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Modelling Complex Warfighting (MCW) Research Agenda

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1. INTRODUCTION

The Defence problem space has expanded. The operating environment spans the cooperation-competition-confrontation-conflict spectrum and is multi-domain and multi-actor. Defence seeks new sources of adversarial advantage to prevail in this contested environment. New operations analysis approaches are required to deal with the grand challenges associated with this problem space.

In 2017 the Modelling Complex Warfighting (MCW) Strategic Research Investment (SRI) program was founded as a means for Defence Science and Technology (DST) Group to address and better respond to these emerging requirements. This document details the next phase of the MCW initiative as it matures in research focus and collaboration opportunities to more appropriately meet the needs of Defence.

1.1. Background

DST Group seeks to enable Defence and national security agencies to prevail in contested environments by delivering high impact science and technology. DST Group research is focused on identifying and exploiting new sources of adversarial advantage. The mandate of the MCW SRI was to develop novel techniques employable by operational analysts to enhance decision-support across the Defence and national security enterprise[1]. MCW was launched in 2017 with an initial five-year horizon. The first phase of the initiative focused mainly on scope definition of wicked Defence problems, establishing collaborative relationships with academia and exploratory research.

1.2. Aim

MCW aims to revolutionise how DST Group undertakes operations analysis[2] (OA). Specifically, the initiative seeks to provide adversarial advantage to Defence and national security agencies by enhancing the ability of its analysts to confidently provide accurate decision-support when investigating:

- the complex interactions of geopolitical, social, behavioural, technological, economic and cultural factors that characterise the operating environment

[1] For a summary of the initial phase of the initiative refer to: https://www.dst.defence.gov.au/sites/default/files/publications/documents/DSC%201936%20Modelling%20Complex%20Warfighting%206%20Pager%20PRO1.pdf

[2] OA – synonymous with operational research – is the discipline that deals with the application of advanced qualitative and quantitative methods to provide decision-makers with evidence-based decision-support. Most militaries apply OA in some manner as an integral part of their capability development and assurance processes.

- the effectiveness of Defence and national security agencies' response options within that operating environment, for both the conduct of current operations and the design of the future force.

These Defence and national security agencies' response options are often required under high uncertainty, and without assumptions of predictability or system stability. These characteristics typically present significant challenges for OA.

1.3. Modelling Complex Warfighting: A New Research Portfolio

MCW's new phase signifies DST Group's increasing confidence and precision in the pursuit of transformational OA methodology and transitioning from research exploration to consolidation to meet the expanded Defence problem space.

This next phase of MCW will create value for the ADF and its partners, with the intent to build significant OA capability to enhance decision-making in Defence and national security programs.

The MCW research agenda presented in this document develops a research portfolio of three projects to support this phase. Each project is designed to focus effort and collectively they will conduct the specific research required to provide transformational OA to current operations and future force decisions. Each project is centred around grand challenges, which are designed to be:

- focused on critical Defence and national security OA problems
- aspirational with the potential to help Defence leap ahead
- inspiring to research partners.

The three projects in the MCW research portfolio cohere under a single MCW grand challenge:

> **MCW grand challenge: How can we model the Defence force and future warfare re effectively and provide innovative operations analysis to enable Australia to prevail in contested environments of strategic uncertainty?**

This MCW grand challenge responds to DST Group's strategic context[3], expanded on in Section 1.4.

[3] For more information on the current DST Group strategy, *More, together: Defence Science and Technology Strategy 2030*, refer to https://www.dst.defence.gov.au/strategy

1.4. Strategic Context

In addition to aligning with DST Group's strategy, MCW's research relevance is firmly anchored within the Australian defence strategic context. From a research perspective, this is expressed here at two levels:

- Force design – research supporting the design, testing, delivery and integration of the future force
- DST Group STaR Shots – research priorities for DST Group as an organisation.

1.4.1. Force Design – Force Structure Planning and Integrated Force Program

1.4.1.1. Force Design

For any defence organisation the act of force design is an essential planning task to enable the making of crucial investment decisions affecting the construction of a future defence force. Force design is made all the more difficult due to the need to select the most appropriate portfolio of capabilities – intended to endure and be maintained over a number of decades – for an uncertain and rapidly evolving future operating environment[4].

1.4.1.2. Integrated Force Program

The Integrated Force Program (IFP) was established in 2019 to provide coordinated support to the Defence's Strategic Centre and to deliver science and technology impact within the design and integration of the future joint force.

The IFP[5] is intended to deliver DST Group-wide support for the myriad of complex design and integration activities related to the future force. The IFP allows for the development of leading edge force exploration and experimentation methods as well as providing deep rigorous analysis for thematic areas. This program partners with Defence's Force Design Division[6] (FDD) and Force Integration Division[7] (FID) within the Strategic Centre[8].

Largely situated within DST Group's principal OA division – Joint and Operations Analysis Division (JOAD) – the IFP is focused on developing the next generation of tools and analytical approaches to enable novel design and integration methods for the future joint force. The

[4] For an introduction to the complexity of the Force Design problem refer to: Harrison K., Elsayed S., Garanovich I., Weir T., Galister M., Boswell S., Taylor R. and Sarke R. Portfolio optimization for defence applications. *IEEE Access*. 2020;**8**:60152--78.

[5] Programs within DST Group are a means to focus research effort across the entire organisation into a mission-driven application area.

[6] https://www.defence.gov.au/VCDF/FD/

[7] https://www.defence.gov.au/VCDF/FID/

[8] The Defence Strategic Centre, headed by the Vice Chief of the Defence Force, was first conceived in the 2015 *First Principles Review* as a mechanism to better coordinate the process of capability development: https://www.defence.gov.au/publications/reviews/firstprinciples/Docs/FirstPrinciplesReview.pdf

anticipatory element of the IFP will advance state-of-art force design approaches and methodologies to support on-going improvements to strengthen decision making.

1.4.1.3. Force Structure Planning

The ADF force structure and the supporting Integrated Investment Program[9] are iteratively updated to take account of changes in Australia's strategic environment, potential threats, opportunities and the pace of technological change. This is primarily achieved through the Defence Capability Assessment Program[10] (DCAP), which involves regular review of capability against both strategic direction from government and changes in operating context. Approximately every four years, the DCAP calls for a Force Structure Plan[11] (FSP) as a fundamental review of current and future capability investments. Supporting the FSP process is a principal OA task for DST Group, and that task is delivered via the IFP.

1.4.1.4. MCW Integration

The IFP seeks to operationalise and implement best-practice OA tools and techniques, including those emerging from MCW, to meet specific, priority ADF requirements in the FSP process. While the IFP delivers outcomes in the near-to-mid-term (e.g. the application of novel methods[12]), MCW's role involves undertaking research in support of force design in the mid-to-far-term (e.g. developing methodologies). It is the intent that MCW products enhance the IFP and FSP processes. To differentiate these respective time horizons, this MCW research agenda refers to the next major force structure planning activity as FSP Next; and the following activity as FSP After-Next. These tangible milestones provide the strategic context underpinning the MCW initiative.

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[9] The Integrated Investment Program is the portfolio of future projects which represents the bulk of investment over a ten-year time span to build the future force. For a detailed description see: https://www.defence.gov.au/WhitePaper/Docs/2016-Defence-Integrated-Investment-Program.pdf

[10] The DCAP is the set of over-arching processes which determines the projects within the Integrated Investment Program. For more information see: https://www.defence.gov.au/publications/docs/Capability-Life-Cycle-Detailed-Design.pdf

[11] The FSP is a major 4-yearly review to ensure Australia's future force structure (including strategy, capability and resources) aligns to changes in the strategic environment. For details of the latest FSP see: https://www.defence.gov.au/StrategicUpdate-2020/docs/2020_Force_Structure_Plan.pdf

[12] Methodology refers to a system or body of methods employed in a particular field of study that provides the justification and rationale for their employment. In contrast, *methods* are particular techniques, procedures, or modes of enquiry employed to achieve specific research objectives (adapted from Merriam-Webster Online Dictionary).

1.4.2. DST Group STaR Shots

DST Group's STaR Shots[13] provide Australia with the strategic advanced research to prevail in contested environments. Figure 1 illustrates the current range of individual STaR Shots. OA has a critical role in the STaR Shots, including:

- problem characterisation
- development of futures and scenarios, providing a consistent application environment in which to test STaR Shot outputs
- assessment of individual and collective STaR Shot methodologies
- providing transdisciplinary OA integration between the individual STaR Shots, identifying potential to transform Defence capability.

The inherent complexity within each STaR Shot means there will be a number of interconnected choices to be made – is an increase in platform range more important than a reduction in platform signature or an increase in platform speed, and in which combination should Defence invest its scarce resources for research? Such questions require deep contextual understanding to manage the large number of internal trade-offs, and to ensure these trade-offs are done to maximise the overall effectiveness of the ADF in future conflicts. Though we appreciate that the STaR Shots are currently in an early phase and largely focused on exploratory research so as to maximise innovation, the application of OA throughout the life of the STaR Shots will help ensure that they are aligned to strategic guidance and that promising, more-mature research is focused on the critical problem. Through clear articulation of our most significant operational and capability-based challenges the STaR Shots can enable a transformation in ADF capabilities.

The ability to undertake this OA campaign is reliant on developing advanced and fit for purpose modelling and simulation, analytical wargaming, and experimentation capability and capacity, as well as integrating and augmenting this with testing, demonstrating and experimenting with technologies and concepts in trials and exercises. This forms the centrepiece of the STaR Shots model in Figure 1.

[13] https://www.dst.defence.gov.au/strategy/defence-science-and-technology-strategy-2030/science-technology-and-research-star-shots

Figure 1: DST Group STaR Shots: May 2020

1.4.2.1. MCW Contribution to DST Group STaR Shots

The MCW initiative has the potential to benefit the DST Group STaR Shots by:

- emphasising each STaR Shot's connection and outcome for the design and integration of the joint force
- providing novel techniques and tools of value across the STaR Shots.

MCW has the potential to provide the underpinning transdisciplinary research program that will deliver game changing OA across each of the STaR Shots with intended benefits consisting of the cross-pollination of novel OA-inspired methods and tools. Of course, this process will likely be symbiotic, as both the MCW and STaR Shot research initiatives co-evolve and collaborate to provide novel and game-changing research for Defence and national security.

In summary, it is envisaged that the novel OA techniques being researched within MCW will ensure that STaR Shots are focused on Defence's most crucial future problems, with a key focus being shaping the individual STaR Shots so as to form an integrated and coherent whole. Through the development and application of OA techniques STaR Shot synergies can be identified and used to help enhance STaR Shot direction, and STaR Shots can be placed within the broader Defence eco-system to ensure they are not only integrated with each other, but also with other Defence systems within a rapidly evolving Defence context.

1.4.3. Transdisciplinary OA and MCW[14]

Taking a transdisciplinary approach in MCW is an opportunity to leverage the ADF's current interest in systemic design and design thinking[15]. Transdisciplinary research integrates academic disciplines, involving academics, stakeholders and practitioners, and brings together formal academic research with the tacit knowledge of practitioners. It is participatory, requires methodological pluralism and engagement with stakeholders and communities of use. It also requires space and time in a programme or project – it is unlikely to happen successfully by chance.

Transdisciplinary research is particularly appropriate when addressing complex problems which require 'thinking about knowledge and inquiry in a world that has become too big to know'[16]. By bringing different fields of knowledge together and incorporating practitioner knowledge with empirical research, the resulting synthesis encourages innovation through a 'leap of inference or intuition'[17]. The act of synthesising information from different sources is an abductive sensemaking process as we make a 'motivated, continuous effort to understand connections'[18]. Transdisciplinary research values both inductive and deductive reasoning but also offers an opportunity to benefit from abductive reasoning or, 'the logic of what might be'[19]. It is an approach that encourages constructive dialogue between inductive, deductive and abductive reasoning.

1.5. Impact

MCW integrates the transformational OA capabilities to assure and accelerate decision-making by Australian Defence, national security, and government on operations, future capabilities and investment. MCW will achieve this by 'partnering for impact' with academia and industry in order to achieve 'more, together'[20]. As the leader of Defence's science and

[14] Gracious thanks to Debi Ashenden for providing her expertise on transdisciplinary research.
[15] https://www.defence.gov.au/ADC/Publications/documents/joint_studies/JSPS_3_Design_Thinking.pdf
[16] Bernstein J. Transdisciplinarity: A review of its origins, development, and current issues. *Journal of Research Practice.* 2015;**11**(1):Article R1.
[17] Kolko, J. Abductive thinking and sensemaking: The drivers of design synthesis. *Design Issues*. 2010:**26**(1);15-28.
[18] Klein, G., Moon, B. and Hoffman R. Making sense of sensemaking 2: A macrocognitive model. *IEEE Intelligent Systems*. 2006;**21**(5):88-92.
[19] Kolko, J. Abductive thinking and sensemaking: The drivers of design synthesis. Design Issues. 2010;**26**(1):15-28.
[20] https://www.dst.defence.gov.au/strategy

technology capability, DST Group's unique role includes translating MCW's research breakthroughs into Defence and national security capabilities.

Evidence of technical success within a transdisciplinary project like MCW comes from multiple sources such as scientific papers, meaningful stakeholder engagement leading to shared understanding across Defence requirements, and researcher expertise on what is technically achievable. Articulating the impact of each MCW project – in both the research, and defence and national security contexts – shall be left to the proceeding sections of this document, along with each project's research plan.

Addressing impact in a more overarching sense, the MCW initiative is already proving a valuable asset for DST Group researchers and academic partners by providing a means to collaboratively develop ideas and cross-pollinate research perspectives – all necessary components for the formation of highly functional transdisciplinary teams. Additionally, activities such as the technical workshops that have already taken place in the first phase of MCW have received positive feedback from both attending academics and members of the ADF. Such activities are already demonstrating MCW's value and are more generally addressing the requirements of taking advantage of collaboration opportunities, articulated in the newly released current DST Group strategy[21].

1.6. Introducing the Three MCW Projects

To meet the challenges presented by DST Group's strategic context, the MCW research initiative will pursue three targeted projects:

- Project 1: Modelling the Grey Zone
- Project 2: Agile Force Design
- Project 3: Artificial Intelligence and Advanced Analytics for Decision-Making

Each project is introduced in brief in the following subsections; and subsequent chapters of this document expand on the individual projects.

[21] https://www.dst.defence.gov.au/sites/default/files/attachments/documents/Defence%20Science%20and%20Technology%20Strategy%202030.pdf

1.6.1. Project 1: Modelling the Grey Zone

Project 1 grand challenge: Influence is the central feature of the contest spectrum[22]. The emergence of social media and other open source information confronts us with new opportunities and challenges in anticipating, recognising, understanding, interpreting and responding to emerging and future events and dynamics. To what extent can we reduce and exploit the apparently high future uncertainty through developing new theories, ontologies and modelling approaches?

Grey zone refers to the contemporary contest spectrum, where clear distinctions between peace and declared warfare are evaporating, replaced instead by a foggy continuum spanning cooperation-competition-confrontation-conflict.[23]

This project proposes to generate an intellectual edge by:

- defining the contours of the future informational operating environment
- developing a coherent set of theories and modelling approaches able to be applied in support of Defence problem solving in the grey zone
- specifically modelling the identification of grey zone activities, ADF response options, and the impact of ADF actions to prevail in the grey zone.

It is intended that this project will link most heavily with the DST Group STaR Shot Information Warfare[24] and proposes a solution approach of three broad lines of effort (LoEs):

1. develop theories and models of grey zone activities that increase our ability to manage uncertainty and identify opportunities to manoeuvre with advantage within it
2. develop and deploy grey zone modelling, simulation, experimentation and wargaming capabilities to inform ADF operations and capability development
3. model the grey zone to reconceptualise the future informational operating environment.

[22] The contest spectrum spans all the levels of conflict (either realised or potential) and the associated operational activities that a Defence force would engage in during these times – from rendering humanitarian aid and disaster relief during periods of relative peace, assertive posturing during strained relations, through to high end warfighting during periods of open conflict. Figure 1 of *Force 2020* provides a convenient summary of the contest spectrum and related activities: https://www.defence.gov.au/Publications/f2020.pdf
[23] Paraphrasing https://cove.army.gov.au/article/building-bridges-the-south-west-pacific-harnessing-armys-part-time-construction-engineers.
[24] https://www.dst.defence.gov.au/strategy/star-shots/information-warfare

1.6.2. Project 2: Agile Force Design

Agile Force Design is framed by a central grand challenge:

Project 2 grand challenge: How to design a force for future success?

This project approaches this grand challenge through three LoEs:

1. Whole-of-force modelling: foster the development of multi-domain, multi-actor whole-of-force models for the ADF that are able to represent dynamics beyond simple 'red' and 'blue' adversarial kinetics. Importantly, it is critical to ascertain an appropriate scale and level of abstraction for these models.
2. Assess force options: determine the best way to assess and compare force options. This includes novel research into metrics definition, advancing methods of assessment, and establishing the most appropriate mixture of methods in this space.
3. Innovative portfolio design: develop the ability to generate practical and innovative Defence portfolio options that maximise the operational success for Defence within an irreducibly uncertain future.

This project has the potential to impact a number of DST Group STaR Shots due to the evaluation capability that is intended to be developed – supporting the understanding of how the design and integration of the joint force may need to change due to technological and structural change based on STaR Shots research. This includes natural links with the Agile Command and Control (C2) STaR Shot[25] insofar as both this project and the STaR Shot will involve modelling and simulation of whole-of-force models which incorporate C2.

1.6.3. Project 3: Artificial Intelligence and Advanced Analytics for Decision-Making

Project 3 grand challenge: What are efficient and effective human-machine problem-solving capabilities that enable agile, robust and resilient decision-making to occur across the contest spectrum and within environments of strategic uncertainty?

This project seeks to develop artificial intelligence (AI), machine learning (ML) and other advanced technologies and apply them to areas of decision-making in future operating environments characterised by inherent strategic uncertainty (e.g. future force design). The research into these technologies needs to consider the human-machine interface where the options and information provided to the decision-makers are transparent, thereby building trust in the system. This project aims to increase efficiency and effectiveness in the decision-making process by pursuing the following LoEs:

[25] https://www.dst.defence.gov.au/strategy/star-shots/agile-command-and-control

1. Automating the decision analysis process: this project seeks to develop processes and advanced technologies that enable a decision-making framework that is robust, transparent and provides context. Since decision making in the future will require increasingly complex human-machine interactions, retaining and building trust within this environment is a fundamental requirement.
2. Apply AI/ML to the decision analysis process: this project seeks to inject AI and related capabilities into whole-of-force wargaming and modelling and simulation, with the intent to learn and exploit novel tactics and strategies using emerging techniques such as reinforcement learning.
3. Advanced collaborative computing environment: AI and advanced analytics for decision-making intends to investigate the development of a collaborative computation environment that will enable the integration of the decision-making and analysis framework. This will be supported through concepts such as a greater understanding of experimental design for more efficient computational data and information synthesis and analysis.

1.7. More, Together: Partnering for Impact

This MCW Research Agenda outlines a formidable set of challenges. Rising to meet them requires more than the singular efforts of any one individual or organisation. By design, the transdisciplinary insights required for success will be achieved through radical collaboration. We can achieve more, together, and DST Group's partnership approach applies in practice the OA philosophy articulated in this research agenda.

Foremost in this partnership is the academic community, collaborating with members of DST Group on the many research endeavours listed within this document. Focussing on the whole-of-force models detailed in the introduction of Project 2: Agile Force Design as a concrete example, it is intended that there will a number of concurrent academic collaborations – enabled by the emerging ORNet[26] multi university agreement framework – in order to construct, verify and validate a number of modelling approaches to determine their utility for evidence-based decision-support. The outputs of these modelling approaches will ultimately be combined via the integration techniques (further detailed in Section 4.1.4 of this research agenda) to enable superiority of key capability-based decisions at the tactical, operational and strategic levels.

A further aim of MCW is to enable DST Group to collaborate with members of industry to rapidly transition any promising research artefacts to products of higher levels of technical-readiness for ADF consumption, if appropriate. Continuing with the whole-of-force modelling example, it is expected that during this phase of MCW, collaborative methods will be

[26] https://www.dst.defence.gov.au/partner-with-us/university/operations-research-network-ornet

developed – either through the Next Generation Technologies Fund[27], or an equivalent mechanism – to rapidly transition meaningful ideas into quality bespoke products. For whole-of-force modelling, examples could include specific models for decision-support developed with friendly user interfaces for direct ADF use, or a suite of validated models with an effective method to integrate their outputs applied to future iterations of the FSP. We welcome appropriate partnerships with Australian industry to enable this goal of rapid transition of meaningful ideas into quality ADF products to become a reality.

1.8. Summary

MCW's OA revolution will seize the opportunity presented by an expanded Defence and national security problem space. OA capabilities will be enhanced by pursuing transdisciplinary research approaches, broadly focussing on novel methods of problem characterisation in high future uncertainty, whole-of-force modelling and simulation, innovative and practical Defence portfolio options and AI enabled decision-making. The pursuit of this research is intended to enable DST Group to provide assured and accelerated decision-making for Defence and national security agencies. MCW research is nested within the strategic context of DST Group's contributions to future joint future generation and the STaR Shots. The three projects in this phase of MCW will generate Horizon 3 spin-offs directly for FSP; and transdisciplinary integration spin-offs for the STaR Shots. By tackling each of the grand challenges, MCW will provide Defence and national security with adversarial advantage to prevail in contested environments and strategic uncertainty.

[27] https://www.dst.defence.gov.au/nextgentechfund

2. MCW RESEARCH COHERENCE

The MCW research portfolio achieves research coherence through three mechanisms: design principles, OA capability integration, and a continuous iteration approach.

1. Design principles:
    - OA philosophy
    - Three-horizon research portfolio
    - Strategic context anchorage
2. OA capability integration:
    - Problem characterisation
    - Methodologies
    - Application environments
3. Iterative research approach with test-and-evaluate processes built-in.

2.1. Design Principles

2.1.1. OA Philosophy

To succeed, the three MCW projects must embrace a new OA philosophy. To identify new sources of adversarial advantage for Defence and national security agencies, our OA philosophy combines fit data, complex methods and a deliberately transdisciplinary approach.

Fit data refers to a capacity to work with both big data (when it is available), and also lean data scenarios. Complex methods refers to mathematical frontiers in the treatment of more open, 'wicked' problem statements. A deliberately transdisciplinary approach searches for new and unique solution insights generated at the intersection of disciplines. This approach drives our collaboration with partners. Our OA philosophy of fit data, complex methods and a deliberately transdisciplinary approach will push the knowledge frontier outwards to deal with an expanded Defence problem space.

2.1.2. Three-Horizon Research Portfolio

DST Group follows a three-horizon approach to research, development and delivery. Intuitively, each of the three horizons corresponds to the expected time taken for the corresponding research to have a direct impact for Defence. For instance, relatively mature research which has been appropriately scoped for prospective applications is categorised under Horizon 1 as it has the potential to be immediately applied for Defence purposes;

either as decision-support or an equivalent application. On the other end, Horizon 3 corresponds to research which has the potential for far-reaching innovative application in the Defence environment, but requires substantial work in establishing its inherent scientific merit, and its utility for practical application. Table 1 presents the delivery timeframe expectations of the three horizons.

Table 1: DST Group's Three-Horizon Research Portfolio

Horizon 1	**Direct Delivery**	Year 1: Mature, scientifically sound research that can be immediately implemented towards Defence and national security programs
Horizon 2	**Anticipatory**	Year 2-5: Research that has been proven scientifically rigorous, but requires additional scoping to determine appropriate application domains within Defence and national security.
Horizon 3	**Targeted Exploratory**	Year 6-10: Formative research which is potentially innovative, but requires considerable work to establish both scientific quality, and practical utility for Defence and national security.

2.1.3. Horizon 2 MCW Spin-Offs

A number of MCW outcomes offer prospective delivery under Horizon 2; that is, in time to support the next iterations of the FSP. MCW research is currently conducted at the OFFICIAL level, hence research outcomes require translation into (or capability development within) the Defence context (at the classified level) in order to implement them within Defence and national security programs. It is intended that in this current phase of MCW, Horizon 2 outcomes to date are therefore lifted from MCW and transitioned by DST Group into Defence and national security programs, including the IFP supporting FSP.

2.1.4. MCW Target: Horizon 3

Most MCW outcomes to date fall under Horizon 3 – Targeted Exploratory Research. Horizon 3 aims to deliver truly innovative methods which transcend current approaches to solving Defence problems. However, this third horizon is not unbounded in MCW, and has the following two assurance measures built in:

2.1.4.1. Goal Clarity

Innovation expert Amantha Imber[28] describes that purely 'blue sky' exploratory research attempts at innovation, without the guiding discipline of 'goal clarity' have a low probability of success. Hence Horizon 3 – Targeted Exploratory Research – is undertaken to address a

[28] Imber, A. *The Innovation Formula*. New Jersey: Wiley; 2006.

specific Defence problem statement. The purpose of such statements is to provide this goal clarity and guide the work. Nevertheless, the scientific process – from problem conception to data collection and analysis and finally conclusion – is a highly non-linear endeavour[29] with many potential stumbling blocks which evolve understanding and problem definition at all stages. Innovation must therefore allow realistic flexibility to enable logical 'evolution' of goals as understanding of the problem increases

2.1.4.2. Transdisciplinary Intersections

Research by Frans Johansson[30] and others has shown that truly innovative solutions are often found at the intersection of separate disciplines. Therefore, it is intended that newly commissioned Horizon 3 work within MCW will purposefully pursue collaborative projects that achieve transdisciplinary intersections. This assurance measure is specifically targeting new research projects, and has been a guiding principle in the world-wide OA community for some time[31].

More broadly, even though Horizon 2 is focused on nearer-term exploitation of 'proven' research products, the MCW initiative wishes to maintain its transdisciplinary approach by encouraging lateral thinking of proven research into as-yet undiscovered applications. In contrast, Horizon 3 has most potential when this research is deliberately transdisciplinary and intersectional, which is best pursued through collaboration. Finally, the Horizon 2 and Horizon 3 research approaches are *integrated*, recognising their interdependencies. This research horizon approach guides how MCW will design its research portfolio; and how MCW's research and development products will be evaluated and transitioned by DST Group into Defence and national security programs; and ultimately the DST Group STaR Shots.

2.2. Strategic Context Anchorage

Together, the strategic context of DST Group's work program in support of Defence's Strategic Centre and future force generation, and the STaR Shots shape the design and coherence of the MCW research portfolio. DST Group seeks to deliver the OA transdisciplinary integration effect for the DST Group STaR Shots. DST Group will achieve this through MCW's revolution in OA, which will integrate OA capabilities (as articulated in

[29] This non-linearity is articulated in Conklin's work on *Wicked Problems* where he states: "problem understanding continues to evolve until the very end of the experiment. Even late in the experiments the designer subjects returned to problem understanding... Our experience in observing individuals and groups working on design and planning problems is that, indeed, their understanding of the problem continues to evolve -- forever! Even well into the implementation of the design or plan, the understanding of the problem, the 'real issue', is changing and growing." Conklin J. *Wicked Problems & Social Complexity.* San Francisco CA: CogNexus Institute; 2006 p. 6.

[30] Johansson F. The Medici Effect: Breakthrough Insights at the Intersection of Ideas, Concepts, and Cultures. Cambridge MA: Harvard University Press; 2004.

[31] Munro I. and Mingers J. The use of multimethodology in practice – results of a survey of practitioners. *Journal of the Operational Research Society.* 2002;**59**(4):369-78.

Section 2.3) and apply them initially to the principal task of FSP, and subsequently to the DST Group STaR Shots.

2.3. OA Capability Integration

The second mechanism by which MCW achieves research coherence is through integrating the following specific OA capabilities: problem characterisation, methodologies and application environments.

2.3.1. Problem characterisation

Problem characterisation refers to identifying and framing the real problem to be solved. Historically, much OA has applied essentially reductionist methods. These methods typically have ergodic assumptions including observations being independent and identically distributed, stationarity, invariant boundary conditions and system stability[32].

However, increasingly 'wicked' problems by their nature tend to breach these assumptions, and require multi-levelled solution thinking; often behavioural change; and defy simple, reductionist problem-solving techniques and approximate methods[33]. Purported solutions using these techniques and methods may therefore be invalid. Problem characterisation involves analysing the stated problem; and reconceptualising, remapping, substituting – or transforming the real problem to be solved.

Included in the challenge of problem characterisation for the MCW research portfolio in the defence and national security context are:

- fundamental uncertainty – both strategic and other
- understanding the current and future operating environments
- scoping the feasible scenario spaces.

2.3.2. Methodologies

Methodologies refers collectively to the OA tools, techniques and methods under development across the MCW research portfolio that are more suitable for problems of the types described above. Particular OA study areas include:

- the human-machine interface: firstly to expand the limits individually of both human and AI problem-solving and decision-making under uncertainty; and secondly to

[32] Ackoff R. The future of operational research is past. *Journal of the Operational Research Society.* 1979;**30**(2):93-104.
[33] Mingers J. and Rosenhead J. Problem structuring methods in action. *European Journal of Operational Research.* 2004;**152**(3):530-54.

understand the complementarity of these two types of intelligence; and test the multiplier effect where the two are effectively interfaced

- the appropriate method mix of simulation, experimentation and wargaming to be applied to obtain superior evidence-based decision-support.

2.3.3. Application environments

Application environments refers here to the supporting research infrastructure that enables OA capabilities: hardware such as high performance computing and the corresponding data storage and software for modelling, simulation and AI research; and workshop facilities enabling robust and potentially sensitive discussions.

A crucial function of the application environment is the ability to test and evaluate specific theoretical, methodological outputs and solutions arising from MCW. In this way, the external and internal validity of outputs is continuously assessed; and allows iterative refinement of MCW through time, both within and between MCW projects. The test and evaluate function is essential to:

- close the feedback loop
- measure the progress and success of MCW – assessed by the degree of application of outputs within the Defence and national security programs.

The MCW research portfolio explicitly seeks to integrate the three OA capabilities of problem characterisation, methodologies and application environments across each of the MCW projects, in parallel. This integration effect is achieved by the projects giving distinguishable weights of emphasis to the three OA capabilities, while each project also seeks to contribute to each capability. Figure 2 shows this graphically. For example, Modelling the Grey Zone seeks to make strong contributions to the ‘problem characterisation’ capability. Agile Force Design focuses on contributions to the ‘application environments’ capability with products supporting in particular the FSP process. Finally, the bi-directional arrows indicate how insights across the three capabilities will be shared iteratively between projects.

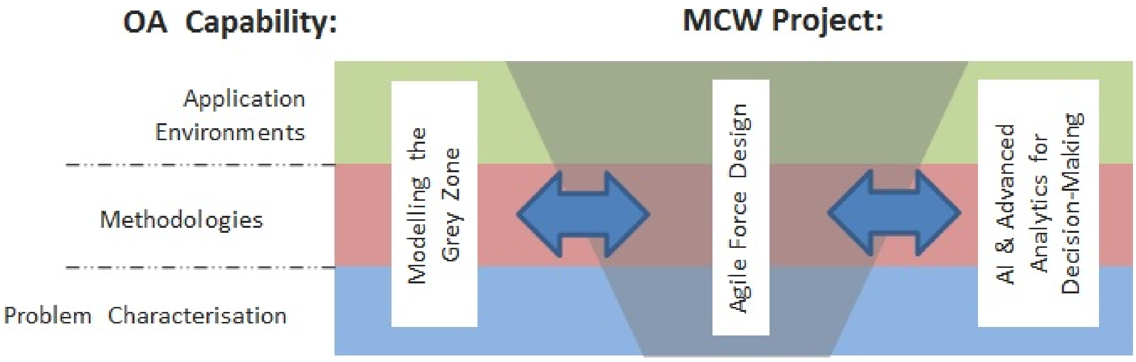

Figure 2: Graphical representation of the three OA capabilities (problem characterisation; methodologies; and application environments) of each MCW project.

The MCW program is further illustrated conceptually in Figure 3. The upper section of the figure characterises the contest-spectrum problem space[34] – from cooperation through to conflict. Just below this spectrum are each of the three MCW projects, represented via rectangles. Furthermore, above the contest spectrum sit the two specific DST Group STaR Shots (Information Warfare and Agile C2) that MCW will likely have most impact into – at least at this formative stage of the StaR Shots initiative. The horizontal placing of the three MCW projects situates each in the area of the contest spectrum where they will likely display the most benefit. For instance, it is intended that of all the three projects, Modelling the Grey Zone will more heavily explore the niche between cooperation and competition, as a sizeable proportion of its research focus will be on the impacts of information and influence on Defence operations below the threshold of conflict. Correspondingly Agile Force Design will likely have the greatest impact on the other end of the contest spectrum as its intended whole-of-force modelling capabilities will heavily focus on the evaluation of capabilities within the future joint force. Lastly, Artificial Intelligence and Advanced Analytics for Decision-Making is intended to apply its research efforts across the problem space.

[34] As originally explained in Section 1.6.1, the contest spectrum spans all the levels of conflict and the operational activities that a Defence force would engage in – from humanitarian aid and disaster relief during periods of peace, assertive posturing during strained relations, through to high end warfighting during periods of open conflict. Refer to Figure 1 of *Force 2020* for a convenient summary of the contest spectrum and related activities: https://www.defence.gov.au/Publications/f2020.pdf

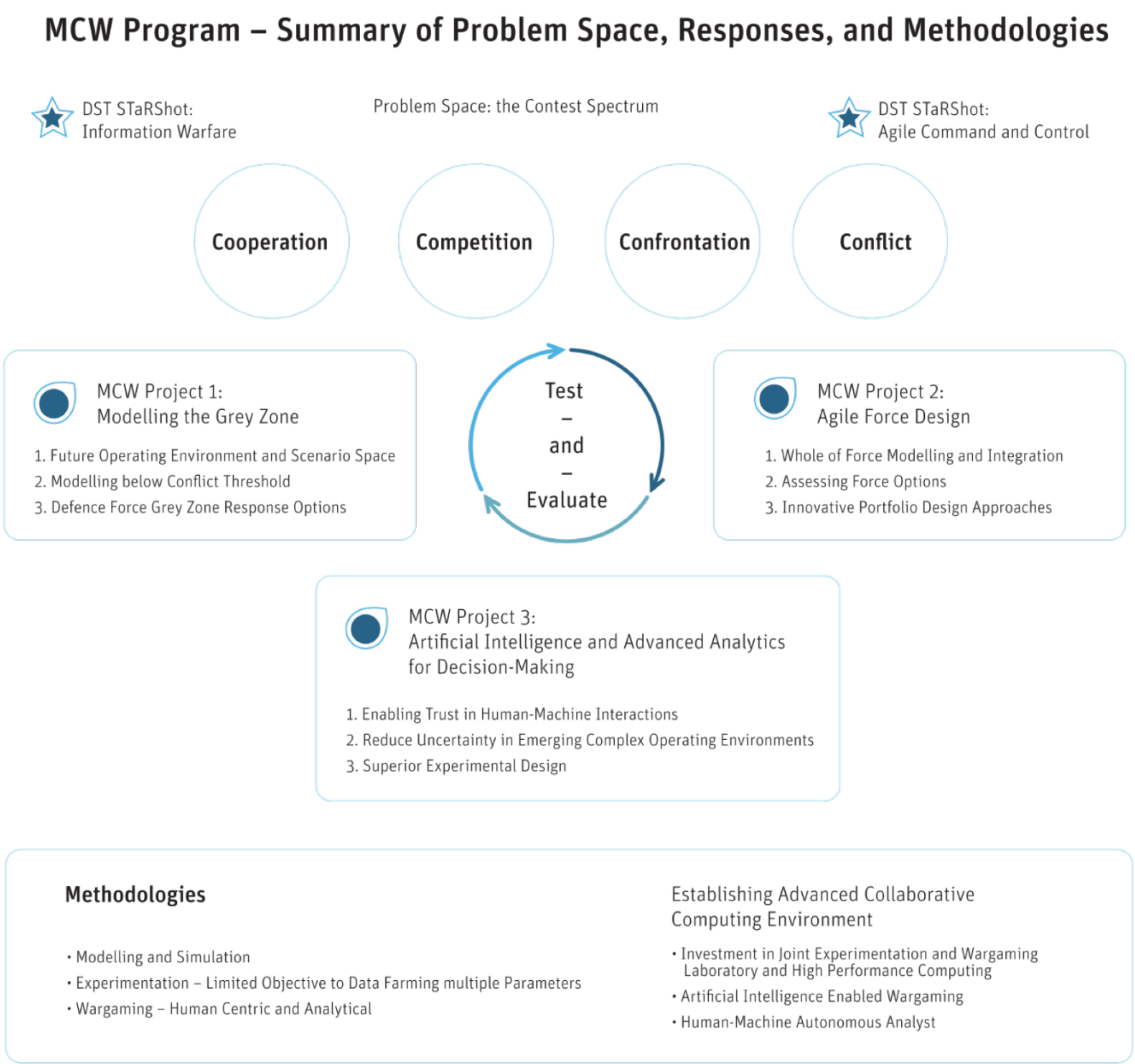

Figure 3: Summary of the problem space and methodologies applied to the MCW program

Furthermore, as articulated in Sections 1.4 and 2.3, the MCW research initiative offers OA methodological links to the DST Group STaR Shots – specifically, problem characterisation, the appropriate scoping of the application environment, of which FSP is a specific instantiation. This is where all facets integrate to deliver impact through a specific task. The lower space of Figure 3 is dominated by the intended methodologies to be applied to the MCW research initiative, which includes the tools of modelling and simulation, experimentation and wargaming – critical Defence OA capabilities. To enable novel techniques in these methodologies we also highlight the establishment of DST Group's Advanced Collaborative Computing Environment. In addition to the high performance computing supercomputer cluster capabilities currently being introduced to DST Group, this includes the Joint Experimentation and Wargaming Laboratory, which is DST Group's major

OA infrastructure. This infrastructure is intended to enable MCW's goal to fuse human and artificial intelligence – taking advantage of the positive multiplier effect that emerges when the strengths of each are effectively combined. Two applications of this fusion of human and AI are given in the figure as AI-enabled-wargaming, and the human-machine autonomous-analyst.

Finally, the circular arrows represent the test-and-evaluate process, which provides iterative, continuous feedback and refinement between both the OA methodologies, and the three MCW projects over time. An important feature of Figure 3 is permeable (and overlapping) boundaries throughout, further reinforcing the continuous exchange of insights between projects which is critical to identifying transdisciplinary insights which are the hallmark of OA's value-add.

2.4. Iterative Research Approach

The third mechanism through which the MCW research initiative achieves coherence is the iterative research approach. This involves:

- continuous exchange of insights between the concurrent projects
- periodic review and adjustment of the projects individually; and the research initiative collectively
- focuss on a specific initial application environment (i.e. FSP), and specifically the test-and-evaluate function, which will provide for continuous feedback and progressive refinement of MCW outputs.

These iteration processes use research 'reconnaissance pull' to identify and exploit as yet undiscovered opportunities to refine and adjust MCW's direction, as these opportunities emerge.

2.5. Coherence Summary

Thus the MCW research initiative will focus on revolutionary OA development, applied to an expanded Defence and national security problem space. This will allow DST Group to provide superior evidence-based decision-support, and enable Australian Defence and national security partners to perform assured and accelerated decision-making. Reiterating, the research problem-space within the MCW program is focused on DST Group's contributions to FSP, the Integrated Force Program, and more broadly the DST STaR Shots. It is intended that the three projects in this new phase of MCW will generate Horizon 3 spin-offs directly for the next iterations of the FSP process, and transdisciplinary research which will provide the revolutionary OA to directly benefit the formative STaR Shots.

In the next sections we articulate the three MCW projects in greater detail. Specifically, explaining their intended problem-spaces situated within FSP, the Integrated Force Program and the DST STaR Shots, and detailing the focal scientific developments that will be pursued by transdisciplinary research collaborations, as well as indicating the perceived impacts of these projects.

3. PROJECT 1: MODELLING THE GREY ZONE

Project 1 grand challenge: Influence is the central feature of the contest spectrum. The emergence of social media and other open source information confronts us with new opportunities and challenges in anticipating, recognising, understanding, interpreting and responding to emerging and future events and dynamics. To what extent can we reduce and exploit the apparently high future uncertainty through developing new theories, ontologies and modelling approaches?

Grey zone refers to the contemporary contest spectrum, where 'clear distinctions between peacetime and declared warfare are rapidly evaporating, replaced instead by a foggy continuum spanning cooperation – competition – confrontation – conflict. In the future operating environment (FoE), there is a premium on those force elements able to operate …across these foggy boundaries.'[35] The grey zone refers specifically to hostile activities by potentially adversarial actors below the clear threshold of conflict; where nonetheless much strategic manoeuvre is occurring.

Much current commentary on the FoE, and the nature and character of future warfare, emphasises a high degree of uncertainty. Indeed, the Australian Army's accelerated warfare concept assumes that much of this future uncertainty is irreducible; and in response advocates for highly agile adaptation to an unknowable future (compared with active anticipation of more specific scenarios). The capability consequences of this thinking are significant, as it may result in an investment hedge across an unnecessarily large range of future capabilities.

The current ADF capstone document, *The Future Operating Environment*, conceptualises the future using the 'four worlds' approach, following the intellectual leadership of the US military. However, this conceptualisation is now dated; and may not be fit-for-purpose in the unique Australian context. The *Defence Enterprise Learning Strategy* underscores the importance of an 'intellectual edge'.

The Modelling the Grey Zone project proposes to generate a uniquely Australian intellectual edge in defining the contours of the FoE and specifically modelling the impact of ADF activities to prevail in the grey zone. Early MCW research developments suggest that MCW can 'do better' for the ADF, than assuming that much of the future is unknowable. Therefore, this MCW project is credibly founded on the premise that some future uncertainty is in fact

[35] Paraphrased from https://cove.army.gov.au/article/building-bridges-the-south-west-pacific-harnessing-armys-part-time-construction-engineers.

reducible; and that the grey zone can be modelled. This MCW package asserts a bold hypothesis:

> Our perception of the future as highly uncertain is partially inflated, because our thinking paradigms are outdated, and we do not yet have the intellectual architecture to recognise what is occurring. Modelling the grey zone will assist in reducing this apparent high uncertainty, by providing new theory, a lexicon and modelling approaches to recognise, understand and interpret past, present and future events and dynamics.

This project will link to the DST Group Information Warfare STaR Shot and proposes a solution approach of three broad LoEs:

- developing theories and models of grey zone activities that reduce our uncertainty and identify opportunities to manoeuvre with advantage within it
- developing and deploying a grey zone modelling, simulation, experimentation and wargaming capability
- reconceptualising the future informational operating environment.

3.1. LoE 1: Theories and Models of Grey Zone Activities

LoE 1 challenge: How can we describe, explain and predict influence activities, particularly in the grey zone, in a way that supports generation of tactical, operational and strategic response options?

LoE 1 will pursue theoretical advances to improve defence and national security resilience and ability to constructively respond to the unexpected, with the ultimate aim to minimise national risk of strategic surprise. This LoE has an ambitious task, to develop theories of influence that will form the basis of empirical hypothesis testing on information and influence effects.

Furthermore, LoE 1 will draw on and develop theories and models of grey zone activities that contribute to: enhanced identification of influence activities; identification and development of response options; and expansion of effect measurement. These theories and models will reduce uncertainty through increasing understanding of influence and its characteristics and dynamics. However, social systems are highly complex, inter-dependent and dynamic and therefore the theories and models will improve understanding of the nature of uncertainty as it applies to influence in the information domain.

3.2. LoE 2: Grey Zone Wargaming Capability

LoE 2 challenge: What theories and models of influence need to be integrated in an influence wargame "engine" to support simulation of grey zone activities, and the articulation and selection of effects?

Information warfare is central to grey zone research, and wargaming is a key OA approach that will be used within the Information Warfare STaR Shot to pull together the various components of information warfare. Existing information warfare wargaming is limited by its relative lack of theoretical and technological understanding of influence effects, as well as limited exploitation of computational and model based representations of the phenomena of interest. Internationally, more quantitative approaches to modelling the Information Domain such as computational social and behavioural sciences are emerging. Foundational work undertaken by MCW is contributing to this emerging field by identifying a range of social and behavioural emergent dynamics in the information domain. For example, artefacts that can be assembled into:

- a social media ontology (actors and relations), with a means to represent this
- codification of second-order social influence and cultural cohesion effects to be applied in general wargaming activities.

Additionally, JOAD's application of wargaming[36] to scenarios developed by the Defence's Information Warfare Division provides an initial nucleus around which to coalesce this LoE. To further the pioneering work in wargaming, LoE 2 will pursue the next three steps:

- codify these behavioural / information dynamics into information actions, effects and impacts
- build a systematic information domain model that enables information actions, effects and impacts to be applied and used for tactics discovery, drawing on outputs from LoE 1
- evolve information warfare OA by developing a grey zone modelling, simulation, experimentation and wargaming capability. This capability is intended to support a future iteration of the FSP activity.

[36] Onyx is a grey zone wargame designed to provide a deep level of player immersion whilst supporting data collection and analysis. It combines military, diplomatic, economic, media and social media effects to explore the application of national capabilities and concepts to generate Influence (both negative and positive). For more information of DST Group's wargaming capabilities applied to the design of the future force see: https://www.dst.defence.gov.au/projects/wargaming-future.

3.3. LoE 3: Reconceptualising the Future Informational Operating Environment

LoE 3 challenge: How can future operating environment conceptualisations integrate the increasing criticality of the information domain?

Informed by the intended research from the first two LoEs in this project, this LoE has the objective of developing a future operating environment concept that will inform the scenario space considerations and potential applications stemming from *the* Information Warfare StaR Shot, as well as future iterations of the FSP. This concept work will largely apply the alternative-worlds paradigm[37], and be informed by grey zone and information warfare theories, models and wargames developed in the previously detailed LoEs of this project. It is intended that this activity will be undertaken in conjunction with Information Warfare Division and Force Exploration Branch within the Defence Strategic Centre, with strong collaboration within DST Group that leverage key centres of expertise in social, behavioural and cultural analysis. In addition to developing of a new multi-domain and multi-actor future operating environment concept, potential off-shoots from this work include:

- expanding the current ADF lexicon of the joint warfighting functions[38] to include an information function
- developing a new information concept for the future operating environment concept, with superior descriptive, explanatory and predictive power regarding information and influence effects, and suggesting effective approaches for the application of Defence information actions
- understanding what ‘fifth generation manoeuvre’ looks like in the grey zone, across the sub-combat contest spectrum
- enabling the development of a ‘future manoeuvre in the information environment’ concept.

[37] Ranta E. and Schaffar W. Alternative paradigms of development in state politics and policy making in the global south: An introduction. *Forum for Development Studies.* 2018;**45**(3):355-61.

[38] Paraphrasing Crosbie T. Getting the Joint Functions right. *JFQ* 2019;**94**(3):96-100; the joint warfighting functions are common concepts across NATO and Five Eyes militaries which act as a list of activities to be performed as a means to achieve desirable effects to enable a specific outcome. In the Australian context the six joint warfighting functions are referred to as situational awareness, C2, force application, force generation and sustainment, force protection and force deployment.

3.4. Defence and National Security Impact

LoE 3 has strong potential for application across Defence and national security programs. A grey zone wargaming capability can be applied most readily within Information Warfare Division and Force Design Division. Additionally, the following impact areas have been identified:

- current operations by Headquarters Joint Operations Command, at the tactical and operational (campaign) level
- future operations by several divisions within the ADF at the strategic level
- assist whole-of-government planning, e.g. with the Department of Foreign Affairs and Trade and domestic national security agencies.

4. PROJECT 2: AGILE FORCE DESIGN

This project is inspired by a simple but provocative grand challenge:

Project 2 grand challenge: How to design a force for future success?

Agile Force Design will pursue this grand challenge through three LoEs:

- Whole-of-force models
- Assessing force options
- Innovative portfolio design.

4.1. LoE 1: Whole-of-Force Models

The introduction described DST Group's unique role in translating research outcomes into Defence and national security. The IFP is a specific example of implementing Horizon 2 research endeavours from the MCW initiative into application-ready outcomes intended to support the next iteration of the FSP process[39].

In this next phase of the MCW initiative, one of the explicit aims is to support the IFP with Horizon 3 research to complement the current Horizon 2 implementation efforts. Therefore, strong linkage between Horizon 2 and 3 is paramount; and understanding the objectives of IFP's Horizon 2 work is important to ensure MCW's design and activities interface with broader DST activities. These strong linkages are achieved via exemplar capabilities. For Agile Force Design, this is conceived as a two-stage process, shown in Table 2:

Table 2: Example linkages between Defence activities and specific modelling capabilities

Horizon	Supporting Defence Activity	Program	Exemplar Capability
H2	Force Structure Plan Next	Integrated Force Program	Whole-of-force modelling
H3	Force Structure Plan After-Next	MCW	Contest spectrum modelling

[39] Specific examples include:

- Portfolio optimization applied to the Defence context: Harrison K., Elsayed S., Garanovich I., Weir T., Galister M., Boswell S., Taylor R. and Sarke R. Portfolio optimization for defence applications. *IEEE Access*. 2020;**8**:60152–78
- Novel Whole-of-Force agent based simulations: Au A., Hoek P. and Lo E. Combat Analysis of Joint Force Options using Agent-Based Simulation. In: *Military Communications and Information Systems Conference*. Canberra Australia 13-15 Nov. IEEE 2018 p. 1-7
- Equation-based optimization of Manoeuvre networks: Kalloniatis A., Hoek K., Zuparic M. & Brede M. Optimising structure in a networked Lanchester model for fires and manoeuvre in warfare. *Journal of the Operational Research Society*. 2020 article in press; DOI: 10.1080/01605682.2020.1745701.

The Horizon 2 exemplar capability of the IFP work program is the ADF's first whole-of-force modelling capability, with targeted delivery in time to support FSP Next. As there are multiple useful scales and representations for whole-of-force, this capability is not envisaged as a single whole-of-force model – but rather a plurality of complementary models.

To complement this, Agile Force Design aims over Horizon 3 to extend this whole-of-force modelling capability across the contest-spectrum, with explicit modelling of sub-conflict dynamics along the cooperation-competition-confrontation-conflict continuum. This contest spectrum modelling capability is targeted for delivery in time to support FSP After-Next, and expressed in the challenge for this LoE:

LoE 1 challenge: How can we capture multi-domain, multi-actor dynamics in whole-of-force models across the contest spectrum?

In order to achieve this extension in current modelling practice, MCW research supporting IFP's whole-of-force modelling capability will pursue several activities:

- Contest spectrum modelling
- output integration
- campaign level simulation tools.

4.1.1. Contest Spectrum Modelling

Current force modelling practice is focused on parameterised kinetic action, occurring at the extreme end of conflict on the contest spectrum. MCW's approach to contest spectrum modelling will focus on:

Application of techniques to extend the depth of coverage within the conflict (combat) component specifically, including:

- mathematical combat modelling
- multi-actor combat modelling.

Application of techniques to extend the breadth of coverage across the spectrum, specifically:

- game-theoretic approaches
- transdisciplinary modelling insights.

MCW's contest spectrum modelling approach is shown in Table 3.

Table 3: Contest spectrum modelling approach applied to agile force design

Cooperation	Competition	Confrontation	Conflict (Combat)
Game-Theoretic Approaches: Cooperative Games	Game-Theoretic Approaches: Non-Cooperative Games		Mathematical Combat Modelling
Transdisciplinary Modelling insights			Multi-Actor Combat Modelling

Extending Depth

Extending Breadth

4.1.2. Extending Depth

4.1.2.1. Mathematical Combat Modelling

Current classical combat modelling is limited both by its standard mathematical methods, and in its representation of the battlespace. Relatively simple mathematics (e.g. the Lanchester differential equations) is used to represent largely homogeneous, kinetic actions. Reliance on this approach is no longer fit-for-purpose in the grey zone contemporary and future operating environment, as it excludes multiple actors (beyond 'red' and 'blue' forces) with a range of contingent interests, relationships and actions. This activity therefore seeks to represent:

- non-kinetic effects, such as information warfare
- Joint warfighting functions[40] such as force application and C2
- multiple actors and dynamics (not limited to kinetic action).

Expected impacts of this activity include:

- improved assurance in force design options beyond subjective judgement alone through quantitative representation of joint warfighting functions
- an accelerated exploration of a more comprehensive range of government strategic guidance.

[40] Crosbie T. Getting the Joint Functions right. *JFQ*. 2019;***94***(3):96-100.

4.1.2.2. Multi-Actor Combat Modelling

This activity focuses specifically on the 'conflict' component of the contest spectrum, with an in-depth examination of combat modelling.

Challenge: how can current, simple adversarial combat modelling be expanded to represent the broader range of agents in the future operating environment?

Solution approach: aligned with the deliberately transdisciplinary philosophy of MCW, this LoE adopts a multi-method approach, by trialling a range of different techniques applied to the same problem. To date, DST Group has developed an experimental 'Blue-Green-Red' model of conflict, with 'Green' representing non-combatants within the battlespace. This LoE will seek to verify and validate dynamics of this model against empirical and/or historical combat reference points before wider application within the contest spectrum modelling capability.

4.1.3. Extending Breadth: Transdisciplinary Modelling Insights

The most common approaches to long-term Defence planning are underpinned by an optimisation mindset, where analysts make predictions of what circumstances might arise (future scenarios) and then generate a force optimised to win under those circumstances. Optimisation is an example of a reductionist approach, suitable for closed problem types, as discussed in the Introduction. However, this optimised force design is typically not robust against circumstances that were outside of the expected future scenarios. Where the future circumstances are highly uncertain, this optimisation approach results in a force design that is highly vulnerable to surprise. An alternative approach is to focus on designing a force that is robust against a range of possible futures. In this context, robustness is considered to be: 'able to withstand change or surprise, by satisfying the performance needs in the majority of possible futures (i.e. traditional robustness); and also adapting to be successful in the new conditions, where the performance is lower than needed or the conditions met are a surprise (i.e. adaptability)'.[41] Aligned with the deliberately transdisciplinary nature of MCW's OA philosophy, the whole-of-force models LoE seeks to model the contest spectrum in the future operating environment through analogies from other disciplines. Two candidate disciplines will be initially considered: ecology and economics.

[41] Maltby J. and Brampton C. Applying robustness to long-term defence planning. *Dstl Technical Report*, 2018:TR107069.

4.1.3.1. The Ecology of Warfare

The discipline of ecology and ecosystem dynamics has independently developed some multi-agent model approaches capable of capturing a range of relationship dynamics. So far, there has been limited application of ecosystem modelling techniques to combat. Some examples include:

- predator-prey type models[42]
- robustness through evolutionary features such as functional degeneracy[43]
- swarm intelligence and tactics, techniques and procedures based on simple 'nearest-neighbour' agent-based behaviours of some insects and birds.

This activity proposes to considerably expand the modelling analogies from ecology to capture the complex dynamics of the future operating environment. This builds on insights gained so far from MCW, specifically examining 'natural analogues' to combat modelling and in particular the emergent dynamics of incorporating C2 into combat modelling using a networked modelling approach.

4.1.3.2. Economics

The discipline of economics has developed a range of modelling approaches to represent complex 'open' economic systems. This activity posits market dynamics and competition as manoeuvre, and seeks to map concept and modelling analogies between economics and warfare. Insights from both disciplines will be evaluated for selective implementation within contest spectrum modelling capability. Transdisciplinary modelling insights represents high potential for the commission of new collaborative research with academic partners under MCW.

4.1.4. Output integration

Challenge: a characteristic of current modelling practice is that individual models are designed and built for a specific purpose (e.g. to explore a particular question) and produce scale-dependent outputs. In contrast, a characteristic of Defence and national security environments is the stratification of effects into tactical, operational and strategic scales. Therefore, currently, modelling outputs produced at one scale are not always readily transferable across scales.

Solution Approach: there is an opportunity to extract much greater value from modelling conducted across the tactical, operational and strategic scales if this output could be

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[42] McLennan-Smith T., Kalloniatis A., Sidhu H., Jovanoski Z., Watt S. and Towers I. Exploiting ecological non-trophic models in representations of warfare. In: Elsawah S, editor. *MODSIM2019, 23rd International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand*, Canberra Australia December 2019, pp. 242–-8.

[43] Whitacre J. and Bender A. Pervasive flexibility in living technologies through degeneracy-based design. *Artificial Life* 2013;**19**(3-4):365-86.

meaningfully integrated to inform strategic investments. This activity involves developing approaches for model output fusion that are scale-independent, and can usefully inform strategic decision-making in aggregated form. The development of a construct or framework to achieve this represents a significant advance. We remark that the ultimate output of this solution is not a single integrator, but rather a federation of integrators intended to meaningfully combine the outputs of a family of models which span from high-fidelity tactical engagements to abstracted strategic scenarios.

4.1.5. Campaign Level Simulation Tools

Another characteristic of current modelling practice, especially in defence and national security contexts, is the conduct of singular simulation activities – i.e. a simulation which represents a highly discretised component of a much larger manoeuvre. However, success in many defence and national security endeavours involves a campaign over time, rather than discrete events. Simulation capabilities at the campaign level, progressively incorporating and representing cumulative effects over time, remain limited; yet offer the prospect of substantial progress in the ability of modellers to inform senior decision-makers on campaign effects. This activity will develop and explore a range of campaign level simulation tools that ultimately seek to improve complex decision-making under uncertainty.

4.1.6. Defence and National Security Impact

Transdisciplinary modelling insights in particular suggests strong potential for application outside the whole-of-force strategic context. Wider Defence and national security areas for which this work has strong relevance include:

- operational planning (e.g. Headquarters Joint Operations Command)
- logistics planning.

For example, there is currently strong demand for an enhanced whole-of-force sustainment model. Ecology uses a range of regeneration models (e.g. seedling recruitment; kangaroo population modelling) that may act as suitable analogies to force sustainment/generation. As the contest spectrum explicitly encompasses the grey zone, strong two-way linkages are sought with Project 1 - Modelling the Grey Zone. In fact, success for this project will only be possible with strong links between Agile Force Design and Modelling the Grey Zone.

4.2. LoE 2: Assessing Force Options

This LoE is motivated by the following challenge:

LoE 2 challenge: What is the best way of assessing and comparing force options?

This challenge will be pursued through the following activities.

4.2.1. Metrics Definition

Challenge: how do you value a force option to enable Defence portfolio selection? In the past this has been based around how well elements of the option can achieve aspects of a well-defined scenario. However, given the ADF does not know the future in which it will need to operate, how can one ensure that these assessments appropriately represent value?

Solution approach: This activity explicitly seeks to develop assessment approaches of the Defence portfolio trade-space, with expected impacts including an improved ability for senior decision-makers to understand, compare and evaluate different portfolio options in terms of expected benefits. Improved transparency and visibility will in turn enhance the quality and assurance of portfolio selections. Two undertakings in particular are scoped:

1. **Benefits realisation:** MCW research undertaken to date has led pioneering work in developing benefits realisation methods. This activity advances this work to the next level that will involve developing (and where possible, quantifying) metrics and the data and subject matter expertise elicitation methods to support those metrics with particular applications to the FSP portfolio. Existing research agreements have forged productive links with the academic business and project management community. This activity is expected to further strengthen the Defence-specific insights from this academic community by initiating new work with economists to apply Defence utility theory (option preferences) to the Defence portfolio selection problem.

2. **Feasible Scenario spaces:** this activity will progress the idea of measuring the value of force options by the futures they are able to address - we refer to this as feasible scenario spaces. This approach is a concept pioneered by Bowden et al.[44] that tries to understand how each option is able to deal with possible futures rather than just how well they might address a given set of futures.

[44] Bowden F., Pincombe B. and Williams P. Feasible Scenario Spaces: a new way of measuring capability impacts. In: Weber T., McPhee M. and Anderssen R. (eds) *MODSIM2015, 21st International Congress on Modelling and Simulation*. Modelling and Simulation Society of Australia and New Zealand, December 2015, pp. 836–42.

4.2.2. Advancing Methods of Assessment

This activity will explore the following themes:

- Risk based assessment

  This activity will develop and further expand the pioneering risk work of Nunes-Vaz et al.[45] specifically the bow-tie framework, and apply this method to the FSP process.

- Wargaming

  The following three undertakings will be pursued to further the novel application of wargaming into assessing the utility of a designed future force:

  1. New effects**:** existing ADF wargaming uses a limited range of joint warfighting functions and effects. Linked to LoE 2 (grey zone wargaming capability) of project 1, the challenge is to extend the conflict/combat focus across the contest spectrum; and this demands the development and incorporation of new joint warfighting functions and effects into wargaming.

  2. Type selection: the initial selection of a specific type of wargaming approach (e.g. matrix, analytical, seminar) conditions the scope and relevancy of wargaming outputs. This activity aims to develop a selection framework to inform that crucial initial choice of wargaming type.

  3. Design principles: linked to type selection, there is a requirement for clearly articulated principles to assist in governing the design of wargames to ensure they meet their intended set of analytical objectives. These potential principles need to be tested to ensure they are fit for purpose and generate the data needed to meet the questions being investigated.

- Experimentation

  One of the key tools used with force design is experimentation. There is a need to examine the use of Defence experimentation activities collectively, and campaign design specifically. This activity seeks to develop and implement rigorous, yet practical, design principles for this purpose.

- Subject matter expert assessments

  Current force design and FSP type activities are heavily reliant on subject matter experts to help understand the likely impacts of force options. The complexity of Defence and the environment it operates within means that there will be a need to utilise such experts in the foreseeable future to estimate the impacts of particular force options, as quantitative models will not be able to capture all aspects of this complexity. To ensure

[45] Nunes-Vaz R., Lord S. and Bilusich D. From Strategic Security Risks to National Capability Priorities. *Security Challenges*. 2014;**10**(3):23-50.

this is done in a robust way there is a need to explore the best ways to extract such expert opinion in the most objective means possible. One such emerging method is the wisdom of crowds. This concept originated with the 2004 publication of *The Wisdom of Crowds*[46] and refers to harnessing superior collective intelligence. There are several critical caveats on this method: firstly, individuals must be 'independently deciding' (rather than being influenced by explicit, implicit and sub/unconscious social pressure). Secondly, current techniques are only able to offer superior returns on certain types of problems or decisions. This activity seeks to:

- extend existing Delphi methods
- explore how collective intelligence can constructively and cumulatively build on discussion threads while minimising risk of 'group think'
- apply the above two points to Defence and national security personnel contexts, where rank hierarchies are common and present particular challenges.

This activity will link to social and behavioural sciences work programs within DST Group, and will, amongst other things, explore social distancing measures and the role of working remotely via technology (e.g. online live chat and video conferencing) as possible enablers for higher-quality and more objective estimation of the potential impacts of capability insertion. This particular activity will initially focus on the idea of *The Wisdom of Crowds* and its applicability to the design of the future force. It will also look for other ways on ensuring expert opinion input is rigorous and robust.

4.2.3. Method Mix

Finally, this activity seeks to understand the mix of transdisciplinary methods that ensures fit for purpose validity of a given study, inclusive of validity spectrums that encompass internal, external and philosophical perspectives.[47] An appropriate method mix is crucial for campaign design that meets the needs of a given problem.

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[46] Surowiecki, J. *The Wisdom of Crowds*. New York: Doubleday; 2004 pp. 336.

[47] Bowden F. and Williams P. A framework for determining the validation of analytical campaigns in defence experimentation. In: Piantadosi J., Anderssen R. and Boland J. (eds) *MODSIM2013, 20th International Congress on Modelling and Simulation*. Modelling and Simulation Society of Australia and New Zealand, December 2013, pp. 1131–7.

4.3. LoE 3: Innovative Portfolio Design Approaches

LoE 3 Challenge: How do we develop practical and innovative Defence portfolio options that maximise the operational success for Defence within an irreducibly uncertain future?

4.3.1. Innovative Design Approaches

Innovative design approaches will undertake novel, and potentially transformative, research on military organisational design and development. The research will focus on the interplay between concepts, force structures and capability systems in an uncertain environment. This activity will explore:

- the design of robust and adaptive organisations
- adaptation under disruptive innovation and technological revolution
- alternative design paradigms such as functional degeneracy and organisational designs patterns that perform well in unstable, dynamic, and complex environments
- how concepts, theories and knowledge about organising and organisation, coordination, adaptation, and evolution inform military organisational design.

The challenge is to develop design approaches that can generate organisational concepts, architectures and capabilities that are: highly competent for planned scenarios but can adapt to unforeseen situations; and disrupt our potential adversaries, by creating surprise and imposing significant costs to counter. The aim is to discover ideas that upset the military enterprise – unexpected approaches that deliver permanent asymmetry that fundamentally change how Defence designs, builds, deploys and fights adversarial organisations.

This activity will also conduct additional research around immersion of stakeholders in future challenges and visualisation of concepts to aid innovative design. The intent is to create impact through development of shared meaning and understanding of the contexts and challenges any future-orientated design must satisfy.

4.3.2. The Defence Portfolio Selection Problem

The Defence portfolio selection problem is broadly the challenge of grouping Defence capabilities, while staying within a given budget envelope, seeking to maximise the ADF's capability against a given scenario set; and across a specified time window representing the acquisition dates of each capability in the bundle. Broadly, there are three discrete steps involved in the Defence portfolio selection problem:

- option development

- option comparative analysis, including broad classes of ranking methods (to date this has involved simple techniques such as multi-criteria-decision-analysis)
- option selection, which to date has typically involved optimisation methods.

Efforts will be focused on two approaches, targeting both mathematical heuristics and alternative solution frameworks for optimisation.

4.3.3. Defence and National Security Impact

All three of these LoEs have strong potential for impact across a number of Defence and national security programs. In addition to the next iteration of FSP, the following potential impact areas are identified:

- Investment Planning Branch, FDD and FID, amongst others within the Defence Strategic Centre
- The Next Generation Technologies Fund
- DST Group's Program Office and management of DST Group's overall S&T portfolio.

Importantly, this project has the potential to positively impact a number of DST STaR Shots due to the portfolio development and assessment capabilities that are intended to be developed. These capabilities will enable the understanding of how the design and integration of the joint force requires altering due to technological and structural change emanating from game-changing STaR Shot research.

5. PROJECT 3: ARTIFICIAL INTELLIGENCE AND ADVANCED ANALYTICS FOR DECISION-MAKING

Imagine if force design and assessment were as engaging as playing Starcraft II?

Considerable skill is required to play computer games such as Starcraft II well. Nonetheless, it stands as a very engaging platform, with integrated 'whole-of-nation' play at 'strategic' and 'tactical' levels. The game also has a capable 'back end' – able to incorporate many players in different locations, with impressive data analytics and warehousing abilities that allow games to be recorded, played-back and mined from within the database.

This project is not proposing to build an ADF Starcraft; nor trivialising the force design and assessment tasks down to a 'game'. However, this project does articulate the aspiration to create a human-computer interface for ADF force design and assessment. To offer some additional context surrounding this project, we remark that AI and Advanced Analytics for Decision Making is not centred on one specific client problem, but focuses on advancing AI/machine learning (ML) enabled decision-support, where appropriate, within the ADF. This project seeks to address the following grand challenge:

Project 3 grand challenge: What are efficient and effective human-machine problem-solving capabilities that enable agile, robust and resilient decision-making to occur across the contest spectrum and within environments of strategic uncertainty?

5.1. LoE 1: Automating the Decision Analysis Process

5.1.1. Autonomous Analyst

A high-value, early output from MCW to date is the development of the autonomous analyst (AA) concept. AA essentially represents algorithm-based AI which is appropriately situated within a problem context. While the algorithms themselves are relatively simple, a substantial body of work exists in appropriately situating AI within complex problem spaces – such as Defence and national security contexts. The challenges presented for OA in these complex problem spaces were described in this document's introduction.

AA tackles the problem of utilising machine reasoning and learning to develop new augmented capabilities for OA. This, in turn, requires analysis to drive the development of autonomous technologies through the specification of analysis problem conditions sufficient to support reliable decision-making under uncertainty, complexity and exposure to terminal failure.

Automation is imperative to improve efficiency; and tackle the information overload faced by analysts and decision makers as the data types arising in these problem domains are complex and dynamically changing. This research will both enable and take advantage of the best of advances in content analytics techniques from across information fusion, machine reasoning, learning, disambiguation, visualisation, narration and many more. Development of AA requires explainable AI to generate an engaging narrative that conveys the 'story behind the data'. This will enable Defence decision makers to rapidly understand, justify and associate appropriate levels of trust to the machine generated outputs; thereby enabling decision superiority and decisive actions.

5.1.2. Socialising AI/ML: Transition to Trusted AI/ML

While a Horizon 3 AI/ML capability for ADF strategic planning may involve minimised human input, the Horizon 2 task is to build both the AI/ML performance capability, and the trust of humans (specifically the ADF) in the process. This project explicitly seeks to engage and socialise the ADF in the AI/ML capability development process. This is required in order to:

- capture the large volumes of subject matter expertise needed to train AI/ML
- build human trust in the outputs of AI/ML, through explain-ability.

Horizon 2 therefore focuses on collaborative AI decision-support, recognised by the corporate sector as an important step towards trusted AI/ML decision-support. Collaborative AI has analogous concepts in the two communities of interest for this project:

- ADF: human-machine teaming
- AI/ML research specialists: human-computer interface.

In response to the necessary step towards AI/ML decision-support which has the full trust of corresponding human decision-makers, this project adopts a deliberately two-Horizon approach. The research in Horizon 2 represents a highly interactive phase for ADF (human) subject matter experts, followed by Horizon 3 which delivers a trusted AI/ML capability involving less labour intensity for ADF personnel.

5.1.3. Themes for Automation and AI

In order to achieve this LoE, two themes are proposed. These target each of Horizon 2 and Horizon 3 timeframes:

5.1.3.1. FSP Workflow (FSP Next)

1. Critically analyse the FSP2019 workflow, as an example of a 'manual' approach to force design and testing, and identify the discrete steps involved from a 'participant' and 'analyst' perspective. This forms the 'baseline' against which improvements in OA assurance and acceleration will be measured. This step will be undertaken in collaboration with Project 2 (Agile Force Design), and will benefit both the FSP process and the Agile C2 STaR Shot.
2. For each FSP2019 step, identify the 'skill level' and 'labour intensiveness'
3. On the basis of (2), identify those steps that are the easiest candidates for the application of autonomous analyst:
    - Automation (for the low-skill, high labour-intensive steps)
    - AI and ML
4. Seek to automate these steps for the FSP-next process.

5.1.3.2. Military Appreciation Process (FSP-after-next)

Both modelling and simulation, and wargaming, are steps within future force design as well as a broader doctrine of the *Military Appreciation Process* (MAP). Automation and incorporation of AI/ML into stages of modelling and simulation, and wargaming development can start with the higher level, more abstract modelling, with development of more detailed models, taking into account the MAP, if and when needed. This theme proposes to critically analyse the decision process (e.g. as undertaken at the whole-of-force level) to:

- identify the steps which are the most ready candidates for automation and/or application of AI/ML
- parameterise these steps (a precursor stage to automation or AI/ML application)
- identify from within the IFP, activities which currently undertake these steps manually. These represent opportunities to collect the required data to train AI/ML.

5.2. LoE 2: Apply AI/ML to the Decision Analysis Process

5.2.1. Problem Structuring for Application of AI

Project 2 of MCW (Agile Force Design) has clearly articulated the goal of conducting whole-of-force wargaming, supported by modelling and simulation. Currently, these are two qualitatively different activities. Experience from MCW to date has shown what types of tasks AI can most readily be applied to, given the current state-of-the-art. Currently, AI requires:

- relatively closed problems, or games, with well-bounded, defined rules of engagement (e.g. a closed-loop simulation)
- extensive data on which to train or learn – this can involve studying many repetitions of similar manoeuvres (for example) and using this to 'learn' how to optimise a specific tactic
- stationary/static boundary conditions.

These types of conditions are currently best satisfied in modelling and simulation activities. Therefore, the phased objectives for this LoE are to apply:

- AI to a whole-of-force simulation
- AI to a whole-of-force wargame.

This LoE recognises that AI can be applied to whole-of-force wargaming at three levels:

- playing the game (i.e. within the game)
- designing the game (i.e. at a meta level)
- analysing the context (i.e. providing a narrative; promoting explain-ability and trust).

These three levels of application represent important capability milestones for AI-enabled wargaming.

5.2.2. AI-Enabled Wargaming

A very promising early output for MCW was the development of the AI enabled wargaming activity[48]. Defence has established the DCAP to ensure that Australia has the military capabilities necessary to meet future Defence and national security requirements. The DCAP uses unstructured seminar wargames to elicit expert opinion as part of force structure analysis and experimentation. As other nations begin to use more advanced analysis techniques (including AI) to support decision making and to analyse military options, it will

[48] For more details regarding the formative stages of AI-enabled wargaming see the Defence Innovation Network via: https://defenceinnovationnetwork.com/wp-content/uploads/2019/07/4.-AI-enabled-Wargaming.pdf

be increasingly difficult for the ADF to maintain decision superiority unless a matching ADF capability is developed. This will require new types of wargames and the incorporation of AI within human-centric wargames.

Recently there has been significant progress outside of Defence in using reinforcement learning (RL) techniques to learn novel strategies in complex games, such as chess, go, shogi and StarCraft. These suggest a possible role for these techniques in military wargaming. However, new wargames need to be developed that support structured decision making with well-defined underlying simulations that have sufficient fidelity to capture the environmental complexity that impinges on the decision making process, but are also able to be run sufficiently quickly to support automated analysis.

As AI techniques become more powerful in the non-Defence sphere, there is a need to understand which of these techniques have most promise for providing enhanced military decision making. Defence needs research to understand the potential role for AI technologies throughout the entire wargaming process. This could also include technologies that can bridge the gap between current seminar wargaming and more structured wargaming, such as technologies that help record and cluster information generated during seminar wargames. Novel approaches to wargame data visualisation and human-machine partnerships are also of interest.

5.2.3. FSP-Next: AI Data Collection Plan

The AI data collection plan is a significant activity in its own right. The plan will focus on gamifying the interaction experience of subject matter expertise capture from ADF wargame participants, to maximise engagement. The plan's design will conform with the principle of parsimony; that is 'what is the minimum set of questions to ask a human that can capture their expertise?' There is strong collaborative scope to involve commercial gamers/designers as well as behavioural and social scientists, in the development of this Plan. Relevant AI ethics considerations are also critical to this plan, detailed in Section 5.4.

5.3. LoE 3: Advanced Collaborative Computing Environment

Implementation of this project requires an underpinning computing environment that can support the considerably expanded data and analytical requirements of AI.

5.3.1. DoE and Data Farming to support Whole-of-Force Modelling

Liaison with counterpart Defence research and technology organisations globally suggests Australia has the potential to develop superior sovereign capability in the design of experiments (DoE)[49] and data farming. When a simulation is run on a multi-parameter

[49] Design of experiments (DoE) is used in this context to refer to the formal discipline of experiment design; and where this interfaces data science and ultimately the targeted application of AI/ML.

stochastic model, in the absence of hypothesised cause/effect relationships, each variation on each parameter would need to be simulated in order to construct an overall picture of the salient emergent features of the model. This can be thought of as 'random' natural selection. This approach is both data-intensive and computationally intensive. In contrast, informed DoE seeks to study the early results of initial simulation, to identify which variables account for the majority of variance – and focus subsequent simulations on enumerating these. In evolutionary theory, the analogy is artificial selection (i.e. human analysts guiding subsequent simulations, based on earlier simulation results).

Applied to modelling and simulation, formal DoE seeks firstly to test hypothesised cause-effect relationships; and secondly, to conduct guided sensitivity analysis to understand the principal sources of variance. Data farming involves a human-computer interface, with an analyst human-in-the-loop. The advantage of data farming is computational efficiency over the more exhaustive, random approach of fully populating all possible permutations on the model parameters.

LoE 3 therefore proposes to follow a DoE / data farming strategy to support the whole-of-force modelling and simulation capability under development for future iterations of the FSP, building on MCW work to date. Moreover, given the unique hardware and software requirements of this LoE, there exists a proposed collaboration between two DST Group Divisions.

5.3.2. High Performance Computing

As data farming at the whole-of-force level is nonetheless data-intensive, this project requires enhanced computing support such as access to DST Group's high performance computing. Within JOAD, strong linkage of this LoE to the Joint Experimentation and Wargaming Laboratory[50] facilities upgrade plan, the JOAD modelling and simulation plan and the JOAD strategic plan is essential, so that hardware and software infrastructure requirements are captured and met.

[50] The Joint Experimentation and Wargaming Laboratory comprisises the bulk of DST Group's major OA infrastructure which takes advantage of hardware such as high performance computing and data storage facilities to enable computationally intensive modelling, simulation and AI research, and workshop facilities enabling distributed wargaming.

5.4. AI Ethics

Ethics considerations are critical for this project. Work undertaken within the project will adhere to the Federal Government's AI ethics principles[51] and other guidance, including that issued by the Defence Artificial Intelligence Centre and the Defence Technology Accelerator ColLab.

5.5. ADF C2 Concept

The ADF's new C2 Concept was launched in 2019[52], centring on 'hierarchical command – agile control'. This Concept provides innovative guidance in its clear demarcation of 'command' – which is an inherently human function, from 'control' – which can be exercised by AI, if this capability is best-placed in the battlespace.

For this project, the inherently human function of 'command' requires strong assurance measures that the application of AI will not overstep: and preserve decision-making in the Human hierarchy. Therefore, critical requirements of this project include:

- AI explain-ability and its associated ethics
- human-machine teaming, focussing on an individual human interfacing to a small number of technological entities
- socio-technical systems, which extends human-machine teaming to focus on multiple humans and multiple technological entities.

5.6. Relating to Uncertainty[53]

Project 3 faces an equal challenge in relating to uncertainty: the fact that current AI capability relies on strong ergodic assumptions, including IID (observations are independent and identically distributed), stationarity, invariant boundary conditions and system stability. As stated in the introduction: this does not accord with the nature of uncertainty or the expanded Defence and national security problem space: and demands a new approach to relate to uncertainty. A major AI capability milestone is the ability of AI to provide coherent response options under conditions of complexity and uncertainty. This stretches the boundaries of our understanding, and what is currently considered possible.

Yet despite the formidable intellectual challenge posed by fundamental uncertainty, MCW is already making appreciable progress. A core hypothesis developed so far is that wicked problems still have some invariant properties that form the basis for reliable decision making. MCW's solution approach is not problem-solving via classical OA reduction, but

[51] https://www.industry.gov.au/data-and-publications/building-australias-artificial-intelligence-capability/ai-ethics-framework/ai-ethics-principles
[52] https://theforge.defence.gov.au/publications/adf-concept-command-and-control-future-force
[53] Gracious thanks to Darryn Reid for providing his expertise on uncertainty surrounding AI.

instead by abstraction. During this new phase of the MCW initiative, this hypothesis will be tested, especially in Project 3, commencing with the initial application of AI & AA to problems with clear 'rules' (or at least laws of physics) which are known and already codified: such as modelling kinetic combat, the 'conflict' component of the contest spectrum. These 'closed' problems are the most ready initial candidates for application of AI, which currently requires clear codification of boundary conditions etc. However, as Project 3 extends across the remainder of the contest spectrum – the strong statistical assumptions are likely to be breached – and other types of solution approaches may be required. The straightforward application of current (algorithmic) AI may be insufficient to solve: a clear opportunity for MCW to innovate.

5.7. Defence and National Security Impact

While this project uses the FSP as a focal point for research, the research products this project will generate have very strong potential for application across a range of Defence and national security programs. Most notably, products have immediate utility for operational-level planning, in addition to the strategic-level planning focused on here. For example, applications within Headquarters Joint Operations Command may include:

- rapid composition of force options in response to short-notice tasking
- partially automating the process of updating the currency of contingency planning based on changing circumstances.

Wider applications to whole-of-government planning and response processes (e.g. emergency services response forces to natural disasters) also have strong potential.

6. CONCLUSION

The three MCW projects presented in this research agenda are integrated by design, and this is achieved through the three integration mechanisms described in the Introduction:

1. Design principles:
    - OA philosophy
    - Three-Horizon research portfolio
    - Strategic context anchorage.
2. OA capability integration:
    - Problem characterisation
    - Methodologies
    - Application environments.
3. Iterative research approach with test-and-evaluate processes built-in.

This MCW research agenda presents the *what* (i.e. the three projects) and the *how* (i.e. the integration mechanisms above). To conclude, we will reiterate and reinforce the *why* (i.e. our essential purpose).

We will measure our MCW success ultimately by our impact – the extent to which we have: delivered adversarial advantage; and accelerated and assured decision-making – to Australia's Defence, national security, and government. We also measure MCW's success by the improvement in our OA capability, which builds enduring expertise equity across organisations and the OA practitioner community. Specifically, MCW seeks to make the following contributions:

- the extension of OA capability across the contest spectrum
- the application of a teamed human-machine intelligence to the contest spectrum
- an improved ability to relate, in context, to uncertainty in the operating environment.

Innovative breakthroughs are made at the intersection between disciplines; hence DST Group explicitly seeks to partner with research teams able to offer diverse expertise. Please reach out and join our mission if you share our:

- drive and urgency to achieve impact in Australia's defence and national security
- passion to make valued contributions to an endeavour larger than us all

- enthusiasm for working co-creatively in teams of diverse disciplinary expertise
- excitement in making and applying research discoveries, and pushing the knowledge frontier ever outwards.

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