Ministry of Defence

SSPD Conference

Information Generator: Keeping the Lights on

Sensor Signal Processing for Defence Conference

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Future Operating Environment: Contested

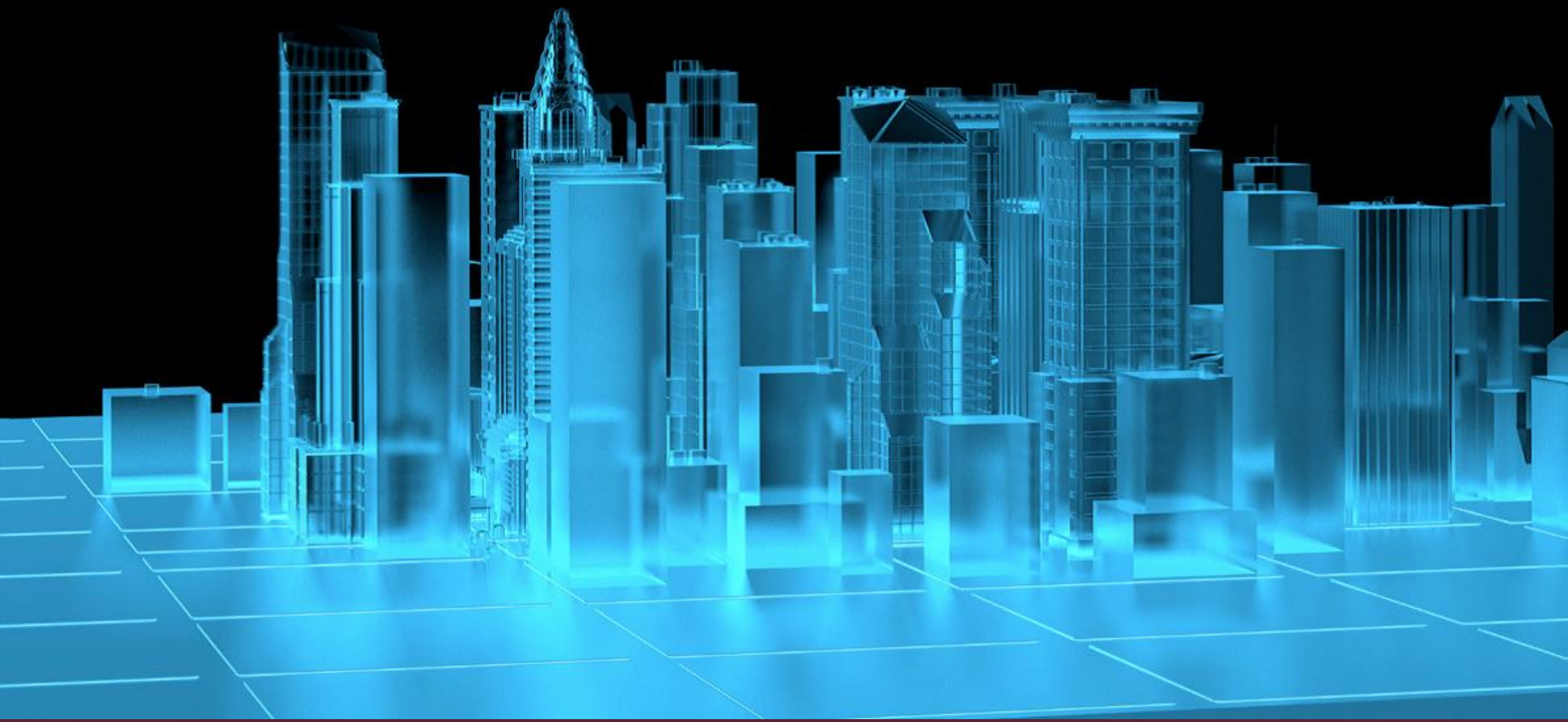
Future Operating Environment: Congested

Future Operating Environment: Information Warfare

Future Sensing Capability Risks

- **Sensor systems**: e.g. connected, agile, affordable
- Detection: e.g. range, noise, clutter, through barriers
- Resilient: e.g. jamming, sensor protection, autonomous
- Operating Environment: e.g. urban, blurred boundaries
- Data into information: signal processing, analysis, fusion, autonomy

Ensure sensor overmatch for near peer state threat for Intelligence, Platform Survivability and Weapons



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Defence Science and Technology

Our S&T Approach

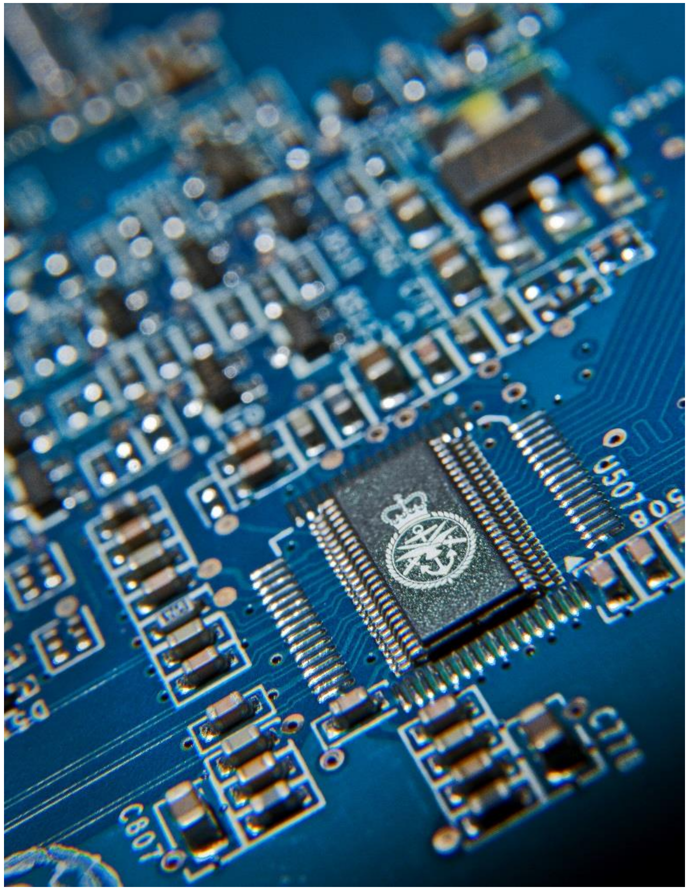
- DST, in Whitehall MOD Main Building, leading MOD S&T
  - Strategy
  - Military User Engagement
  - Research Commissioning
- Dstl leading on delivery of S&T
- International by design
- Investing to maintain S&T capability

Our S&T Approach (2)

- Sensing research will be focussed on ‘Driving’, characterised by

Speculative — **High achievement risk** but often high reward

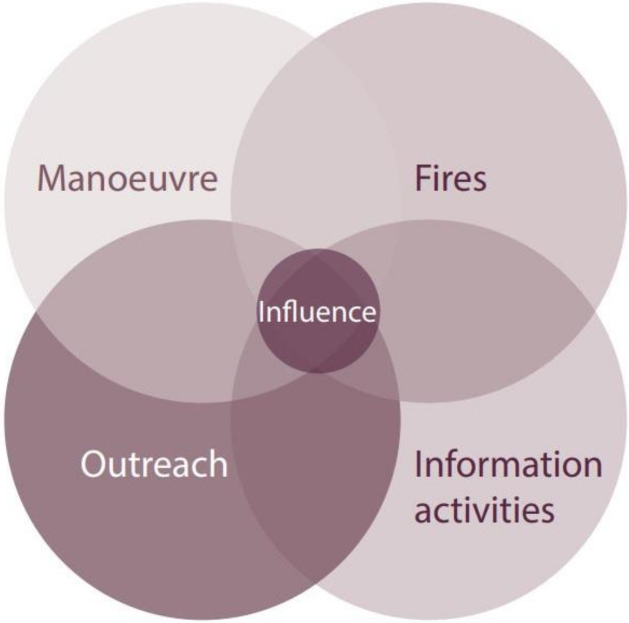
Strategic — **Future opportunities** through User capability development and growth



Signal Processing in Defence

- Military action fits into ‘Joint Action’ model
  - Focus today on Information Activities

- For this talk will give Signal Processing examples across
  - Multi-sensor exploitation
  - Single Sensor
  - Sensor Protection



Example Signal Processing Challenges

Multi-Sensor Exploitation

Radar Electronic Warfare

Imaging inside buildings

Distributed Electronic Warfare

Imaging through Obscurants

Electronic Protection Measures

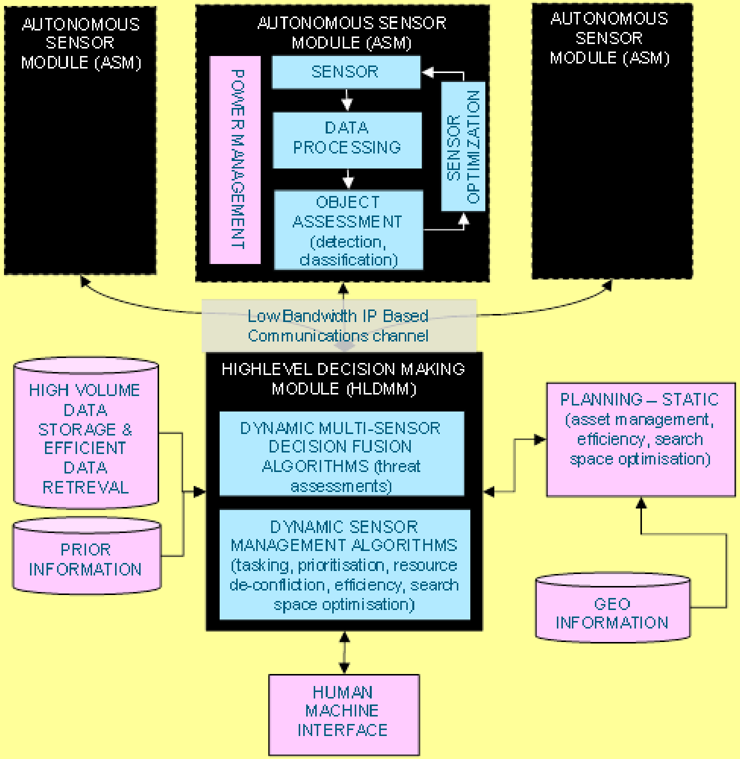
Multi-sensor Exploitation: SAPIENT Project

Raw data channelled to a human analyst

Rely on human cognition for Detection, Threat-assessment and Sensor-management

- Autonomous persistent sensing
- Reduced operator burden
- Flexible / Reconfigurable
- Low cost – reduces requirement for bespoke system design
- Multiple complementary sensor technologies
- **Supplying information rather than raw data to the end user**
- Multi-use over Defence, Civilian, Security domains

SAPIENT proposes a concept of Modular, Autonomous sensor units, sending only low bandwidth processed messages to a fusion centre which performs decision fusion and sensor management.



SAPIENT: *Sensing for Asset Protection with Integrated Electronic Networked Technology*

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Multi-sensor Exploitation: SAPIENT Project

Enables a variety of innovations in **High Level Decision Making Module (HLDMM)**

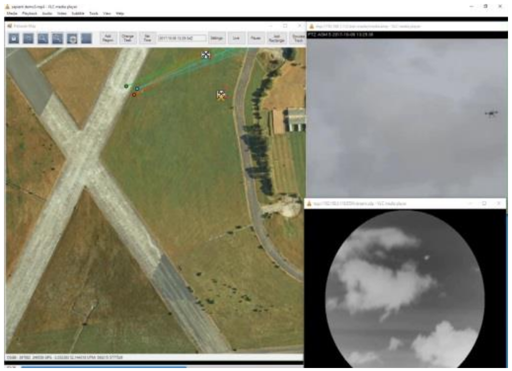
- Bayesian multi-target search algorithm derived from an information theoretic approach
- Data Fusion process tightly integrated with an Trust Model which maintains a model of the real-world performance of each sensor

Base protection

Enables a variety of innovations in **Autonomous Sensor Modules (ASMs)**

- SVM regression based pedestrian activity estimation
- Radar beamforming
- Scanning Laser Rangefinders (SLRs), providing shape, tracking and description to enable intelligent object recognition

Counter UAV



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Multi-sensor Exploitation: What next?

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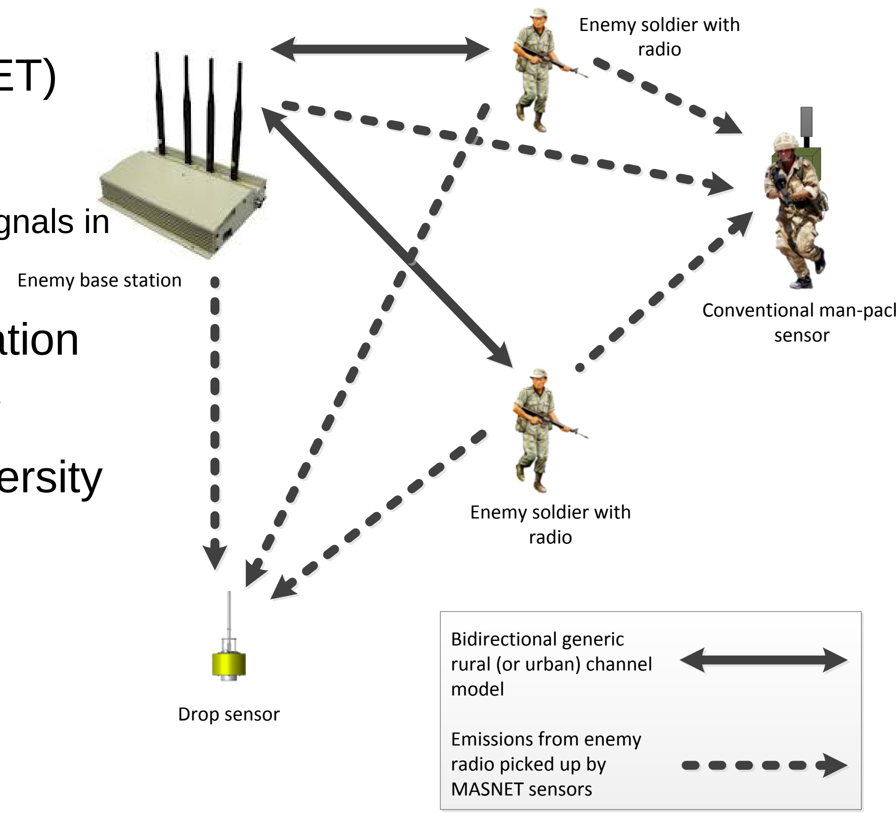
Multi-sensor Exploitation: What next?

Distributed Sensors

- Multiple Ad-hoc Sensor Network (MASNET)
  - Numerous sensors networked together
  - Collaboratively detect, position fix and decode signals in an operating environment.
- Key solution to solving many Communication Electronic Surveillance (CES) challenges
- Task about to commence under the University Defence Research Collaboration
- Three phases:
  - Mathematical modelling
  - Simulation and statistical analysis phase
  - Real-world verification and robustness testing phase



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Radar Electronic Warfare

Electronic Warfare is Military action that exploits Electromagnetic energy to provide Shared Situational Awareness and achieve offensive and defensive effects

Electronic Surveillance
Visualise & understand the EME

Identify & locate emitters

Assess threat level

Electronic Attack
Targeted degradation of adversary's radar performance

Electronic protection
Mitigate incoming Electronic Attack & other interference

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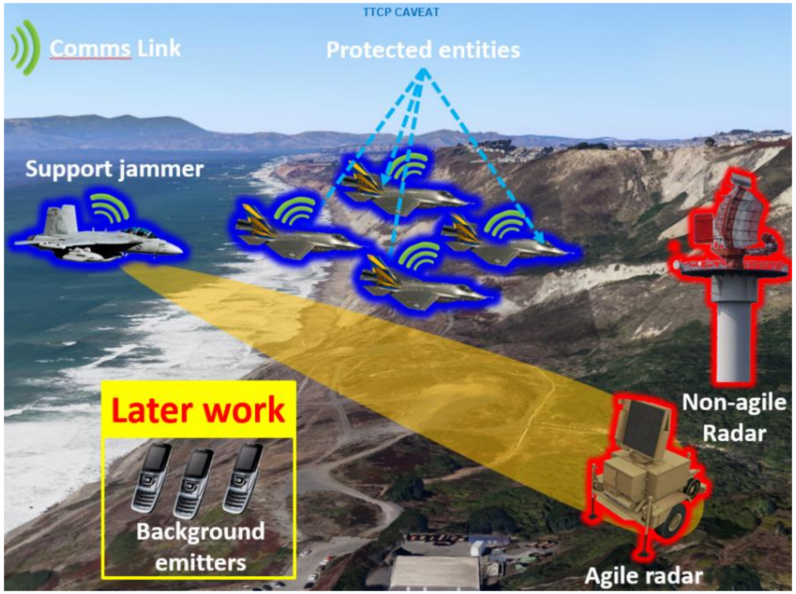
Cognitive Electronic Warfare

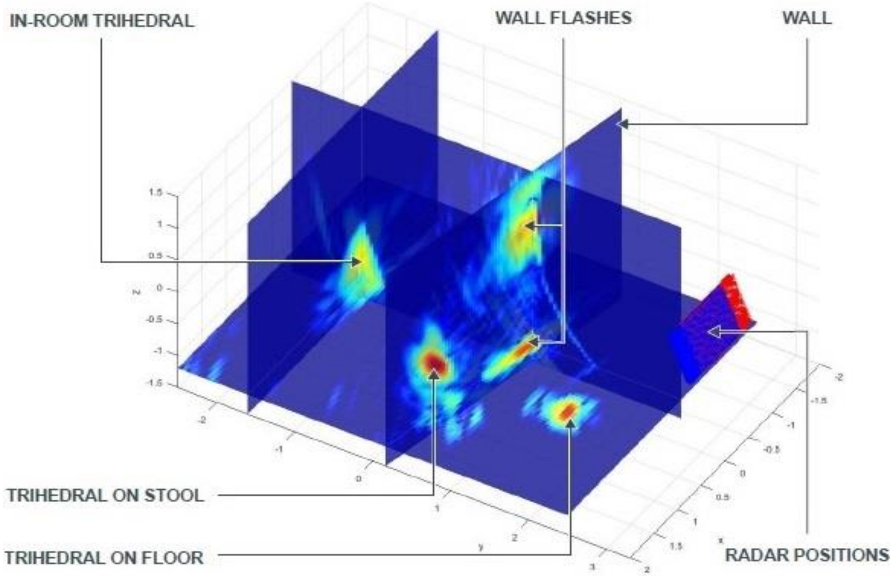
- Some threat radars exhibit **adaptive multifunction behaviour**
- Cognitive EW is likely to:
  - Incorporate **machine learning** algorithms
  - Feature a **short-term** (within mission) and **long-term** (between missions) **memory**
  - **automatically update the rules** that determine how it should operate
- We believe **Cognitive EW** might be able to help us:
  - understand the electromagnetic environment
  - reliably identify modern radar threats
  - adapt to changes made in the threat radar since our last intelligence collection



- If these hypotheses are true, then Cognitive EW will help us to **maintain our ability to penetrate defended areas.**

Thru-wall RF Imaging

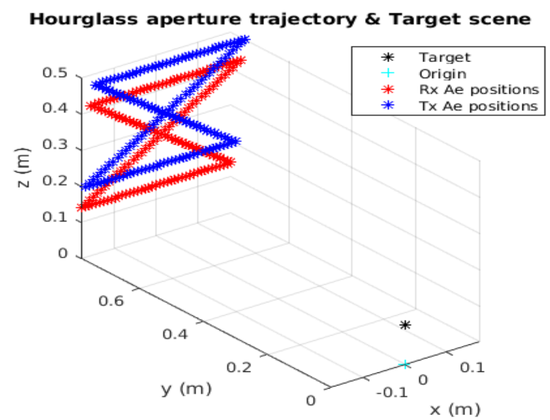
A 2D array of radar measurements can be used to form a 3D radar image. Low Frequency (LF) radar penetrates many building materials. Lab-based experiments are being used to assess the performance of 3D image formation algorithms.

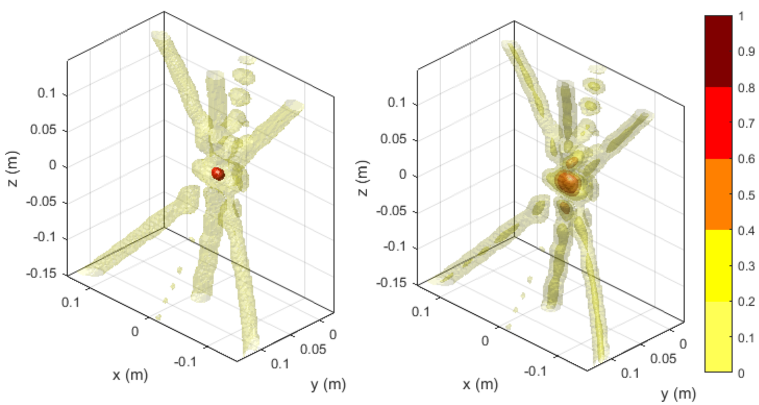


Thru-wall RF Imaging: Incomplete data

- It may not be possible to obtain complete 2D array of measurements
- Determining optimum sampling strategies and image formation schemes is a signal processing challenge
- This will allow efficient data gathering to be achieved in contested urban environments
- Look out for the “Bright Sapphire II” open source challenge (EUSAR 2018)

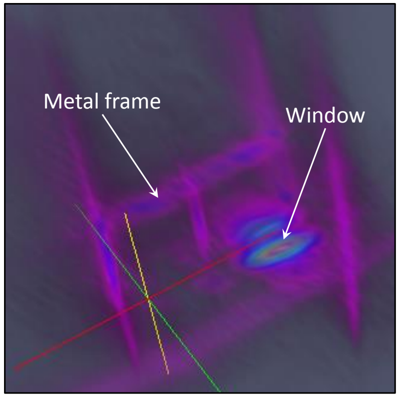
See Electronics Letters, Vol. 53, No. 15 for background on Bright Sapphire II (operated by Airbus) and other thru-wall techniques

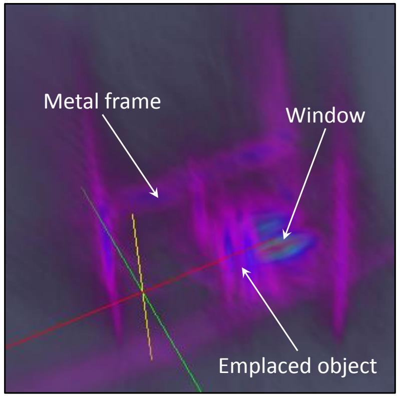


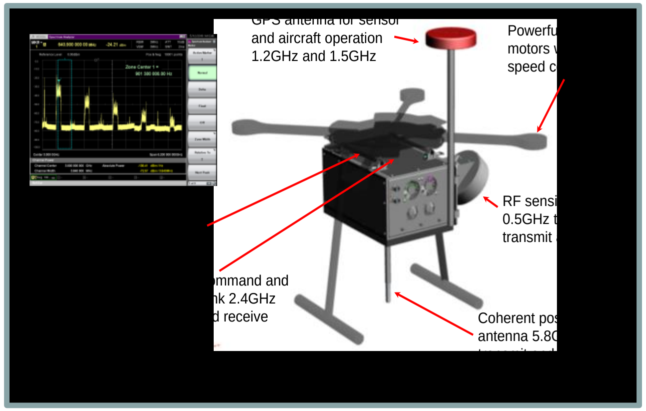


Thru-wall RF Imaging: What next?

- Parasitic SAR
  - Remote intelligence from inside a building







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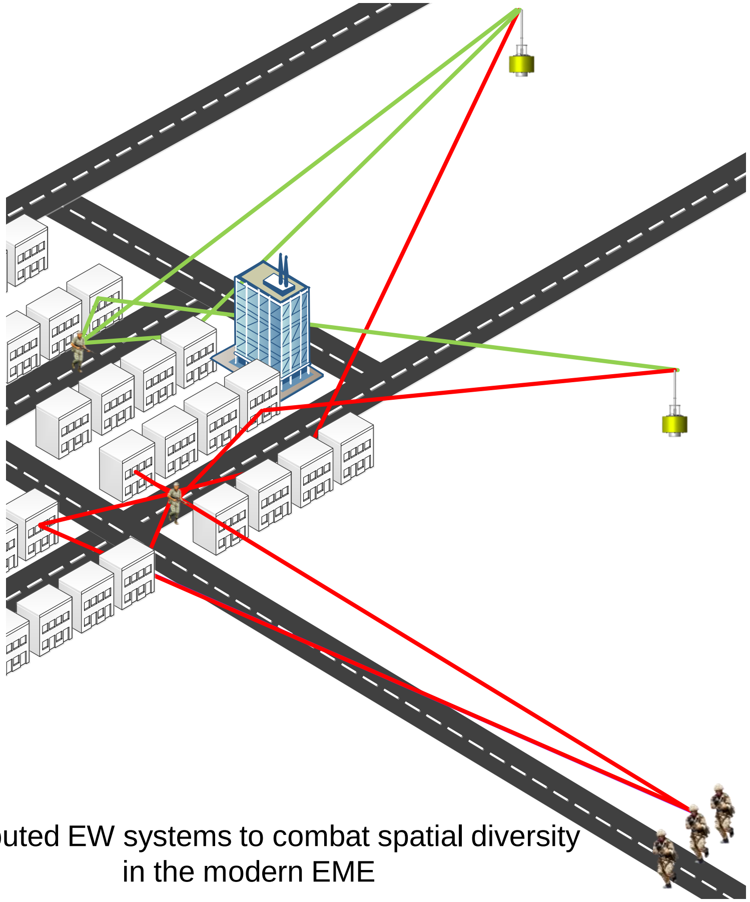
Distributed EW: Challenge

Conventional EW practice

- Deploy a few high performance transceivers standing off from the threat.
- Signal processing focuses on detecting and recognising a signal at each receiver. Post-processing intercept data shared for combined geolocation and Situational Awareness.
- ‘Multifunction’ equipment time-shares hardware resource – can’t jam and monitor simultaneously.

The challenge

- Modern/future communication signals are expected to become increasingly
  - Wide band, low-power, exploit spatial techniques (MIMO, etc.)
  - Systems will dynamically optimise their RF channel to achieve channel capacity
- The conventional techniques are significantly impaired in this environment



Distributed EW systems to combat spatial diversity in the modern EME

Distributed EW:
Role of Signal Processing

EW test bench Novel signal processing will be developed to realise:

Distributed Virtual Arrays

- Applying single platform array processing techniques to distributed platforms to provide :
  - Non-line of sight geolocation in complex RF channel environments
  - Distributed, joint detection and demodulation

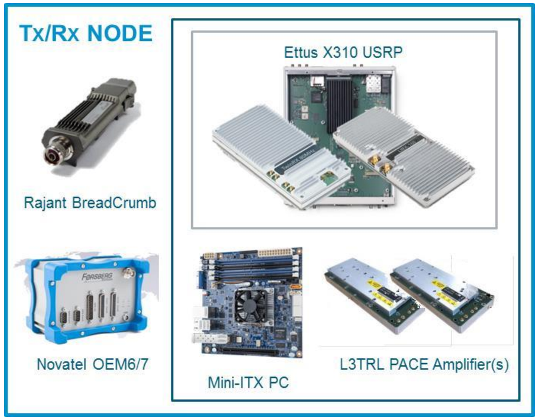
Full Duplex EW

- Inhibit Electromagnetic Environment while retain SA by developing advanced signal cancellation techniques.

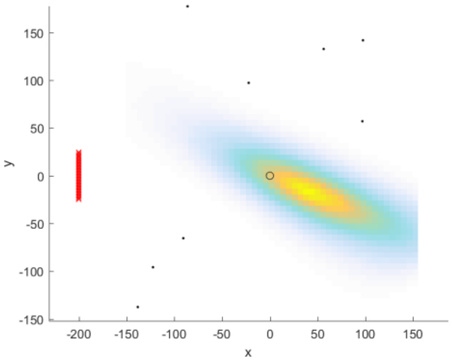
Military benefits

Required to secure our ability to operate in a modern EM environment

- Detect recognise and locate threats
- Restrict adversary use of EME



Distributed EW test bench



Novel non-line-of-sight geolocation techniques

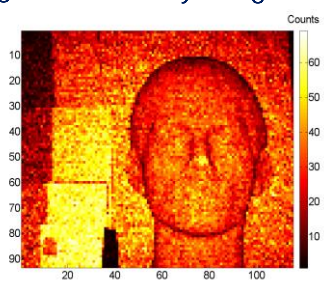
Imaging Through Obscurants

- Military uses include: Pilotage in degraded visual environments, ISR in fog and rain, and Targeting through cloud
- Single photon counting LIDAR is one potential technology that can detect the small returns from beyond highly scattering media

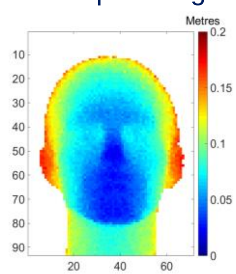
Successful imaging through smoke - heavy scattering and sparse photons can make the images difficult to interpret, particularly with limited acquisition time

Visible wavelength image

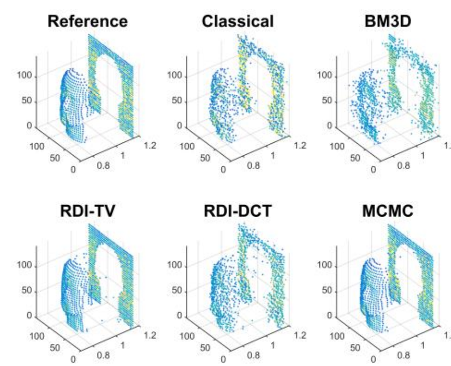
Intensity Image



Depth Image



Signal processing compared for computational efficiency/image quality – showing potential for effective imaging at reduced acquisition time

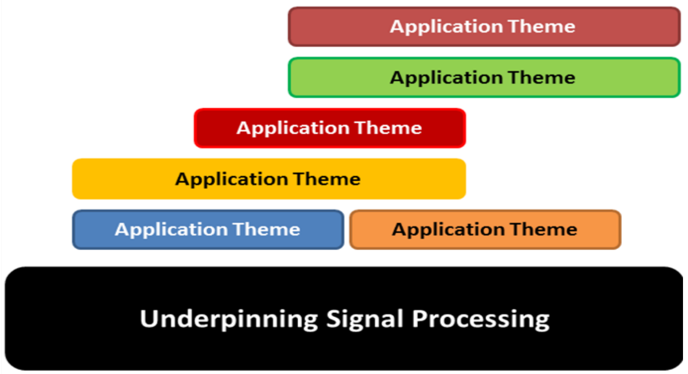


Lidar images and image processing courtesy of Heriot Watt University - Prof Gerald Buller and Dr Abderrahim Halimi

Electronic Protection Measures

- Use of EM spectrum is increasing the congestion and unintended conflict (jamming) within the EM environment.
- RF countermeasures create a range of effects in RF sensors e.g. obscuration, seduction, confusion, overloading
- Focus on protecting radar & electronic surveillance systems from deliberate/un-intentional interference
- One approach is signal processing: alternative/parallel pulse compression & CFAR, methods to detect characteristics of false targets e.g. blind separation

Novel S&T Approaches **UDRC Phase 3:**
Signal processing in the information age



Signal processing on large, multidimensional data

- Needles in multidimensional haystacks (and needle stacks)
- Data with high and asymmetric uncertainty
- Non-traditional correlation
- Assessing the information content of complex data

High-volume Signal Processing

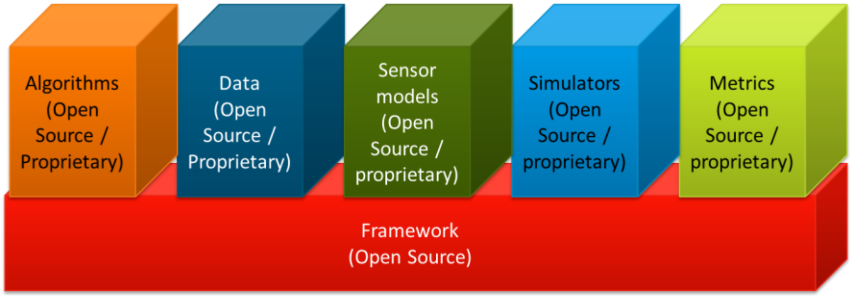
- Anomaly, outlier and correlation discovery.
- Fleeting and highly non-stationary signals
- Non-centralised and pipeline processing
- Verification of machine-learned models in other domains/scenarios

Challenges of the 'Information Age'

- Management of very different types of uncertainty
- "Hyper-fusion" – Data fusion writ large
- Automated structure discovery
- Resource constrained sensor management
- Trust and provenance of information sources

"Stone Soup"

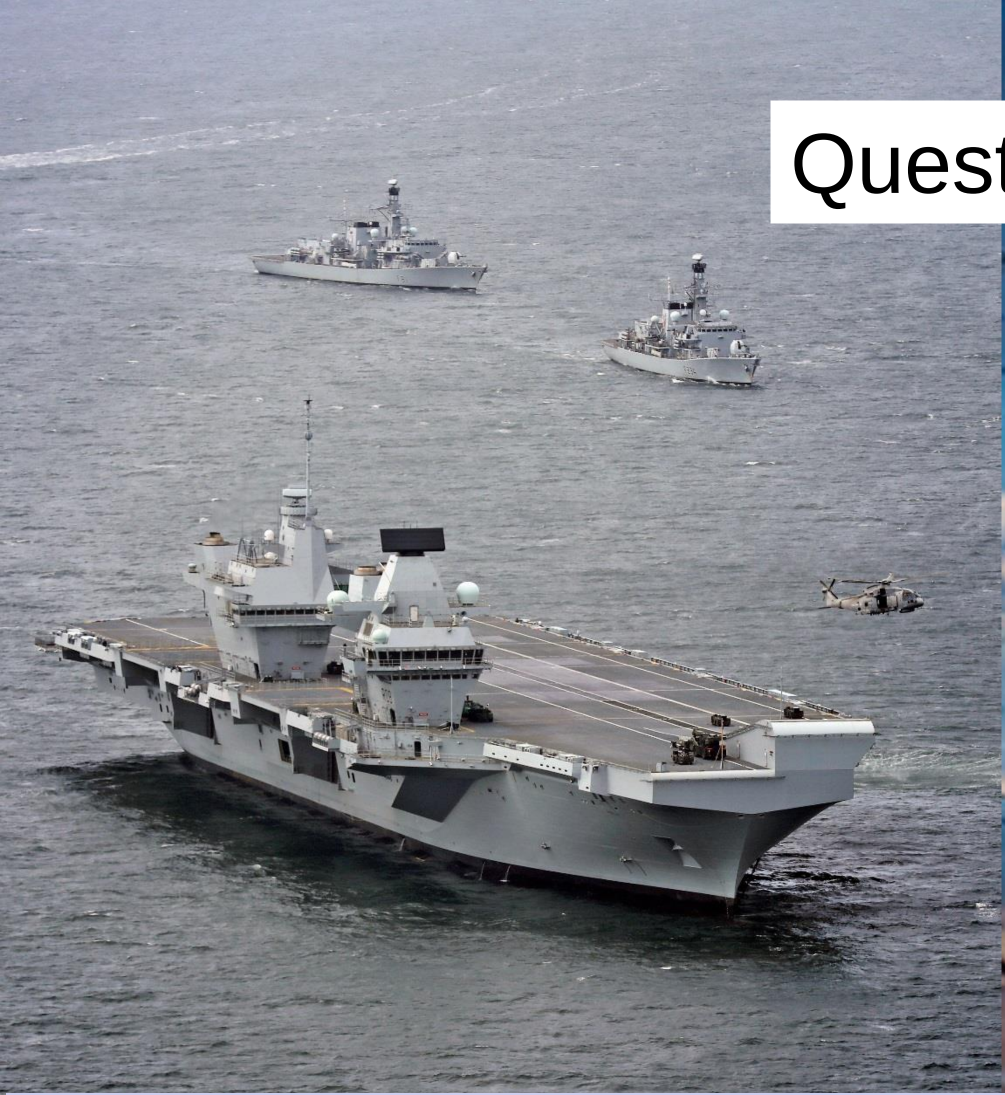
Open Source framework for Tracking and State Estimation

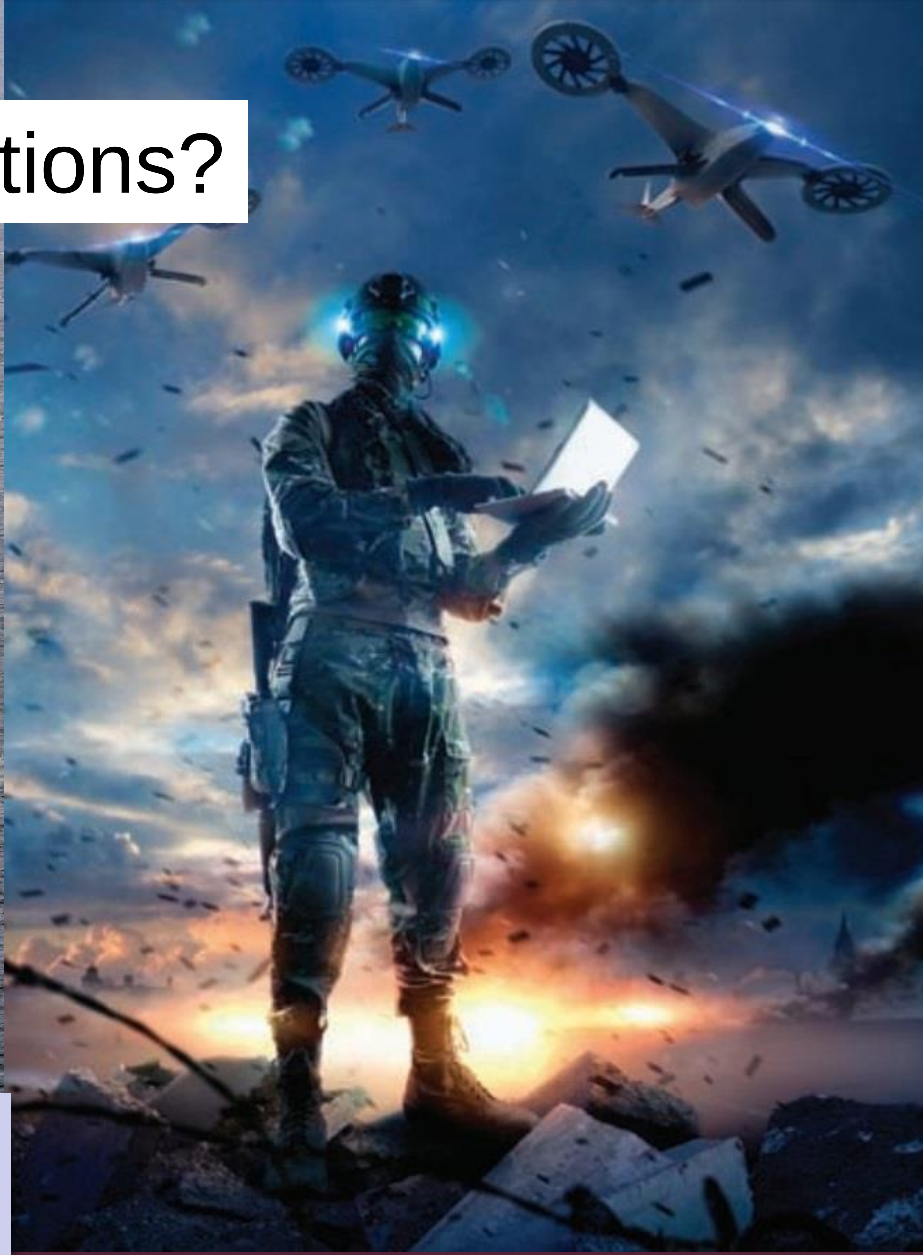


Information Generator: Keeping the Lights on

1. To keep the “lights on” we need an information generator
2. The Information generator requires collection of data and signal processing
3. MOD needs access to world class ideas, algorithms and technology

Questions?





Thank you to Dstl MOD colleagues for the S&T examples in this brief:

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