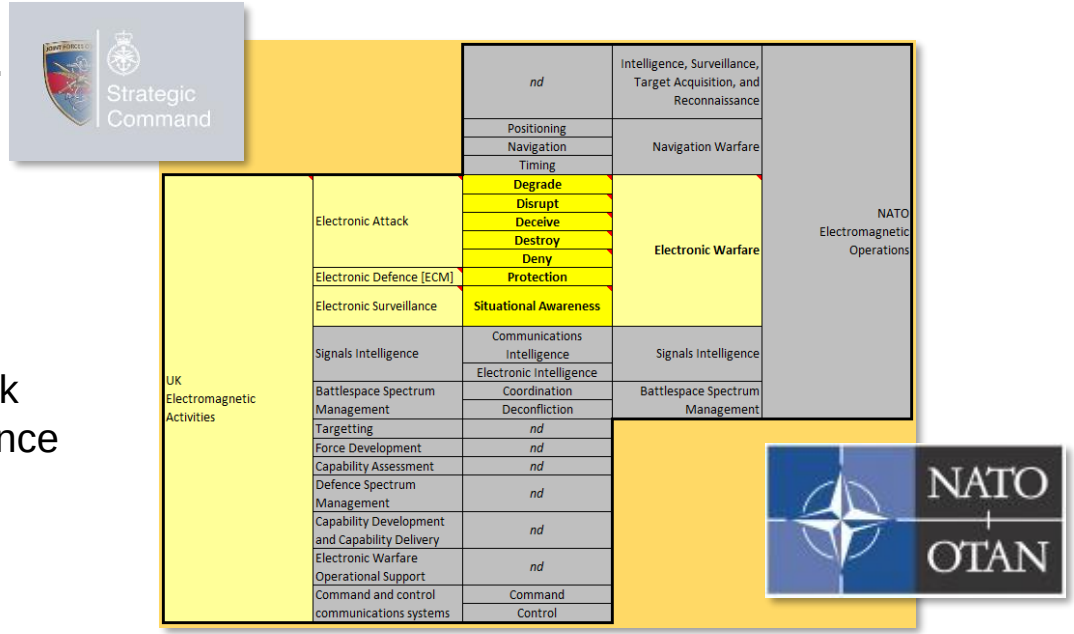
The Project Operating Environment

Limit

What fundamentally limits our ability to deliver Electronic Warfare effects over a specified EM spectral band?

EM Activities

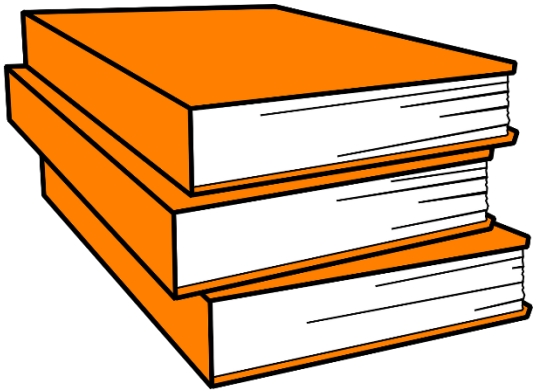
- Ends (Desired Military Effects) i.e.
  - Degrade
  - Disrupt
  - Deceive
- Ways, i.e.
  - Electronic {Electromagnetic} Attack
  - Electronic {Electromagnetic} Defence
  - Electronic Surveillance
- Means, e.g.
  - Signal Processing in the EM Environment



Defence Capabilities and Desired Effects

Some Background Reading

- MOD Science and Technology Strategy2020 (2020)
  - This document outlines the MOD's vision to secure future advantage through science and technology.
- DOD EMS Superiority Strategy (2020)
  - USA strategy for superiority when operating in the electromagnetic spectrum.
- MOD The Integrated Operating Concept 2025 (2020)
  - Integrated Operating Concept calls into question the traditional approach to war fighting.
- MOD Electromagnetic Spectrum Blueprint (2019)
  - This document outlines how the Ministry of Defence will make progress towards its objective to share 750 MHz of public sector spectrum by 2022.
- MOD Cyber and Electromagnetic Activities (2018)
  - Describes the framework that UK defence will use to co-ordinate cyber and electromagnetic activities at the operational level and enabling support activities.
- MOD Global Strategic Trends: The future starts today (sixth edition) (2018)
  - The sixth edition of Global Strategic Trends, published by the Development, Concepts and Doctrine Centre, describes a future context for defence and security out to 2050.



NATO OTAN NATOTerm The Official NATO Terminology Database NSO

https://nso.nato.int/natoterm/Web.mvc

[Accessed November 2020]

Operational Freedom of Manoeuvre

- Example: Carrier Strike
  - Area Defence
    - Type 45
      - Radar

- Freedom of Manoeuvre in the EM Environment
  - Examples through Signal Processing
    - Super Resolution
      - Electromagnetic Protection
        - » Adaptive Beam Forming
      - EW Systems
        - » Function of Received Waveform
        - » Capability of Received Waveform
    - Signal Sub-Space
      - Reduced Size Weight and Power EW Systems
      - Reduced Computational Load

HMS Queen Elizabeth and HMS Dragon

Example Vignette (this is not an official threat assessment)

- Battle of Ilovaysk, 2014
- The encirclement of Ukrainian forces by Russia's Armed Forces
  - involved the deployment of battalion tactical groups, reconnaissance and sabotage groups including Electronic Warfare units
- Electronic Warfare assets tasked with:
  - suppressing radio communications at tactical and operational levels
  - fixing and locating enemy forces by identifying EM Spectrum usage
  - disrupting Command and Control
  - blocking mobile phone networks
  - spreading false information

Roger N. McDermott, International Centre for Defence and Security, Russia Electronic Warfare Capabilities to 2025: Challenging NATO in the Electromagnetic Spectrum, 2017, page 26.

Donetsk People's Republic storming Ilovaisk

https://commons.wikimedia.org/wiki/File:DPR_storming_Ilovaisk.png

Industry 4.0 – Threats and Opportunities

- Ready Access to Commercial Off The Shelf (COTS) technology
  - Undermining technological advantage in Defence
- For Example
  - Defence and Security Accelerator ‘The Invisible Battlespace’ DSTLX-1000131432
  - Active radar, passive radar, and electronic surveillance on one COTS device
- The outputs of this short research study have shown
  - powerful adaptive RF sensing tool that has the potential to provide a step change in off-the-shelf capability
  - may underperform bespoke designed systems that are focused on a single task, but no doubt stands alone in its ability as a multi-role adaptive RF sensing tool

XILINX RF System on a Chip

https://www.xilinx.com/products/boards-and-kits/zcu111.html [Accessed October 2020]

Signal Processing Challenges in the EM Environment

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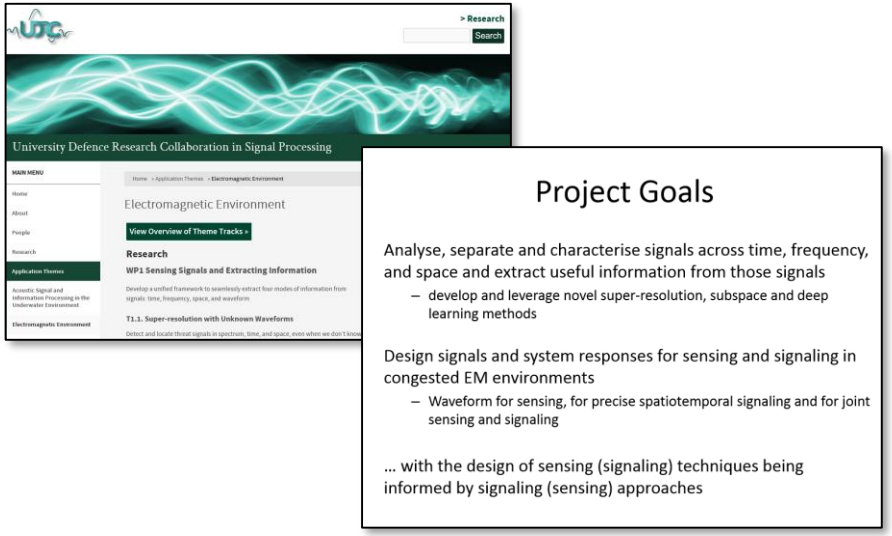
- CEME S&T Challenges
  - Rapid Waveform Analysis
  - Simultaneous Transmit and Receive
  - Congested RF Environment
  - Increased dimensionality of information extraction from spatiotemporal signals
  - Signal Sub-space methods
  - Precise spatiotemporal delivery of energy
  - Signal Pre-distortion
  - Efficient signal disruption
  - Response to tracking waveforms

EPSRC/MOD Call for Proposals 2018

https://www.gov.uk/government/publications/university-defence-research-collaboration-in-signal-processing [Accessed October 2020]

UDRC EM Environment Application Theme

- WP1: Sensing Signals and Extracting Information
  - Super-resolution with Unknown Waveforms
  - Low-probability-of-intercept Signal Detection/Classification
  - Learning for the Super-Resolution Framework
- WP2: Signal Designs and Delivery
  - Waveform Design for Sensing beyond the Ambiguity Function
  - Waveform Design for Precise Spatio-Temporal Signaling
  - Joint Waveform Design for Sensing and Signaling
  - Hardware and Nonlinearity Resilient Waveform Design



Imperial-UCL Consortium

https://udrc.eng.ed.ac.uk/electromagnetic-environment [Accessed October 2020]

Towards an S&T Roadmap for an Electronic Warfare Machine

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1. Artificial Intelligence, Machine Learning and Data Science
2. Architecture and Operating Systems
3. Effector Technologies (Electronic Attack)
4. Integrated systems engineering and technology
5. Sensors (Sensor Fusion)
6. **Digital Signal Processing**
7. Simulation technology
8. Effector Technologies (Cyber)
9. Sensors (ES)
10. Autonomous Systems and Robotics
11. … 65.

- Extensible
  - i.e. to develop solutions that are scalable and that can be deployed in a range of scenarios
- Efficient
  - i.e. to extract information from noisy and or low latency signals
- Assured
  - i.e. to realise understandable signal processing techniques
- Aware
  - i.e. to detect, track, recognise and identify new and emerging signals, including from distributed adversary systems, and potentially without a priori knowledge
- Effects-Based
  - i.e. to understand the EM spectrum in order to manage access and exploitation
- Integrated
  - i.e. to realise distributed Electronic Warfare system design
- Multi-Function
  - i.e. in support of sub-system or system designs that minimise analogue hardware
- Reduced Burden
  - i.e. to maximise information exploitation using passive techniques
- Resilient
  - i.e. to operate in the contested EM environment

Alignment of Work to Example Defence Challenges

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Example Defence Challenges		Sensing signals and extracting information			Signal Design and Delivery			
		T1.1 Super-resolution unknown waveforms	T1.2 LPI signals detection /classification	T1.3 Learning for the super-resolution framework	T2.1 Waveform design for sensing beyond the ambiguity function	T2.2 Waveform design for spatio-temporal signalling	T2.3 Joint waveform design for sensing and signalling	T2.4 Hardware and non-linearity resilient waveform design
Signal Processing Challenges in the EM Environment	Rapid Waveform Analysis	X	X	X				
	Simultaneous Transmit and Receive					X	X	
	Congested RF Environment					X		
	Increased dimensionality of information extraction from spatiotemporal signals	X	X	X				
	Signal Sub-space methods		X		X			
	Precise spatiotemporal delivery of energy				X	X		
	Signal Pre-distortion					X		X
	Efficient signal disruption		X					
	Response to tracking waveforms							
Towards an S&T Roadmap for an Electronic Warfare Machine	Extensible i.e. scalable solutions	X	X	X	X			X
	Efficient i.e. information from noisy / low latency signals	X	X	X	X	X	X	
	Assured i.e. understandable techniques							
	Aware i.e. ..., potentially without a priori knowledge	X	X	X				
	Effects Based i.e. understand the EMS	X	X	X				
	Integrated i.e. distributed system design				X	X		
	Multi-function i.e. minimise analogue hardware			X				X
	Reduced Burden i.e. passive techniques				X			
	Resilient i.e. operate in CEME				X	X	X	

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