# UDRC Highlights on activities, exploitation and training the next generation of defence signal processors

## Consortium Directors

### Prof. Mike Davies, Edinburgh Consortium

- University of Edinburgh
- Heriot-Watt University
- Queen's University Belfast

### Prof. Jonathon Chambers, LSSCN Consortium

- Loughborough University
- University of Surrey
- Strathclyde University
- Cardiff University
- Newcastle University

[dstl]

EPSRC
Engineering and Physical Sciences Research Council

# Structure of Presentation

## Communication, engagement and education

- Publicity and marketing
- UDRC Summer School
- SSPD Conference
- Related Events
- PhD Studentships
- Awards
- People

## Defence and industry

- Strategic Partners
- Industry Days / Workshops
- UDRC Themed Meetings and Challenge Competitions
- Funding Streams - an overview
- Highlights
- Data

## Conclusions

# Publicity and Marketing

Two websites - www.mod-udrc.org
www.sspdconference.org

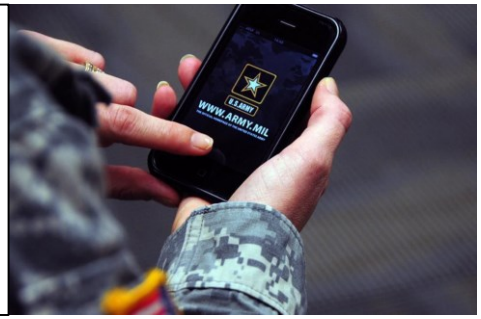
18 Articles (Including Financial Times, The Herald, Forbes, MOD Defence Contracts Bulletin, BBC).


FT Magazine

Science: Interpreting the theatre of war

Forbes

**Academics Launch Bid to Lift The Digital Fog Of War**




BBC **New sonar device mimics dolphins**

# Communication, engagement and education: – UDRC Summer School

4 day school

- Statistical signal processing
- Radar processing and tracking

} Edinburgh led

- Machine learning
- Source separation and beamforming

} LSSCN led


**In 2017**

- 95 people registered over 4 days
- 19 different countries represented
- 29 separate organisations

In phase 2 - delivered 5 summer schools and graduated 360 students

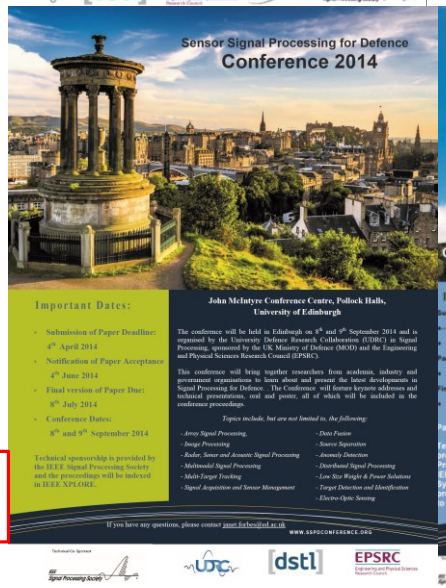
Experts from:
UDRC Universities, Czech Technical University Prague, Hellenic Air Force, Leonardo, Seebyte, UCL.

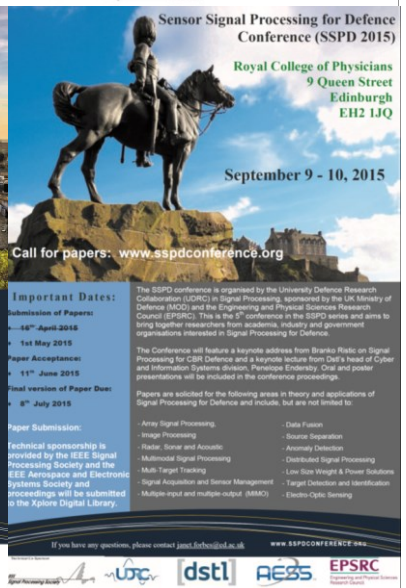
# Communication, engagement and education: – Sensor Signal Processing for Defence Conference Series (SSPD)

- Annual conference
- 7 successful to-date
- 100 – 120 people in attendance
- Industrial and military panels
- Academic and defence keynotes
- Invited speakers on specific topics; radar, tracking and sonar.
- Peer reviewed papers
- Best paper award
- Sponsored by;
  - IEEE Signal Processing Society,
  - IEEE Aerospace and Electronic Systems Society.

**Next SSPD - 9th to 10th May 2019 in Brighton**





# Communication, engagement and education: – Related Events

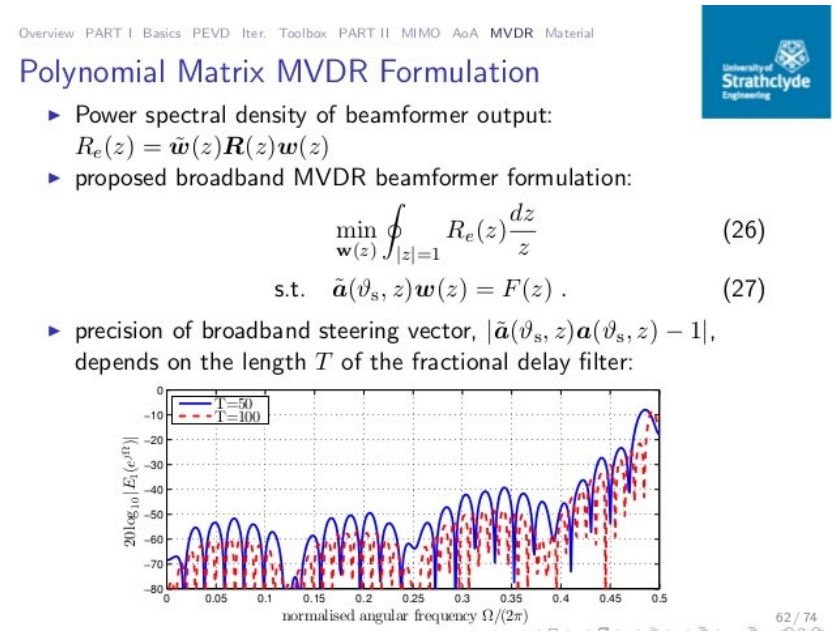
- Warfare in the information age (WitIA) event
  - UDRC presented work on:
    - anomaly detection in networks and WAMI
    - compressed sensing and sparsity
    - tracking and sensor management
    - efficient implementation
- Int. Symposium on communications control and signal processing (ISCCSP)
  - UDRC presented special sessions featuring:
    - Analysis dictionary learning based on Nesterov's gradient with application to SAR image despeckling;
    - Reuse of fractional waveform libraries for MIMO radar and electronic countermeasures.
- Keynotes
  - Int. Conference on Pattern Recognition Methods 2014
  - Electronic Warfare Symposium 2015
  - SPAWC 2016
  - International workshop on compressed sensing theory
  - IMA conference on mathematics in signal processing

# Impact – Years 1-4 UDRC II

- Royal Society, Kavli International Research Centre, Chicheley Hall, 25th – 26th August 2016

"Workshop on Polynomial Matrix Decompositions and their Applications" Professor John McWhirter FRS & Dr Stephen Weiss

THE ROYAL SOCIETY



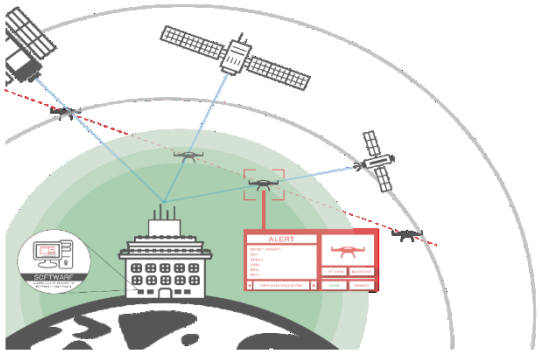
# Communication, engagement and education: – PhD studentships

- 20 additional studentships provided by UDRC Universities to work on UDRC problems
- 9 industrially sponsored studentships funded by industry (Leonardo, Roke Manor, Seebyte, ST Microelectronics, Mathworks, Thales)

# Communication, engagement and education: - Awards

Highlight: Dr Carmine Clemente and his team at Strathclyde won the overall European Satellite Navigation Competition.

- Development of satellite-based, early detection system capable of early drone detection and tracking.
- The project will receive an extensive package to support further development and market entry.



# Communication, engagement and education: - People

## PHASE 2 UDRC

25 academics, 26 Postdoctoral Researcher Associate (PDRA), 20 PhD students

### PhD students who have graduated:

- Lecturer, Nanjing Technical Univ., China
- PDRA, Loughborough University x 2
- Research Scientist, State Key Lab of Space-Ground Integrated Information Tech, Beijing, China
- PDRA, Kings College London
- NATO, CMRE, La Spezia, Italy
- PDRA, Surrey University
- PDRA, Strathclyde University
- Engineer, Aveillant.
- Engineer, AnyVision
- Researcher, Fraunhofer FKIE
- Robotics Engineer, I Robot
- CEO, Autuo.ai

### PDRAs who have moved on:

- NATO, CMRE, La Spezia, Italy x 2
- Academic, University of Edinburgh
- Researcher, International Council for the Exploration of the Sea.
- Academic, Dublin University x 2
- Academic, Lincoln University
- PDRA, Cambridge University
- Engineer, AnyVision
- Software Engineer, Blackmagic Design
- Software Developer, ARM
- Engineer, NCTech

# Defence and Industry: – Strategic Partners

## Strategic Meetings

- provide feedback on research
  - timely and relevant
- advise on the programme strategy
  - change of direction as required (mid-term review)
- identify current knowledge gaps
  - from industrial viewpoint
- create potential exploitation opportunities
  - consultancy/PhD research

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Innovation deployed
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seebyte
Texas Instruments

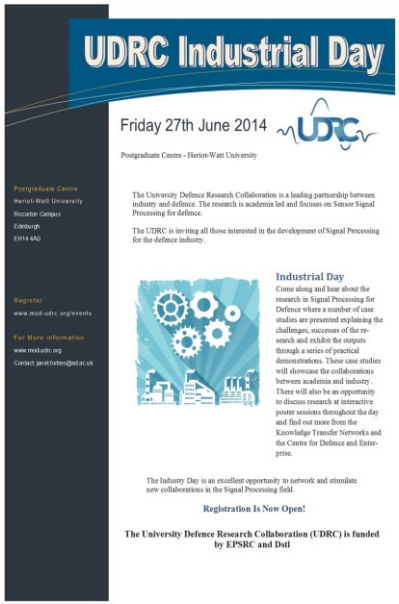
# Defence and Industry: – UDRC Industrial Days / Workshops

- UDRC Industrial Day – showcase joint collaborations

- UDRC Aim Day – companies submit a question or commercial challenge which gets addressed by UDRC academics

- Specific topic workshops
  - Polynomial matrix workshop
  - Advanced processing for sonar workshop
  - Space surveillance and tracking
  - AFRL and US Army scoping meetings

➢ Presenting case studies explaining challenges and successes of the research
➢ Knowledge transfer and exploitation opportunities

# Defence and Industry: – UDRC Themed Meetings

Lively meetings with industry, defence and academia where there is the opportunity to enter defence challenges.

Technical meetings have been held on:

- Source separation and sparsity
- Network and Information Sciences International Technology Alliance
- Autonomous systems and signal processing
- Hardware and implementation
- Image and video processing
- MIMO and radar signal processing
- Space surveillance and tracking
- Underwater sensing, signal processing and communications
- Data science and signal processing (with Alan Turing Institute)

# Defence and Industry: – UDRC Challenge Competitions

- 1-2 per meeting
- Run during themed meetings
- Addresses current signal processing challenge
- Well-constrained
- Comes with data
- Short horizon
- Prize

- 11 challenges in total
- ~100 data sets distributed
- 7 winners
- 3 entries attracted further funding from MOD
- 1 ended up in a commercial product
- at least 6 entries have ended up making their way into Dstl research projects

GPR Anomaly Detection

Temporal Anomaly Detection

Underwater ATR

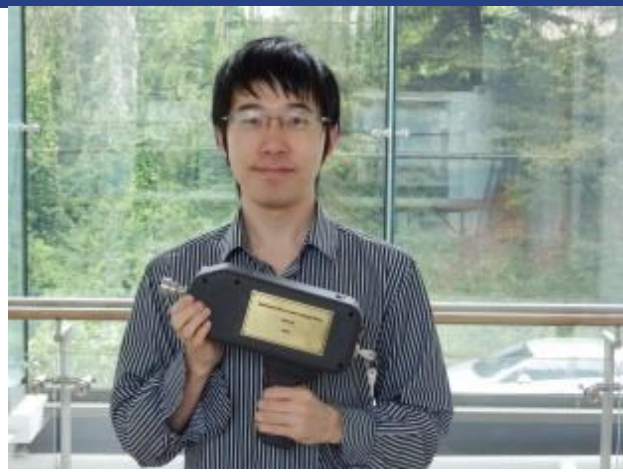
WAMI Anomaly detection

# Defence and Industry: – Challenge Competition

## Highlight: fast Raman spectral deconvolution

- Themed meeting Challenge
  - Enabling agreement
    - baseline correction
    - complexity reduction
  - Enabling agreement 2
    - prototyping
    - Industry involvement
  - Enabling agreement 3
    - technical refinement
  - Contract with industrial supplier
  - Licensing agreement

< 3yrs



**Fast Sparse Raman Spectral Unmixing for Chemical Fingerprinting and Quantification**

Mehrdad Yaghoobi[a], Di Wu[a], Rhea J. Clewes[b], and Mike E. Davies[a]

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[b]CBR Division, Dstl, SP4 0JQ, UK

ABSTRACT

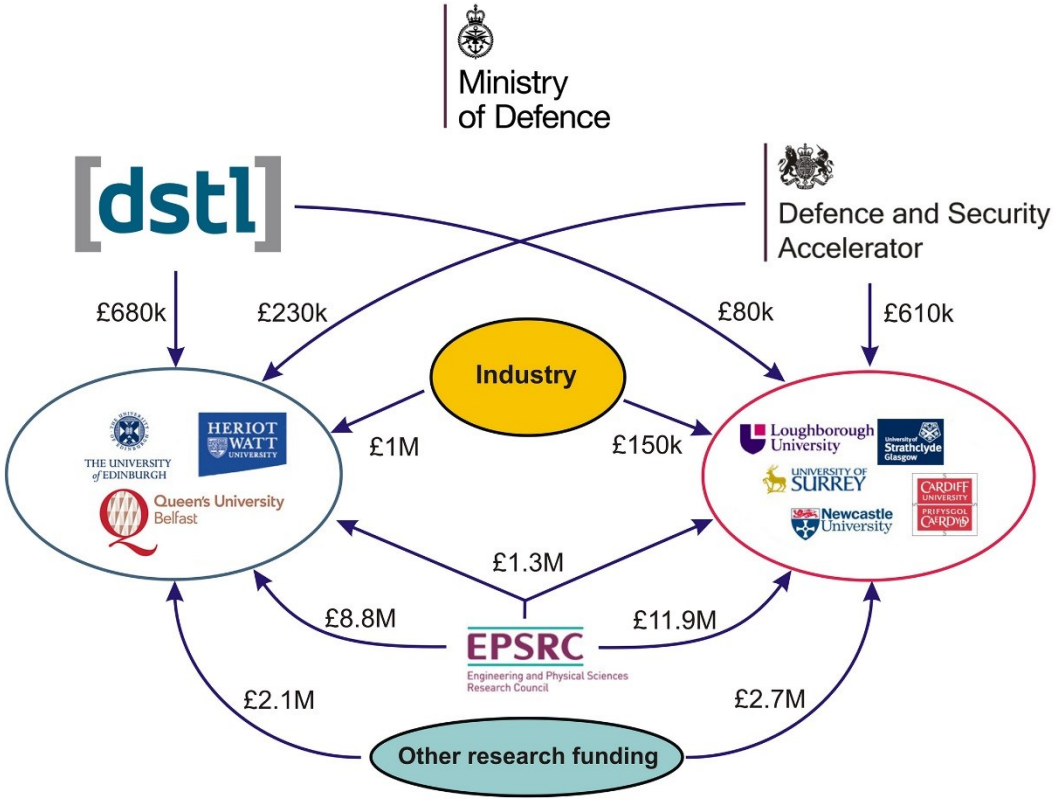
Raman spectroscopy is a well-established spectroscopic method for the detection of condensed phase chemicals. It is based on scattered light from exposure of a target material to a narrowband laser beam. The information generated enables presumptive identification from measuring correlation with library spectra. Whilst this approach is successful in identification of chemical information of samples with one component, it is more difficult to apply to spectral mixtures. The capability of handling spectral mixtures is crucial for defence and security applications as hazardous materials may be present as mixtures due to the presence of degradation, interferents or precursors. A novel method for spectral unmixing is proposed here. Most modern decomposition techniques are based on the sparse decomposition of mixture and the application of extra constraints to preserve the sum of concentrations. These methods have often been proposed for passive spectroscopy, where spectral baseline correction is not required. Most successful methods are computationally expensive, *e.g.* convex optimisation and Bayesian approaches.

We present a novel low complexity sparsity based method to decompose the spectra using a reference library of spectra. It can be implemented on a hand-held spectrometer in near to real-time. The algorithm is based on iteratively subtracting the contribution of selected spectra and updating the contribution of each spectrum. The core algorithm is called fast non-negative orthogonal matching pursuit, which has been proposed by the authors

# Defence and Industry: – An Overview

**In addition to main UDRC Grant, the consortia secured the following related funding streams**

- Related EPSRC funding - £21M
- Other (EU/ERC/Royal Society) - £4.8M
- Industrial Contributions (Studentships and consultancy) - £1.1M
- Dstl Enabling Contracts - £760K
- Defence and Security Accelerators - £840K



# Defence and Industry: – Highlights

UDRC have provided signal processing expertise to people and projects in MOD, wider Government and industry.

- from exploratory workshops covering a broad range of topics
- to more focussed and in-depth work which looks at a particular defence need.

Secondments

| | | |
|---|---|---|
| Strathclyde | ⇒ | Thales |
| Heriot-Watt | ⇒ | Roke Manor |
| Heriot-Watt | ⇒ | Dstl, Porton Down |
| Heriot-Watt | ⇒ | Purdue University |
| Edinburgh | ⇒ | Aalto University |

Visiting Positions

| | | |
|---|---|---|
| Dstl | ⇒ | HWU |
| Dstl | ⇒ | Strathclyde |

Total £760K in associated enabling contracts on MOD problems and challenges including work in:

- Underwater tracking and motion analysis
- Space surveillance and tracking
- Temporal anomaly detection
- Mobile Ad-Hoc Sensor Network (MASNET) Modelling
- Algorithms for the Detection of Advanced Radar Signals (DARS) testbed
- Raman Spectral Analysis

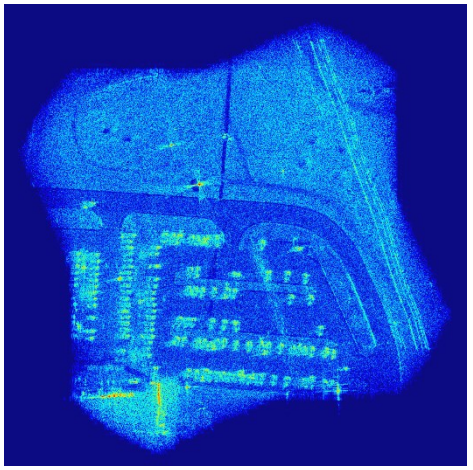
# Defence and Industry: – Data

Working with Dstl's data to improve research

- Dstl - Application of novel tracking and association methods for Space Situational Awareness
- (Processed raw data from ground-based radars and optical sensor systems)

Working with industrial partners and use their data to test and evaluate algorithms and models

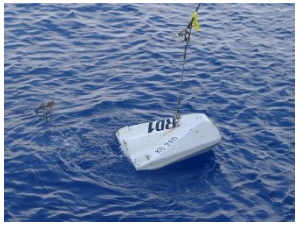
- Roke Manor - How to reliably count the number of co-channel signals in the presence of spatially correlated noise
- Cubica Technologies - Rapid multi-sensor deployment using automatic calibration.
- Thales - Application of polynomial matrix decompositions in broadband processing for underwater systems
- Atlas Elektronik - Sparse sensor arrays for conformal arrays on submarines

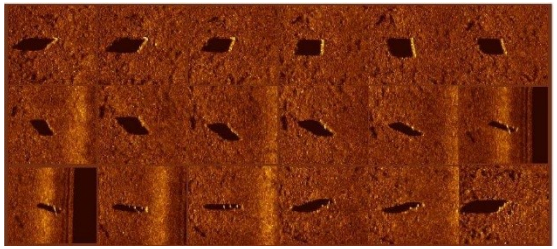


# Defence and Industry: – Joint International Defence Trials

## UDRC Data collection - Joint trials between UDRC and NATO Centre for Maritime Research & Experimentation

- Broadband sonar data was collected with the Hydrason BioSonar ultra-wideband sonar array. This novel hardware relies in part on research outputs from the UDRC phase 2.
- The trials delivered a vital data set which addresses fundamental questions about coherence as well as material to develop recognition algorithms based on coherence processing.





# Defence and Industry: – Spin-outs and Companies

**Anyvision**

- A visual security company focussing on face recognition in surveillance started in 2015
- As of 2018 AnyVision employs 85 people in UK, Israel and the USA and partners with major players including Bosch, Almaviva, NVIDIA and Verint.

**AutuoAI**

- An early-stage startup company - developing technology that gives machines variable perception in complex environments
- Developing ultra-sensitive LiDAR systems and Deep Learning solutions for the CUAV, autonomous vehicles (AV) and autonomous rail (AR) market
- Enables autonomous systems to operate safely in harsh environmental conditions, e.g. heavy fog or rain and snow
- Developing new software solutions that allows machines to perceive and interact in any complex environment using multiple sensors

**University of Strathclyde**

- Development of satellite-based detection system capable of early drone detection and tracking.
- The project received an extensive package to support further development and market entry.

AUTUO
Making autonomy safer

Puneet Chhabra (Heriot-Watt) and Jameel Marafie (Imperial College London)

# Conclusions

**A unique combination of research, exploitation, engagement and communication**

Signal processing community of interest of 1150 active members. Over 300 UDRC publications published.

Register your interest at www.mod-udrc.org

More information can be found at:
Research / White papers / Videos
www.mod-udrc.org/research/

Publications
www.mod-udrc.org/publications

# Any Questions?