RESEARCH INTERNSHIPS WITH DST GROUP
INT-0424

Defence Science Technology Group - Round 1

LAND DIVISION

Distributed Decision-Making Application to support Autonomous Systems in Military Land Vehicles
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop novel solutions to enhance the adaptability, tactical effects and resilience of critical services on Army's future land vehicles, which operate in contested and resource-constrained environments. This may be achieved through exploitation of redundant functionality afforded by distributed digital vehicle systems and utilisation of sensors and effectors on co-located vehicles in the land battlespace. To realise these capabilities, the AVS group is investigating the application of autonomic computing approaches and goal-driven software agents to achieve self-management of vehicle systems and services.

It is important that AVS understands key concepts that support the desired behaviour of our envisaged solution. This will provide awareness of relevant considerations and dependencies relating to their application in our environment. One such concept is the ability for goal-driven autonomous systems to respond to changes in their environment that require these systems to adjust their goals. That is, they are capable of goal reasoning. In cases of multiple vehicles operating collaboratively, this becomes a challenging task and requires coordination between agents. Agent-based decision-making methods have been investigated by AVS as a means to facilitate coordination for functions such as task allocation, resource management and maintaining state information. These techniques form the basis for decisions made by autonomous agents in our context. The potential for applying similar methods for coordination of goals between disparate autonomous systems is an outstanding area of research for AVS. Research in these areas aligns with the organisational focus on autonomy and is critical for enabling autonomous capabilities in the end product being developed by AVS.

Research to be conducted - Conduct research to enable distributed application of goal-based reasoning techniques in autonomous systems being developed by AVS. This will consider:

1. The inclusion of appropriate agent-based distributed decision-making methods to support distributed goal reasoning processes.

2. The application of distributed goal-based reasoning to facilitate alignment of goals within agent federations (e.g. conflict resolution).
3. Mechanisms for performing distributed goal-reasoning, enabling newly formed goals to inform task allocation (distributed action assignment) and resource management (distributed resource sharing) functions in a federation of agents.

Swarm Decision Making - Act locally for global benefit
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. AVS is interested in multi vehicle robotic/AI systems and distributed mechanisms of behaviour design. These systems need to make decisions in environments in which communication is contested and information is not readily available. As such, the individual systems, which collectively work as a whole, require the ability to make decisions locally based on partial/incomplete information. The required effect of individuals making their own local decisions is that of an emergent globally beneficial behavior, as per a swarm. Consider for example the manner in which fish school or birds flock; the individual entities make local decisions which lead to the desired global behavior. AVS seeks to investigate whether the decision for a local agent to make such a decision can be learnt.

Research to be conducted - The research project will explore and identify the computational intelligence-based techniques which can be applied to enable an agent to learn the way it should behave based on the (incomplete) information it has at hand so as to benefit the swarm as a whole.

Evaluation of novel antimicrobial therapeutics against biothreat agents.
Location: Fisherman's Bend, Victoria
Duration: 5 months
Start Date: August 2018

Bacterial antimicrobial resistance is of major concern to the medical community, especially with the emergence of bacteria harbouring multiple antibiotic resistances rendering many conventional antibiotic regimes ineffective. Of concern to Defence is the potential of a highly virulent biowarfare agent acquiring antimicrobial resistance either by natural or artificial means. Thus, there is a necessity for the development of novel antimicrobial therapeutics, that are broad spectrum, preferably by targeting conserved bacterial enzymes and/or virulence determinates that have never been targeted previously by antibiotic therapeutics.

Research to be conducted – This research is aimed at determining the efficacy of a suite of novel antimicrobial compounds being developed by our collaborators against a variety of biothreat pathogens. Further to this, the ability to augment the potency of existing antibiotics with selected novel antimicrobial compounds will be explored. This research contributes directly to an international program under the CBR MoU.

Dynamic Loading and Armour Material Failure
Location: Fisherman's Bend, Victoria
Duration: 5 months
Start Date: September 2018

Response and failure of armour materials under the dynamic loadings from blast and ballistic impacts is a very important area of research that is critical to the protection of mounted soldiers against the blast and ballistic threats to our deployable combat vehicles.

Experience in advanced numerical modelling, material models and blast and ballistic loading and protection, together with recent relevant PhD research experience or PhD and a security clearance will be required. Based on collaboration to date, RMIT University is identified as the optimum university to partner for the proposed project.

Research to be conducted

1. Simulation of dynamic loading from blast and ballistic impact using advanced numerical methods: Develop the numerical modelling capability for simulation of dynamic loads from blast and ballistic impact and armour material response utilising the most modern numerical techniques which have become available, including consideration of optimisation.

2. Assessment of welded armour steels under dynamic loading: Understand the effects of welding on the mechanical, blast performance and failure of different grades of armour steel.

3. P-I loading and failure: Commence initial studies on the influence of pressure-impulse loading on material failure.

Distributed Contextual Awareness
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July-Nov 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. These vehicles will implement self- managing, adaptive software systems as a key component of their mission systems. An important consideration here is the development of contextual awareness amongst multiple vehicles.

Each military land vehicle needs to be aware of its context based on policy that is provided to it and data that it senses. A challenge is to exchange data with other vehicles in order to update each vehicle's contextual assessment for itself, for others and for the group, and in how this information is stored, disseminated and combined. Data networks that support land vehicles are generally characterised by low data rates, and intermittent connectivity. While vehicles with good network connections may have the ability to exchange more detailed context-related data, those with poorer connections may only be able to exchange very limited data. In order to exchange the contextual data of greatest value it is important to develop appropriate representations of the data types, data properties and their interrelationships.

The Advanced Vehicle Systems (AVS) team expects that contextual data can be structured using appropriate ontologies and that the use of agent-based mechanisms can facilitate the exchange of appropriate data to make best use of the available networking resources. This context-related data should be represented in a distributed knowledge base.

Research to be conducted - The research project will explore and identify:

1. Appropriate mechanisms for the representation of context related data
2. Agent-based mechanisms for exchanging context related data

The research will include an analysis of the technologies that would support the establishment of a distributed knowledge base for the purpose of supporting decentralised contextual awareness in a federated land vehicle deployment.
The research will include a simulation that demonstrates the implementation of the contextual awareness mechanisms responding autonomously to the changing communications environment.

Autonomous System Control under Adversarial Action
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July-Nov 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. AVS is interested in multi vehicle robotic/AI systems and distributed mechanisms of behaviour design. These systems need to exhibit situational awareness and autonomy by reacting appropriately to their environment which also includes enemy agents and other autonomous agents. In

open environments this is challenging due to limited sensing capability of each agent, unpredictability of the environment and the other playing agents.

We seek a PhD intern with relevant expertise in one or more areas of game theory, adaptive control, computational intelligence, symbolic AI, numerical optimization, systems design or similar to tackle problems in resilient and adaptive behaviour design in uncertain and adversarial conditions.

Research to be conducted - The research will explore and identify the most successful approaches in the literature relating to the design of behaviours for intelligent tactical systems in the context of adversarial enemy actions and/or system faults. Techniques and applications will be investigated to address the design of appropriate distributed decision making and adaptive control behaviour to enhance survivability of fleets of land vehicles via semi-autonomous management of their distributed tactical systems.

In light of enemy intent and adversarial actions, investigation will be conducted into intelligent distributed decision-making techniques. These may include:

- Situation, risk, vulnerability and damage assessment under conditions of imperfect, incomplete, misleading or irrelevant information
- Multi-objective decision making
- Reciprocal interaction, game theory, complex adaptive systems, theory of mind, red-teaming, irrationality, redundant functionality
- System behaviour modelling for non-linear environmental effects (e.g. in terms of tipping points, cascades, chaos and instability)
- Other topics relevant to the objectives as uncovered in the investigations

---

Flexible Behaviour Design for Autonomous Systems
Location: Fisherman's Bend, Victoria
Duration: 5 months
Start Date: Flexible July-Nov 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. AVS is interested in multi vehicle robotic/AI systems and distributed mechanisms of behaviour design. These systems need to exhibit situational awareness and autonomy by reacting appropriately to their environment which also includes other autonomous agents. In open environments this is challenging due to limited sensing capability of each agent, unpredictability of the environment and the other playing agents. Therefore, flexibility and reusability of behaviour design is of key importance for successful robotic and AI agents.

We seek a PhD intern with relevant expertise in one or more areas of game theory, adaptive control, computational intelligence, symbolic AI, numerical optimization, model checking, cyber-physical systems design or similar to tackle problems in resilient and adaptive robotic/computer-games agent behaviour design in uncertain and adversarial conditions.

Research to be conducted - The research project will explore and identify the most successful approaches in designing flexible and adaptive behaviour for distributed agents in the literature that have proven success in challenging robotics and game industry applications. Novel ideas and adaptations will be targeted to address the flexible behaviour design problem of this project for fleets of land vehicles under uncertain and adversarial conditions with applications in distributed vehicle intelligence/network/survivability management.

WEAPONS & COMBAT SYSTEMS DIVISION

Machine Learning and Data Fusion for Threat Object Detection
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

A number of technology solutions are currently being used for IT detection. Operational teams in conflict situations must make near-real-time (NRT) decisions using sensor outputs. Weak target detection signals in dynamic and noisy environments, high false alarm rates and the evolving nature of threats and operational environments have become the biggest challenge in IT detection. It is highly desirable for any IT object detector to have high probability of detection and low probability of false alarms. In order to minimise casualties and maintain freedom of movement in ADF operations, modernisation of Counter-IT (C-IT) detection capability is an enduring requirement. The complex nature of operational scenarios makes it very difficult to design a universal detector. Advanced signal processing and machine learning techniques are therefore needed in order to develop a robust detection scheme, which can compensate for changes in the background conditions.

The project seeks to explore approaches to reduce these limitations by developing robust Automated Target Recognition (ATR) and advanced decision support systems. As the first step, advanced NRT ATR algorithms will be developed to detect IT objects using individual sensor outputs. Subsequently, new state-of-the-art computational intelligence approaches (deep learning artificial neural networks, fuzzy sets, and evolutionary computation) will be used to aggregate multi-sensor outputs at feature and decision levels.

Research to be conducted – Line of Effort (LOE) 1 – Validation/development of Real-time Automatic Target Recognition (ATR) algorithms for individual IT detection sensors.

The main objective of this LOE is to further improve GPR, MD and Non-Linear Junction Detector (NLJD) performance through novel ATR algorithms to real-time stand-off IT object detection applications.

LOE2 – Development of an advanced intelligent Multi-disciplinary Fuzzy Decision-making Support (IMFDS) system for IT object detection scenarios.

Develop Methodology for Creating 3D-printable Solid Fuel Propellant Geometrics with Tailored Progressivity
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

3D printing has the potential to create step changes in performance for solid fuel propellants used in both guns and rockets. The geometry of the propellants plays a key role in their performance, and conventional methods of manufacture limit the geometrics able to be produced and therefore their performance. 3D printing will allow more complex and novel geometrics to be created leading to greater performance that can be specifically tailored for a given application.

Research to be conducted – There are two key areas of focus for this project:

1. Develop an understanding of propellant grain regression for the arbitrary geometries
    a. Interior ballistic modelling has been performed for some candidate geometries, but the geometries are limited as analytical equations have been used for the propellant regression. More complex geometries required for greater performance necessitate a numerical approach to determining regression profile.
2. Research and propose methods for creating classes of propellant geometries for a given gas generation profile.
    a. Tailored gas generation rates can be determined via a deconvolution method for a defined gun/rocket system to achieve a desired performance objective. Translation of the gas generation rates into viable 3D printable geometries remains a key challenge in the optimal exploitation of this technology.

Modelling and Simulation of High Power Microwave Effects
Location: Fisherman's Bend, Victoria
Duration: 5 months
Start Date: July 2018

In an era dominated by electronic warfare facilitated by advances in electronics technology and with the increasing use of information technology for command and control, a high-power microwave (HPM) directed energy weapon (DEW) technologies are of increasing interest to Defence.

The power density/fluence required on a target to produce functional kill depends not only on the target but also on the parameters of the HPM power, frequency, waveform etc. It is expensive and extremely time-consuming to test every target over a wide range of HPM DEW parameters. Accordingly, there is a significant need for computer-based modelling and simulation (M&S) that can be used to estimate target responses to a wide range of HPM DEW parameters.

This project is to conduct an analytical/numerical study on HPM effects and develop a predictive modelling software tool to model and predict the responses of electronics for both lethality and survivability assessments.

Research to be conducted

1. Develop understanding of the high-power microwave technologies and systems, RF coupling and propagation and target susceptibilities.
2. Based on electromagnetic equations, semiconductor physics and thermal equations, conduct an analytical/numerical study on HPM effects and develop a predictive modelling software tool for analysing HPM effects on semiconductor components.
3. Validate the feasibility and accuracy of the developed simulation algorithms using the existing experiment data if there is any.

Modelling and Simulation of Graphene Characteristics, Structure and their Shieling Effects against Electromagnetic Radiations
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

The modern warfare weaponry is dominated by electronic circuits and sub-systems that are quite susceptible to exposure to Directed Electromagnetic (EM) radiations and when subjected to these radiations, their electronic circuity can be badly damaged and thereby leading to the failure of weapon system functionality. Consequently, EM radiation protection requirement for electronic system has become increasingly important for the survivability of Defence assets and civilian infrastructure.

Smart materials such as Graphene are becoming increasingly popular for EM shielding and absorption. In particular Graphene is a two-dimensional material consisted of a single layer carbon atom in hexagonal honeycomb lattice has attracted increasing attention in many research areas owing to its excellent properties, such as optical transparency, flexibility, mechanical stiffness, strength and elasticity, and most importantly the tunability of its conductivity.

Research to be conducted – It is envisaged that consistent research and developmental activities in context to graphene material are to be taken to develop effective shielding measures against EM radiations. The prospective APR Intern is to conduct modelling and simulations of graphene characteristics, and design customised graphene that can provide maximum shielding against EM radiation. The key research activities to be undertaken are as follows:

1. Develop a model for analysing graphene characteristics in regards to EM absorption and transmission across the material, and its shielding effects against EM radiations. It is expected that the developed model should be able to be used in MATLAB/Simulink environment.

Use of Reactive Non-Equilibrium Chemical Kinetics in Hydrocode Modelling of Reactive Materials

Location: Edinburgh, South Australia
Duration: 6 months
Start Date: August 2018

Structural Reactive Materials (SRM) present an opportunity to advance warhead design options previously not achievable. While qualitative performance outcomes have been demonstrated, there is little understanding of how the effects are achieved, how to measure them and how to utilize them effectively.

Warheads Effects Group in the Weapons and Combat System Division of DST is interested in developing required deeper understanding through the application of computational fluid dynamics (CFD) techniques. The CFD simulations will require development of multi-phase materials models that need the individual mechanical and chemical characteristics of the phase species of the SRMs applicable to the warhead effectiveness and design problems. The successful candidate would therefore require an appreciation of material shock loading characteristics, high strain rate material response, and computational physics.

Research to be conducted

1. To specify chemical reaction kinetics that could be associated with the processes occurring in SEMs at high strain rate conditions typical of warhead detonation and target impact, and
2. To apply the kinetics to multi-phase material models implemented in modern hydrocodes for simulation of scenarios typical for the warheads involving SRMs

---

NATIONAL SECURITY & ISR DIVISION

Radio Frequency Interference Rejection in Ionospheric Sounder Ionograms
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

Ionospheric sounders are used by skywave radar and HF communication systems to derive ionospheric maps for the purpose of frequency channel selection and geolocation of targets. These sounders acquire raw signals that are processed to form ionograms that may be analysed to extract features using either human visual or computational interpretation systems. For this project we are concerned with improving the ionogram processing by reducing ionogram corruption caused by radio frequency interference. Improved clarity in the ionogram will in-turn improve the performance of feature extraction algorithms.

Radio frequency interference causes an impulsive noise response in the sounding as the sounder scans past the interference frequency channel. DST is seeking a candidate with strong adaptive signal processing skills with aims to develop a technical solution to the impulsive noise problem.

Research to be conducted - The first objective of the project is to statistically characterise the radio frequency interference and its manifestation in the sounder ionograms. The second objective is to propose candidate signal processing technical solutions to the interference problem, including interpolation based restoration techniques. The third objective is to develop and analyse the performance of a selection of these techniques. A test set of Jindalee ionospheric soundings with required software will be made available for analysis on PC platforms.

Tailoring Social Media Data for Network Construction
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

It is widely accepted that the current military operational environment must give due consideration to the socio-economic, cultural and ethnic characteristics of the friendly, neutral and enemy populations. Information from local sources transmitted via social media is especially useful for building a picture of the situation on the ground during crises due to natural disasters or conflicts. Social media spaces have also become platforms for strategic tools that can be used to inform, confuse, manipulate and attack societies (often through the use of sophisticated bots and hybrid human/bot systems). It follows that the "territory" that Defence needs to protect includes the information environment; moreover, strategies for mitigation against attempts to manipulate public sentiment, provoke negative reactions and incite violence are a requirement for Defence and National Security. A well-founded social media analysis

capability is crucial to understanding the human and informational complexity that characterizes the emerging information environment.

Previous research has assumed that pre-existing theories of offline communication (e.g. social network analysis (SNA) can be directly applied to online communication. Yet, the social media environment is associated with certain idiosyncrasies and restrictions that are not present in the offline interactions from which these theories were developed. It is argued that the social media interaction space is more similar to a semi-structured fluid that constantly changes its shape than a network that indicates actual social structure. Understanding this environment requires new data modelling and analysis strategies that allow us to follow the unfolding of social issues and to model information-spreading individuals and organised systems of botnets. Despite the vast quantities of time-stamped data from blogs, information exchanges and social networking, the highly fluid networks appearing in the cyber domain are not easily defined and the mechanisms of social diffusion in this medium and how they relate to the social world are not well understood.

A significant effort in DST's social media analysis research is dedicated to constructing meaningful interaction network models using new dynamic network concepts and associated algorithms. The approach we are taking to addressing the big data problem inherent in social media analysis is to tailor data filtering and processing to the research questions rather than trawling through large amounts of data looking for interesting patterns. The project requires skills in statistical and/or data analysis along with a good understanding of the characteristics of human and social data, and how they should be handled.

Research to be conducted - This project forms part of a larger research program that addresses requirements for current and future conflicts for a social media capability. Outcomes of this project will inform the ongoing development of RAPID – a real-time social media data processing system developed through a long-standing collaboration with the University of Melbourne.

The research is based on the fundamental premise that making sense of social media data entails understanding the dynamic and social nature of online behaviour. For example, in the case of Twitter, networks can be classed as three quite different types of networks for analysis: the relatively static and user-focussed follower networks; the typically localised networks of discussions; and the highly diffusive retweeting networks.

In particular, this project will contribute to:

- Evaluation of data extraction methods for the construction and analysis of online discussion networks.
- Detection and analysis of social processes, including conceptualisation and implementation of various measures.
- Finer temporal analysis of the evolution of "issue networks" and characterisation of influential gatekeepers and brokers.

Accuracy Prediction for Over-the-Horizon Radar
Location: Edinburgh, South Australia
Duration: 4-5months
Start Date: July 2018

Skywave over-the-horizon radar (OTHR) uses refraction of radio waves in the earth's atmosphere to achieve coverage ranges well beyond line-of-sight. This technology is a key surveillance asset for Australia. Models of detection and accuracy performance can be used as tools to design future network enhancements and to validate the achieved system performance against expectations. However, the atmospheric ionisation that supports skywave propagation is highly variable over daily, seasonal and multi-year solar cycles, and thus the characterisation of radar performance is challenging.

DST is seeking an early career researcher with expertise in statistics, signal processing, or physics to help design an OTHR system model to forecast achievable accuracy with high enough fidelity to be practically relevant.

Research to be conducted - The overarching aim of the program is to derive a Cramer Rao Lower Bound on estimation accuracy, which is to say a theoretical measure of the best performance achievable for the system. This is already possible if we over-simplify the system, the challenge is to extend this to be more realistic. The first research objective would be to incorporate numerical methods to estimate the statistical properties of the propagation path and transforms to combine this with modelled radar measurement accuracy. The second objective would be to explore marginalisation techniques to allow evaluation over large volumes in achievable time.

DST already has a numerical ray tracing engine for HF propagation and this could be combined with archived atmospheric sounder data to improve model fidelity.

Forensic Intelligence Collection and Analysis for National Security
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018

Forensic science is the application of scientific methods and techniques to matters under investigation by a court of law but can also include military, national security or intelligence objectives. Traditionally, forensic science is in support of a single case for prosecution in a court of law however, forensic intelligence is an emerging disciple in law enforcement agencies. Forensic intelligence is defined as the accurate, timely and useful production of logically processing forensic case data for investigation and/ or intelligence purposes and has a multi-case, multi-disciple focus. It provides knowledge on criminal activity and may support proactive approaches through disruption and prevention. Forensic intelligence has only recently been applied to the military domain and is a valuable model for the

provision of timely forensic intelligence fused with all-source intelligence to meet the Commander's intent and intelligence requirements while preserving the prosecution option. Forensic intelligence enables identity intelligence operations and thus meets the needs of law enforcement, national security, military and National Intelligence Community (NIC).

Identity intelligence is the fusion of forensic biometrics and biometric-enabled intelligence (including contextual information) with forensic intelligence and document and media exploitation (DOMEX). Identity intelligence operations deny adversaries their anonymity and enable attack the network operations through targeting, prevention and disruption. Biometrically-enabled intelligence such as DNA and fingerprints underpin forensic intelligence and identity intelligence to provide linkage of objects, people or events.

Defence does not currently have a deployable forensic and technical exploitation capability, but currently has dispersed forensic capabilities that do not operate as a joint capability. Land 154 Weapons Technical Intelligence (WTI) project will introduce into service (FY 19/20) a deployable level 2 exploitation capability that focuses on providing a joint intelligence capability on threat weapon systems and material for ADF and Whole-of-Government national security. The WTI laboratory is a contained solution consisting of predominately scientific laboratory type facilities across biometrics, document and material exploitation, digital forensic and weapons technical analysis. The WTI project component will entail the construction of two deployable WTI facilitates in Australia.

Research to be conducted – The primary objective of the internship is to utilise and apply forensic intelligence principals to the national security operational environment. The National Security Science and Technology Centre (NSSTC) in collaboration with the US DoD Combatting Terrorism Technical Support Office (CTTSO) have funded the development of several forensic science techniques that can be applied to forensic intelligence for identity intelligence objectives. These techniques include collection and analysis of latent DNA from touched items (Flinders University) and immunogenic fingerprint collection (University of Technology Sydney). A future national security project has been proposed for the provenance of soil to track the movement of people or assets.

The aim of the project will be to validate and verify the application of these techniques by military, national security, intelligence and law enforcement forensic intelligence operations.

JOINT & OPERATIONS ANALYSIS DIVISION

Technology Foresighting

Location: Fairbairn, Australian Capital Territory
Duration: 5 months
Start Date: July 2018

Technology continues to develop. The rate of technological innovation is occurring at a pace never before experienced in history. As a result, Defence organisations across the world are increasingly being pressed to employ a range of disparate technologies in new and innovative ways to retain a persistent

capability advantage over potential adversaries. Those that embrace and exploit those new technologies in a considered manner are better positioned to adapt and respond to emerging threats, develop superior capabilities, evolve their operating concepts, and shape their force structure.

The DST technology foresighting approach developed by TFF consists of a series of activities beginning with horizon scanning and then a series of increasingly detailed analyses which inform a range of outputs. Technology Watches are short reports on a subset of the topics identified in the horizon scan, where potential benefits and threats are examined briefly, with deep dive activities such as the Emerging and Disruptive Technology Assessment Symposiums (EDTAS) conducted on particular themes or technologies assessed as being of particular significance.

DST is seeking someone with expertise in foresighting methodologies, which could include data analytics, expert elicitation and workshop design. The particular focus of the team is technology foresighting, implications analysis and future concepts research.

Research to be conducted - The research to be conducted under this program would be to build on the current expertise in expert elicitation and workshop design, data analysis as applied to technology foresighting to develop novel scientifically-based foresighting methodologies. This research will assist in continuing to develop worlds-best-practice futures and foresighting approaches which will be applied in the Defence and National Security domains.

The exact details of the project will be negotiated dependent upon the unique skills of the APR Intern recipient. However, depending on the particular skills of the successful applicant, the aim of the internship may be to develop a sound basis for the conduct of technology foresighting workshops. An alternative objective will be to assist in the development of the next version of the DST technology foresighting software which assists in the horizon scanning that seeks to identify potential technologies which may have a disruptive impact on Defence and National Security.

Using Systems Dynamics Modelling to Identify Potential Levers for Performance Improvement in a Combined Arms Team

Location: Edinburgh, South Australia
Duration: 6 months
Start Date: July 2018

The Combined Arms Team, which combines combat, combat support and combat service support elements, is the core mechanism that delivers land combat fighting power to decisively win in close combat and realize success in contemporary conflict.

A key challenge in developing effective Combined Arms Teams is to understand the dependencies and interactions that exist between force elements involved in Combat, and how the individual performances of these elements combine to impact combat outcomes. This information can then be

used to identify performance improvements that have the greatest potential to increase our chances of winning.

A systems dynamics model could be one way to capture the relationships between combat elements. This model can then be used to identify potential performance levers, i.e. potential systemic changes that could improve the Land Force's chances of winning.

Research to be conducted - The objective of this work is to identify opportunities for technology investment which will impact the effectiveness of combat. The PhD student will do this through:

1. Building a systems dynamics model of Land close combat.
2. Identifying the potential levers for impacting the dynamics of the system (for example through various technologies') to help identify how a force could change its chances of success.
3. Identify ways of quantifying changes in the systems dynamics as a result of technology insertion to assess the effectiveness of identified levers.

Statistical Characterisation of Navigational Sensor Data from RAN Ships
Location: Sydney, New South Wales
Duration: 6 months
Start Date: July 2018

The Defence Science and Technology Group (DST Group) of the Department of Defence is developing a capability to rapidly and exhaustively analyse navigational data produced by Royal Australian Navy (RAN) ships. This is one component of a wider program in big data analytics aimed at optimising Defence's day to day operations. Navigational data includes readings from a number of sensors, including position, water depth, wind and ocean current data. In order for DST Group to be able to fully exploit this data it needs to understand exactly how the sensors behave and what additional information can be gleaned from them. For example, if we look closely at ship position data and how much it deviates from a smooth course, can we determine details of the sea state (wave conditions), particularly when we look at the statistical behaviour of these deviations over longer periods of time such as an hour? Sensor data may also have errors and deviations caused by sensor electronics or by local variations that result from a ship's interaction with the environment (e.g. wake turbulence).

An APR Intern has completed an initial assessment in 2017 that provided very interesting insights and this proposal seeks to build on this work.

DST Group is seeking an APR Intern to undertake further analysis of the data collected by the navigational sensors to statistically characterise their behaviour and so give us insight into the shortcomings in, and opportunities for, further exploration of the data provided by the sensors. The intern will be provided with the original analysis and data sets at varying resolutions covering different

time periods for a range of different vessels, from different fleets, and operating at sea or alongside in different locations and environments. The work will be complicated by changes to ship sensor installations over time, and by the patchiness of the data. The intern will have to relate the navigational data to other data sets such as weather and ocean data. Also, while this project will not specifically look at the physics, engineering, or functional operation of sensor, the intern will have to be guided by a high-level understanding of what these sensors do and what they measure.

Research to be conducted:

- Statistical analysis of ship behaviour and experience that can inform RAN operational practices.
- Exploration of data to determine if there is additional information about the experience of vessels that can be inferred from the longer term statistical character of the data such as Sea State.
- Improve the Maritime Mathematical Science Group's ability to use data from platforms to support evidence-based decision making

---

Modelling Situational Context for Narrative Generation
Location: TBC
Duration: 5 months
Start Date: July – Dec 2018

Situational awareness is a key requirement for operators, decision makers, and analysts. In the normal course of their roles this is achieved, in part, by immersion, exploration and manipulation of the information space in order to produce the evidence or products needed to support their actions, decisions, or analysis. This helps establish the context, and determine what is known, what is not known, what is important and what is not important to a particular situation. When automation is introduced to handle the 'big data' problems of volume, velocity, and variety, this pathway to situational awareness is largely lost. Storytelling, or narrative, is widely regarded as an effective mechanism for experientially engaging an audience and making sense of complexity, and thus can establish the context needed to achieve situational awareness in these circumstances. Automated generation of narrative is therefore a possible means of providing users with the information needed to achieve and maintain situational awareness when automation is used to support an operator, decision maker, or analyst. DST is currently conducting R&D looking at various techniques for automated narrative generation to describe complex military situations.

Research to be conducted - In the course of normal social interaction a narrative style of discourse is only (usually) provided when the speaker recognises that some context needs to be set so that the listener(s) can correctly understand the information being conveyed. An automated narrative generation capability similarly needs to be able to recognise what information needs to be provided in a narrative form based on its understanding of the user preferences, prior knowledge, and interactions

with the system. In particular, it needs to be able to recognise when the context associated with the interaction has changed. DST has developed a capability based on Rhetorical Structure Theory (RST) that allows the generated narrative to be tailored to the user's needs.

The goal of this project is to develop a model for situational context and how this maps to manage the generated narrative, and potentially implement a proof of concept capability that could be evaluated.

Application of Causal Mapping to the Analysis and Development of Military Operating Concepts
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018, negotiable

LCA Branch in DST Group applies operational research methods, tools and techniques in order to assess the operational effectiveness of the Land Force and support decisions on future force structures and capabilities. A key component to the development of future Land Forces are military operating concepts. These documents aim to describe how a future force could operate in order to meet a Government's strategic intent. They also seek to describe in broad terms how the force could address future challenges, as well as identify potential approaches that exploit emerging technologies. The primary purpose of operating concepts is to guide changes in how the military operates, its' force structure and equipment.

A well-structured concept will demonstrate clear links between proposed capabilities and strategic guidance, as well as articulating how these capabilities will overcome the challenges of the future operating environment. The concept will also possess sufficient detail to guide the development of more detailed sub-concepts, the design and analysis of new force structures and broad direction for the development of new capabilities/equipment. Failure to achieve this intent may mean that senior military leadership may not endorse the concept; furthermore, proposals for the resources required to develop the future capabilities articulated by the concept may be unsuccessful.

Consequently, writing highly effective concepts is an important goal for any military organisation, but it is not straightforward. DST Group is examining the application of operational research methods to assist the Army to improve the way it develops and employs its operating concepts. One such method is causal mapping.

Causal mapping is a problem structuring/analysis and solution exploration method underpinned by a system thinking approach for managing complex situations and enabling shared understanding across multiple perspectives. Its benefits in application to military concepts are that it seeks to establish a means- ends hierarchy which is ideally suited to testing the logic of a military concept and provides a scalable visual representation of the concept that incorporates the 'big picture' as well as the detail.

Research to be conducted - The objective of this project is to develop causal maps of representative military operating concepts from Australia and other nations. Key questions to be explored include:

1. What insights can be gained from causal mapping of military operating concepts?
2. How do these differ from insights gained from other analysis methods?
3. What are the limitations in this method as applied to military concepts?
4. What are the key similarities and differences between Australian military concepts and those from other nations?
5. How could causal mapping be used to develop military operating concepts?

The outcomes of this research will support an ongoing program of work within DST group helping Army to develop its future operating concept and subsequent design and assessment of the future Land Force.

Efficient, Dynamic, Threat-Aware Pathfinding and Tactical Positioning for Combat Simulation
Location: Edinburgh, South Australia
Duration: 5 months
Start Date: July 2018, negotiable

DST Group use combat simulation as an analysis tool to explore the potential impact of modifying technologies, tactics, concepts, and force structures in the context of military operations. Combat simulation for analysis requires modelling behaviours that represent military tactics, techniques, and procedures for manoeuvre and engagement against an active enemy.

The outcome of simulated combat can be sensitive to differences in the positions and routes chosen by simulated entities. It is believed this issue can be overcome through the design of a set of algorithms that model seemingly intuitive choices of such positions and routes, which enable the opportunity to engage the enemy while avoiding exposure to the enemy.

There are many bespoke solutions to this problem that have been implemented in various military simulations and computer games, but these impose too many constraints to be dynamically used during a simulation run, too few constraints to produce a valid tactical behaviour, cannot be consistently implemented across a range of simulations, or are computationally inefficient during simulation runs.

An efficient and robust solution would enhance the validity of combat simulations, thereby increasing their usefulness to a wider scope of problems, as well as reduce the programming effort required to manually implement, adjust, and maintain individual positions and routes to achieve the same effect.

This would result in enhancements to DST Group's capacity and capability to use combat simulation as an analysis tool.

Research to be conducted - The objective of this project is to research and design a suite of algorithms that simulate tactical decision making regarding positions and routes in a close combat context. When integrated with a combat simulation, the suite should enable calculation of the following for a simulated entity:

1. What is the fastest route to reach a given destination point?
2. What is the 'safest' route to reach a given destination point, using cover and concealment to minimise my exposure to known/likely enemy positions?
3. What is the 'best' tactical position 'near' me that enables me to use nearby cover and concealment but still maintain line of sight to the enemy or a given feature/area?

The intent is for these algorithms to be employed by simulated entities dynamically during a simulation run (in order to take into account dynamically changing conditions).

MARITIME DIVISION

Target Echo Strength Modelling

Location: Fisherman's Bend, Victoria
Duration: 4 months
Start Date: July-Sept 2018

The project is to benchmark the DST Group Target Echo Strength software using a specified set of models. These models will be analysed by four other countries, UK, Netherlands, Germany and Canada, and the results will be compared. The models will also be tested in a round-robin experiment for comparison with the numerical results.

DST group is seeking a PhD candidate in maths or physics to use the DST Group modelling software to predict the target echo strength of the comparison models.

Research to be conducted - The aim of this project is to analyse the software performance and identify where errors might occur, as well as explore alternate approaches to modelling that target echo strength.

Small Craft as a Wave Buoy

Location: Fisherman's Bend, Victoria
Duration: 5 months
Start Date: July-Sept 2018

DST is assisting the ADF with enhancements to ocean modelling tools and also concepts for improving the performance of military crewed and uninhabited vessels. Better characterization of the ocean surface conditions can provide the opportunity for the ADF to adapt their behavior and planning in order to improve their overall effectiveness in the maritime environment. In the case of vessels at sea, adaptive control approaches may allow for crewed and uninhabited vessels to improve their seakeeping performance. In the case of planning, the sparsity of observational data for data assimilation schemes that correct ocean model continues to be a limiting factor in ocean modelling skill, especially in littoral and regional modelling. Wave-buoy data that can provide a direct characterisation of the sea surface is particularly sparse.

The concept being investigated with this project is the use of a small, uninhabited craft to substitute for a wave-buoy sensor. The dynamic behavior of a small vessel can be highly non-linear and so the project will combine vessel dynamic modelling with prediction tools. There is also a possibility that there will be full-scale at-sea data and model-scale tank test data available for validation purposes. This is part of a larger research program intended to improve the modelling and seaway performance of small military vessels.

Research to be conducted:

1. Review key problems related to the use of a small craft as a wave-buoy.
2. Formulate an analytical approach to resolving the problem
3. (If possible) validate the approach using model-scale and full-scale data
4. Co-author findings

Precision Photonic Sensing
Location: Edinburgh, South Australia
Duration: 3-5months
Start Date: July 2018

The Advanced Sensing Lab in DST's Maritime Division has world leading expertise in short cavity fibre lasers and their application to precision undersea sensing. The scope of our research includes the design and development of distributed feedback fibre lasers, basic laser physics, precision measurement techniques and development of novel undersea sensors. In the past, much of our focus has been on acoustic sensing technologies and their application to lightweight remotely deployable sonar for undersea surveillance. Recently we have been increasing interested in non-acoustic sensing techniques such as magnetometry.

We are seeking an experimental or theoretical physicist with a photonics background and an interest in precision measurement and sensing. Depending on the skills and interests of the intern a number of specific projects may be available including:

a) cavity-optomechanical magnetometry
b) feedback induced instability in distributed feedback fibre lasers

c) Relaxation oscillation noise suppression in ultra-high cavity-Q fibre lasers
d) Digitally enhanced frequency demodulation of fibre laser sensors.

Research to be conducted - The intern would undertake *one* of the following projects depending on their skills and preference:

a) Cavity optomechanical magnetometry
b) Feedback induced instability in distributed feedback fibre lasers
c) Relaxation oscillation noise suppression in ultra-high cavity-Q fibre lasers
d) Digitally enhanced frequency demodulation of fibre laser sensors

---

AEROSPACE DIVISION

Synchronisation of Real and Virtual environments
Location: Fisherman's Bend, Victoria
Duration: 5 months
Start Date: July 2018

This project will advance the state of our science supporting integrated Live, Virtual and Constructive (LVC) environments for training and experimentation.

The AOSC XR lab conducts applied Human-Computer Interaction research on Augmented/Mixed/Virtual Reality, supporting projects for Army, Navy and Air Force. The lab has leading edge equipment for immersive visualisation, including eye/head/body tracking and 3D environment scanning and ready access to advanced manufacturing workshops.

Integrating real word objects with virtual worlds is challenging. IR optical marker tracking (e.g. Optitrack, VICON), laser multilateration (lighthouse) and accelerometers are functional for tracking discrete points in indoor spaces, but perform poorly outside, and are incapable of capturing the appearance or tracking natural objects (trees, clouds) or untracked participants, and require considerable effort to attach and calibrate the fragile trackers.

Photogrammetry techniques allow real-time capture of shape and textural information. Multi-View Stereo Structure-from-Motion (MVS-SfM) is a method to incorporate the information from multiple cameras, generating a 3D point cloud. The point cloud can be used to build a 3D polygonal model, or to track the motion of known objects through the scene.

Research to be conducted –The goal of this project is to employ MVS-SfM techniques to capture complex dynamic scenes in real time, track known objects, and update environmental scenery (traffic, pedestrians, clouds and shadows). Existing open source and commercial for MVS-SfM will be used where possible, with a focus on real-time processing and tracking.

Unlocking the Potential of Additive Manufacturing (AM) for Aircraft Fracture Critical Structures using Surface Enhancement Technology
Location: Fisherman's Bend, Victoria
Duration: 4-5 months
Start Date: July 2018

The cost of ownership and the operational availability of air capability are major concerns for the ADF [DST Strategic Plan 2013-2018]. Given fatigue failure of any of fracture-critical structures may result in loss of an aircraft, to maintain the fleet airworthiness and readiness, the new AD strategic plan has recently identified Innovation Sustainment (iSustainment) – one of the three new S&T themes [AD Plan – A catalyst for the Future 2018]. Titanium alloys such as Ti-6A1-4V forgings are widely used for aircraft fracture-critical components due to their high specific strength and fracture toughness. These fracture-critical components are conventionally machined out to die forgings and hand forgings, resulting in typical buy-to-fly ratios more than 10:1 with lengthy lead times and high costs [Kobryn et al/AFRL, 2006]. Although, in recent years, extensive R&D efforts have been devoted to achieving lower cost fabrication of Ti alloys using AM, the successes are so far tempered by challenges that fatigue durability of the today's AM manufactured parts can only match that of casting counterparts, but not that of the forged Ti alloys due to the AM process defects (such as lack-of-fusion voids and pores) and surfaces roughness [Airbus Additive Manufacturing 2017].

Research to be conducted

1. To apply deep surface rolling (DSR) to enhance fatigue durability of AM Ti-6A1-4V for the applications of aircraft fracture-critical structures; and
2. To understand the mechanics of DSR introduced beneficial compressive residual stresses at the surface, but more importantly, the mechanisms of how DSR can induce nanocrystallization, and microstructural solid-state transformation for fatigue strength enhancement.