

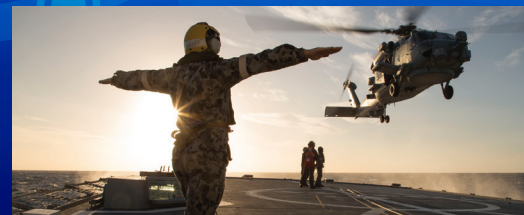


Australian Government

Department of Defence  
Science and Technology

# Modelling Complex Warfighting

Strategic Research Investment Program



**DST**

Science and Technology for Safeguarding Australia

## Background and Aims

Defence Science and Technology (DST) sponsors a portfolio of strategic research initiatives focussing on high impact priority areas for future Defence capability, the Strategic Research Investment (SRI) program. The Modelling Complex Warfighting (MCW) SRI was launched in 2017 as one of these initiatives with research plans and a timeline of five years.

Force design is the planning and decision-making process regarding military equipment and future defence operations. Such decisions are often made under conditions of high uncertainty, and without assumptions on predictability or stability of the system.

### **Problem: rational decision-making under extreme complexity**

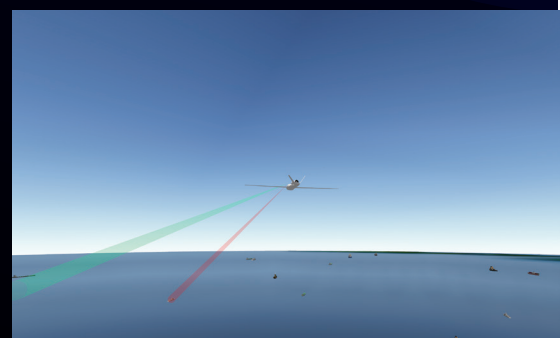
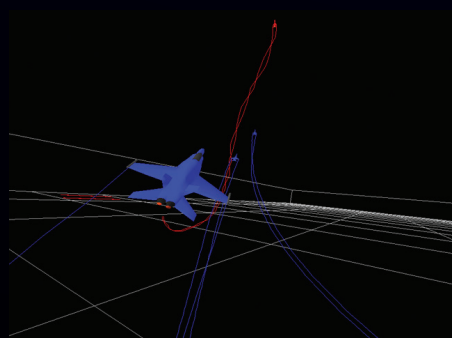
The determination and evaluation of options for the effective allocation of limited Defence resources to future force composition and employment, where the consequences of resource allocation decisions are realised in future scenarios the decision-makers cannot fully control nor know at the time of the decision.

### **Aims**

The MCW SRI seeks to revolutionise DST operations analysis to better manage the interaction of complex geopolitical, social, technological, economic and cultural factors for employment of the current force and design of the future force.

The MCW SRI aims to address the force design and future defence force employment problems under four broad research themes:

**Conquering Uncertainty, Innovative Simulations,  
Knowledge Synthesis, and Modelling Complexity**



## 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.

## Research Projects – Strategic Responses

Seven Strategic Responses (SR) – research projects – are under development within the MCW SRI. The above diagram indicates their alignment with the research themes and the two epochs for force design, Current and Future Force.

### SR 1 – Machine Discovered Behaviour

**The Defence Problem:** *Employ and integrate a force to maximum effect.*

**Project Aims:** Evaluate, adopt and develop methods and techniques for the optimisation, generation and discovery of novel behaviour to maximise the effect of new capabilities in complex scenarios.

Methods from a range of fields are being considered; including (but not limited to) artificial intelligence, machine learning, optimisation, evolutionary algorithms and optimal control in scenarios ranging from the tactical to the operational and strategic.

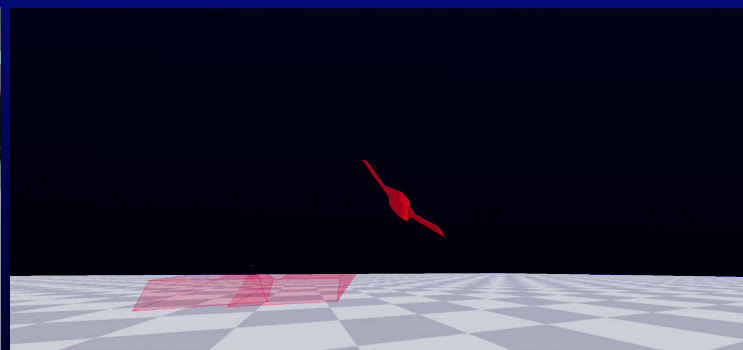
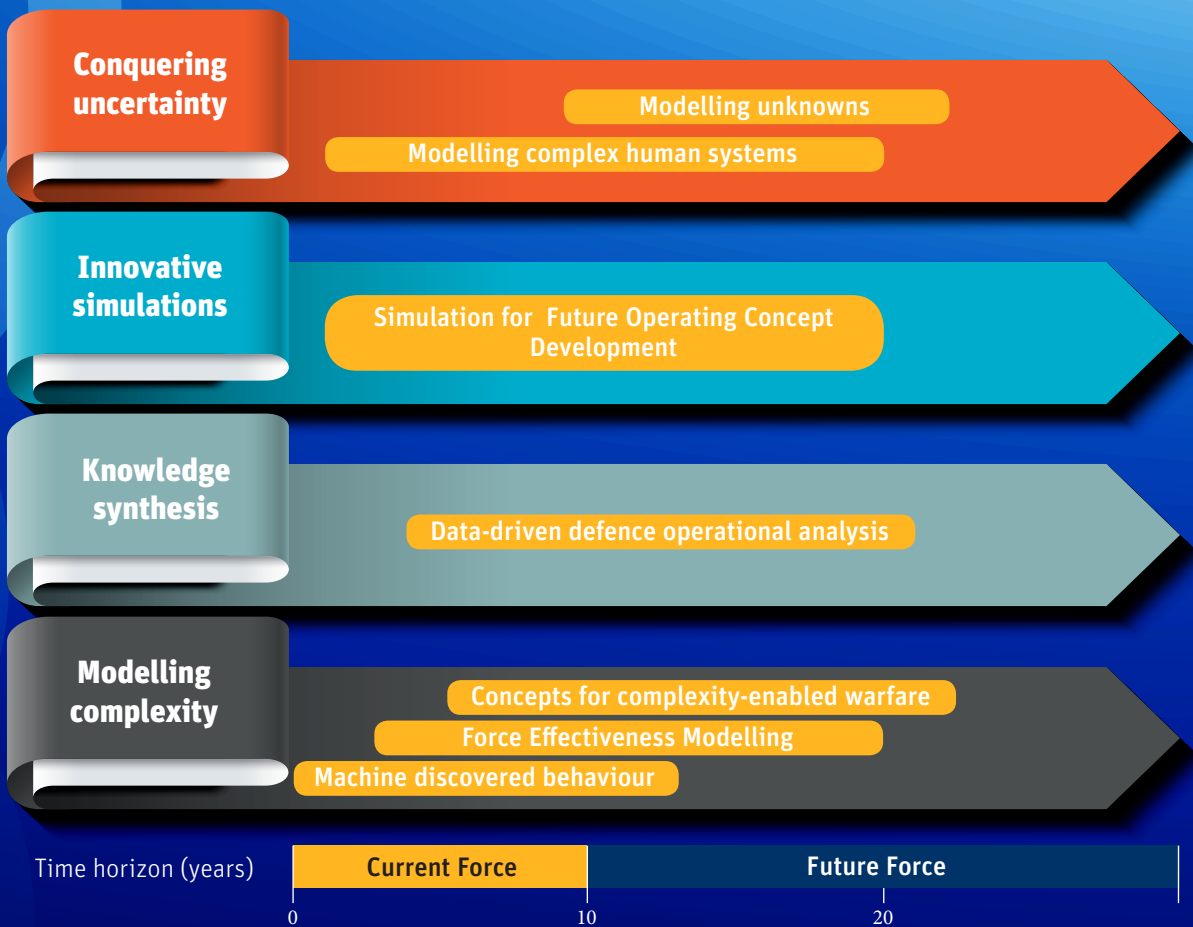
The goal is to develop a long term capability that employs current and proposed forces in the most effective manner.

#### S&T Challenges:

- ▶ Adapting known techniques from AI and machine learning to the military domain
- ▶ Scaling known techniques to the complexity of addressing issues in joint force design
- ▶ Integration of techniques into existing simulation technologies and environments
- ▶ Trade-offs between model fidelity and computation speed
- ▶ Scalability of techniques to force design problems.



## Schematic of Force Design timeline and MCW SRI Research Themes



### SR 2 – Simulation for Future Operating Concept Development

**The Defence Problem:** *The complexity of modern defence operations makes it increasingly problematic to rely on intuition for Force Design.*

**Project Aims:** Develop whole-of-force HPC-simulation capability for analysing and developing ADF operating concepts. Use data farming to execute experiments of the modelled force against simulated threats.

#### S&T Challenges:

- Complexity of future friendly and enemy forces as highly integrated and interdependent systems
- Computational intractability in large scale simulation despite HPC-simulation availability
- Difficulty of deriving insights from high-dimensionality problem spaces
- Developing analysis strategies for high level concepts explored with data farming
- Developing modelling strategies to represent high-level concepts in HPC-simulations.

### SR 3 – Data-driven Defence Operational Analysis

**The Defence Problem:** *Evidence-based force design decision making increasingly depends on large data catchment and analysis.*

**Project Aims:** Investigate tools, technologies and methods for collecting, storing and curating data for analyses to support force design.

**S&T Challenges:**

- ▶ How should data be collected so that opportunities to use it (in scientific analyses) are maximised?
- ▶ What types of technical solutions are compatible with data from a variety of ADF systems and operations?
- ▶ What technical approaches (e.g. data lakes, schema-on-read) will enable improvements to the data management lifecycle within feasible resource constraints?
- ▶ What governance components are critical in improving access to data for scientific purposes?

### SR 4 – Modelling Complex Human Systems under Uncertainty

**The Defence Problem:** *The operational environment is fundamentally changing as we observe a continual trend to the development of hybrid, information and other types of warfare, which provide key challenges to the design of the future Australian Defence Force.*

**Project Aims:** Develop an S&T capability for better appreciation of the inter-subjectivity of the non-material cultural, social, human, and political factors and the material components, including but not limited to technology and capabilities, in disruptive future operating environment; evaluate kinetic and non-kinetic, traditional and non-traditional force design options and operational effects.

**S&T Challenges:**

- ▶ Analysis and synthesis of non-material and non-kinetic effects for campaigns and battle outcomes, their magnitudes, dynamics and interplay with traditional effects
- ▶ Novel mixed-method approaches and pilot studies for inclusion of some emerging cultural, social, human and political factors in the force design process
- ▶ An advanced suite of qualitative and quantitative methods and tools/decision making aids for development and delivery of agile resilient force
- ▶ A prototype of/business case for interactive software platform to support experimentation and decision making in force design.

### SR 5 – Force Effectiveness Modelling

**The Defence Problem:** *The need for a rigorous, consistent and defensible process throughout the Capability Life Cycle to measure the effectiveness of a force or investment project.*

**Project Aims:** Develop an understanding of the best methods and techniques to measure the effectiveness of different “force” options across a range of scales (i.e. from individual platforms to a Joint Task Force). This will be accompanied by a suite of tools to capture and process data for different aspects of this problem, with guidelines of when and how to apply which one.

**S&T Challenges:**

- ▶ Gaining an understanding of how problems from different domains (Air, Land, Maritime and Joint) and different scales (Tactical, Operational and Strategic) relate to each other and can leverage off similar tool suites
- ▶ Maximising rigour and fidelity in modelling the effectiveness of a force whilst minimising the resourcing for time, data and SME usage
- ▶ Modelling the unknowns of military operations in the future
- ▶ Understanding when the ‘best’ solution has been found.

## SR 6 – Concepts for Complexity-Enabled Warfare

**The Defence Problem:** *The lack of understanding of how complexity behaviours characterise the success or failure of the Force to achieve a range of warfighting missions let alone how such systems may be effectively controlled or guided.*

**Project Aims:** Provide new Operations Analysis scientific tools for future Force Design efforts by delivering high-level network- and complexity-enhanced combat models and the Measures required to detect the thresholds for, and the levers for control of, resilience and advantage of a Future Force.

### S&T Challenges:

- ▶ Linking dynamical network models with traditional and more modern combat models
- ▶ Translating physics based critical phenomena concepts into domain of large finite Defence application systems representations
- ▶ Translating classical self-organised critical models to Defence application contexts
- ▶ Contextualisation of dynamical models of Blue and Red forces into Game Theory approach.

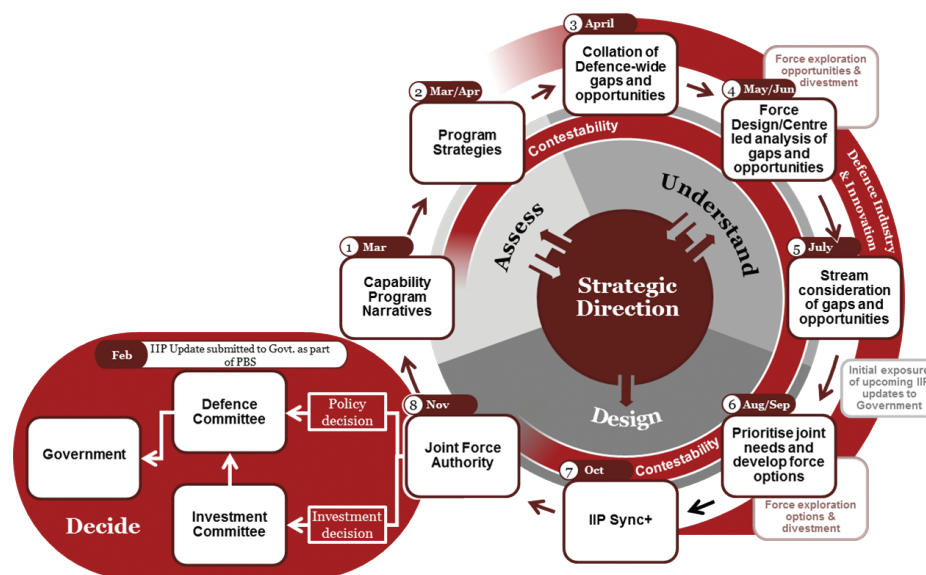
## SR 7 – Transdisciplinary Approaches to Modelling Unknowns

**The Defence Problem:** *The knowledge required for force design decisions is often incomplete, unknown, and in some cases unknowable.*

**Project Aims:** Explore a range of approaches to elicit, understand, model and manage diverse unknowns faced by force design decision makers, considering both technical and non-technical approaches; individual, group, organisational, and social aspects; and the impacts of complexity and emergent behaviours at the tactical and strategic level.

### S&T Challenges:

- ▶ Identify and develop new approaches that are applicable to support force design decision makers to appropriately and successfully manage unknowns in their decision-making.



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