Australian Government
Department of Defence
Defence Science and Technology Group

Modelling Complex Warfighting – a Strategic Research Investment

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(on behalf of MCW SRI Community)

Defence Science and Technology Group
Australia

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Joint & Operations Analysis Division

The JOAD Vision

To be Australia's most trusted source of evidence-based analysis, shaping Defence decision making across the capability lifecycle.

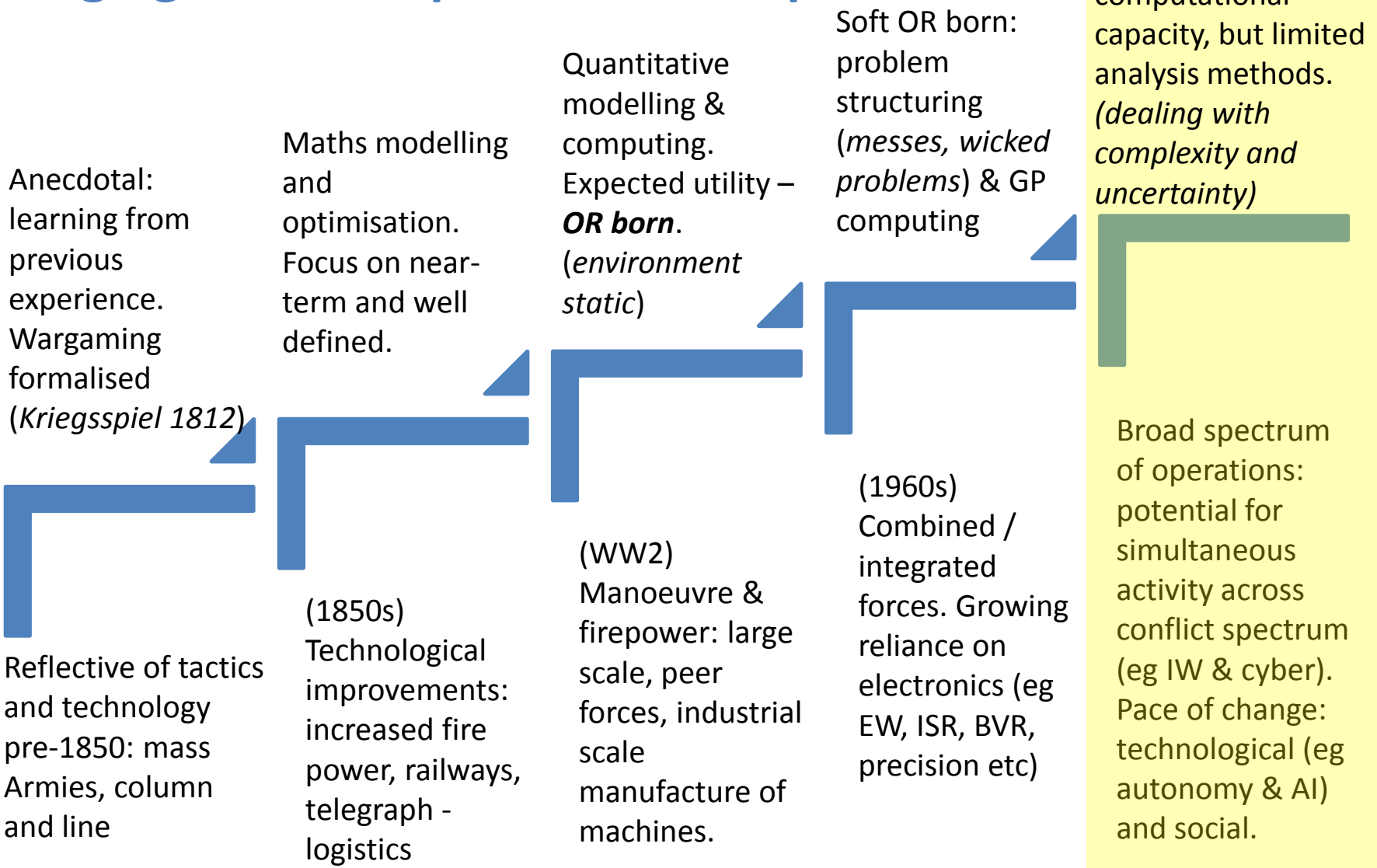
The JOAD Mission

To develop trusted analytical methods that give Defence decision superiority across all aspects of force design and employment.

JOAD Strategic Thrusts

- Whole-of-Force Design
- Warfighting in Complex Environments
- Trusted Autonomous Systems
- Next Generation Tools & Methods

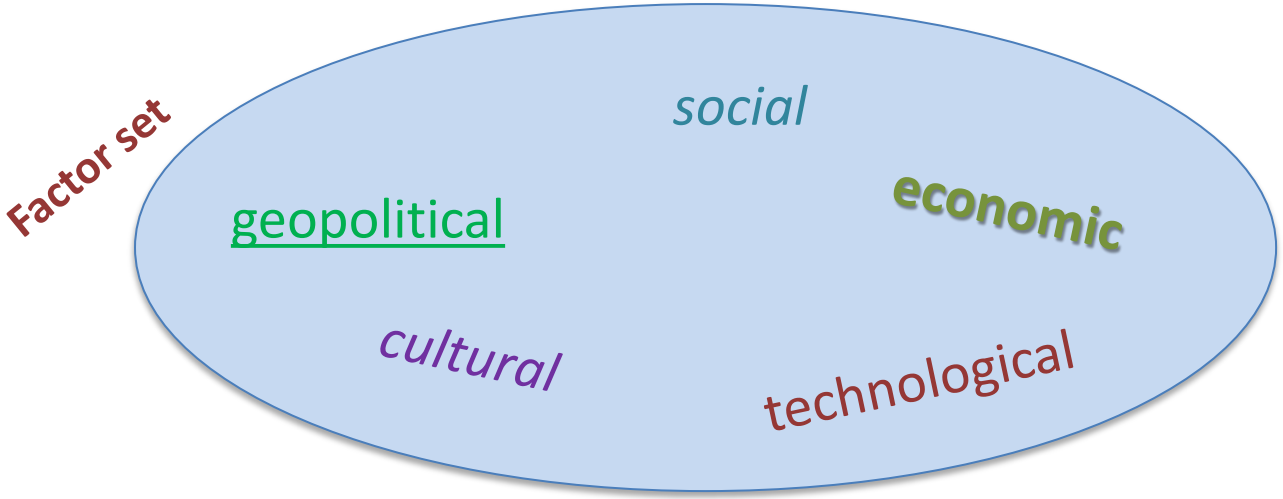
Changing nature of problem conception



MCW SRI Goal

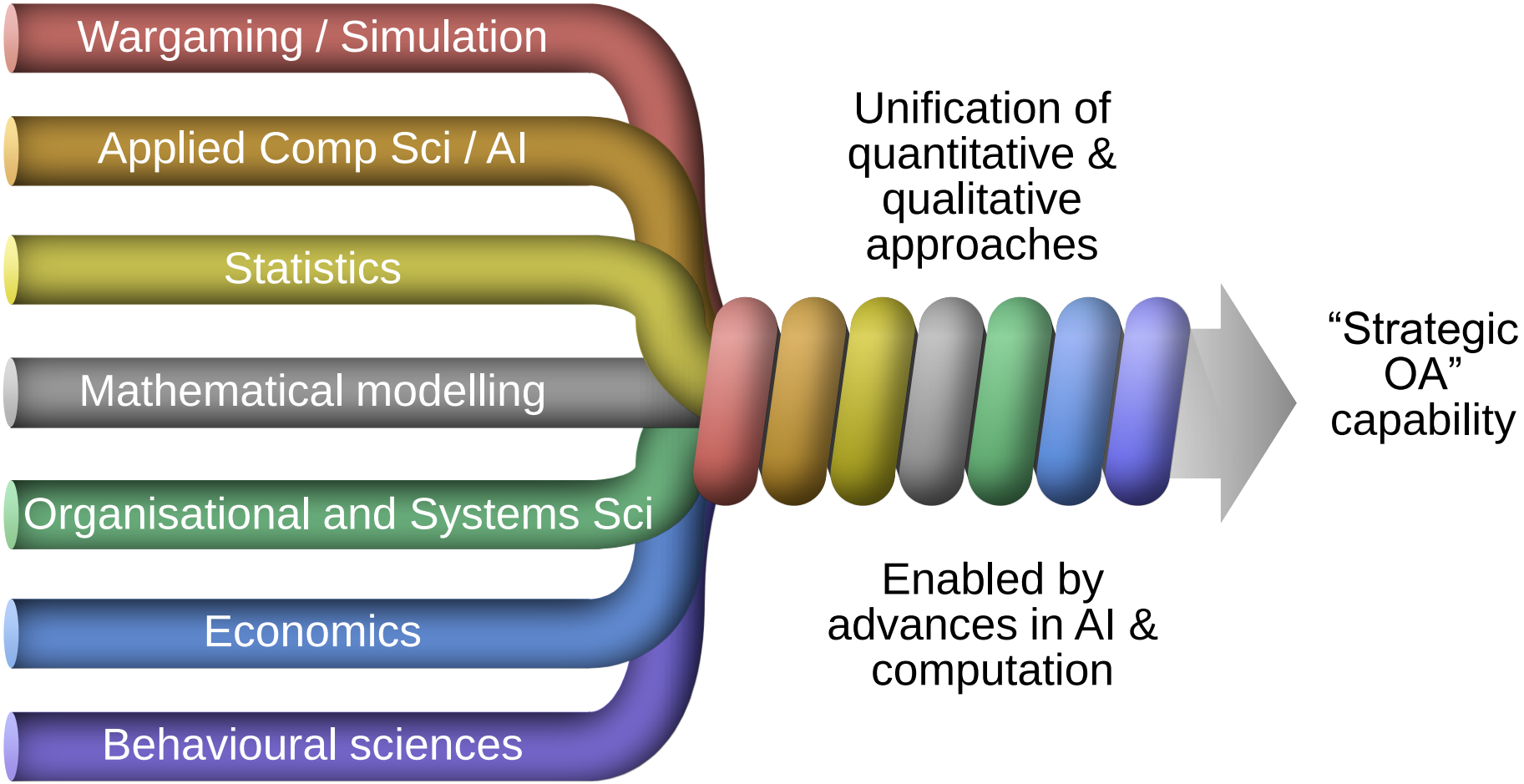
Revolutionise how DST Group undertakes OA to handle the interaction of multiple complex factors for:

- **design of the future force, and**
- **employment of the current force**

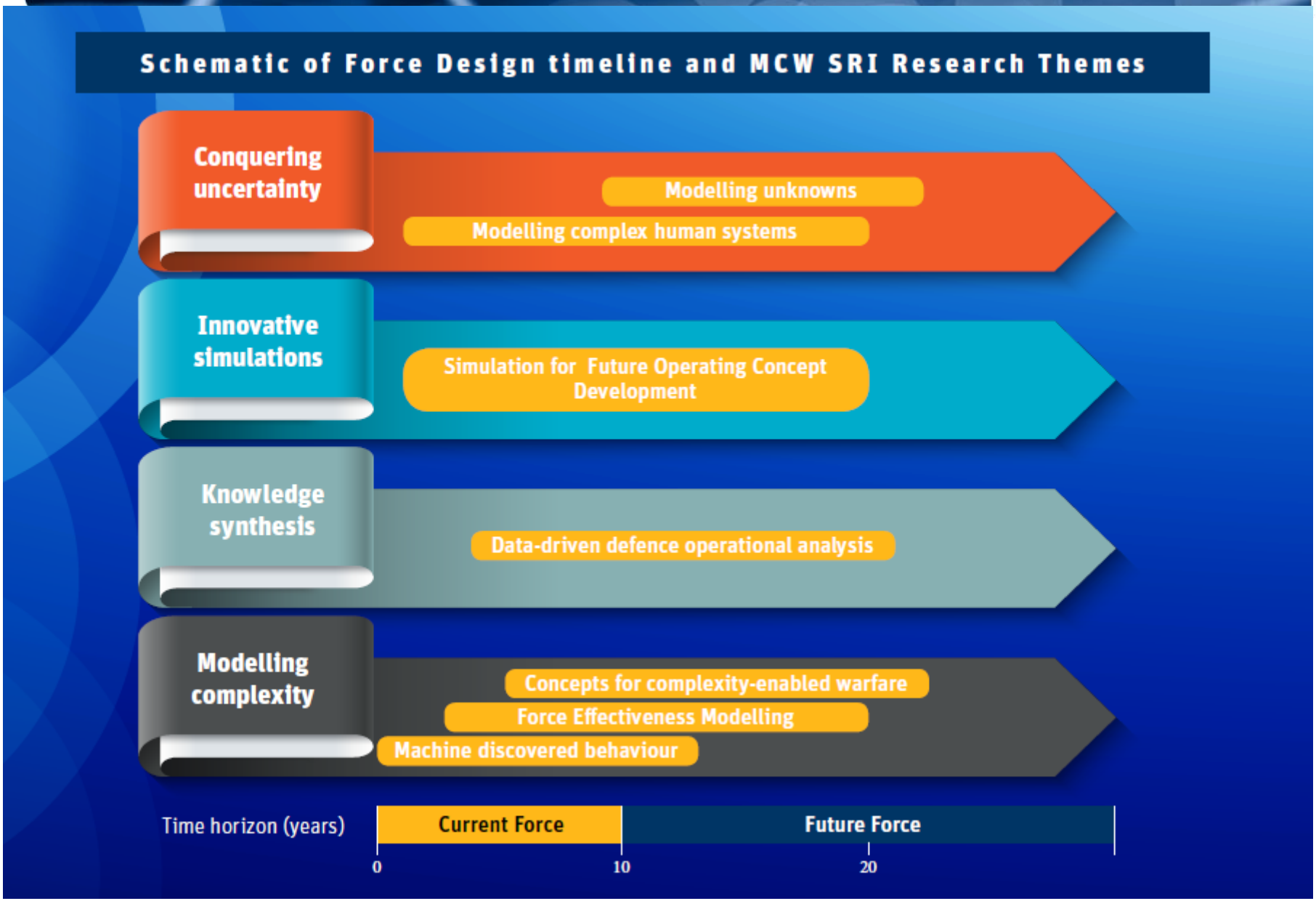


MCW SRI is focussed on novel problem conception

Revolutionising Operations Analysis




MCW SRI Research Themes
Conquering uncertainty
Scientific methods to enable robust Force Design decisions to produce a resilient force through the understanding and management of uncertainty in Defence.
Innovative simulations
Novel modelling and simulation techniques to enable exploration of whole-of-force warfighting concepts and force options.
Knowledge synthesis
Synthesis of analytical and simulation results to support development of a joint force which is integrated by design.
Modelling complexity
Methods to enable understanding of properties of the joint force emerging as a result of nonlinear interactions between the many constituent elements.


Schematic of Force Design timeline and MCW SRI Research Themes
Conquering uncertainty
Modelling unknowns
Modelling complex human systems
Innovative simulations
Simulation for Future Operating Concept Development
Knowledge synthesis
Data-driven defence operational analysis
Modelling complexity
Concepts for complexity-enabled warfare
Force Effectiveness Modelling
Machine discovered behaviour
Time horizon (years)
Current Force
Future Force
0
10
20

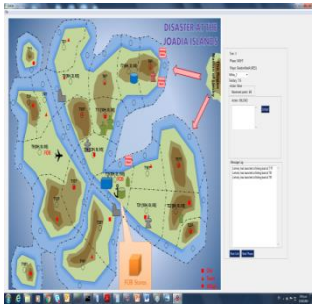
SR1 – AI Enabled Wargaming

- Using AI to help design a better Defence Force
  - Explore tactics and strategy, given existing force
  - Provide recommendations for modifying a force structure to increase effectiveness across a range of scenarios
- Techniques Explored include:
  - Alpha Zero
  - Deep Q Learning
  - Meta-Heuristics (Genetic Algorithms / Simulated Annealing)
  - Hyper-Heuristics
  - Monte Carlo Tree Search, Minimax, and others…

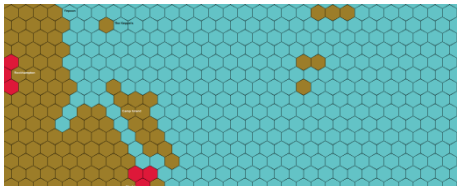
Wargames of many varieties have been used for centuries to explore concepts, examine force structures and to predict outcomes.

AI Enabled Wargaming – Key Steps

- Better understand how classic wargames might be developed and used to support decisions about the design of the ADF through the development and play testing of an innovative wargame
- Convert that wargame into a rich computational simulation with the necessary hooks for the integration of an AI player
- Investigate the capability for AI to attain super-human levels of performance on these types of game

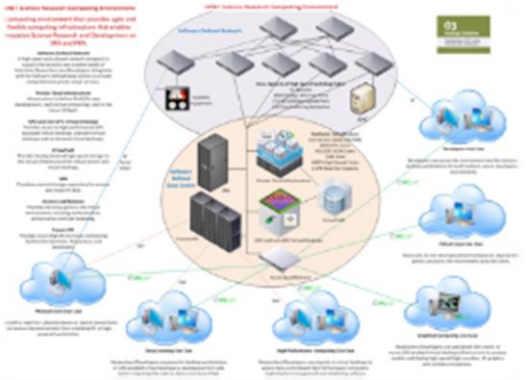


JOADIA – DST Wargame



Computer based versions of classic board-games are now commonplace and AI is being use to play these games. Shown here is the PC version of the classic wargame “Ogre”.

SR2 – Simulation for Operating Concept Development



Problem: **Force Design relies heavily on qualitative approaches, which are challenged by increasing complexity of modern operations.**

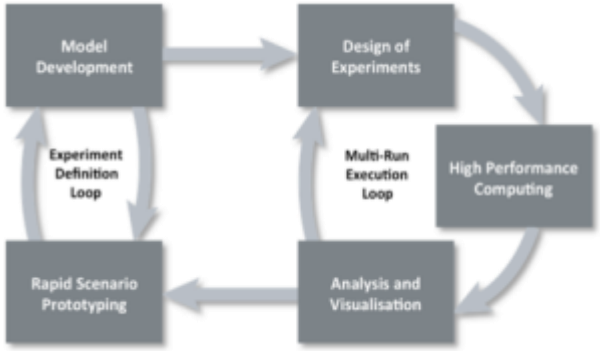
Objective:

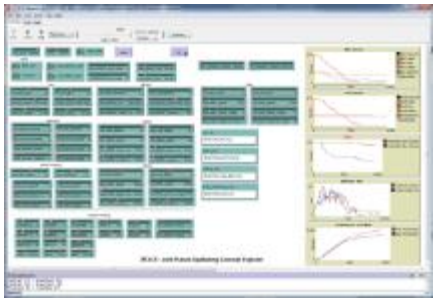
- **Deliver modern simulation capabilities for developing & quantifying impact of complex whole-of-force (WoF) operating concepts**

JFOrCE†

Research areas/techniques:

- Whole of Force Modelling
- Data farming architectures
- Design of experiments
- Analysis & Visualisation

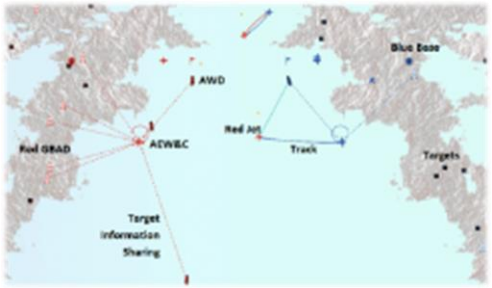


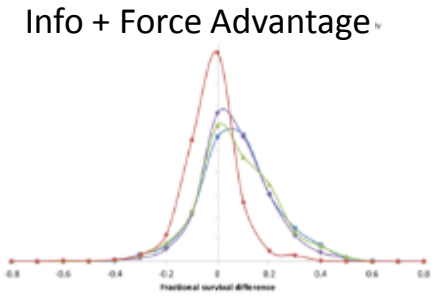


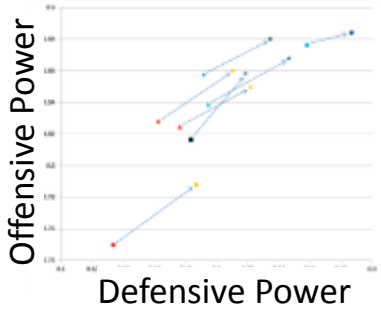
†JFOrCE: Joint Future Operating Concept Explorer

Achievements to Date

- Developing JFOrCE WoF sim & realising future operating concepts for rapid modelling of complex operations
- Contributing to development of “Bayesian Optimisation” heuristic & applied to WoF sim to optimise force options
- Applying sim analysis to quantify benefits of investing in force vs information advantage for force design
- Leveraging advances in analysis techniques & tech for insights & solutions into complex Defence problems

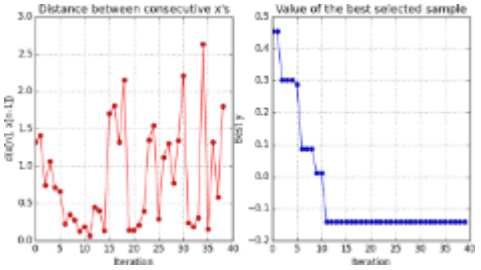


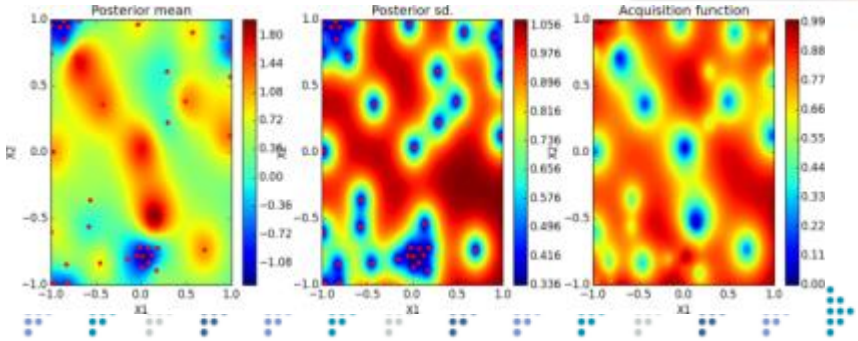


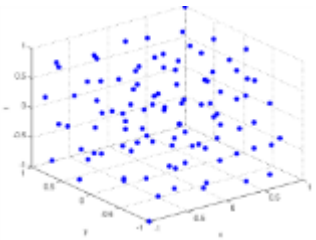


Current Research

- Transform force design from decisions made subjectively into one that considering objective analysis from sim
- Develop ability to rapidly model, run & evaluate complex ADF operations & future operating concepts with sim
- Identify complex emergence in sim to advantage ADF against adversaries across broad range of operations







SR3 – Computation enabled OA

Employing Artificial Intelligence (AI) and Data to analytical advantage for force design

Problem: While AI & autonomy offer immense possibility for decision support and analysis, current capability in dealing with complexity and uncertainty is limited.

Research areas:

- Autonomy for operations analysis capacity and capability improvement
- Knowledge corpus: data discovery, acquisition, storage, analysis, modelling and visualisation
- Dynamic machine reasoning under uncertainty

Objective: Research and develop cutting edge tools and methodologies that enables knowledge synthesis and analysis to support evidence based force design.

Current research

- Engaged the DIN* to support building research collaborations with a network NSW Universities
- Research proposal to examine the complexities surrounding the data management and knowledge synthesis necessary to develop an intelligent decision support system to support force design

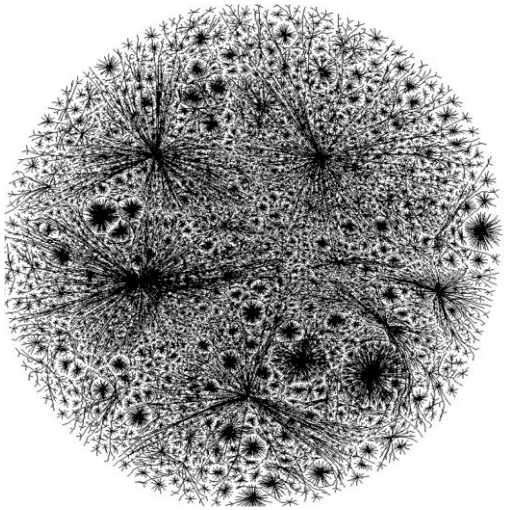
DEFENCE INNOVATION NETWORK

To go far, go together

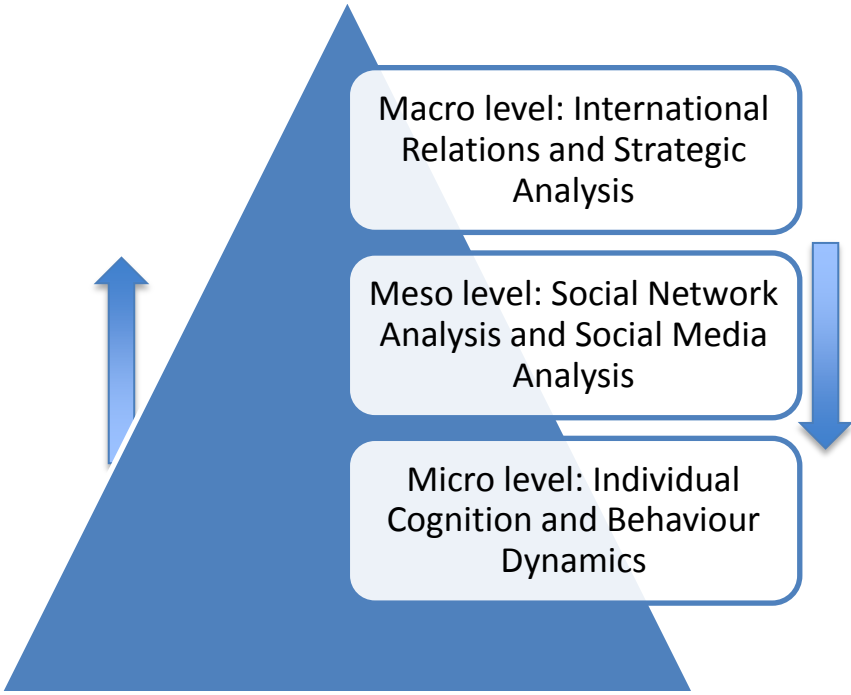
** A NSW State Government initiative facilitating partnerships between Defence, Academia and Industry*

SR4 – Modelling Complex Human Systems under Uncertainty

(a case study for unification of approaches)



Objective: Develop the capability to model the inter-subjectivity of the non-material cultural, social, human, and political factors and the material ***components***, including the evaluation of non-kinetic ***effects*** and non-traditional force design ***options***



Current Research

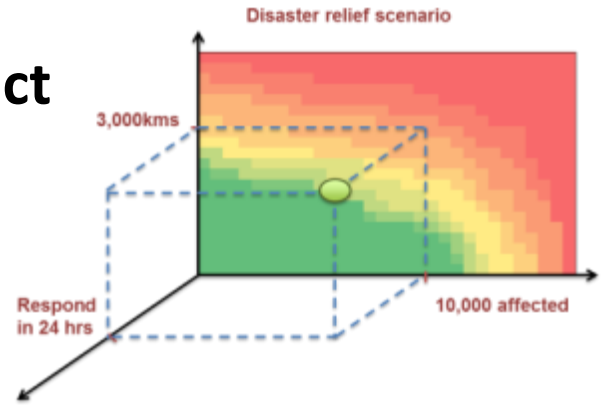
An integrated suite of multi-disciplinary tools and methods that provides:

- A multi-level framework for understanding the observed and potential trends in the operating environment;
- A new mechanism for understanding the required operational effects along with the corresponding operational concepts; and
- Principles for designing force structures and options that are capable of delivering these effects in the digitally transformed operating environment.

Information Warfare / Influence provides context to MCW SRI

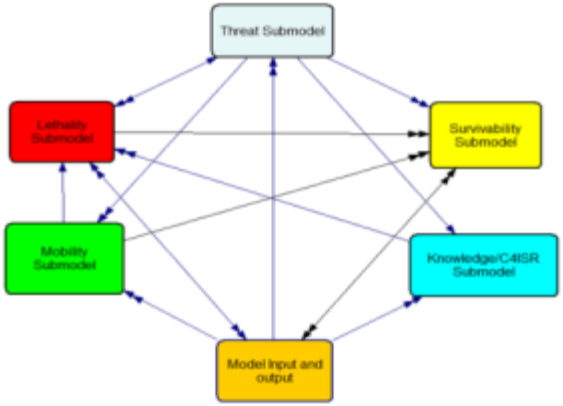
SR5 – Force Effectiveness Modelling

Problem: Need a rigorous, consistent, defensible decision process throughout the capability life cycle to measure the effectiveness of a force or investment project



Research areas/techniques:

- Multi-objective optimisation methods
- Bayesian Networks
- Evolutionary Algorithms
- Computational Intelligence
- Game Theory
- Project Benefit Analysis
- Wargame design
- Feasible scenario spaces



Current Research

New suite of benefit analysis and optimisation techniques allowing tradeoffs across complex and interrelated systems.

Transparent metrics (**value**) for the following scales of decision are available:

Project

- Best platform of a given type

Program

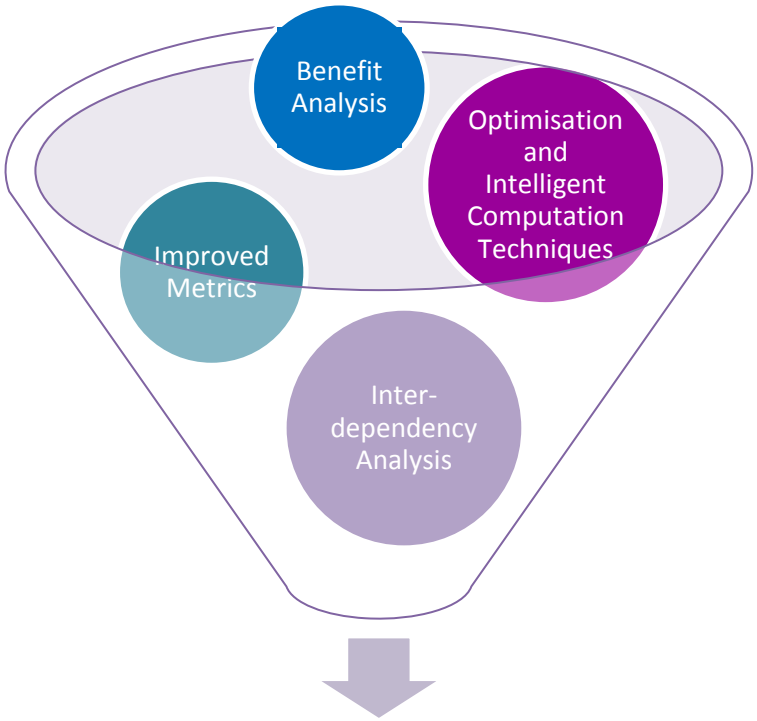
- Best combination of platforms and processes to deliver a given capabilities

Joint Task Force

- Best combination of capabilities for given contexts

Whole of Force

- Best overall force design for possible futures



New investment decision methods

Combine techniques for robust force effectiveness modelling with portfolio optimisation that accounts for interdependencies.

Improved force effectiveness measures

Improved force option development techniques

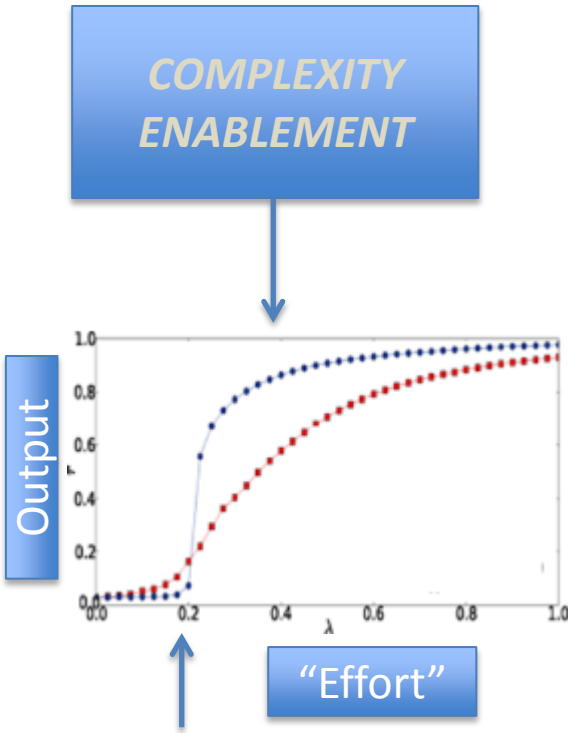
Achievements to date

- Collaborative Defence-academia research in:
  - application of project benefit analysis to the Defence context
  - intelligent computational methods for multi-objective multi-period planning
  - extend current multi-criteria decision analysis (MCDA) and Bayesian approaches to larger scales and exploration of associated fuzzy techniques

SR 6 - Concepts for complexity enabled warfighting

Problem: Warfighting is becoming increasingly complex, congested and contested. Relevance of analytical capabilities are fast eroding. Need new modelling approaches to capture the complexity.

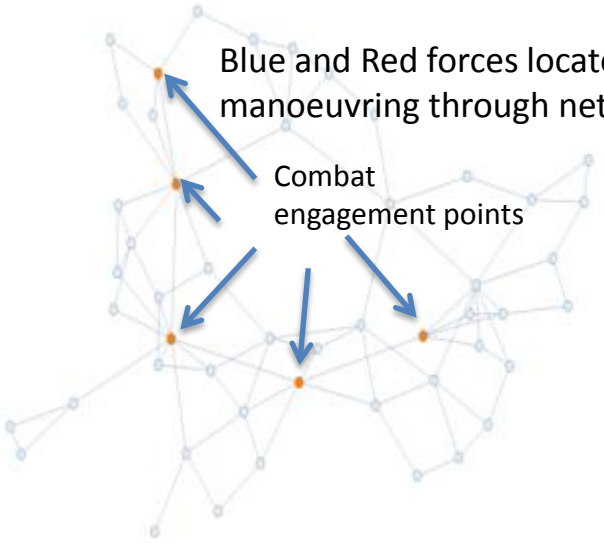
- Employ relatively simple mathematical models which recognisably exhibit ***complexity***
- Build them into representations of the activity of a Military Force
- Understand how complexity in the resultant models provides advantage to that Force through
- Derive Concepts for Complexity-Enablement



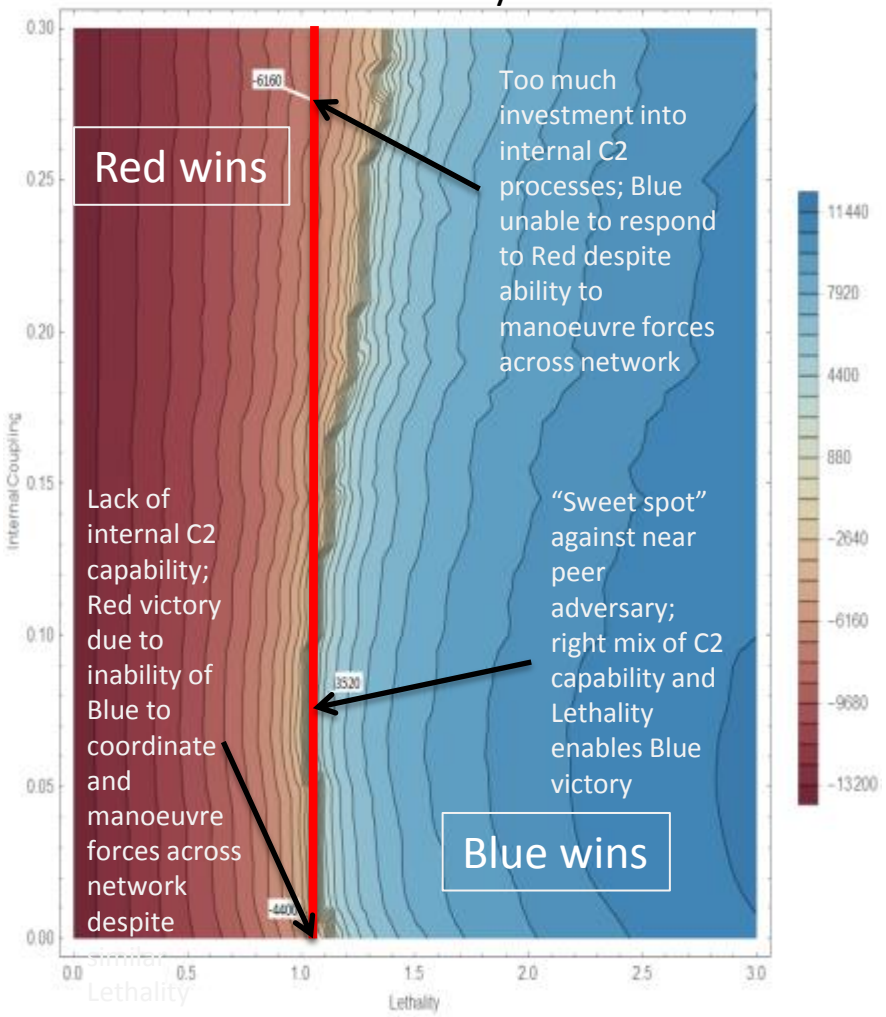
The Blue Force gains a non-linear boost in output for minimal increase in effort through a 'first-order' phase transition.

Current Research

- Generalisation of Lanchester Combat Model to account for Tactical Positioning, Directed Fires and C2 in one modelling environment
- Initial explorations of Game Theory within such models
- Decision synchronisation models to multiple populations (Blue-Red-Green) in the battlespace



Trade-off space for Blue investment options: C2 systems vs Enhanced Lethality for fixed rate of manoeuvrability of the Force for near peer Red adversary



SR7 – Transdisciplinary Approaches to Modelling Unknowns

Problem: The knowledge required for whole-of-force design decisions is often incomplete, unknown…and even unknowable

Research areas/techniques:

- Representation of unknowns
- Decision-making involving unknowns
- Engineering uncertainty
- Communication of unknowns
- Cross-domain approaches to unknowns
- Organisational models of collective unknowns

Objective: An Australian whole-of-force design capability that plays to our nation's strengths and is founded upon revolutionary modelling concepts that support reasoning over both unknowns and knowns.

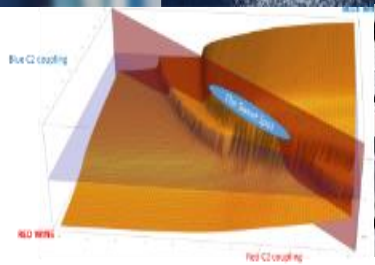
Achievements to Date

- Devise an effective transdisciplinary approach, assembled an effective multi-university team from essential disciplines.
- Studied strategies to integrate with existing tools and methods to grow the capability of operations research.
- Produced a roadmap and essential capabilities for transferring best practice in the civil sector to defence applications.

Modelling Complex Warfighting

Strategic OR capability: novel problem conceptions leading to **analysis methods** that provide **deep insight** into **force design and employment** problems that we presently cannot address.

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