Optimisation technology in the effective utilisation of EW systems

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CSIR

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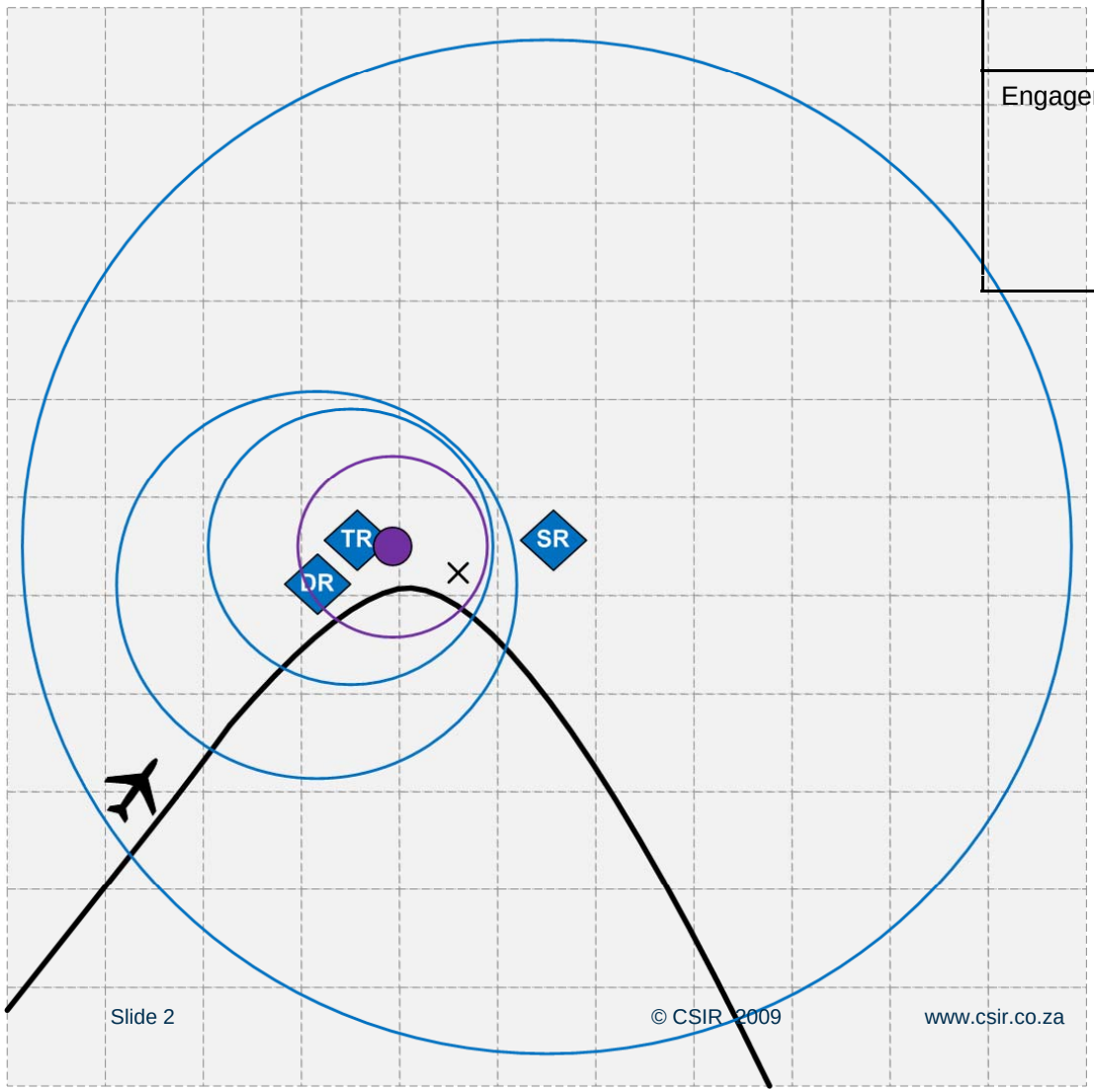
Example Mission

Engagement	Threat (prioritised)	Objective (prioritised)
Engagement 1	1) Early Warning Radar	1) Avoid detection
Engagement 2	1) Designation Radar	1) Avoid detection
	2) Early Warning Radar	2) Avoid detection
Engagement 3	1) Tracking Radar	1) Break lock
	2) Designation Radar	2) Avoid detection
	3) Early Warning Radar	3) Avoid detection



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Example (assumptions)

Objective:

Decide how the EW system should be used

- Assumptions:
  - Only a single “engagement”
  - The enemy systems’ positions are known
  - None of the other systems on own platform can influence the EA system’s performance
  - The ES system is perfect and threat identification is 100% correct
  - Enemy radar systems are not networked
  - Enemy radar systems are not reactive to jamming
  - Assume there are no other friendly forces that can be influenced by the EW system
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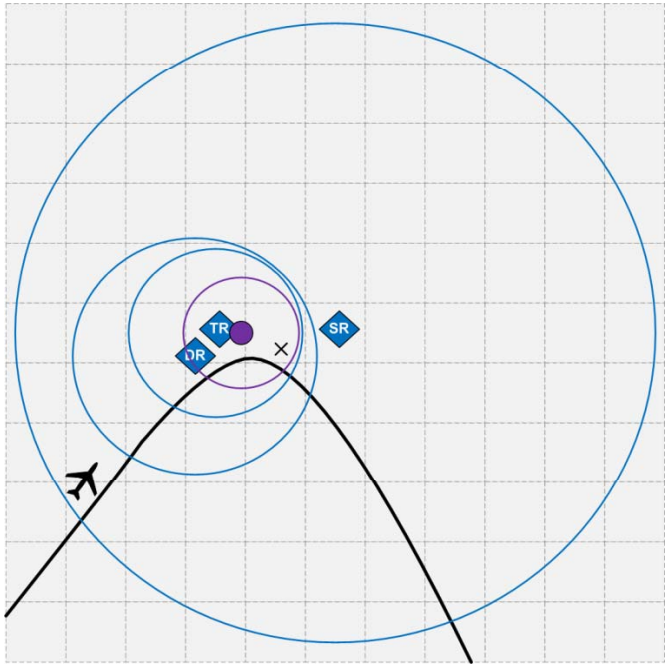
  - Assume the effectiveness of EA techniques are fully understood
  - The EW uses a simple technique lookup system based on the detected threat



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Example (assumptions)

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Decide how the EW system should be used

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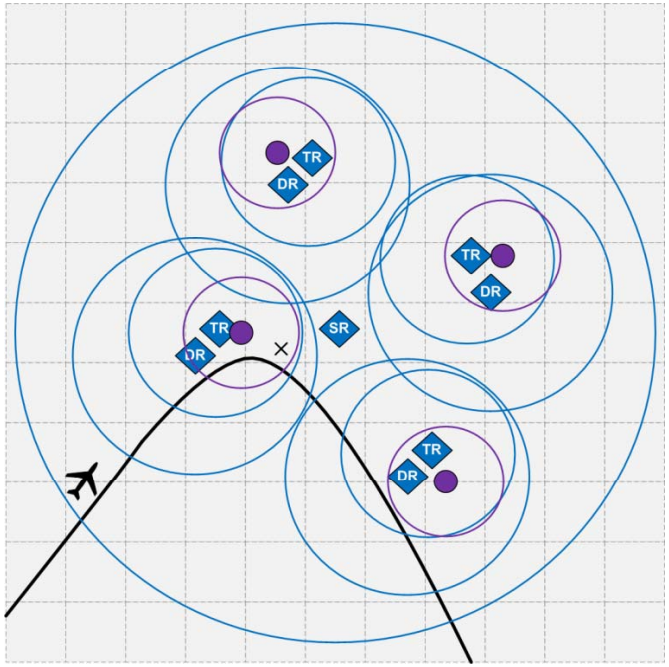

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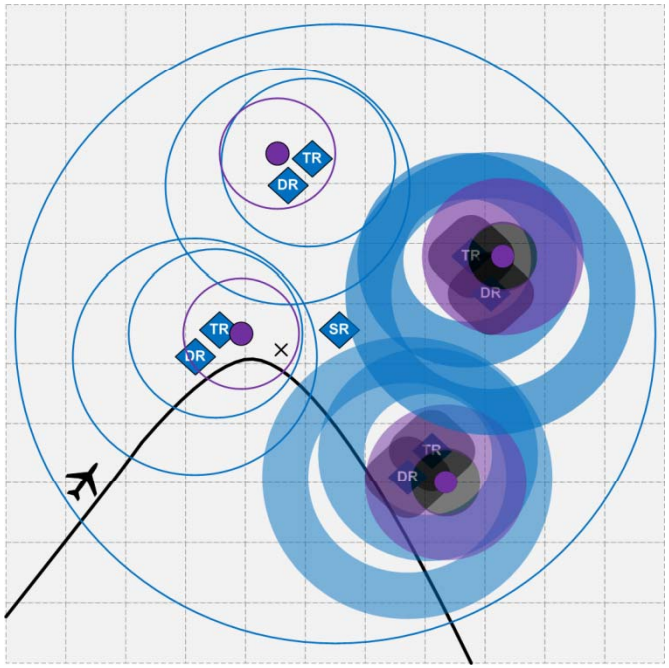

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Example (assumptions)

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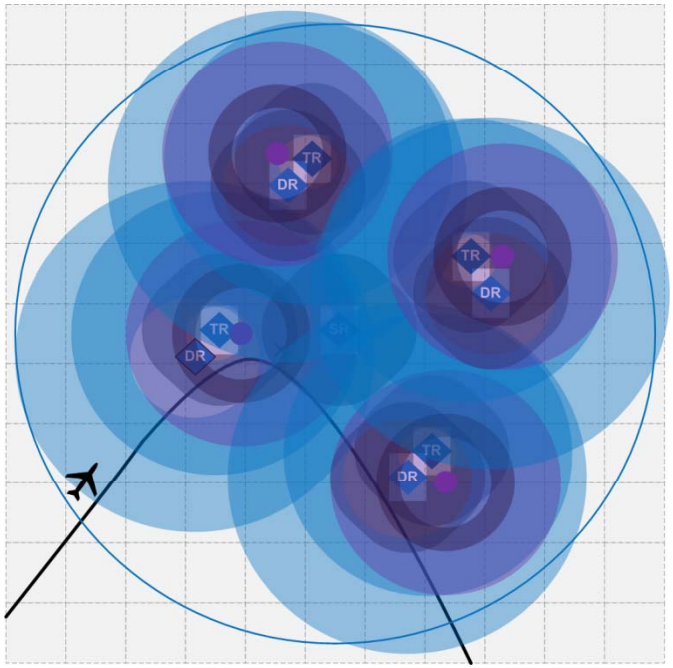

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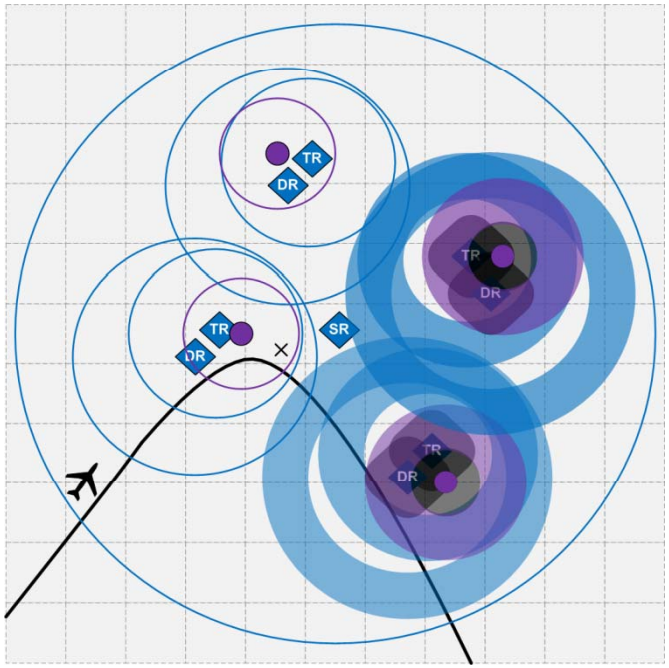

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Example (assumptions)

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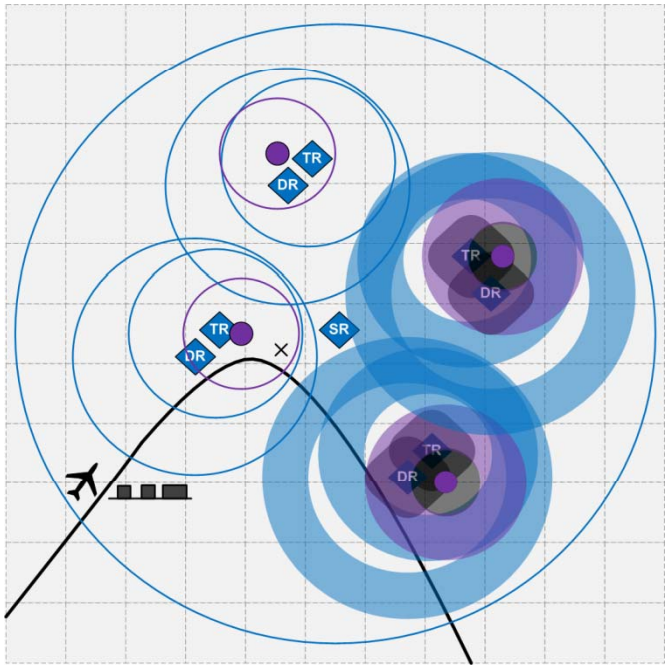

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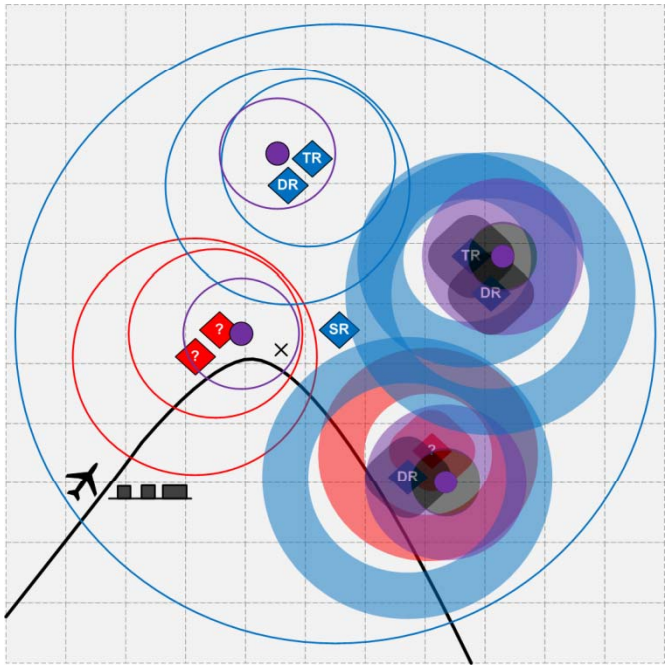

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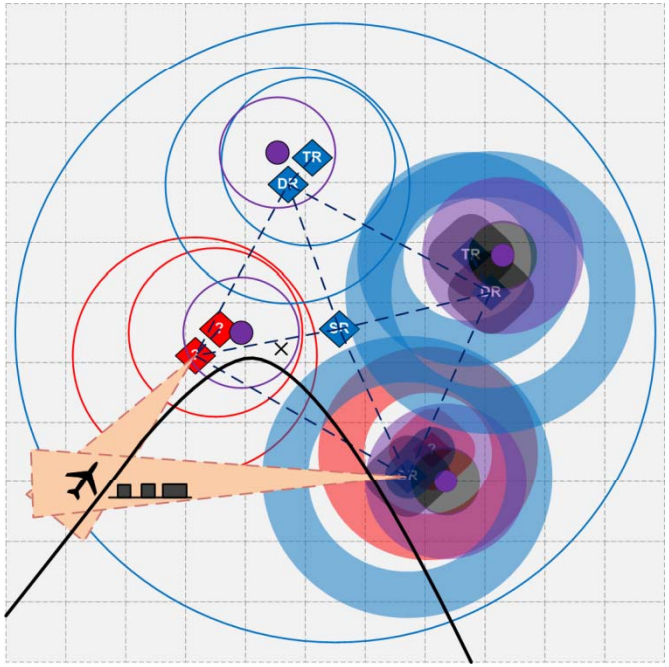

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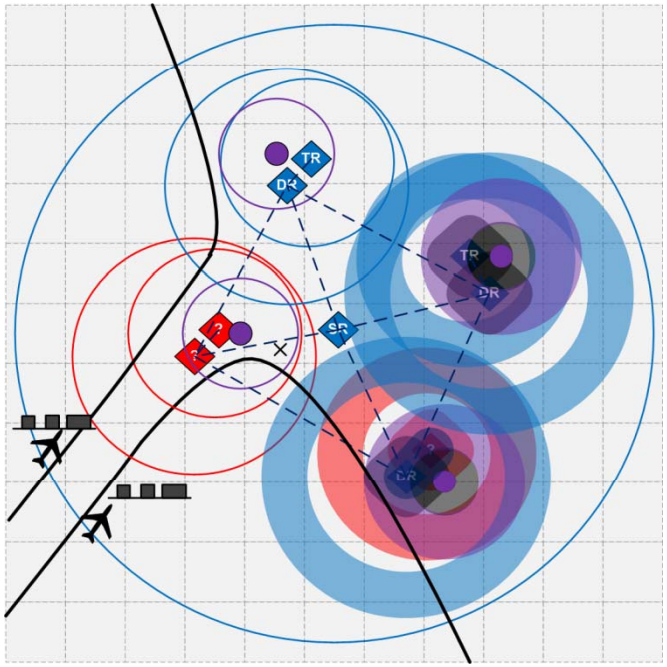

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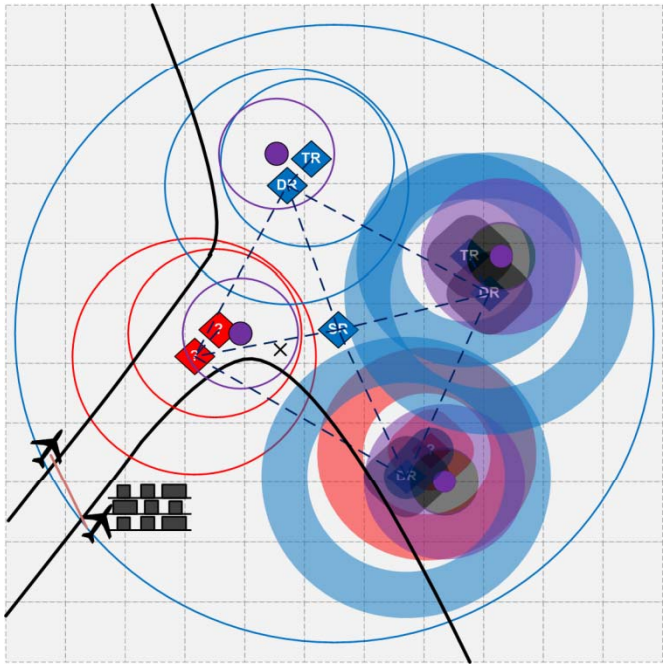

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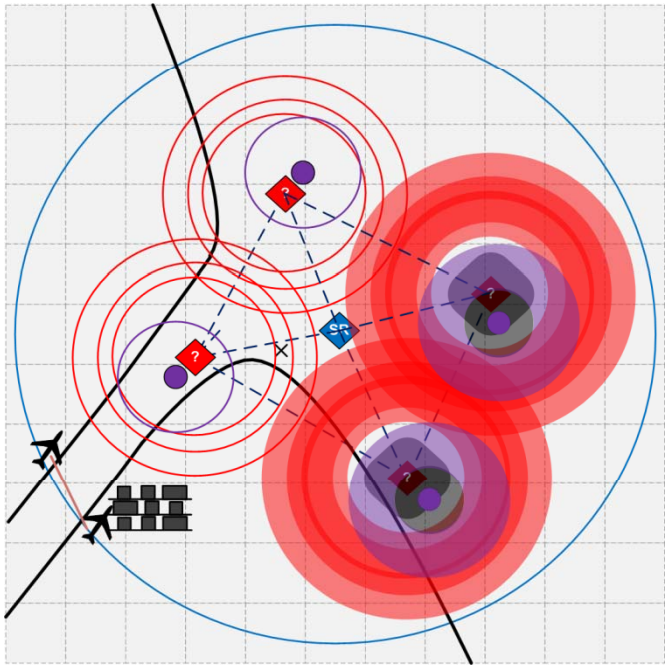

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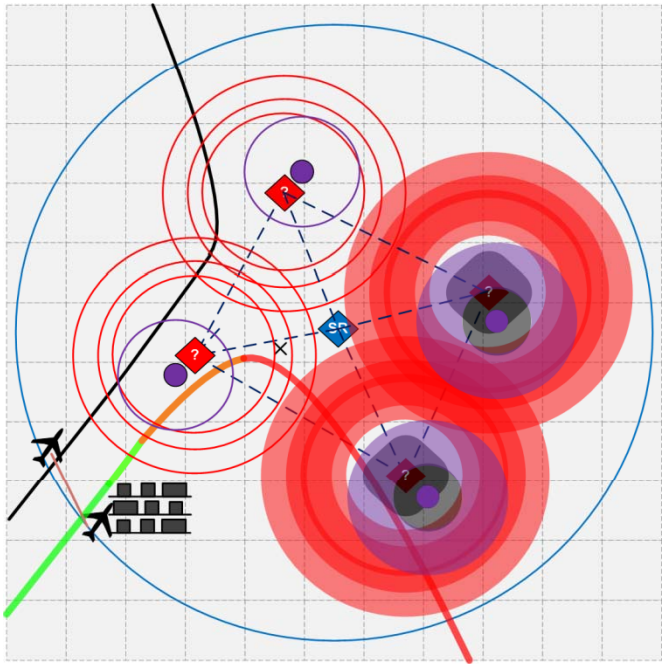

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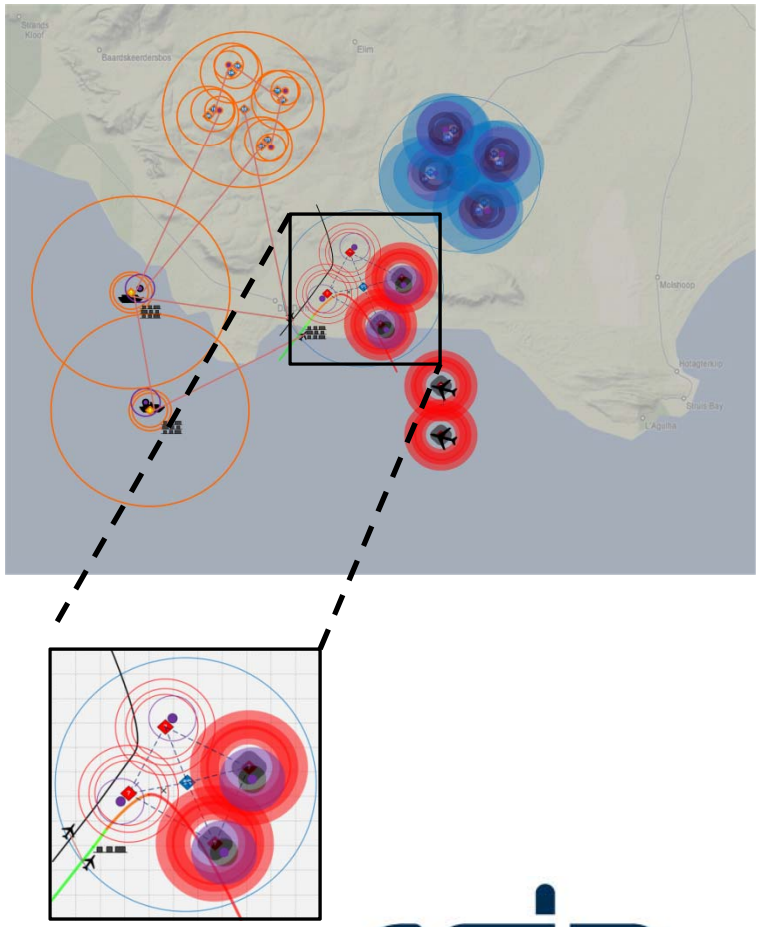
  - Expendables (chaff and flares) are used
  - There are terrain features that can influence the performance
  - Assume the effectiveness of EA techniques are based on models with inaccuracies
  - The EW system uses a complex selection and programming engine
  - The EW system has multiple EA resources
  - The operation is joint with other AOS
  - Multiple communication links are available with input from several sources
  - Coordinated EA/ES can be done between platforms
  - …

Objective:

Decide how the EW system should be used



Bottom line:

- Future (and current!) EW systems utilisation is not a simple problem!
  - Complexity
  - Reaction time
  - Uncertainties/Statistical nature of performance of EW
  - Interoperability

Overview

- An example
- Nomenclature: Optimisation
- Why is optimisation relevant for EW in the future?
- More detail on optimisation and what contribution can be made to EW systems
- What is happening at the CSIR?

Nomenclature: Optimisation (in the context of this presentation)

Definition: Numerical Optimisation

A numerical algorithm to determine which solution selected from a possible set of solutions is the optimal solution given a specific objective

In this context:

- We focus on numerical optimisation
- Selecting optimal ways to use an EW system
- Selecting optimal ways for subsystems in an EW system to operate

Out of this context:

- Optimal design of systems

  Numerical optimisation used in designing a system (for example the curve of a wing)

Why is optimisation relevant to EW in the future (and today!)? A few reasons

- Complexity of the battle-space
  - Warfare in high emitter/threat density environments
  - Uncertainty in mission scope/intelligence
  - Uncertainty in system effectiveness
  - Combination of older and modern hardware (Take into account asymmetrical warfare)
  - Adaptable and simultaneous multifunctional systems
  - Interoperability requirements
- Processing requirement
  - Lots of inputs
  - Require output very fast
- Integrated warfare system approach!!

Bottom line:

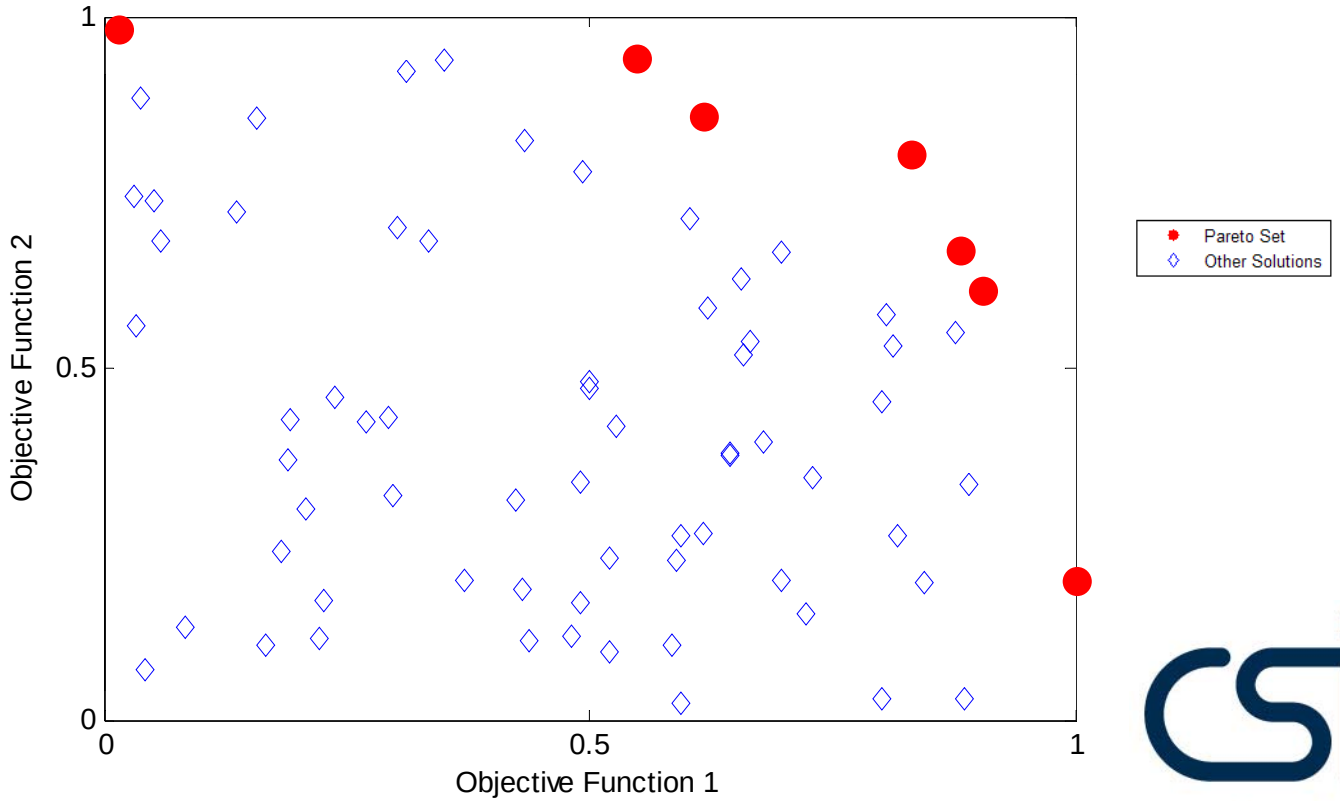
- Optimisation is necessary for effective use of (future) EW systems and the use thereof because humans inherently cannot:
  - Process the ever increasing complexity of the battle-space by hand
  - Process the changing mission quickly enough to react timeously

Optimisation Methods/Classes

- Single-objective optimisation
  - Also called “Mathematical Programming”
  - Finding the best or optimal element in a set of alternatives
  - Evaluate Objective Functions (OF), method depends on characteristics and nature of OF, examples thereof:
    - Linear programming
    - Nonlinear programming
    - Robust programming
    - Heuristics
    - Dynamic programming
- Multi-objective optimisation
  - Creation of a single Aggregate Objective Function (AOF) reduces the problem to single objective optimisation, but reduces the ability of the “user” to discriminate between similar solutions
  - Pareto ranking is a system to present optimal solutions
  - The most popular method:
    - Evolutionary Algorithms

Pareto optimality

A set of solutions exist such that, for each solution in the set, there exists no other solution that performs better in ALL objective function dimensions



Optimisation technologies in EW

Main Areas of benefit (in EW)

- Planning
  - Mission planning
    - Assist in investigation of trade-offs in mission planning
  - Doctrine development
    - Assist in investigation of trade-offs
  - OT&E planning
    - Reduction of test set so that best information/cost rates can be achieved
- System programming
  - Design optimal programs for EW/Radar systems
    - ES (for example search patterns)
    - EA (for example technique selection)
    - EP (for example waveform selection)
- System “fitted with” Functions
  - Use in intelligent systems
  - Built-in optimisation algorithms for real-time optimisation
- (*Optimal System Design*)

Optimisation technologies in EW

Relevant Main Implementation Categories

- Offline

  Requires an optimisation system to be designed into mission planning

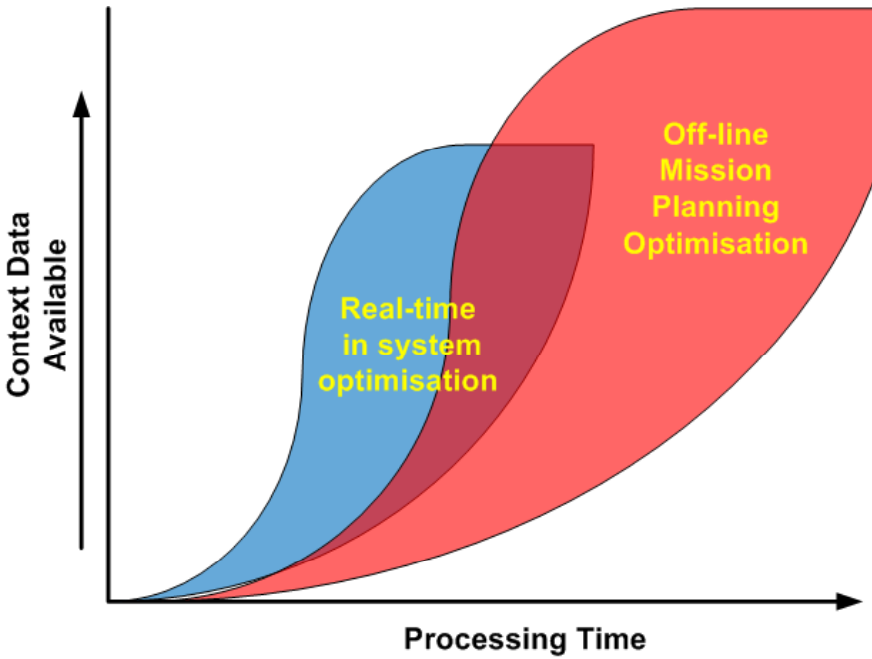
  - Mission planning
  - System programming

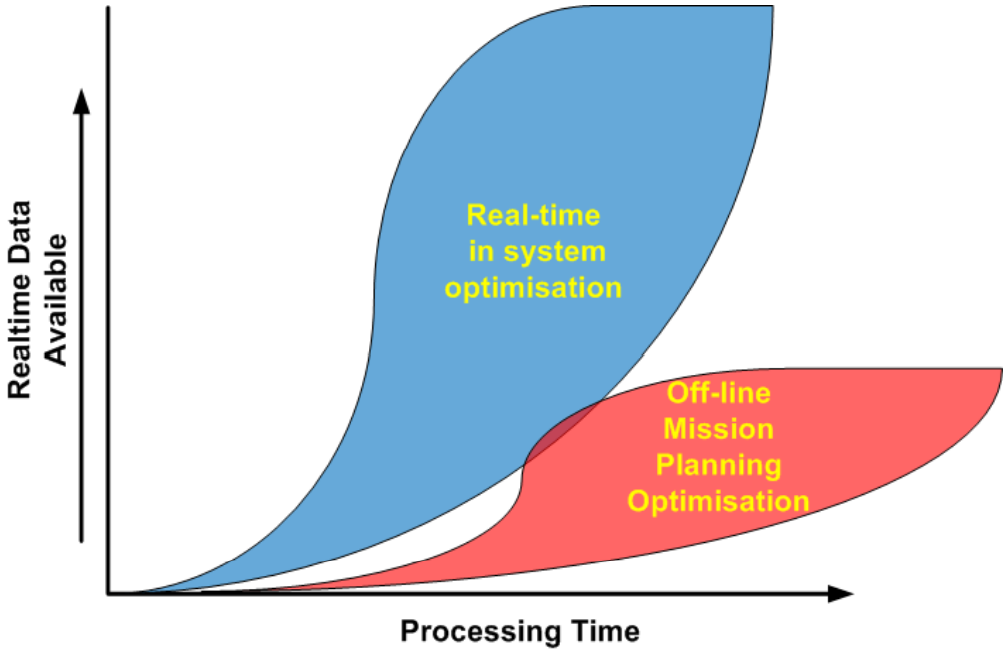
- Real time

  Requires an optimisation function to be designed into the system OR real time system re-programming can be done

  - Technique parameter optimisation (for example: search patterns, bandwidth)
  - Technique selection optimisation

Role of optimisation in context of data/information availability and algorithm processing time – typical graphs



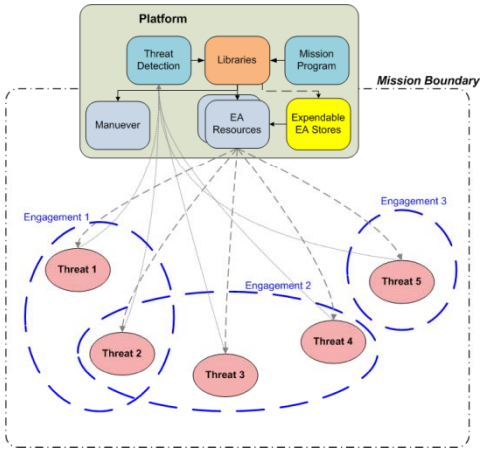


Bottom line:

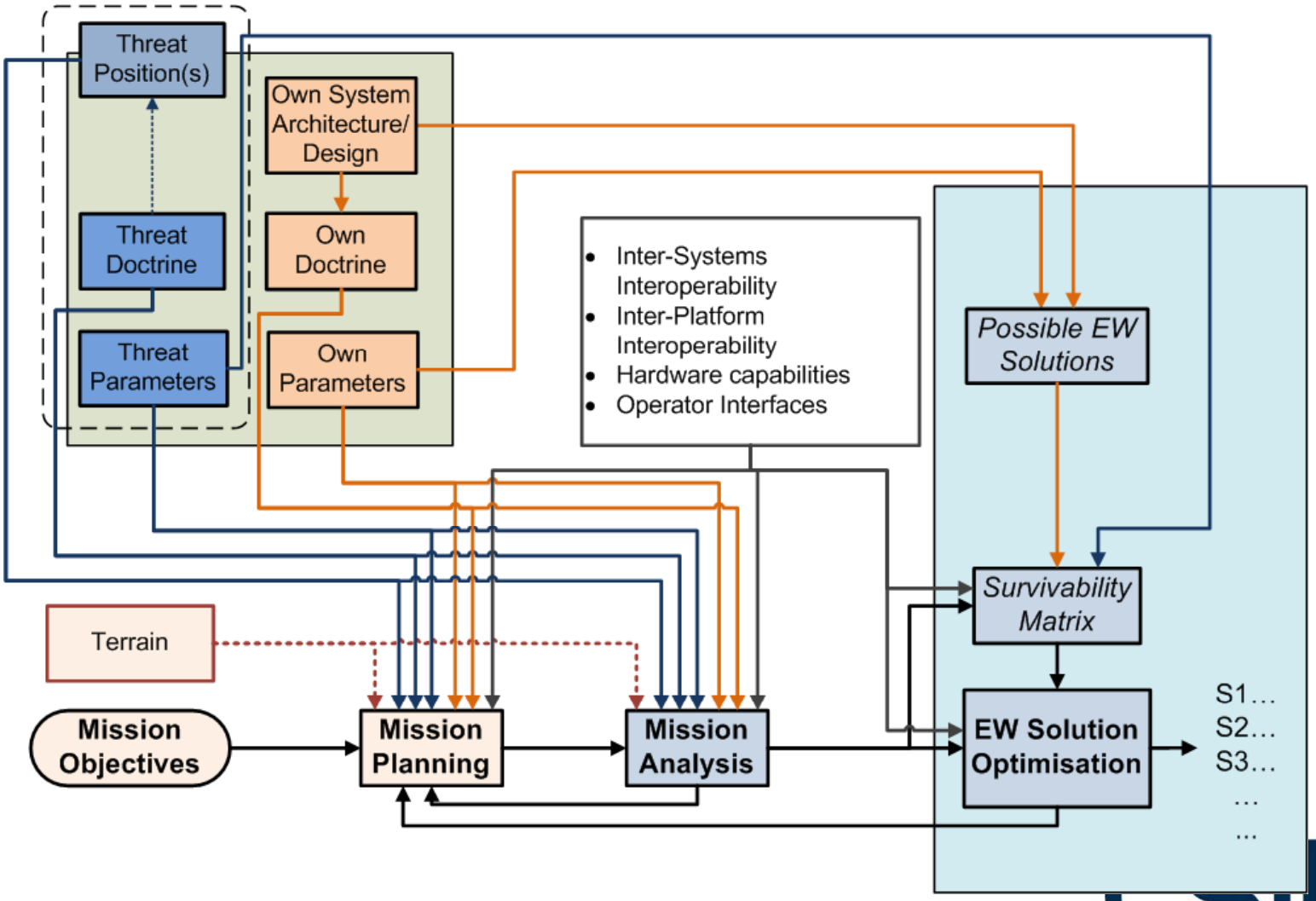
- Optimisation methods are a viable solution/method to assist in the effective use of EW systems
  - Increase survivability of friendly forces
  - Improve understanding of complex missions/scenarios and assist in planning
  - Improve system performance
  - Cost reduction for OT&E and operational planning

R&D at the CSIR

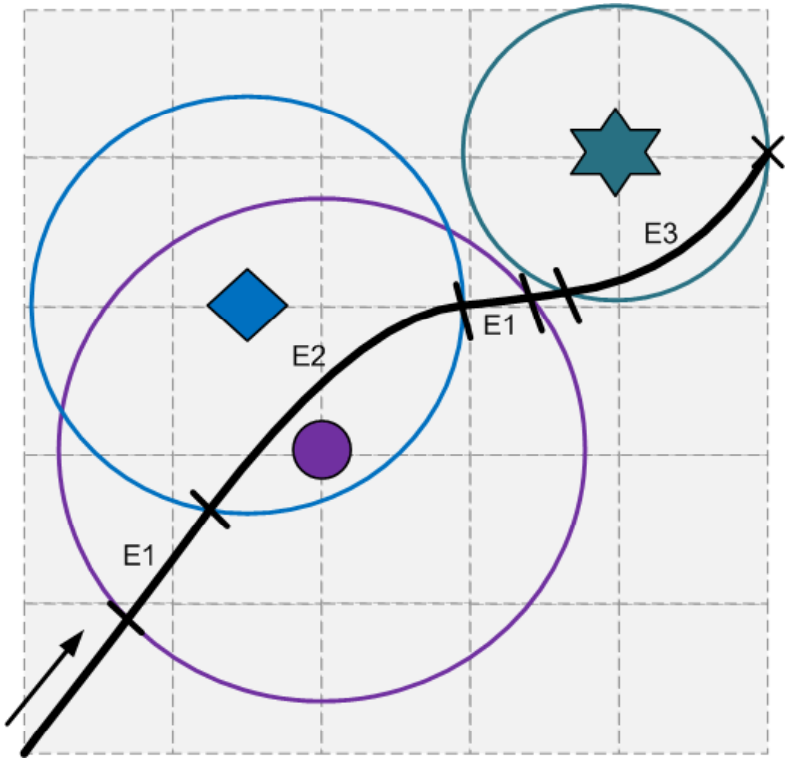
- Developing capability in optimisation methods
  - Focussing on multi-objective optimisation
- Developed a basic software architecture for evaluating optimisation for EA technique programming
  - Active EA techniques
  - Expendable countermeasures
  - Interoperability with other systems



Optimisation System Architecture



Wanted outputs (picture example)



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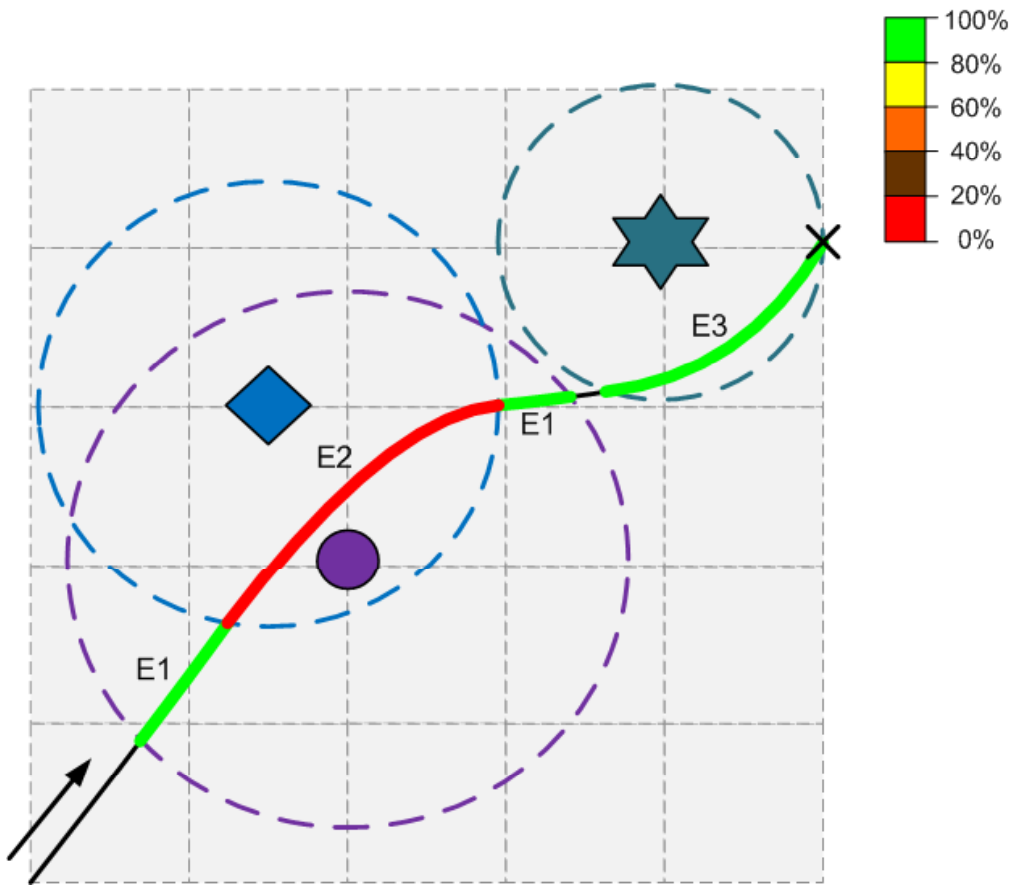

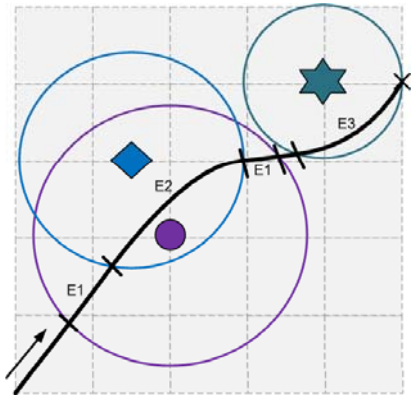

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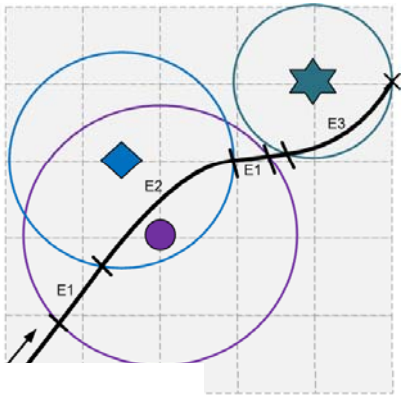
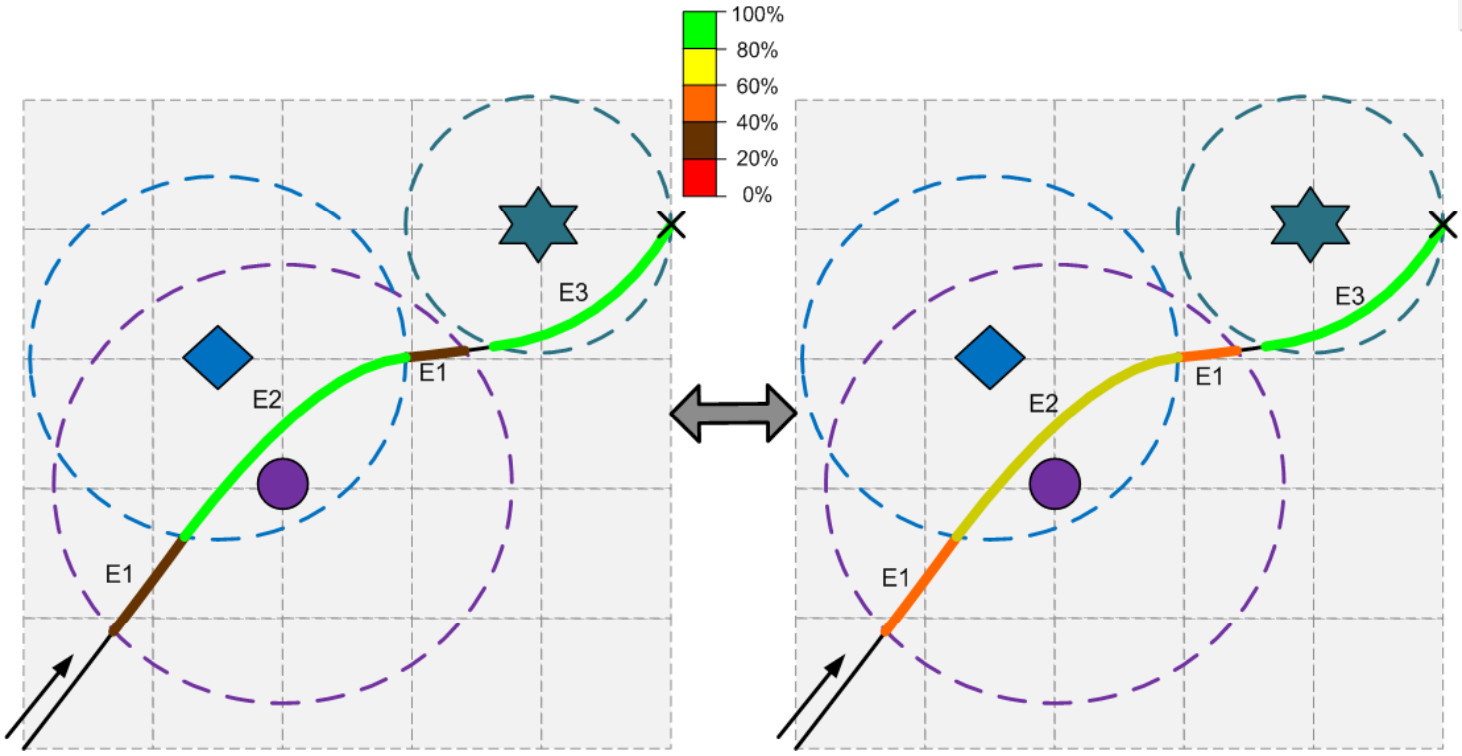
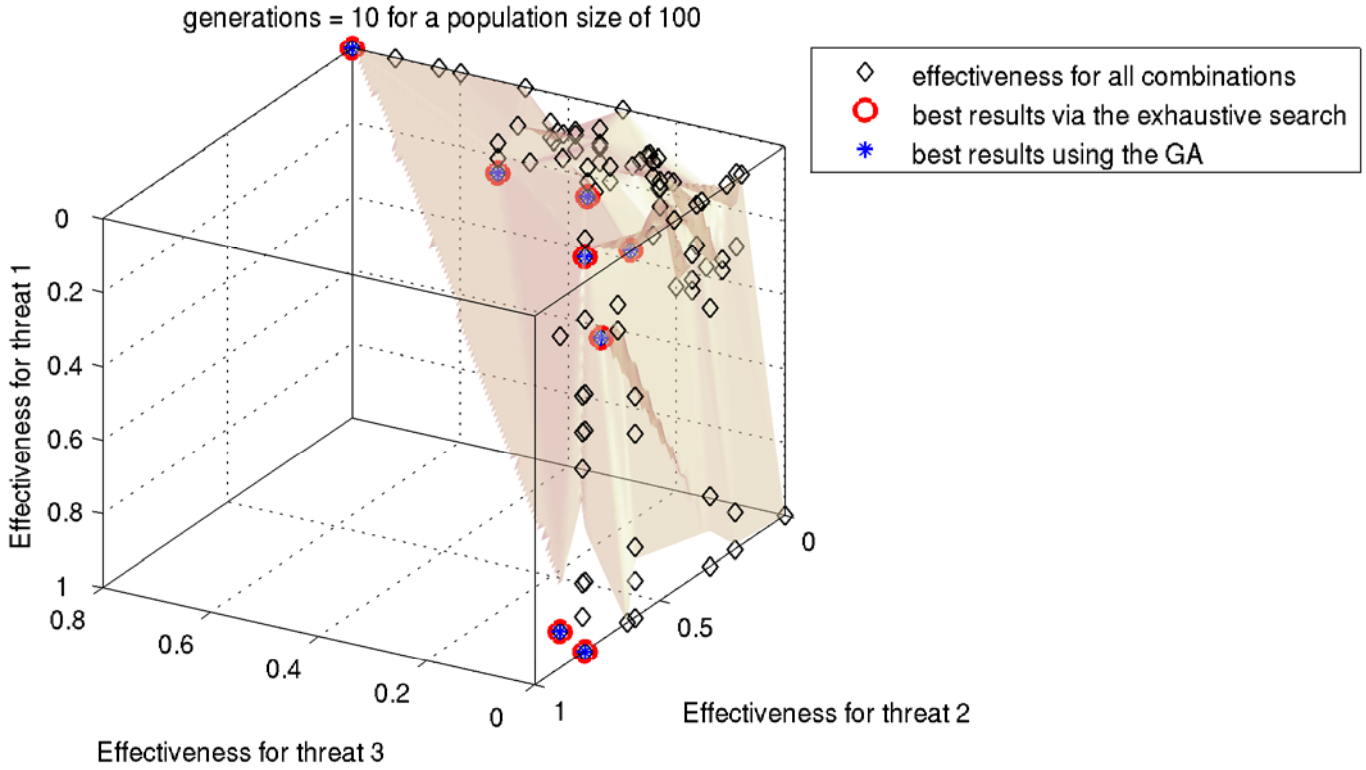




Example of results: Local optimisation – Pareto optimal subset



Conclusion (the most important ones)

- Optimisation methods is a necessary part of modern EW systems:
  - Operational Planning
  - Operations
  - OT&E
- Optimisation will improve survivability

Questions/Inputs/Discussion?