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Optimisation of CB sensing

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DSTL/TR137935

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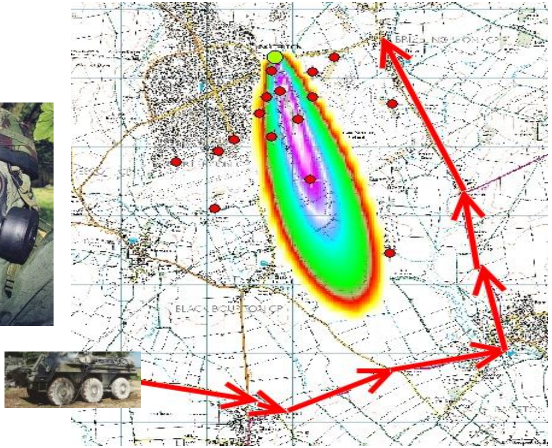
Ministry of Defence

Overview

- Motivation
  - Hazard identification and characterisation
- Background
  - Decision Support Tools
- Background
  - Sensor Placement Tool (SPT)
- Latest SPT developments
  - Correlation
- Future focus
  - Complex sensor systems

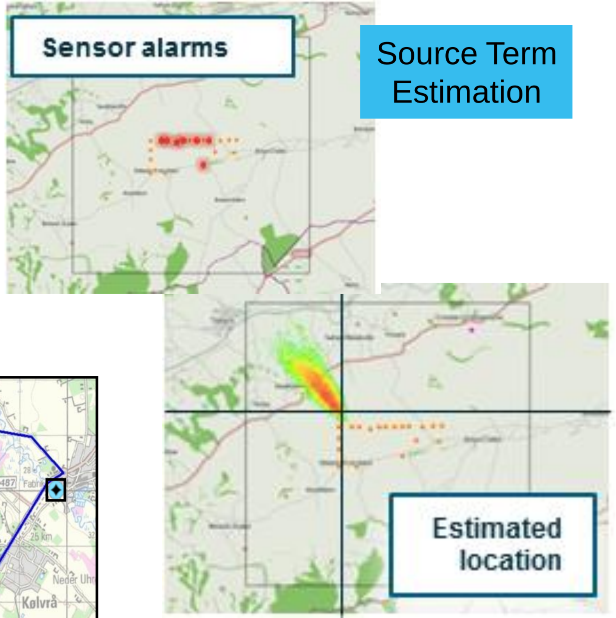
Motivation: Situational Awareness

- To reduce casualties and maintain tempo during a CBR event it is necessary to understand the downwind hazard
- Immediate impacts
  - Masking/de-masking strategies
    - Minimise casualties
  - Alternative courses of action
    - Hazard avoidance
    - Minimize protection requirement
- Medium-term response
  - Decontamination (from deposition)
    - Personnel
    - Assets
  - Medical countermeasures
    - Minimise use
- Long-term response
  - Forensics
    - Examination of release location

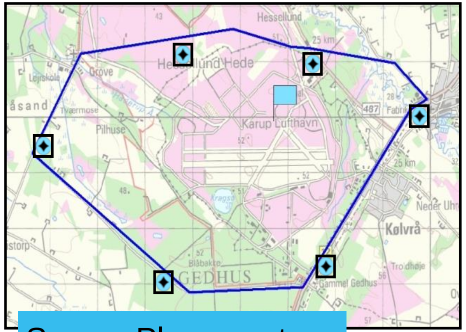


Background: Decision Support Tools

- Decision support tools have wide-ranging application to support the military commander
  - Strategic through to tactical command levels
    - Pre-deployment planning
      - In support of acquisition programmes
    - Deployment / pre-event
      - What should be deployed and where?
    - During / post-event
      - Mitigation strategies
      - Consequence management
      - Maintain operational tempo
  - Two key capabilities
    - Sensor Placement Tool
    - Source Term Estimation



Source Term Estimation



Sensor Placement

Sensor Placement Tool

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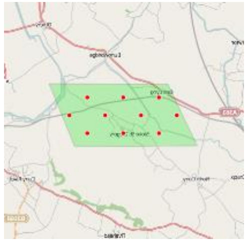
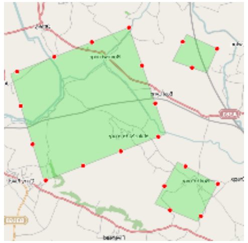
- UK MOD requires expert advice to ensure optimum benefit from and cost effectiveness of the CB sense capability

- This advice is supplied through the Sensor Placement Tool (SPT) which has two main uses:
  - To support procurement of sensor technologies by assessing and scoring various configurations of sensors
  - As a planning capability identifying optimal locations in which to place sensors

Dice-5



Perimeter



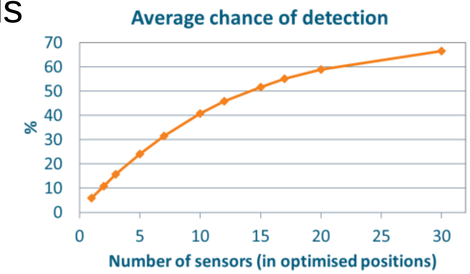
Picket fence

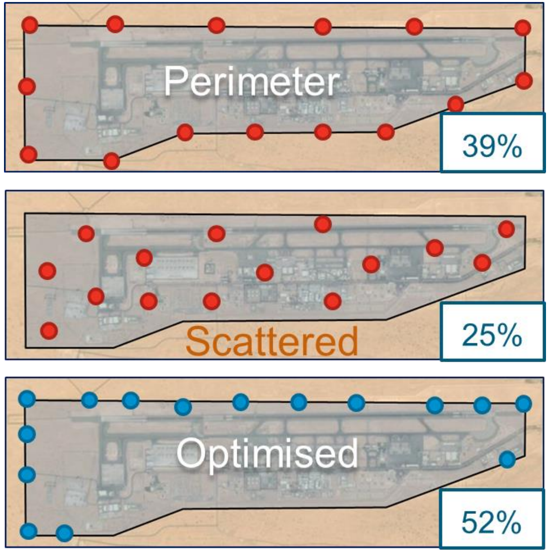
SPT: Application

- Sense system performance depends on numerous factors:
  - Meteorology / Threat details / Quality and quantity of sensors

- Sensor Placement Tool
  - Assesses sensor systems
  - Provides analysis of protection levels
  - Optimises sensor placement

- SPT has been used to:
  - Identify what is achievable
  - Inform requirements
  - Down-select system concepts
  - Generate laydowns for Bio sense capability operationally





SPT Approach

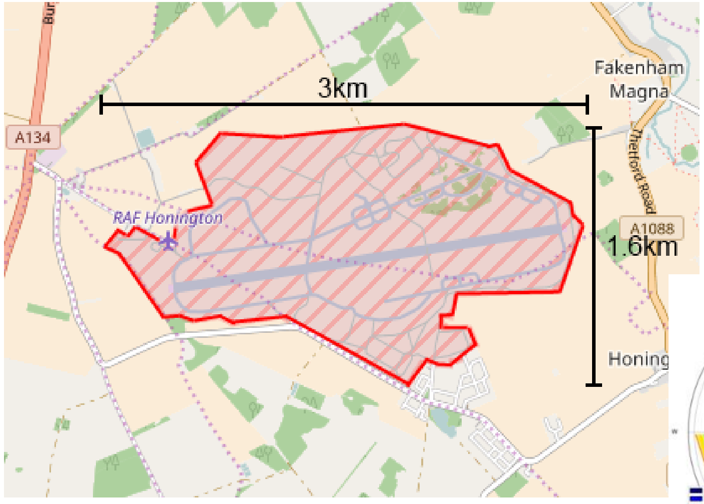
- Fitness function designed to assess a given sensor placement based on criteria of interest:
  - Probability of detection
    - Probability of one or more sensors detecting a threat over the length of the simulation
  - Warning time
    - Specify a desired warning time and asses ability of a group of sensors to alarm in a timely manner
  - Desirability
    - Allows algorithm the assign preferential weights to areas where sensor placement is more convenient or exclude / penalise areas where sensors can’t be placed (e.g. runways)
- Optimisation algorithm run to find best fitness value
  - Modified simulated annealing approach
  - Set a maximum number of iterations (typically 1×10^6)
  - Modifications to avoid getting stuck at local extrema

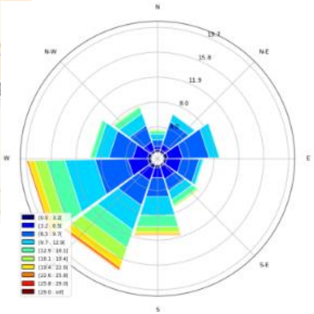
SPT: Demo Exercise

Overview: Provide a sensor placement laydown for RAF Honington to support a Biological Surveillance Collector System (BSCS) user field trial

Information we require:

- Base Location:
  - 52.335N, -0.7754W
- Base Dimension:
  - See map
- Threat Type:
  - Biological sprayer
  - Off-base releases up to 2 km away
- Meteorology:
  - Historical (current month)
- Sensor Type:
  - Up to 15 BW collectors
  - Collectors must be placed on-base
  - Avoid placing collectors on the runway





Where Do I Place My Sensors?

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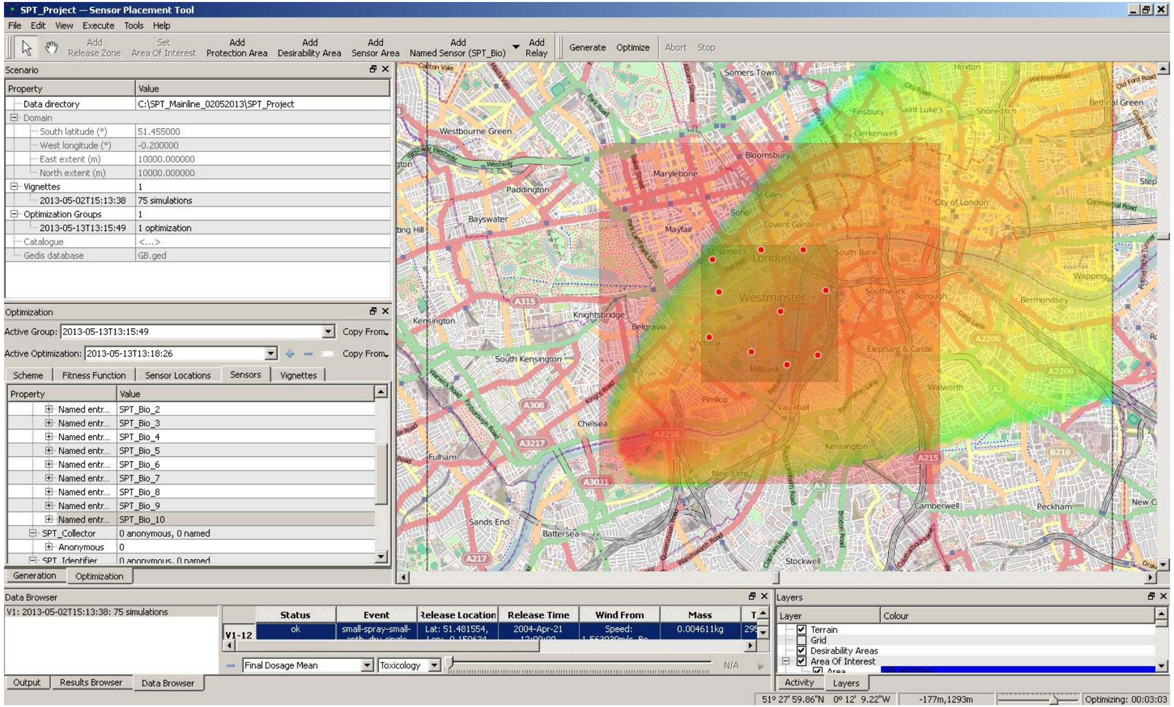

Optimized Sensor Placement provided through the **Sensor Placement Tool**

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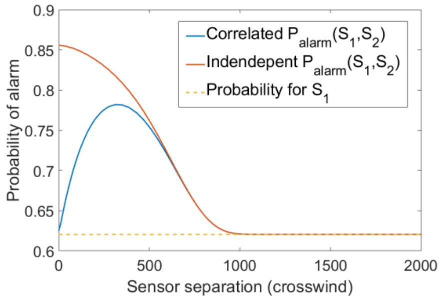
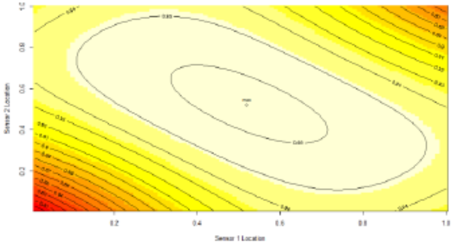
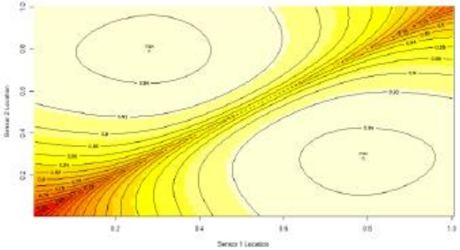
SPT Challenges



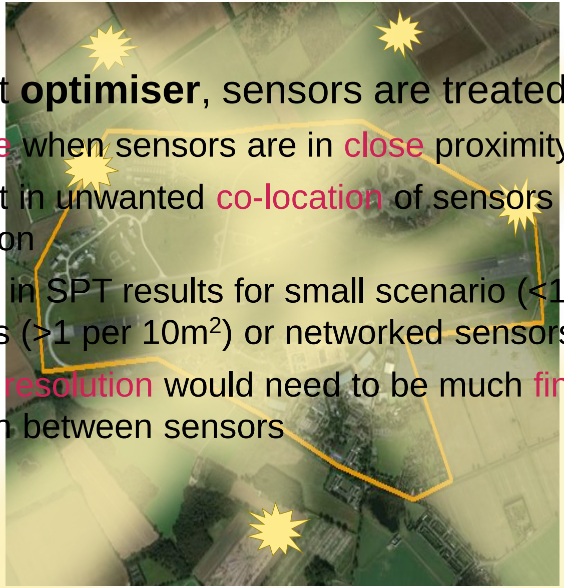
Probability of Detection (uncorrelated)



Probability of Detection (correlated)



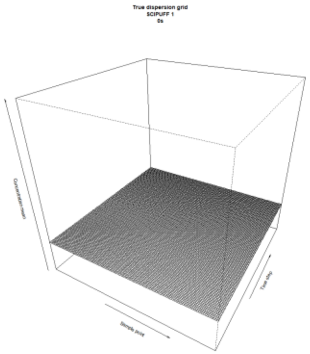
1. SPT **threats** are generated first and stored as data grids for multiple time points
   – 1 minute temporal resolution; 6 hour periods
   – Large amounts of data (~20Gb)

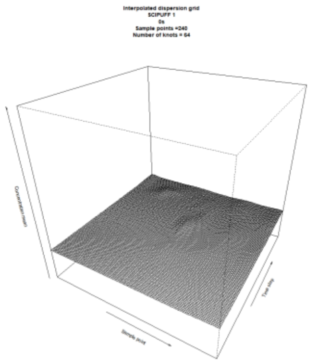


2. In the current **optimiser**, sensors are treated independently
   – Inaccurate when sensors are in close proximity
   – Can result in unwanted co-location of sensors from sensor optimization
   – Limitation in SPT results for small scenario (<1km^2) , large number of sensors (>1 per 10m^2) or networked sensors
   – Temporal resolution would need to be much finer to incorporate correlation between sensors

Latest SPT Developments

- Initial investigation into correlation algorithm identified opportunity in rapid dispersion modelling
  - Dispersion model emulation
    - Data compression
  - Threat data storage not required





- Fundamental change to SPT approach
  - Enabler for moving sensor capability
  - Expands deployment potential

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Latest Developments – work with University of Liverpool (1)

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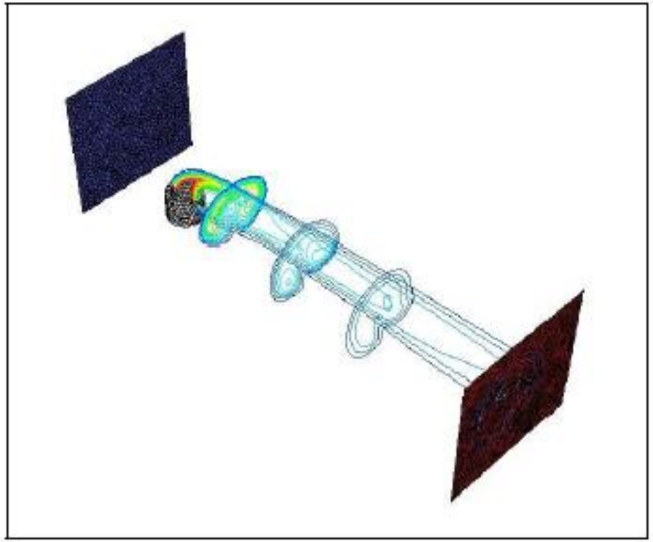
Work to-date has included:

- Use of Gaussian processes to estimate spatio-temporal correlations for large number of sensors
- Development a testbed which includes:
  - Efficient method of calculating probability of alarm, with pair-wise correlation between sensors
  - Algorithms designed to reduce memory usage during optimisation phase
- Validation studies for correlation algorithms
  - CFD simulations using ANSYS Fluent
  - Analysis of existing wind tunnel data from Dstl



Fluent simulation of smoke from a chimney

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Ongoing work:

- Integrating the data compression algorithm into the testbed to remove dependence on the grid and reduce storage required
- Testing of different optimisation algorithms within the testbed
- Further validation studies using wind tunnel data to determine correlation between real sensors

Credit: I. Hall

Future focus

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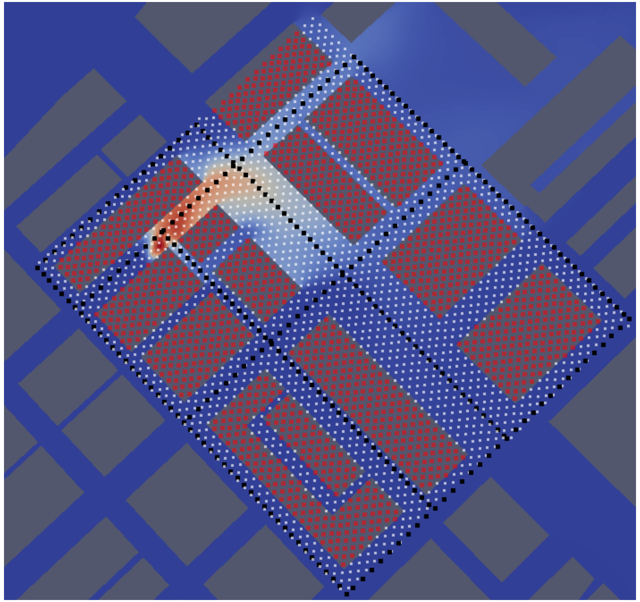
- Development of an SPT-type framework that operates across a continuous parameter space
- Application to complex sensor systems
  - Optimisation of the path of moving sensors
  - Assessment / optimisation of networked sensor systems
- Optimisation for source-term estimation
- Deployment and real-time operation on hand-held devices



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