Australian Government
Department of Defence
Science and Technology

HPR*net*
Human Performance Research network

PARTNERING IN HUMAN SCIENCES FOR TOMORROW'S CHALLENGES...

What is **HPR*net*?**

DST and the Australian Army have established the Human Performance Research network (**HPR*net***, pronounced hip-er-net) to enhance the performance of Australia's military personnel.

Led by DST, **HPR*net*** brings together leading research teams from academic institutions across Australia to provide cross-disciplinary expertise to enhance soldiers' performance, physically and cognitively.

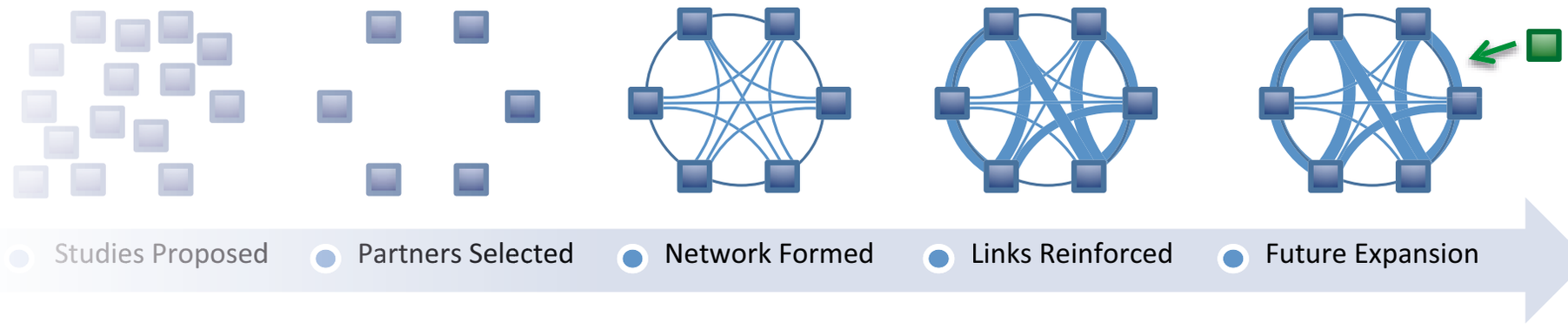
HPR*net* is based on a model of mutual investment and open engagement. Its aim is to establish an enduring partnership with, and between, members of the Human Performance Research community.

A total of $4M over four years has been committed to the establishment and operation of **HPR*net***. There is the potential for further investment to expand and extend **HPR*net*** in the future.

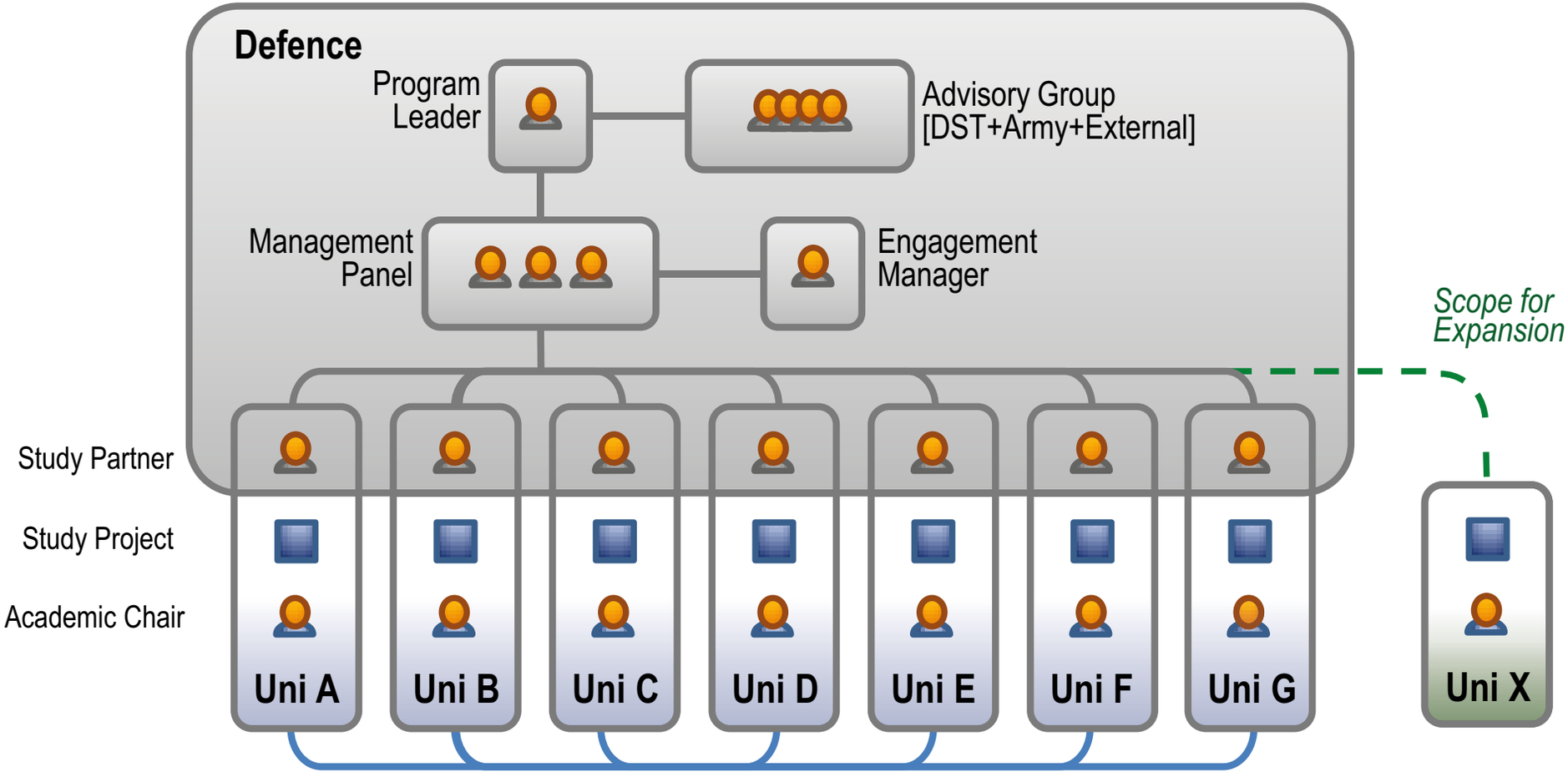
The current members of the **HPR*net*** partnership are Australian universities and signatories to the Defence Science Partnering Deed. Seven universities are currently part of the network:

- Curtin University
- Deakin University
- University of Canberra
- University of New South Wales
- University of South Australia
- University of Western Australia
- Victoria University

Formation


Studies Proposed
Partners Selected
Network Formed
Links Reinforced
Future Expansion

Governance


Defence
Program Leader
Advisory Group [DST+Army+External]
Management Panel
Engagement Manager
Scope for Expansion
Study Partner
Study Project
Academic Chair
Uni A
Uni B
Uni C
Uni D
Uni E
Uni F
Uni G
Uni X

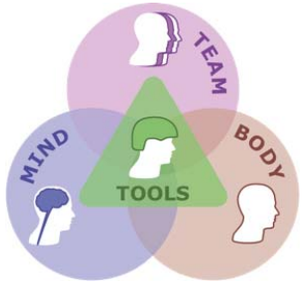
Warfighter Framework

Human performance is recognised across Defence as a critical factor for ensuring a capability edge in a future where technological overmatch cannot be guaranteed.

THE HUMAN SYSTEM

Human systems are generally complex and interconnected. A broad range of research disciplines centered on physiology, psychology, social science and human systems integration are required to understand and advance the human-system.

DST maintains critical expertise in each discipline, grounded in an understanding of the warfighter operational environment. These experts combine with researchers from other disciplines, both within DST and externally, to form multidisciplinary teams focused on enhancing the human system.



The Human System

THE OPERATIONAL LIFECYCLE

Military personnel work within an operational lifecycle throughout which there are different opportunities to improve their ability to perform.

DST's Human Science capabilities are focused on opportunities to Physically & Cognitively, Prepare & Augment personnel to achieve an enhanced level of operational performance and resilience.

The Operational Lifecycle

THE TIME HORIZON

Military stakeholders and research teams exist across each of these three time horizons focused on sustaining current capability, iteratively enhancing capabilities or transforming capability to meet a future threat or opportunity.

DST aims to maintain a balanced portfolio that identifies and supports opportunities for capability enhancement through research and advice across each of these horizons.

The Time Horizon

Research questions to be addressed

COGNITIVE PREPARATION (CP)

CP1 - How can Army select and prepare individuals to make effective decisions in challenging operational conditions?

CP2 - How can Army select and prepare adaptive and resilient individuals to perform effectively in challenging operational conditions?

CP3 - How can Army prepare teams to operate effectively in challenging operational conditions?

PHYSICAL PREPARATION (PP)

PP1 - How can Army select and prepare personnel to be physically resilient for roles conducted in challenging operational conditions?

PP2 - How can Army exploit emerging methodologies to optimise the physical performance of personnel in challenging operational conditions?

PP3 - How can Army optimise nutrition and feeding systems to enhance performance in challenging operational conditions?

COGNITIVE AUGMENTATION (CA)

CA1 - How can Army exploit emerging information systems to reduce cognitive burden and enhance performance in challenging operational conditions?

CA2 - How can Army mitigate the performance decrements of personnel on sustained operations?

CA3 - How can Army exploit wearable technologies to enhance and track cognitive performance and behaviours?

CA4 - How can Army team personnel with autonomous systems to increase combat effectiveness?

PHYSICAL AUGMENTATION (PA)

PA1 - How can Army develop load-sharing systems to enhance physical performance?

PA2 - How can Army continually develop and improve platforms, individual equipment and clothing to allow soldiers to thrive and survive in challenging operational circumstances?

PA3 - How can Army exploit wearable systems to enhance and monitor physical performance?

PA4 - How can Army exploit emerging food and drug technologies for the enhancement of physical performance and resilience?

HPR*net* studies

CURTIN UNIVERSITY

A dynamic and temporal perspective to optimise team resilience.

UNIVERSITY OF WESTERN AUSTRALIA

Selection, training and intervention strategies to improve warfighter situation awareness.

UNIVERSITY OF NEW SOUTH WALES

Trusted human-autonomy teaming in teleoperations.

UNIVERSITY OF SOUTH AUSTRALIA

Psychological methods for improving cognitive performance.

UNIVERSITY OF CANBERRA

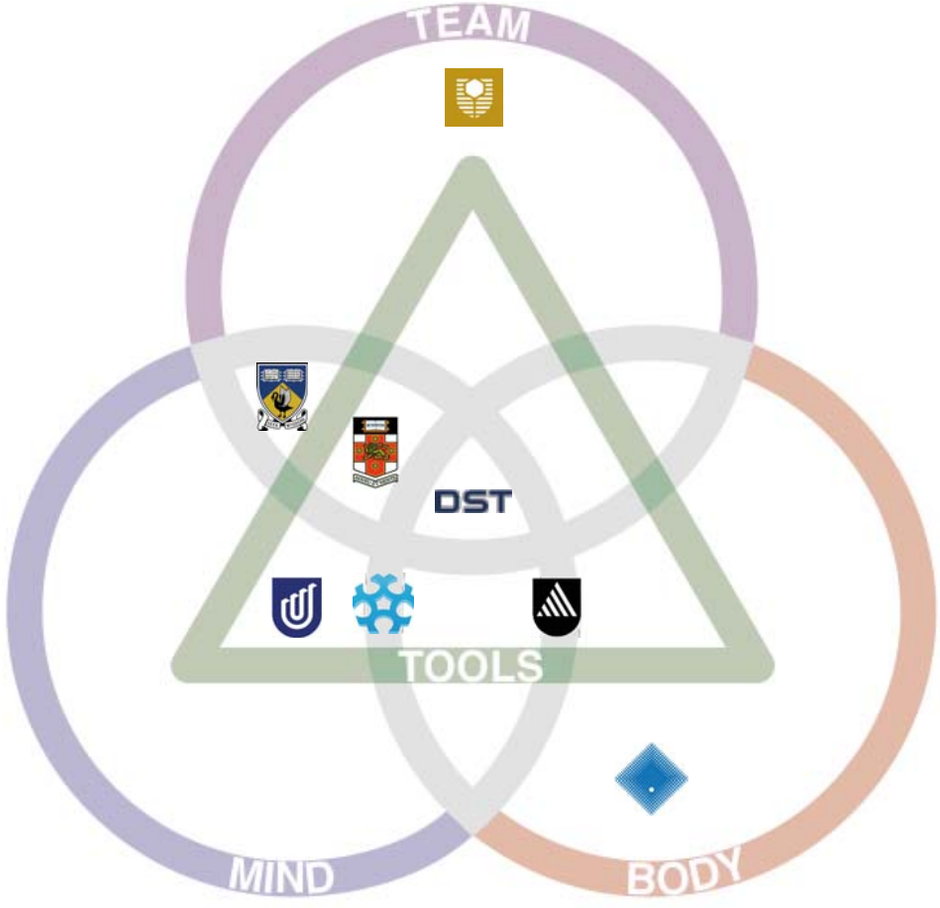
An integrated approach to enhancing cognition and decision-making under stress.

DEAKIN UNIVERSITY

Soldier performance management: monitoring and modelling of load, adaptation and performance.

VICTORIA UNIVERSITY

Combat genes & bioinformatics for physical training.



This figure maps the current HPRnet studies to Army's four human performance domains [Body/Mind/Team/Tools]

Combat genes and bioinformatics in physical training

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

ISEAL
INSTITUTE OF SPORT,
EXERCISE AND ACTIVE LIVING

Australian Government
Department of Defence
Science and Technology

ANTICIPATED OUTCOMES FOR ARMY:

- Ability to identify genetic predictors of baseline physical performance in new recruits
- Ability to identify genetic predictors of the response to physical training, and the likelihood of sustaining an injury during basic training

PARTNERS

- Victoria University and the Institute of Sport, Exercise and Active Living - Prof David Bishop
- Defence Science and Technology Group - Dr Dan Billing

COMBAT GENES & BIOINFORMATICS FOR PHYSICAL TRAINING

Under the project, scientists are performing novel research to inform Army on how best to select personnel to be physically resilient for roles conducted in challenging operational conditions. While limited research has been conducted with military personnel, there is some evidence that genetic variations are associated with physical fitness test scores and lumbar disk disease in army recruits.

The team will extract DNA from approximately 1000 recruits, and, using high-throughput technology, will sequence up to one million markers (variants) across their genome. They will then use advanced bioinformatics tools, with the aim of identifying genetic variations that predict physical performance attributes relevant to the future Army. While the group will focus on physical attributes (for example, strength, power and endurance), the same data could be shared with other members of the research network to investigate genetic determinants of susceptibility to injury or the ability to make effective decisions. There are clear benefits to the future Army of employing personal genomics technologies to aid the selection of new recruits who are most likely to be physically resilient.

In the mid-term, the research will address how Army can prepare personnel to be physically resilient and how the Army can exploit emerging methodologies to optimise the physical performance of personnel. A study published in the prestigious Nature journal, reported that the response of UK army recruits to 10 weeks of basic training depended on their genotype (improvements in strength-endurance were 11 times greater in recruits possessing a particular genetic variation). Subsequent research (not in army recruits) has reported that gains in aerobic fitness can be predicted by a combination of genetic variations.

During this stage of the research, scientists will investigate if genetic technologies can be used to help select recruits who are likely to have the greatest improvements in physical fitness with training, and least likely to sustain serious, career-ending, injuries. In the longer term, the findings of this proposed research would contribute to the development of personalised medicine' for the future soldier. In the next ten years, it will be possible for every soldier to have access to the complete DNA sequence of his or her genome for a modest cost. Advances in genome sequencing technology could then be used in the assessment of personnel at all stages of their military service, from recruitment, individualised conditioning and rehabilitation, to assignment of (active & non-active) duties. This would ultimately contribute to the development of a future Army able to repeatedly outsmart, outperform and outlast a lethal, agile, adaptable and well-connected adversary.

Soldier performance management: Monitoring and modelling of load, adaptation and performance

DEAKIN UNIVERSITY AUSTRALIA

CSR CENTRE FOR SPORT RESEARCH

Australian Government
Department of Defence
Science and Technology

ANTICIPATED OUTCOMES FOR ARMY:

- Development of tools to inform personnel management regarding training loads
- Assessment and description of the physical demands and physiological responses of soldiers during military training
- Prediction of soldier outcomes and responses from sources including wearable sensor data and psychometric inventories

PARTNERS

- Deakin University - A/Prof Paul Gastin
- Defence Science and Technology Group - Dr Jace Drain

SOLDIER PERFORMANCE MANAGEMENT: MONITORING AND MODELLING OF LOAD, ADAPTATION AND PERFORMANCE

Defence personnel are the military's greatest asset. Like athletes, each soldier is an individual with unique psychophysiological characteristics where "one size fits all" training programs and interventions do not work. As such, Defence personnel must be empowered to self-monitor their performance capabilities and capacities, and senior leaders must ensure the resources and environment are conducive to optimising human performance.

Under this project, scientists are seeking to leverage expertise and experience in elite sport to enhance soldier performance and command management through the assessment and monitoring of soldiers in circumstances where the physical and cognitive demands are high.

The specific aims of the project are to:

1. Assess and describe the physical demands and physiological and psychophysiological responses of soldiers in the field.
2. Validate and/or develop methods to detect maladaptive responses from wearable sensor data.
3. Develop prognostic tools that can alert or provide early warning for the likely onset of maladaptive responses.

The project is multi-disciplinary in its approach and spans exercise and sport science, psychology, and information technology. In particular, the project draws on expertise in personnel and activity monitoring, wearable technologies, data acquisition, management, modelling and prediction. Data will be collected from basic and initial employment training as well as field exercises. Data collection phases will range from intensive assessment of specific tasks and training exercises through to less intrusive monitoring over longer periods to establish serial patterns and relationships. Data will be collected by various methods including wearable sensors (heart rate, accelerometer, GPS, gyroscope), activity logs, video filming, and self-report questionnaires (e.g. psychological scales). Performance, injury and illness data will be included where available.

The data collected will be analysed to describe the relationships between physical demands and responses, and as a foundation for providing recommendations for a monitoring framework that is feasible, insightful and minimally intrusive. Data processing techniques will also be used to develop and then evaluate the feasibility of using wearable sensor data to classify and auto-detect soldier activities in the field.

An integrated approach to enhancing cognition and decision-making under stress

UNIVERSITY OF CANBERRA

RESEARCH INSTITUTE FOR SPORT & EXERCISE

Australian Government
Department of Defence
Science and Technology

ANTICIPATED OUTCOMES FOR ARMY:

- Identification of factors that enhance or impair a soldier's capacity to sustain cognitive performance under the combined effects of physical and mental stress
- Development and validation of a practical approach to characterising individual and team resilience under physically and mentally challenging conditions, including complex decision making
- Modelling of the risk factors associated with cognitive performance decline, and development of methods to detect and mitigate them
- Development and evaluation of interventions suitable for: (a) training individual stress resilience; and (b) supporting resilient cognitive performance under operational conditions

PARTNERS

- University of Canberra, Research Institute for Sport and Exercise (UCRISE) - Dr Richard Keegan
- Defence Science and Technology Group - Dr Eugene Aidman

AN INTEGRATED APPROACH TO ENHANCING COGNITION AND DECISION-MAKING UNDER STRESS

Tactical athletes in military settings face unique combinations of physical and mental challenges, demanding high performance across diverse tasks, in often variable and uncertain conditions.

Military settings can generate a disproportionate number of high-pressure situations where it is critical to manage both physical and mental demands to produce optimal performance and outcomes. With significant advances in technology, equipment and physical training, this research focuses on understanding and improving cognition and decision-making. The project will identify the predictors of resilient cognitive performance in soldiers: both stable traits and variable factors such as fatigue, frustration and mood.

Scientists will map out the conceptual framework underpinning cognitive performance, leading to the identification and testing of specific hypotheses within the 4-year project. Given recent evidence of close interdependencies between physical and cognitive performance, the team will develop an integrated understanding of how best to support cognitive performance under pressure – spanning physical, affective, cognitive, and psycho-social factors.

Taking into account current understandings of the factors affecting military-specific cognition and decision making, particularly army and land-based operations, the team will develop practical tools for effective monitoring of key factors that influence performance in these areas.

The team will also develop and test interventions and strategies for supporting, enhancing and recovering soldiers' cognitive performance. Once they have created a clear conceptual understanding, tested evidence to support key relationships, and developed tools to monitor key variables, they will evaluate a tailor-made intervention to determine whether soldiers receiving the program deliver more resilient cognitive performance than those training under current best-practice conditions.

The project will provide the ability to integrate understanding regarding the interface between physiology, cognitive, and psycho-social factors, as well as the cognitive performance of soldiers during both training and operations. The research will provide evidence that can inform training, preparation, recovery and best-practice and a deeper understanding of how best to maintain cognitive performance – applicable within and outside military settings.

Selection, training and intervention strategies to improve warfighter situation awareness

THE UNIVERSITY OF WESTERN AUSTRALIA

Australian Government
Department of Defence
Science and Technology

ANTICIPATED OUTCOMES FOR ARMY :

- Creation of a 'cognitive profiling tool' to assess individual differences in key cognitive skills underlying soldiers' situation awareness
- Creation of a skills-based intervention to train key cognitive skills underlying situation awareness
- Evaluation of the performance gains in situational awareness attainable by tailoring technological displays and automation to the individual 'cognitive profiles' of the operator.

PARTNERS

- University of Western Australia – A/Prof Troy Visser
- Defence Science and Technology Group - Dr Susannah Whitney

SELECTION, TRAINING AND INTERVENTION STRATEGIES TO IMPROVE WARFIGHTER SITUATION AWARENESS

Major advances in computer hardware, software, and sensor technology have greatly enhanced the operational capabilities of warfighters, while simultaneously raising serious concerns about how to best integrate human and technological systems.

A particularly critical variable in this relationship is situation awareness (SA), which refers to an individual's understanding of "what is going on" around them, including perception of relevant information, situational comprehension, and prediction of future outcomes. When SA is lost, because technology fails, unexpected events occur, or operational demands, stress and fatigue overwhelm the limited cognitive capabilities of human agents, serious accidents frequently occur. To address this serious problem, this project will develop selection and training tools to enhance SA across domains by increasing cognitive preparedness and augmenting cognitive capabilities.

The research is aimed at:

a) creating a “cognitive profile” selection tool that validly assesses individual differences in key cognitive skills underlying SA;

b) creating an engaging, skills-based adaptive training application to augment key cognitive skills underlying SA, thereby increasing cognitive preparedness;

c) demonstrate that SA can be enhanced by tailoring technological displays and automation to “cognitive profiles” in order to effectively augment cognitive capabilities.

These aims will be accomplished using both participants from the university community as well as military personnel in analog and realistic simulated conditions, across four research programs.

Program 1 will create a test battery to assess performance on key cognitive skills linked to SA, and then validate that performance on the battery predicts SA and outcomes in simulated vehicle operation and command-and-control (air-traffic control) tasks analogous to those commonly required of Defence personnel.

Program 2 will develop a computer-based training program to enhance specific cognitive skills associated with SA, and verify that resulting increases in cognitive preparation can benefit SA and performance during later simulated tasks. Training will initially focus on three perception/attention skills – VSTM, AC, and multi-tasking – drawn from the “cognitive profile” tool due to their theoretical link with SA, and empirical evidence that training yields generalizable skill gain.

Program 3 will validate the operational effectiveness of the training program developed in Program 2 with expert warfighters and Defence-relevant simulations.

Program 4 will examine whether tailored technological modifications designed to reduce cognitive load or automate some functionality can augment SA and performance more when modifications focus on compensating for areas of reduced cognitive skill (as identified by the profiling tool developed earlier.

Trusted human-autonomy teaming in teleoperations

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

Australian Government
Department of Defence
Science and Technology

ANTICIPATED OUTCOMES FOR ARMY :

- Designing methods for improving the mission effectiveness of teams comprising humans and autonomous systems
- Formulating metrics for measuring the mission effectiveness of teams comprising humans and autonomous systems
- Designing protocols that facilitate intent management and mutual predictability during teleoperation of autonomous systems
- Defining cognitive, behavioral and task complexity indicators to balance the load distribution of sub-tasks among human and non-human actors
- Creating novel methods for real-time load balancing in teams comprising human and autonomous systems
- Development of indicators of trust and trustworthiness
- Delivery of a fully integrated and modular trust-aware closed-loop system for teleoperation and augmented teleoperation

PARTNERS

- University of New South Wales at ADFA, Canberra – Prof Hussein Abbass
- Defence Science and Technology Group - Dr Justin Fidock

TRUSTED HUMAN-AUTONOMY TEAMING IN TELEOPERATIONS

The primary aim of this project is to develop methodologies and metrics for improving and measuring mission effectiveness of human-machine teams.

Decoupling the operator from the operating platform reduces risks for the operator and reduces cost, with a remote operator being able to operate multiple assets simultaneously. However, teleoperation, especially in a war-fighting context, comes with its own challenges. While it removes soldiers from danger, mission effectiveness can be limited if there is not a clear understanding of the operators' cognitive performance in these settings and how that might relate to combat effectiveness. Cognitive performance may be impacted by any number of factors including fatigue, multi-tasking, even having to switch from a civilian to a war-fighting setting.

With these challenges in mind, the primary aim of the project is distilled into four sub-questions:

1. Using wearable technologies, how can human activities during the teleoperation of autonomous systems be automatically recognised? This recognition task facilitates intent management and the development of mutual predictability.
2. What is an appropriate set of cognitive and behavioural indicators for humans, and task-complexity indicators for the task, to enable the distribution of sub-tasks among different human and non-human actors to be effectively load-balanced?
3. What is an appropriate methodology for real-time load balancing between humans and autonomous entities in remotely supervised tasks? Scientists will develop a closed-loop system to allow cognitive indicators from humans and task indicators from the overall system (including autonomous entities) to be used to ensure appropriate load balance between the human and the machine to maximise the effectiveness of the mission.
4. How to assure trustworthiness in a team made of humans and autonomous systems during teleoperations? Trust assurance is necessary to ensure the effectiveness of teleoperation missions.

Psychological methods for improving cognitive performance

University of South Australia

Australian Government
Department of Defence
Science and Technology

ANTICIPATED OUTCOMES FOR ARMY:

- Wearable technology protocols for monitoring cognitive functioning which will be systematically evaluated for their capacity to detect confusion, fatigue and emotional states in soldiers performing realistic operational tasks
- Cognitive monitoring protocol(s) to optimise information flow and task interactions informed by real-time assessment of operator functional states
- Mental training protocol(s) for cognitive performance enhancement in realistic operational tasks
- Evaluation of VR/VA synthetic environments to assess their capacity to deliver the best performing mental training protocol(s)

PARTNERS

- University of South Australia – Prof Mark Billinghurst
- Defence Science and Technology Group - Dr Diane Pomeroy

PSYCHOLOGICAL METHODS FOR IMPROVING COGNITIVE PERFORMANCE

Defence personnel are selected and trained to operate in complex, high-risk environments while interacting with technology. This project aims to create an optimal cognitive screening and training environment by bringing together world-class expertise in virtual, or augmented reality and wearable computing, cognitive neuroscience and mental training.

State-of-the-art mobile recordings of electrical brain activity (EEG) and other physiological signals will monitor cognitive performance while subjects are immersed in detailed virtual simulations of vehicle control, tactical situations and command control environments. Unmanned systems are a new and complex addition to the battlespace that create a cognitive load on operators, exacerbated by immature interfaces. By embedding these virtual unmanned systems in virtual reality it will be possible to assess and mature more effective interfaces.

Simulated environments will allow scientists to devise scenarios for determining vocational aptitude and to assess how cognitive enhancement through mental training impacts on performance. Sophisticated wearable monitoring of cognitive function (using wearable EEG and other physiological sensors) will also be tested and evaluated. Ultimately, these techniques will enable online performance monitoring during real operations to detect confusion, fatigue and possibly heightened emotional states. They will further allow for optimised online information delivery based on individual brain states.

A dynamic and temporal perspective to optimise team resilience

Curtin University

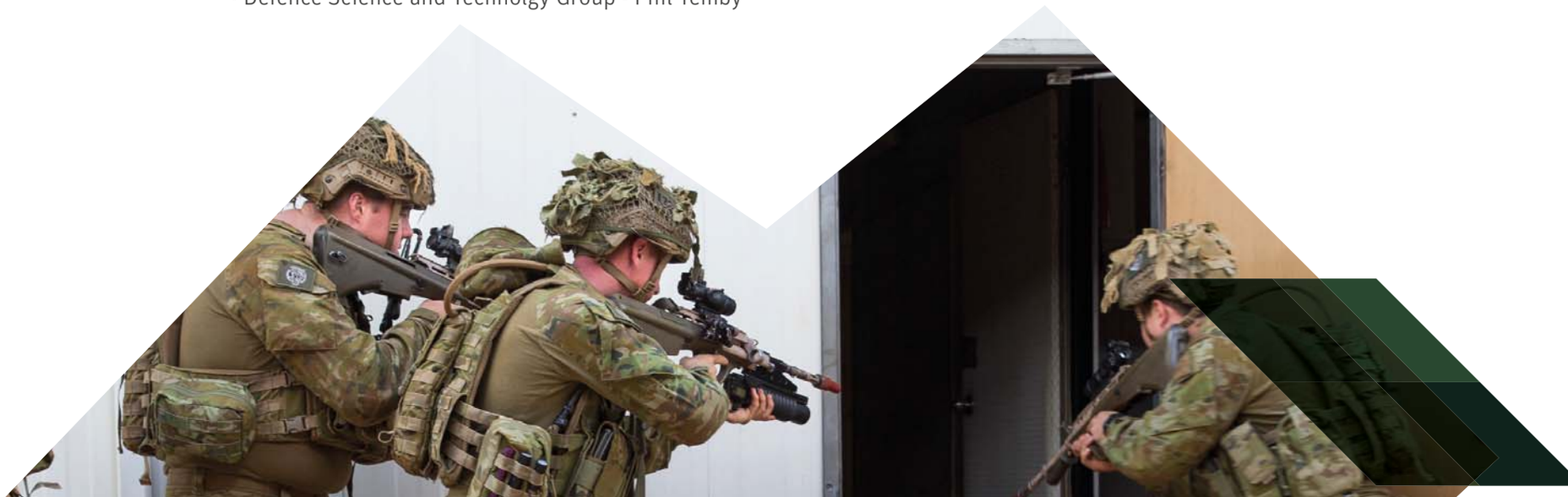
Australian Government
Department of Defence
Science and Technology

ANTICIPATED OUTCOMES FOR ARMY:

- Greater understanding of team resilience in the ADF, and factors influencing teams' capacity to withstand and recover from adverse events and stressors that threaten their functioning, viability and development
- Clarification of the temporal dynamics of team resilience and develop guidelines for intervention design, timing and metrics of success
- Development of strategies to translate research evidence into practice in order to foster and sustain team resilience
- Identification of the most promising behaviour-change techniques suitable for implementing team resilience-enhancing strategies

PARTNERS

- Curtin University - A/Prof Daniel Gucciardi
- Defence Science and Technolgy Group - Phil Temby



A DYNAMIC AND TEMPORAL PERSPECTIVE TO OPTIMISE TEAM RESILIENCE

The notion that teams have the collective capacity to withstand or recover from adverse events or stressors that threaten their functioning, viability or development – referred to as team resilience – has intuitive and practical appeal. However, in contrast to the rich literature on individual resilience, research on team resilience is limited and hampered by weaknesses that render such work inadequate for advancing theory and informing practice.

This project aims to enhance understanding about what team resilience looks like in Army, when and why it matters for Army personnel, and how Army can facilitate this critical team-level outcome.

To address this overarching research aim, scientists will conduct research:

- to generate the necessary theoretical foundations regarding team resilience;
- refine and test these conceptual hallmarks using innovative methodologies that are commensurate with its dynamic and emergent nature; and
- translate this information into recommendations for interventions or practice.

In the first research phase, scientists will gather information that will provide a rich descriptive foundation for theorising about contextually salient components and process mechanisms of team resilience in Army by observing teams in lab-based and field-based settings.

A diverse range of approaches including audio and visual recordings, questionnaires, interviews, and physiological assessments will be obtained to examine the content, structure, and sequencing of interpersonal dynamics between team members during these observations.

In the next research phase, teams will be observed longitudinally to provide clarity on the temporal dynamics of team resilience and therefore when to intervene and what to target.

In the final phase, scientists we will work directly with psychologists and other human behaviour specialists to develop strategies by which the theory and evidence generated in the earlier research can be translated into practice to foster and sustain team resilience in Army.

The network in action...

In addition to the current suite of **HPR*net*** activities, there is potential for current Defence programs to partner to extend collaborative Physical and Physiological Performance (P3R) research.

The objective of this work is to create a profile of the physical, cognitive and physiological (including genetic) parameters that predict *suitability* and *sustainability* for employment in Army.

It is hoped that this work will provide a better understanding of the interplay between cognitive, physical and physiological inputs to task performance and enable the identification of potential genetic predictors of performance and injury, which will inform the design and selection of tailored training methods to match individual soldiers' profiles.

Ultimately, the research will help to improve the *through-career* management of personnel from a physical capacity and injury prevention perspective.

To optimise outcomes for Army, cognitive and genetic data, as well as objective training load measurements from **HPR*net*** studies will be incorporated into the scheduled P3R studies.

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