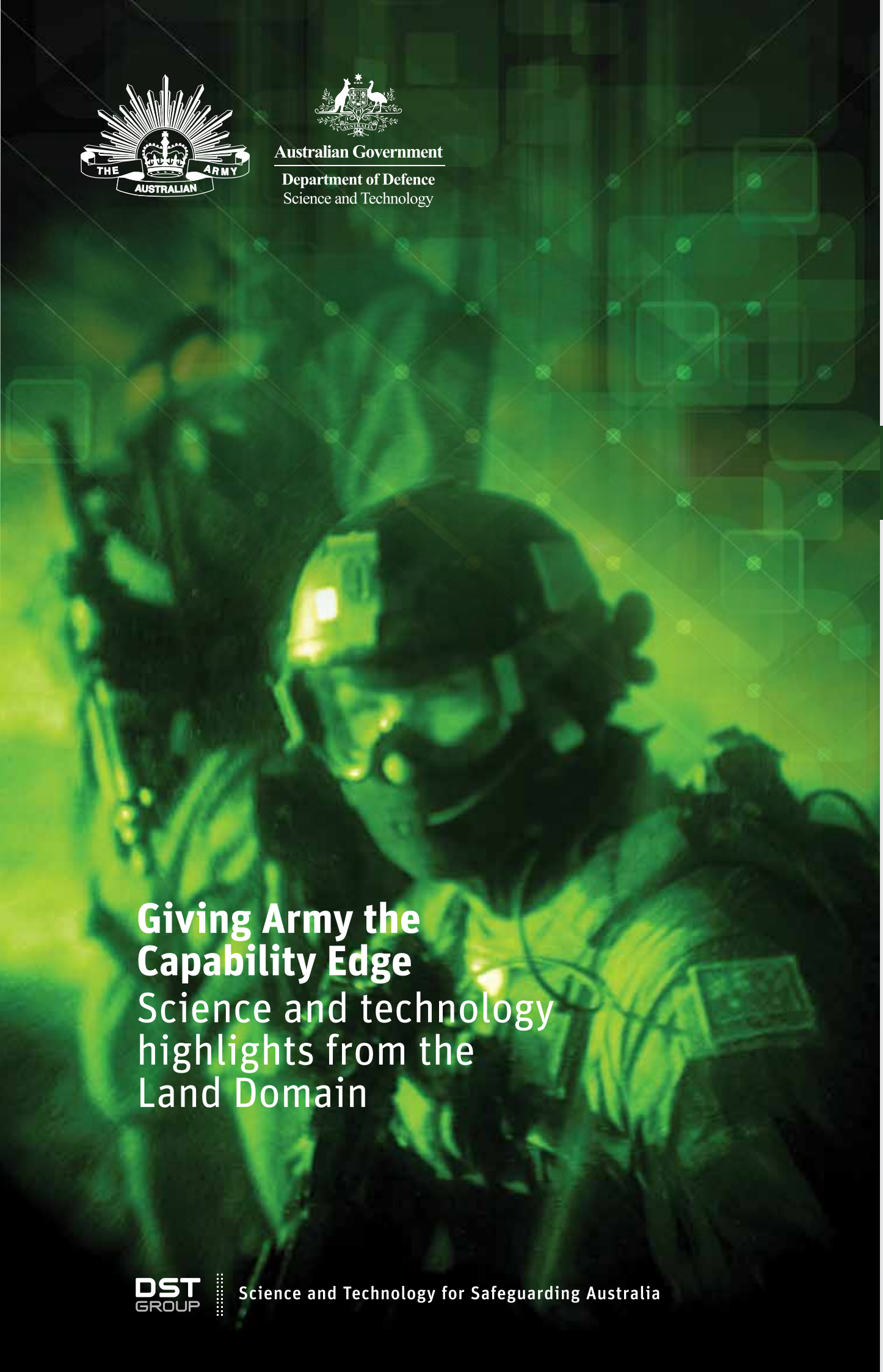


Australian Government
Department of Defence
Science and Technology

Giving Army the Capability Edge

Science and technology highlights from the Land Domain

DST GROUP | Science and Technology for Safeguarding Australia

Giving Army the Capability Edge

Science and technology highlights from the Land Domain

Contents

Capability enhancements in the Land Domain through science and technology – highlights of the partnership between DST and Army

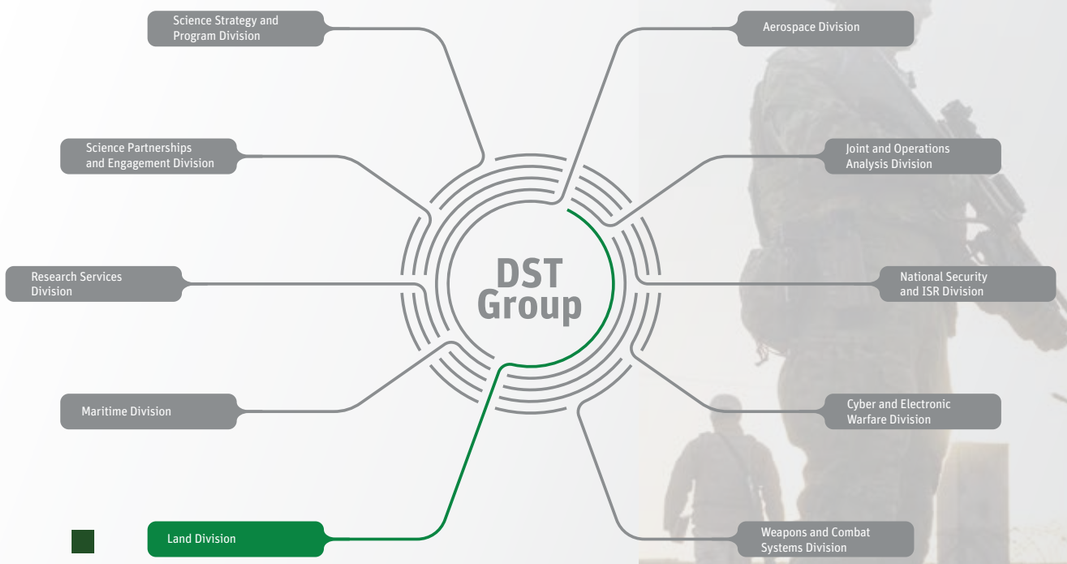
Foreword

DST Group (DST) has partnered with Army on science and technology (S&T) for many decades. This fruitful partnership has produced a wide variety of outputs, ranging from new soldier combat ensembles and enhanced combat rations through to life-saving vehicle armour. DST supports current Defence operations, investigates future technologies for Defence application and ensures Australia is a smart buyer and user of defence equipment. In addition, DST develops new defence capabilities and enhances existing capabilities by increasing performance, adaptability, security and safety while also reducing the cost of ownership of defence assets.

Over the last few years, Defence has been through a rapid transformation in the way it does business. The partnership between DST and Army has also seen much change and transformation. Development of the Army Modernisation Lines of Effort (AMLEs) has provided a strategic framework for the prioritisation of S&T projects. The AMLE framework has also highlighted the accelerating need of S&T support in areas to which Army and DST have not traditionally applied intensive effort. These areas include cyber defence, electronic warfare (EW) techniques, information architectures and intelligence, reconnaissance and surveillance (ISR) capabilities. We are working hard to access deep expertise in parts of DST that have traditionally supported other domains.

The invigorated partnership between DST & Army recently culminated in the launch by Chief of Army of the document, *Shaping Defence Science and Technology in the Land Domain 2016-2036.*[1] This document sets out Army's S&T needs for the foreseeable future, and is closely aligned with the *Army Modernisation Plan.*[2] DST would like to showcase recent highlights of our work with Army, demonstrating the capability enhancements delivered. We do this from the framework of the strategic S&T needs articulated in this document. The sections are grouped into S&T Focus Areas aligned with the AMLEs. Individual outcomes address the military objectives and capabilities listed in the document.

DST welcomes feedback on the scope of the Land S&T program and ideas for future work. We are looking to continually build and develop our partnership with Army. We seek to develop innovative new ideas and to test exemplars and prototypes directly with Army in exercises and trials. We hope you are as excited as we are by the many developments under way, and are willing to contribute to our relentless push to make Army technologically superior to its competitors.



[1] https://www.dst.defence.gov.au/publication/shaping-defence-science-and-technology-land-domain-2016–2036

[2] The Army Modernisation Plan. http://legacy/TeamWeb2010/ARMY/ahq/mspdivision/plans/TAP%20Shared%20Documents%20Library/Forms/AllItems.aspx

Background

DST consists of seven research divisions and three corporate divisions – see organisation chart on the previous page. Land Division provides an integrated research program to Army, supporting all areas of integration from the individual soldier through to integrated combat vehicles and electronic systems. A broad range of scientific disciplines is applied to investigate the design and function of Defence land systems as a means of delivering evidence-based options that enhance safety and effectiveness while achieving the objectives of the ADF. Land Division's four major science and technology capabilities (MSTC) are Chemical and Biological Defence, Land Human Systems, Land Personnel Protection and Land Vehicles Systems. All DST research divisions make major contributions to DST's Land S&T Program. Additionally, DST relies on its international and national partnerships in defence R&D, academia and industry to deliver a comprehensive S&T program in support of the Land Domain.

This booklet mirrors the structure of the document *Shaping Defence Science and Technology in the Land Domain 2016 – 2036* (the sections in italics further on being taken directly from it) while telling the story of the progress DST has made in delivering S&T outcomes to modernise Army.

With the Land S&T Program having been set up to support Army's S&T Focus Areas, closely aligned with the AMLEs, DST has correspondingly appointed AMLE leads, who are listed below.

AMLE	DST Lead	(e-mail)
Force Projection and Application	Mr Brian Reid	brian.reid@defence.gov.au
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1. Force projection and application

Force Projection and Application is focussed on enhancing the combat effectiveness *of Army's collective warfighting capabilities; with a specific focus on the Combined Arms Fighting System and select Special Operations combat capabilities. It is structured to focus on its integral close combat, combat support, and land-based cross-domain capability sub-systems. Army requires integral aviation support capable of providing reconnaissance, surveillance, attack, escort, coordination of joint forces, counter air, command and control, special recovery operations, aeromedical evacuation, electronic warfare and intelligence collection, air mobility and air assault. In addition, this Focus Area includes a dedicated line of research focus for the development of Army's contribution to the nascent Australian Amphibious Force.*[3]

a. Support to acquisition decisions and improvements in tactics, techniques and procedures

Coalition operations within a contested urban environment

The urban arena will be an important operating environment for coalition forces in the future. This battlespace is cluttered with people and infrastructure. In addition to difficulties with the physical terrain, there will be complex social, political, economic, cultural and religious factors to accommodate. To address the complexity of coalition operations within the contested urban environment, the Five Eyes science and technology community through The Technical Cooperation Program (TTCP) established a strategic challenge group to conduct scientific studies and experiments to understand urban stressors, future capability needs and the potential of current and emerging technologies. The Australian Army and DST are contributing to this initiative by developing operational scenarios and capability concepts and supporting technology seminar wargames. A series of technology trials has been planned for 2017 to explore the concepts of wide-area surveillance in support of tactical operations on the ground as well as human terrain understanding and characterisation.

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[3] Excerpt from *Shaping Defence Science and Technology in the Land Domain 2016 – 2036*, p. 4
https://www.dst.defence.gov.au/publication/shaping-defence-science-and-technology-land-domain-2016–2036

b. Architectures and networks

Open vehicle architectures

In February 2015, the Chief of Army announced that the approach to command, control, communications, computers, intelligence, surveillance, reconnaissance and electronic warfare integration in the Land Domain would be based on the adoption of an Open Vehicle Architecture Standard (OVAS). This strategy had long been advocated to Army in briefings by Land Division, e.g. through publications such as *Approaches to Open Technology Systems Specification* released in May 2012 and the OVAS adoption advice that was offered to the Head, Strategic Planning and Modernisation – Army in August 2014. OVAS are standardised architectural approaches to the provision of electronic and software infrastructure in support of an integral vehicle mission system. They are believed to reduce the rework needed to achieve and maintain interoperation and integrity of vehicle mission systems, lead to a smart use of space, weight and power, accelerate mission system upgrades, and provide appropriate management of the rising complexity and rate of advance of technology. The Chief of Army's announcement, supported by DST advice, thus hails a new era of Australian land vehicle mission systems that will be more likely to withstand the test of time.

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Land vehicle autonomic self-management

While developing a system called Ravos to enhance and protect the operation of combat vehicle mission systems, the thinking of Land Division researchers has been influenced by three factors:

- Digital age combat systems (sensors, services, effectors and processors) will rarely be isolated and will have some level of communication.
- Systems working together within vehicles and in between vehicles can provide a significant capability advantage beyond single systems.
- In an ever-increasingly complex digital environment, there is a strong risk that an operator may be overloaded by the cognitive demands of not just using all these systems, but managing and configuring them.

Ravos will deliver a mission system across vehicles with autonomic self-management that is aware of and responds to changing context (such as challenges, loads and tasking activities) without relying on operator interaction. In a contested and degraded environment, Ravos monitors the mission system components for performance and wellbeing and applies changes to protect and heal those systems. Ravos will also arrange the components and modes of the system in appropriate configurations to enhance overall functionality and to optimise performance. The outcome for the warfighter will be a resilient and versatile vehicle combat system that reduces cognitive load on the operator during many modes of operation.

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c. Weapons and mission systems and effects

Development of enhancement options for ADF blast and fragmentation grenades

During the period 2011-2014, DST was tasked by Army Headquarters (through OPSTSR 134) to investigate cost-effective options for delivering a range of blast grenade concepts. It was also tasked to identify and quantify the lethality of the current in-service F1 grenade and to investigate simple modifications to increase its lethality. During this period, DST undertook several experimental programs involving more than 230 firings. A variety of explosive formulations were characterised, including high performance pressed formulations that were manufactured using a new mixing technique known as Resonant Acoustic Mixing. Three separate blast grenade concepts were developed and this included the F4 modular system (single module NEQ =150g, two modules NEQ = 350g), the F4-300 Heavy Offensive blast grenade and the F4-400 Anti-Structure Munition (for Special Forces use).[4]

Investigation of the F1 grenade resulted in a revised design (F1AX). A number of these grenades were manufactured and a comparative trial was undertaken to compare the relative performance of the old and revised designs. The new design used modified explosive pellets that contain approximately 12% more explosive due to the removal of the detonation wave shaper and a new fragmentation liner consisting of a dual layer of larger diameter fragments. While fragment velocity remained about the same, the fragments, being heavier, delivered higher energy on target. The redesign of the matrix liner ensured a more even spatial distribution of fragments.

DST is currently working with Thales and Army Headquarters to investigate the potential to incorporate these into future locally-manufactured ADF products.

Land 400 lethality assessment

Over the last twelve months, DST has developed a hydrocode modelling capability to evaluate the performance of tungsten heavy alloy armour-piercing projectiles against modern light and medium armour configurations. These configurations included complex material and spatial arrangements and orientations.

The model was developed alongside an extensive experimental program where detailed measurements of penetration, preformation and spall data were obtained by performing experiments on available ammunition and target materials. The experiments were designed to capture features relevant for developing the model and of importance for future lethality assessments, in particular, the depth of projectile penetration and spall damage zones.

The data were used to help validate the model and formed the basis for penetration and preformation predictions on proposed future ammunition calibres with a broader set of engagement conditions.

This work provides fundamental data and models for the lethality studies of interest to Land 400, and has informed the design and content of the target model being built for those lethality studies.

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[4] NEQ – net explosive quantity.

d. Combined arms team effectiveness

Analysis of Land 400 Combined Arms Team effectiveness using combat simulation

DST is conducting combat simulation-based analysis on the impact of proposed Land 400 vehicle options on the tactical effectiveness of future combined arms teams. This analysis focuses on the tactics employed by elements of a combined arms team and the enemy in a range of environments, and emphasises the interdependencies within the team rather than the operations of single vehicles.

Combat team performance is analysed using the US-developed combat simulation, Combat XXI. This is a detailed combat simulation requiring extensive modelling of the relevant vehicles and enabling systems as well as the development of suitable representations of the physical terrain, enemy systems and the range of tactics that may be employed.

A combined arms team in the assault mode of operations.

The combat simulation capability is currently supporting Phase 2 of Land 400 by conducting a comparative evaluation of the tendered Phase 2 Combat Reconnaissance Vehicle options and configurations. This evaluation analyses combat team performance when conducting key missions as identified in the operational concept document. Preliminary combat simulation support is also being provided to the next phase of Land 400 (Phase 3) to evaluate the operational impact of possible infantry fighting vehicle options. This analysis focuses on the impact of major physical characteristics of the vehicles being considered (i.e. wheeled or tracked fighting vehicles) and whether the differences these present in terms of the mobility, protection and firepower at the vehicle level impact on combat team effectiveness. Plans are in place to provide ongoing support to the Land 400 fleet through life via the analysis of the operational impact of proposed upgrades.

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e. Structural integrity of aircraft and accident investigations

Support to Army aviation

DST has an extensive S&T program that supports ADF throughout the complete life cycle of Army (and Navy) helicopters. This includes support offered during the needs and requirements phase through to the acquisition, preparation and operations phases. The S&T work also includes support for helicopter maintenance and repairs, crashworthiness assessment and enhancement, armour protection, accident investigations, risk reduction, support to introduction into service of the Armed Reconnaissance Helicopter (ARH), Multi-Role Helicopter (MRH 90) and Chinook (CH-47F) helicopters, support to brownout mitigation and air crew situation awareness, and support for night vision devices, combat survivability and load carrying.

For the first time, all ADF helicopters will be required to operate in the maritime environment with all the challenges this implies. DST has an active research program that will investigate many of the aspects associated with this new operating environment. The research program is helping to reduce the risks associated with first-of-class flight trials as well as investigating the impact of the corrosive environment on aircraft components.

In addition, the Helicopter Advanced Fatigue Test Technology Demonstrator Program supports the structural integrity management of helicopters through the demonstration of technologies required for full-scale fatigue tests. This addresses the problem that, for helicopters, these tests typically take too long to complete to obtain meaningful results for fleet management. The objective of the program is to enable the completion of full-scale fatigue tests in a condensed timeframe, allowing early identification of potential risks during long-term helicopter operation.

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f. Unmanned systems

Trusted Operation of Remote Vehicles in Contested Environments (TORVICE)

TORVICE is a major collaborative initiative involving a partnership of DST with the US Army Research, Development and Engineering Command. It straddles a range of technology areas and cuts across multiple DST Divisions. The primary aims are to demonstrate reliable tele-operation of a semi-autonomous unmanned vehicle at Woomera from continental US via a satellite link in order to understand the vulnerabilities of an unmanned vehicle that could be exploited by an adversary, and to propose and demonstrate solutions to these vulnerabilities. In this partnership, the strengths of the world-class technologies in vehicle autonomy developed by the US Army Tank Automotive Research Development and Engineering Center are harnessed with DST's strengths in pulling together multi-disciplinary teams in sensor systems, surveillance and reconnaissance, electronic warfare, information architectures, satellite communications (SATCOM) capabilities and precision navigation and timing to perform a red-teaming role against the vehicle. This program is part of a long-term strategy to develop confidence in the use of autonomous vehicles and to explore their utility in human-machine teaming.

The first trial was successfully completed at Woomera in September 2016, and provided insights into the complexity of tele-operating vehicles from the other side of the globe. A follow-on trial towards the end of 2017 will investigate intensive red teaming of the vehicle through electronic warfare and communications techniques. Further trials will then seek to mitigate exposed vulnerabilities. The trials series is an excellent opportunity for DST and Army to form a strong enduring partnership with one of the leading military vehicle R&D organisations in the world. More discussion about the trials and SATCOM technology development will be provided in the section on SATCOM-On-The-Move later in the booklet.

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Trusted autonomy

DST is conducting a multi-year Strategic Research Initiative (SRI) on trusted autonomy. This SRI spans a broad range of challenges in realising autonomous systems in a military context. Under the Next Generation Technologies Funds announced in the Defence White Paper, this initiative is now transitioning into a major Defence Cooperative Research Centre. A particular land-focused activity within this program is investigating multi-mission autonomous systems for urban applications. This has the goal of enhancing military operations in cluttered, complex and contested urban environments through the use of autonomous systems, including unmanned aircraft systems (UAS) and ground robots.

Entirely new capabilities for urban missions are being enabled by integrating sensors, algorithms and computational hardware with reduced size, weight and power demands, and by utilising heterogeneous robotic teams.

The early stages of the research in the previous year focused on creating adaptable UAS for missions in urban canyons and indoors by:

- exploiting developments of lightweight ranging and imaging sensors (chip-based radar, electro-optical, infrared, and low-light sensors never before trialled on autonomous vehicles); and
- demonstrating mapping algorithms for use with such sensors.

In addition, novel algorithms were developed and validated to support information exchange (tactical radio communications) between end-users operating in open terrain and radio frequency (RF) contested or denied environments (e.g., as a result of jamming) through the use of a fleet of autonomous UAS.

In 2017, the focus is on multi-modal sensing that permits navigation and ISR data collection under challenging and variable conditions (e.g., in darkness, outdoors in strong sunlight, and with visual obscurants). Novel algorithms controlling autonomous UAS to enable tactical radio communications in outdoor urban terrain and contested RF environments will also be developed and tested.

The SRI activity is leveraging international collaboration with TTCP nations in support of the Contested Urban Environment Strategic Challenge and a Program Arrangement (PA) with US Air Force Research Laboratories on UAS-enabled radio communications (Project OPAL), as well as a PA with Singapore on UAS navigation in urban terrain.

For example, data collected during a recent TTCP trial held in DST's Indoor Flight Laboratory showed a parking area just outside the laboratory and an interior portion of the laboratory that was visible to the ranging sensor through windows and other openings in the building.

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2. Human performance

Human Performance is focussed along four subordinate themes: Body, Tools, Mind, and Social. The 'Body' line of effort (LOE) relates to the physiology of an individual. Modernisation initiatives and milestones under this LOE include defining and prioritising performance attributes for individual conditioning, potentially leading on to real-time physiological state monitoring and development of artificial or self-repairing tissues/organs. The 'Tools' LOE sits between Body and Mind and relates to the equipment, consumables, systems, facilities and documented knowledge designed to augment an individual's physiological or cognitive abilities. Modernisation of tools under this LOE is exemplified by the intent to develop Human Performance Centres, load sharing equipment, hybrid vision devices and Combat Resilience Centres where immersive and adaptive training systems provide realistic training across live, virtual and constructive domains. The 'Mind' LOE relates to cognitive abilities and includes modernisation initiatives to develop advanced decision-making techniques and improved resilience, leading to cognitive function development and training before the introduction, if required, of augmented cognition. The 'Social' LOE relates to the development of capable teams and adaptive institutions that support our people through initiatives such as the alignment of training and education with organisational needs, leading to the maturation of Army as a learning organisation.[5]

a. Cognitive sciences

Within the process of designing and selecting tools to support the training and cognitive performance of individuals and teams, important opportunities are at hand for enhancing Defence capabilities. DST research into eye-tracking for room clearance and immersive simulation technologies for vehicle training are positioning Army to identify and seize the opportunities these emerging technologies offer. Further innovations such as DST's unpowered operational exoskeleton and the fielding of wearable sensor technologies all help push the boundaries of warfighter performance and raise the overall capabilities of Defence.

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Cognitive sciences research laboratory.

[5] Excerpt from *Shaping Defence Science and Technology in the Land Domain 2016 – 2036*, p. 6
https://www.dst.defence.gov.au/publication/shaping-defence-science-and-technology-land-domain-2016–2036

b. Human-centred physical sciences

The human performance and resilience aspects of the land force capability are increasingly recognised to be critical given a future in which technological superiority cannot be guaranteed. Army identified Human Performance as one of its key lines of effort for modernisation, and has worked closely with DST to define and pursue these critical land force research priorities. DST has a strong track record of driving practical enhancements to land capability. This capability has been expanded through research partnerships and is focused on the performance of the warfighters along with their enabling platforms and equipment.

DST's human-system focused research and advice has made a critical contribution to the continually expanding catalogue of successes that the Diggerworks partnership of Army, the Capability Acquisition Sustainment Group (CASG) and DST has achieved since its formation in 2011. A notable example is the evolution of the Tiered Body Armour System, which delivered a truly fit-for-purpose body armour system informed at every step by DST's research results on the protective performance of in-service systems on operations. Other examples include mobility constraints and organ coverage. Numerous additional soldier combat system components have been enhanced on the basis of rigorous assessment including the camouflage uniform, combat helmets, packs and water purifiers, to name a few.

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A more subtle but far-reaching contribution to the capability of Army and broader Defence has been the establishment of Physical Performance Standards (PES). Initially developed for Army, PES has spread to better address the particular physical demands of all trades across the Army, Navy and Air Force. DST's rigorous and robust methodology for identifying and setting the critical physical competencies required for individuals to safely and effectively complete the functions of their assigned trade does much more than support the ADF's progress towards removing gender discrimination. The implementation of PES is providing all three services with the tools to improve an individual's performance in their trade tasks and to reduce the ever-present risk of injury along with the substantial costs associated. When multiplied across the tens of thousands of Defence personnel, the annual contribution to ADF capability is huge.

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DST scientists Alison Fogarty and Greg Carstairs keeping ADF personnel safe from the risks associated with extreme heat.

c. Food and nutrition sciences

Another research contribution that might appear modest, but actually scales into a substantial impact on Defence capability is the research that informs the fresh and combat ration feeding of the ADF. DST's targeted research into the feeding needs of the Defence population, and in the quality of the foods provided, is cumulative. One line of research is helping Defence to understand and shape eating behaviours while another line is incrementally raising the quality and acceptability of the food provided to Defence personnel. Systems that rely on sustaining peak performance of personnel cannot afford to underestimate the contribution of food and nutrition to their overall performance and reliability.
While these examples demonstrate impacts achieved, the human sciences are pursuing leading-edge enhancements to capabilities that promise to deliver advances in the future. In the area of food and feeding, DST is working in partnership with universities and industry to develop an exciting new food processing technology known as microwave-assisted thermal sterilisation that has the potential to 'raise the bar' for the quality of shelf-stable food provided to Defence personnel.

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d. Social sciences

Special Operations Headquarters functional analysis

DST conducted functional analysis of the Special Operations Headquarters from May to August 2015. By applying a variety of qualitative techniques, the analysis identified seven key insights into the Headquarters' functions and processes, developed eight approaches to fix the identified issues and problems, and proposed four structural options. The analysis was received very positively. The Special Operations Commander, Major General Sengelman, commended the study, noting that, "The insights your team have provided will ensure that I am armed with the information required to redesign the organisation with a focus on effectiveness and efficiency."

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e. Human performance partnerships

DST analysts became aware many years ago that the number of opportunities for enhancing Defence capabilities through human performance research far exceeded DST's internal capacity to investigate. A strategy was therefore formulated for establishing co-invested partnerships, which has delivered a range of productive collaborations including the PES Centre of Expertise, the Centre for Food Innovation and international partners within TTCP. The overall result has been a continuing stream of research outcomes for Defence. The latest initiative arising from this strategy is the Human Performance Research network (HPRnet) in which Army and DST are drawing on the expertise of universities across Australia to further expand the reach of human performance research in order to tackle Land Domain research priorities.

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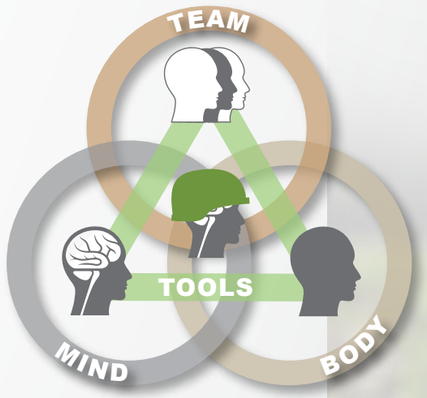

Systems diagram depicting research partnerships.

3. Force protection

Future land forces need to be structured, trained and equipped with integrated passive, reactive and proactive force protection measures which allow them to survive to fight in the future littoral urban environment. The reinforced combat brigades will be able to conduct all operations in a Chemical, Biological, Radiological, Nuclear and Explosives (CBRNE) environment, whether caused by deliberate attack or industrial accident; physical threats to personnel, vehicles and structures will be minimised; networks and systems operating within the electromagnetic spectrum will be protected from electronic and cyber attack; and the commander's freedom of action, and the integrity of his force, will be protected through counter-surveillance and deception measures.[6]

a. Chemical, Biological, Radiological, Nuclear and Explosives defence science

Land Division's Chemical Biological Defence and Land Personnel Protection branches provide specialist training and support to Special Operations Command (the Special Operations Engineering Regiment (SOER) in particular) to further their understandings of the hazards posed by Chemical, Biological, Radiological and Nuclear (CBRN) materials and how to best use their equipment while operating in proximity to them. The training includes lectures and laboratory activities as well as exercise support that enables SOER to gain realistic experience of all kinds of CBRN incidents in a safe environment. DST Chemical Biological Defence scientists also offer 24/7 'reach back' support via the Science and Technology Cell that provides SOER with expert support on site. Should the need arise, they can provide specialist scientific advice channelled through the Senior Scientific Adviser at SOER, and additionally, assistance can be given 'on the ground' via a Forward Deployed Scientist attached to the regiment.

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Tender evaluation

Land Division provided significant support to CASG for the LAND 2110 Phase 1B Tender Evaluation. All assessments and advice were rapidly completed during this time-limited activity, including assessment of radiological detection equipment, chemical detection equipment and CBRN protective clothing ensembles and human factors.

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Black Canary

Land Division's chemical biological defence scientists are developing a mobile-phone sized low-cost detection technology, called Black Canary, that immediately alerts wearers to the presence of toxic chemical vapour. Removing the human from the loop, the device uses multiple machine-read optoelectronic-reactive colour cartridges to detect and then identify threats. Sophisticated pattern-recognition algorithms remove false positives. Automated two-stage self-alarming is built in, as is Wi-Fi for communication with commanders or other platforms. This reusable device integrates eight swappable disposable cartridges, the make-up of which may be targeted to known threat options or used more broadly as a screening tool. Current configurations can positively detect and identify eight toxic industrial chemicals, and cartridges for many other targets have been identified. Work with a local manufacturer to develop Black Canary to technology readiness level, TRL8, is continuing.

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Black Canary – a wearable chemical detector.

[6] Excerpt from *Shaping Defence Science and Technology in the Land Domain 2016 – 2036,* p. 8
https://www.dst.defence.gov.au/publication/shaping-defence-science-and-technology-land-domain-2016–2036

Respiratory protection

Maximising protection against CBR threats while minimising the burden associated with respiratory and dermal protection is key to enhancing mission effectiveness in a CBR environment. DST has partnered with the Defence Materiel Technology Centre to develop a concept nanofibre composite material to improve dermal protection against aerosol threats. DST has also partnered with Defence's Rapid Prototype Development and Engineering facility to develop broader-spectrum longer-lifetime respirator canisters.

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CBRNfx modelling

The Chemical, Biological, Radiological & Nuclear Effects Modelling (CBRNfx) team has provided rapid analyses to support operational decision-making. These analyses provide modelling predictions of the consequences of potential releases of CBRN materials. The team also provides ongoing training, support and advice to SOER in atmospheric dispersion hazard modelling. Advice is also provided to a range of national security agencies, for example, in the planning of major events to characterise the threat from potential terrorist use of CBR materials. For the past several years, the CBRNfx team has collaborated with Geoscience Australia (GA) to estimate the remediation cost following a terrorist attack involving a chemical or biological weapon on an Australian city. This collaboration has involved combining DST predictions of the extent of contamination with GA modelling of the clean-up costs. This information is used by the Australian Reinsurance Pool Corporation (ARPC) to support decisions on the size of the reinsurance pool, which was set up by the Australian Government following the global withdrawal of terrorism insurance after the 2001 Amerithrax incident in the US.

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Disease surveillance

The Bioterrorism Preparedness Strategic Research Initiative is developing an infectious disease detection and forecasting capability. This has recently been successful in securing significant funding support (A$1.2 million) from the US Coalition Warfare Program to develop decision-support tools and applications for epidemic and pandemic management. DST is working with the US Department of Homeland Security on a joint action plan to examine options for health and disease information-sharing and joint development of disease surveillance systems. As such, Australia is well positioned to contribute as an international partner to share data and collaborate on a global bio-surveillance network.

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Radiological defence

The Radiological Defence capability has provided specialist training, advice and support in radiological detection and identification to SOER. This group has also been conducting research to provide SOER with a niche capability in standoff imaging radiation detection through development of a prototype gamma-ray imager. The gamma imager provides a 'heat map' image of radiation intensity, allowing the operator to locate and characterise a radiation source without needing to do a manual search that could expose personnel to radiation or other hazards associated with a radiological device. The gamma imager has been made available to SOER for exercises, and the evaluation with feedback it has offered is being used to improve imager functionality. DST is pursuing a patent for the imager and looking for partners to develop and commercialise it.

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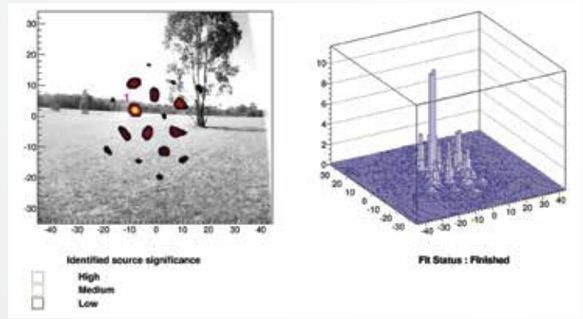

Heat map image of radiation intensity.

Prototype gamma ray imager.

Global-reach military sensor network – demonstrating the internet of military things

While the 'internet-of-things' (IoT) takes on a flourishing life of its own in the commercial world, its impact in the military context is less prevalent. Land Division is investigating novel military applications of IoT concepts and techniques through integrating innovative technologies to exploit the benefits of the IoT. The current technology demonstration under way involves integrating two innovative and very new technological capabilities to achieve a unique global-access chemical vapour sense-and-warn capability for tactical land forces. The concept combines the prototype Black Canary chemical sensor with a state-of-the-art low-cost commercial satellite transceiver and network, designed and operated by Myriota Pty Ltd. This system has the potential to deliver crucial threat warnings directly from the battlefield to those anywhere in the world who need to know, thus significantly improving their situational understanding.

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b. Improvised threat countermeasures

The Huckleberry is an improvised explosive device (IED) countermeasure capability that was developed by DST in response to an urgent operational need arising from the emergence of new threats. Huckleberry was integrated, technically certified and introduced into operational service in 2015. It increases the capability of the current in-service ADF counter-IED system, and provides enhanced protection to ADF personnel against new threats. In addition to saving lives, this research outcome also saved Defence several million dollars in acquisition, system and vehicle integration and on-going sustainment costs. Huckleberry is estimated to have saved about $5 million directly and about $1 million per annum in sustainment costs.

REDWING family of counter-IED devices.

The REDWING program has delivered a suite of low-cost robust lightweight protection systems developed by DST to counter IEDs. In 2015, REDWING units were sold and delivered to the Afghanistan National Security Forces. After a visit that year to Afghanistan by the Australian Military Sales Office, Afghanistan placed an order for a further 55,000 units, bringing the total for units sold to 160,000. REDWING Phase 2 development is scheduled to commence in 2017.

DST has provided support to enhance vehicle-mounted ground-penetrating radar and metal detector systems through the application of expertise, characterisation of sensors and development of automatic target recognition algorithms. Comparative performance analysis of operational and evolving ground-penetrating radar systems has been conducted to identify existing capability gaps and inform Army of potential solutions.

S&T advice has been provided on LAND 154 Phase 2 Detection Capability Development for IEDs. Input has been made to the ADF Request For Information to tenderers. Capability analysis and evaluation trials have been planned.

c. Soldier, vehicle, aircraft and infrastructure survivability

Integrated personnel protection

The Integrated Personnel Protection group within Land Division undertakes work to provide dismounted combatants and first responders with integrated protective measures that offer wearers freedom of action for the conduct of operations in all environments.

The group applies evidence-based problem-solving and undertakes enabling research and development. Areas of expertise include ballistics and blast mechanics, the development of composite and textile materials and personnel armour systems (including specifications and standards), personnel vulnerability modelling, electromagnetic signature management development and assessment, textile treatments and properties, flammability, battle damage assessment of personnel armour systems, functional materials and electrical power systems. A research program in power and energy has now reached a mature stage of development (described later in this booklet), and related programs in other enabling capabilities such as autonomous systems, augmented reality and bioinformatics are currently being developed.

Within this R&D area, the Blast and Ballistic Effects science team investigates light-weight personnel protection systems being used to protect dismounted personnel against the effects of ballistic or other kinetic impacts and blast overpressures.

R&D is also undertaken into functional materials and sensors to investigate material characteristics that may be applied to the protection of personnel in operational environments.

This includes investigations into integrated sensing technologies that assist with threat detection for a dismounted combatant. In addition, electromagnetic spectral signatures are captured of environments of interest to ADF personnel and assets within those environments, and modelling is undertaken in order to simulate and evaluate the effectiveness of signature treatments for personnel and high value assets.

Vehicle survival

Comprehensive vehicle survival S&T support to ADF and national security clients is provided to enhance survivability of occupants, maintain vehicle mobility and achieve mission success under a wide range of threats.

Large-scale blast, ballistic and chemical energy test and modelling capabilities are used by DST researchers to understand the protection mechanisms available to defeat evolving threats and to gain an understanding of resultant human injury levels. Vehicle protection S&T focuses on minimising these injury levels in order for personnel to survive without significant impairment. This work enables ADF to be both a smart buyer of military vehicles as well as a smart user of its current vehicle fleet when operating in high-threat environments. The ability to adapt the base protective vehicle hull to defeat evolving threats provides scope for growth in threat survivability. Generally, this adaptation would take the form of a multi-role armour applique.

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Blast protection applique

DST has a thorough understanding of the injury mechanisms resultant from blast effects on vehicle platforms. Given that any increases in vehicle mass impact on vehicle mobility, DST is examining the use of already-carried fluid mass as part of a blast mitigation system. Solutions with a focus on deformation reduction – deformation being a key failure mode that leads to injury – have shown great promise according to empirical blast results. DST researchers are concentrating on understanding and refining the parameters that will allow the technology to be applied on Defence vehicles.

High speed 3-dimensional measurement of threat protection

During a landmine event, whether a person lives, dies or is injured is mostly determined within the first 2-20 milliseconds. Filming these events with high-speed cameras gives a view of how they unfold. To fully understand them, they need to be filmed with a 3D camera array. The space involved can thus be calibrated, allowing moving objects to be tracked and measured within that space. Measurements of trajectory, velocity, and acceleration can then be made to enable the formation of understandings on what happens, when it happens and where it happens. The findings of this work allow for the targeting of areas with substantial payoffs while those that are not as important can be given less attention.

Smarter lighter materials – ultra high molecular weight polyethylene

DST has conducted world-leading research into lightweight materials, including ultra high molecular weight (UHMW) polyethylene, that offer significantly improved ballistic and fragmentation protection for vehicles. The research work, involving many instrumented experiments, provides a new understanding of how thick-section composites reinforced with UHMW polyethylene fibres behave under ballistic impact. Additionally, innovative physics-based analytical and numerical tools have been developed that enable detailed analysis and rapid and accurate performance predictions to be made for this very promising armour material. This work included high-quality international collaborations on numerical modelling with the Fraunhofer Ernst-Mach Institute in Germany and resulted in significant international recognition by world-leading international peers. The work is now being applied and further developed in support to LAND 121, LAND 400 and National Security vehicle protection programs.

STANAG panel on armoured vehicle protection

DST's Land Division hosted the first-ever meeting of the Armoured Vehicle Protection NATO STANAG 4569 Team of Experts (ToE) Panel on Australian soil in Melbourne in October 2016. The panel, working on a full consensus basis, agreed to future updates in the existing STANAG documents, with most of the panel's effort focused on developing a new document that defines protection against a new class of threats. This government-to-government panel is composed of over 40 scientific and military experts from 16 countries. It defines vehicle ballistic and blast protection levels and related vehicle test and evaluation against a range of symmetric and asymmetric threats. Its work is critically important to Australia since it supports the definition of the protection levels of the Australian Army's fleet of new armoured trucks and is used to specify what protection Australia's next generation of combat vehicles will afford to Australian soldiers. Discussions and outputs of the STANAG 4569 ToE also further Defence's understanding of the protection performance of military vehicles on operations. DST gained Australian membership on the panel in 2013, and our participation is in line with the intent of both Australia and NATO to deepen dialogue and practical co-operation.

In the past year, DST has strengthened key alliances with the US Army Research Labs via an exchange scientist position and with the UK Dstl by collaborative studies.

d. Signature measurement, management and control

Non-acoustic signature management – electromagnetic signature control in the land environment

The Electromagnetic Signature Control (ESC) Group within DST's Maritime Division supports the Land Program by:

- Understanding the land forces surveillance threat environment, including emerging and disruptive surveillance capabilities, to advise on the development of counter-surveillance requirements for platform acquisitions and to direct our research into signature modelling, evaluation methods and materials development for signature remediation.

- Evaluating (in collaboration with measurement experts from other DST Divisions) signatures of newly acquired, upgraded or candidate platforms to inform acquisition decisions and tactical usage decisions. An example from recent years is the evaluation of visible, thermal and acoustic signatures of the Navy special operations vehicle for JP2097.
- Testing the effectiveness of signature management systems, such as camnets and applique multispectral camouflage systems, for land vehicles and equipment. This includes laboratory testing of the radar-absorbing properties of materials as well as field-testing the visible and infrared signature effects of systems when installed on vehicles and equipment.
- Evaluating signatures of in-service platforms and equipment, using image capture and analysis, field observation and photo-simulation – a recent example being evaluation (in collaboration with Land Division field operations experts) of camouflaged vehicles and field installations during the Predators Gallop and Predators Strike exercises.
- Modelling platform signatures for operationally relevant evaluations. ESC Group's visible signature modelling capability for land vehicles is at an advanced stage of development and aims to allow signature evaluation to be undertaken in synthetic imagery constructed of any operational environment of interest. ESC group conducts modelling of thermal infrared signatures of maritime platforms, some techniques of which can be applied to predicting the thermal signature of land platforms and equipment.
- Developing signature management materials and solutions. ESC Group has developed and fielded effective radar signature management material solutions for ships and submarines and has also developed solutions for land forces watercraft and land vehicles. It has additionally developed thermal infrared signature management systems for ships, some techniques of which could be leveraged to support land force signature management requirements. ESC group partners with universities to conduct research into technologies that may be developed into adaptive camouflage solutions.

Specialised coatings technology support for Land

The Specialised Coatings Technology (SCT) Group provides support for the Land Program in a range of areas:

- The development and introduction into service of signature management coatings (effective in the visible, near-infrared and thermal infrared parts of the electromagnetic spectrum). The APAS 0502 Army vehicle coatings, for example, are designed to reduce detectability in both the visible and near-infrared portions of the electromagnetic spectrum, and are now routinely specified in all acquisition projects including LAND 121 and LAND 400. SCT Group conducted the initial laboratory-based formulation and testing of these coatings, then prepared the requisite specification documentation and subsequently worked with industry to introduce them into service.
- The development of disruptive-pattern paint schemes for Army vehicles and equipment that are effective in both the visible and near-infrared portions of the electromagnetic spectrum.
- The provision of advice to acquisition projects on coatings selection and application requirements.
- The provision of technical advice and problem-solving when coating defects arise in-service.

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e. Sensor systems

Integrated threat warning and situational awareness capability development

TTCP Electronic Warfare Systems Technical Panel 6, Task 7, seeks to develop and demonstrate integrated threat warning and situational awareness (TW&SA) capabilities for all platforms. The initial demonstration of a multinational sensor and signal processing integration for TW&SA will be performed with Land Domain platforms. The concept of integrated TW&SA extends from the data fusion of disparate sensor technologies within a single platform to the distribution and sharing of this data amongst platforms within a formation. The breadth of this concept is achievable using just one underlying sensor communications architecture. The goal of the activity is to demonstrate improved survivability for platforms operating both independently and in a multi-platform multi-national deployment through real-time data sharing and interoperability. This builds on successful DST developments of hostile fire indication upgrades for helicopter missile warning systems.

The first prototype system laboratory test is scheduled to take place at the US Communications-Electronics Research, Development and Engineering Center (CERDEC) in Maryland during 2017. A field test involving the use of weapons is planned for August 2019.

Integrated hardware-in-the-loop facility for countermeasure and tactics development

The Land Tactics & Survivability Validation Program in conjunction with LAND 400 is developing an integrated hardware-in-the-loop facility for countermeasure and tactics development. The facility, managed by the Electronic Warfare Operations branch, incorporates a multispectral simulated environment for high-fidelity electronic warfare sensor stimulation in an immersive multi-threat scenario including rocket-propelled grenades, machine gun fire and anti-tank missiles. The facility will enable testing of military-off-the-shelf electronic warfare equipment integrated to land platforms and the associated survivability improvement, and will also allow the development of processing upgrades for additional capability. Primary areas of development include artificial intelligence for active self-protection cueing, enhanced threat warning and geo-location of hostile fire, and situational awareness display to crew for enhanced mission effectiveness.

Integrated hardware-in-the-loop facility for the development of countermeasures and tactics.

Land Advanced Vehicle Architecture development

DST has developed the Layered Approach to Service Architectures for a Global Networked Environment (LASAGNE) open architecture framework, which was originally developed for aerospace applications at a cost of around $10 million, constituting seven years of research funding investment. Based on LASAGNE, a new Land Domain information model called the Land Advanced Vehicle Architecture (LAVA) is now being developed. The purpose of LAVA is to assist research and experimentation on future-vehicle computing and information architectures to support the integration of active self-protection systems into land vehicles. The work is being done in collaboration with the UK Dstl and the UK Ministry of Defence's Icarus Active Integrated Protection System programme.

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4. Command, control and communications

Implementation of modernisation of mission command, greater access to communications and intelligence and surveillance data, and an increased ability to share information is likely to see a change in the Army's operating practices. Enhancements in automated decision making, digital networks, information management and command systems and processes will impact our modernisation practices. The improved inter-linkage of communication systems will see Land Forces being increasingly enabled through access to digital networks. New applications such as autonomous unmanned ground and air vehicles will need to be serviced by networks for Command and Control (C2) and data offload.[7]

a. System level optimisation

Improved understanding of land tactical data networking radios

Land Division has undertaken detailed analysis to understand the Adaptive Networking Wideband Waveform (ANW2), a military radio protocol for mobile ad-hoc networks. ANW2 is implemented in Army's latest tactical software-defined combat radios and represents an improved capability for multi-mission radios, i.e. radios that can be tailored to the specifics of a military mission. Land Division's in-detail ANW2 analysis focused on the waveform's features and their behaviours, investigating key performance sensitivities with regard to radio link qualities, network scalability, radio mobility and traffic patterns. This has informed projects LAND 2097-1B (Enhanced Special Operations Capabilities) and LAND 2072 (Land Tactical Networks) on the networking capabilities of Army's new radios and implications for their use by Australia's tactical land forces. The work has directly influenced project decision-making to date, and enables Australia's Special Forces to utilise their newly acquired radios and data networks to best effect. It has also raised interest with the New Zealand Defence Force and the special forces of the Five-Eyes community for its in-depth analysis and reflections on the implications for tactical network employment.

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Innovative tactical network performance analysis tool

DNAT field Trial.

The DST Network Analysis Tool (DNAT) has been developed in-house by Land Division to provide in-depth network performance testing of modern tactical military radios. It provides three key features: autonomous radio sampling, 'turnkey' master-slave network control, and scripted multi-protocol stimulation and logging. The software was initially developed for field testing of Army's Enhanced Position Location Reporting System radios, which host the wireless data network supporting Army's Battle Management System. DNAT was utilised for the first time for the large-scale network testing in Exercise Talisman Saber 13 and was praised by Army for its utility and the surprising insights it produced. Since then, the DNAT software has been enhanced to support multiple tactical radio types, including those considered for acquisition by Project LAND 2072 (Land Tactical Networks). The tool is now being used successfully by Army's Land Network Integration Centre for tactical data network field experimentation and proving of network design concepts. Radio manufacturers have also shown an interest in accessing the 'smarts' behind this tool, particularly because of its ability to undertake controlled network analysis in the field.

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[7] Excerpt from *Shaping Defence Science and Technology in the Land Domain 2016 – 2036*, p. 10
https://www.dst.defence.gov.au/publication/shaping-defence-science-and-technology-land-domain-2016–2036

Adaptive C3 Land Information Management System

Maintaining robust tactical command, control and communications (C3) will be increasingly challenging in complex and contested urban environments due to the need to distribute increasing amounts of data across enduringly disrupted, intermittent and limited tactical networks. Land Division is developing a semi-automated context-based distributed information management system (known colloquially as a 'signaller in a box') designed to help the human information manager (signaller or commander) cope with these increasing demands. Digitally captured information about the operational and network context will be used to dynamically target, prioritise and filter C3 information disseminated over tactical networks and to improve the relevance and presentation of that information to the tactical decision maker. Such dynamic information management will lead to greater information resilience in highly contested environments, reducing the commander's cognitive load and enhancing situational understanding at the tactical edge.

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b. Protected satellite and radio communications network and EM interference suppression and avoidance

SATCOM-On-The-Move

DST is undertaking R&D to deliver a practical high data-rate wideband satellite communications capability for land vehicles, called 'SATCOM-On-The-Move', to meet Future Land Force requirements. Following the successful conduct of a Capability and Technology Demonstrator program that delivered a Ka-Band tracking antenna land vehicle application, DST has succeeded in significantly increasing the performance of the technology by applying advanced communications signal processing. The antenna system in use was developed by Australian company, EM Solutions, and was originally trialled with a third-party modem – the modem being a device that transforms digital information into a waveform suitable for transmission over a satellite. Significant connection outages were found to occur with the system either because the modem and waveform were unable to recover quickly from blockages or because complex motions of the vehicle (and thus the antenna) caused significant Doppler frequency shift events. DST responded by developing a waveform that provides reliable operation through short duration blockages, fast recovery following longer duration blockages, and operates through complex Doppler scenarios. The combined system was successfully trialled on a vehicle in late 2015 using the OPTUS C1 spacecraft, thereby demonstrating the enhanced performance of the high data-rate SATCOM-On-The-Move and bringing the capability one step closer to meeting the Future Land Force's requirements.

SATCOM-on-the-move.

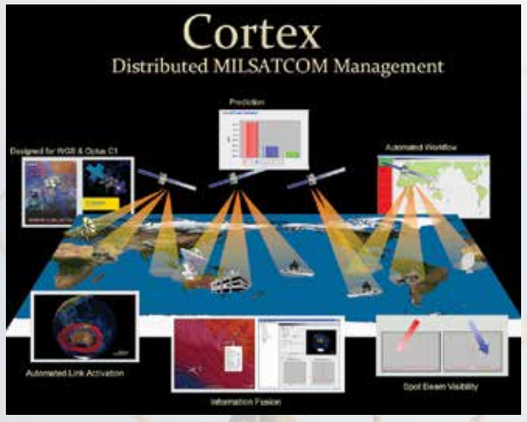
Preparation for the TORVICE trial in the third quarter of 2016 has been instrumental in facilitating greater collaboration between Australia and the US on SATCOM-On-The-Move, with DST staff making information-sharing and exploratory visits in the second quarter of 2016 to the RDECOM, TARDEC, CERDEC and SPAWAR agencies. This has enabled advice to be provided to Army on R&D for next-generation technologies such as low-profile SATCOM antennas for land vehicles and digital beam-forming in the land environment.

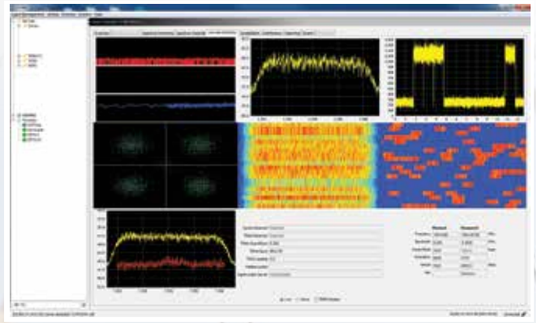
Following the successful 2015 road trial of the combined DST-EM Solutions Ka-band SATCOM-On-The-Move, a second-generation system has subsequently been constructed including a new EM Solutions antenna and a new DST trial support unit, both of which were deployed in the TORVICE trial in Woomera in September 2016.

SATCOM network defence

DST is conducting long-term research in the delivery of satellite communications network defensive capabilities to the ADF. This work has delivered CORTEX, an experimental distributed-agent system that provides enhanced awareness of the ADF satellite network and connects planning, link establishment, monitoring and troubleshooting processes into information-rich and cohesive operator tools. The CORTEX capability also provides for the centralisation of complexity to the SATCOM network operators and away from deployed users. This supports the land environment where small terminals are often used without specialist SATCOM operator support in the field. Current research is focused on detecting and characterising interference and anomaly events in the contested spectrum environment through the application of digital signal-processing and machine-learning techniques. A duplicate of the CORTEX capability together with an expanded monitoring infrastructure has been delivered to ADF SATCOM operators in the Chief Information Officer Group (CIOG).

The DST CORTEX SATCOM network defence system has been upgraded in collaboration with CIOG to provide greater real-time situational awareness of Australia's MILSATCOM operations. This enables the Defence Network Operations Centre to provide greater support to ADF's deployed users and contributes to delivering a more resilient MILSATCOM capability for Australia.





CORTEX SATCOM Network Defence.

Research on SATCOM network defence has been extended to the introduction of machine learning for anomaly detection across the whole of the Australian wideband MILSATCOM capability. Initial work was presented at an international conference in late 2015.[8] This research aims to provide an effective means to monitor the whole wideband MILSATCOM enterprise in real time – a task that significantly exceeds the capacity of the human resources available. Ultimately, machine-based monitoring will provide cueing of human operators and potentially support autonomous responses to anomalies. This activity is particularly relevant to the land environment where the number of terminals deployed can be large and the cadence of setting up and bringing down SATCOM links can be high.

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c. Convergence of EW, communications, SIGINT and cyber

The Cyber Sensing and Shaping MSTC provides support to the Land Domain in S&T areas related to electromagnetic cyber. This includes bespoke technology development for RF sensors (antennas and transceivers) and signal processing capabilities to understand, defend and exploit communications networks through the electromagnetic spectrum.

DST collaborates with its international partners on electromagnetic cyber under the Cyber Strategic Challenge of TTCP. Army Cyber and EW operations staff from 7 Signals Regiment have been closely engaged in these TTCP activities, contributing to program shaping and, in turn, being influenced by TTCP developments. There is scope to leverage other elements of the S&T program involving signals intelligence conducted in support of the intelligence community for the Land Domain. More details on this program requires briefings at a higher level of classification.

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[8] *Anomaly Detection in Satellite Communications Networks using Support Vector Machine,* Arbon, E., Smet, P., 2015 AIAA International Communications Satellite Systems Conference (ICSSC) 7-10 Sep 2015, Gold Coast, Australia.

5. Situational understanding

The increasing complexity of the future operating environment will increase demands for a force that is capable of sensing, discriminating and tracking potential adversaries. As such advances in reconnaissance and surveillance capabilities that are linked to a central intelligence system will be crucial to maintaining decision superiority.

The Army must develop a better understanding of the opportunities and threats presented by the human terrain and how to influence and exploit this avenue through international engagement activities, and through all phases of operations. Finally, the Army needs to develop a better understanding of own-force vulnerabilities that can be exploited through the space and cyber domains, as well as enhance our own understanding of how to exploit the vulnerabilities of others through these mediums.[9]

a. Sensor systems

Passive radar

Passive radar provides the capabilities of a radar system (target geo-location and tracking) without the characteristic emissions that aid electronic warfare systems to identify, geo-locate and attack a conventional radar system. The DST experimental passive radar system has been deployed on a number of land exercises where it has successfully demonstrated the utility of the technology.

Giraffe radar

The Giraffe radar is operated by 16 Air Land Regiment for air surveillance and air defence as well as to provide a ‘sense and warn’ function against rockets, artillery and mortars. Since radar emissions are easy to detect and locate, they can be used by an adversary to support hostile action. In response to this vulnerability, Army requested DST to investigate the feasibility of radar decoys to confuse adversary sensors. Within six months, the Giraffe radar emissions were collected and characterised, a technical report on radar decoy options was published, and a prototype decoy was constructed and evaluated in Exercise Hamel 16. This rapid response to remedying a capability deficiency illustrates the value and cost-effectiveness of an agile S&T organisation with deep technical expertise and knowledge of the operational domain.

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[9] Excerpt from *Shaping Defence Science and Technology in the Land Domain 2016 – 2036,* p. 12 https://www.dst.defence.gov.au/publication/shaping-defence-science-and-technology-land-domain-2016–2036

Electro-optic processing and exploitation

The Electro-Optic Processing and Exploitation (EOPE) Group within DST's National Security and ISR Division (NSID) is responsible for enhancing Defence electro-optic (EO) ISR capabilities. These EO capabilities range across the electromagnetic spectrum from visible to long-wave infrared light. EOPE has developed a complete understanding of all principal domains of EO radiation (spatial, spectral, temporal and polarimetric) and the operation and performance of current-generation EO sensors used for surveillance and intelligence gathering from land, sea, air and space-based platforms.

DST's Defence Experimentation Airborne Platform (DEAP).

The Intelligence Systems (IS) Branch within NSID operates the Defence Experimentation Airborne Platform (DEAP) – a Beech 1900C aircraft fitted with an array of EO and RF surveillance sensors for the development of new capabilities in ISR. This aircraft participates in many military exercises, providing an ISR overwatch capability from which activity-based intelligence can be extracted. This research feeds directly into the Army's UAS program run out of 20STA. Meanwhile, guidance has been provided for the development of an ISR processing exploitation and dissemination hub for Army along the lines of that currently established for Air Force (DGS AUS).

EOPE has acquired extensive expertise in the field of visible radiation emissions and reflections from Land Domain assets along with the manner in which this radiation passes through the atmosphere and is detectable by a range of potential surveillance systems. This expertise has enabled the establishment of a comprehensive capability in EO signature measurement, which features calibrated quantitative instrumentation that can perform initial and detailed assessments of the EO emission and reflection signatures of land assets.

EOPE has also developed a significant program in hyper-spectral imaging – an advanced sensing capability that can identify material types, detect targets in deep-hide camouflage at a sub-pixel level and discriminate camouflage from natural surroundings. EOPE's operational expertise in the use of these advanced sensors has provided verified performance data of these technologies for Army.

Another research field within EOPE's area of expertise is the capability offered by overhead and space-based ISR sensors. By studying the performance of these sensors and the data obtained from them, EOPE has been able to inform Army about how such sensors can assist normal operations along with some vulnerabilities involved in their use.

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Human terrain situational understanding: the connected technology piece

The Human and Social Modelling and Analysis (HSMA) Group of Intelligence Analytics Branch within NSID has traditionally undertaken medium-term research activities contributing to non-Land Domains; however, its research also has potential benefit to Army's Situational Understanding AMLE requirements. More recently, HSMA has commenced activities of relevance to human terrain situational understanding within highly networked contested urban environment contexts. The research emphasis is on understanding social media relating to influence and social network analysis in addition to developing theoretical concepts spanning the human and social dimensions.

Research areas include:

- understanding the application of social media and dynamic social network analysis for situational understanding, which involves modelling information diffusion enabled by social networking and arriving at meaningful understandings about the influence of individuals, groups and society.
- Developing conceptual models and frameworks for social influence as well as understanding threats, social conflict and terrorism.
- Introducing social media understanding into ground-based activity scenario vignettes. This activity is contributing to the Situational Understanding AMLE and is being conducted in collaboration with TTCP partners as part of the Contested Urban Environments (CUE) Strategic Challenge Group (SCG).
- Refining techniques for 'big data' collection using dynamic topic tracking. This research tool – referred to as RAPID – is being developed in collaboration with the University of Melbourne.

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b. Integrated ISR architectures and systems

NSID supported the TORVICE trial with its Evolutionary Layered ISR Integration Architecture (ELIIXAR). ELIIXAR provides an exemplar of the enterprise Integrated ISR system whereby ISR information is brought together in a single point of presence and made available to operators supporting an ISR mission.

During the TORVICE trial, motion imagery from DEAP sensors and EW geo-location information from the EW Battle Management System were brought together within the ELIIXAR system. This information was made available both at the trial location in Woomera and at DST Edinburgh after transmission via a satellite link.

This deployment was the first in the TORVICE trial series, and provides a baseline that will assist the introduction of additional functionality in subsequent trials.

6. Combat service support

a. Logistic decision-support methods

Combat service support (CSS) force design

Defence regularly undertakes various forms of concept development and force structure review as part of modernisation efforts. In the CSS domain, a broad logistics and combat service support technology scan was completed to support Army Headquarters with development of the CSS Functional Concept 2030. In other work, progress has been made on the development of a conceptual framework for CSS force structure design and application of the Enterprise Modeler® software to produce a concept demonstrator and visualisation of this design approach.

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b. Distribution technologies

Additive manufacturing and repair

Additive manufacturing and repair (AMR) has the potential to significantly change the way Army conducts its logistic operations in the field. DST is working with Army, military coalition partners and broader Australian defence stakeholders to consider ways that this technology might be integrated into military support networks, and how the competitive advantage it offers can be brought to bear in the modern battlefield.

More recent work has included:

- An examination of the application of AMR to current Defence and military inventory management practice
- Conduct of an Interactive Project Agreement with BAE Systems to investigate additive manufacturing in the context of supply chain enhancement
- Work within TTCP Land Group Technical Panel 6 (Land Logistics Planning, Support and Distribution) on the projected application of this technology by potential coalition partners and possible concept and capability options for land forces to consider.

Autonomy and automation

A program of work is being undertaken on CSS autonomy and automation, leveraging efforts of TTCP Land Group Technical Panel 6 (Land Logistics Planning, Support and Distribution) supported by a range of exploratory activities with Army CSS stakeholders. The initial outcomes of this work include an analysis of key trends and challenges and the mapping of emergent technologies for potential CSS applications.

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c. Maintenance technologies

Land force maintenance

As part of the process of understanding key maintenance and sustainment characteristics of Army's principle vehicle fleets, DST conducted a study on ASLAV sustainment performance with subsequent effort being applied to the armoured personnel carrier, M113. This work helps inform the ongoing development of ground combat vehicle capabilities for both existing fleets and their LAND 400 successors. Allied to this and in order to exploit the benefits of vehicle health usage and monitoring systems, a collaboration between DST, CASG and Deakin University (Institute for Intelligent Systems Research and Innovation) is seeking to develop and apply prognostic algorithms in support of condition-based maintenance. These algorithms will enable the health and remaining useful life of target components and sub-systems used on board land platforms to be forecast earlier and with greater precision.

Additionally, DST commissioned a study to understand the role that health and usage monitoring might play in the life-cycle management of transparent armour. Principally through the application of reliability-centred maintenance logic and the synthesis and analysis of subject matter expert advice, the study sought to provide greater clarity on how monitoring systems should be used and the priority their application should be given in order to facilitate condition-based maintenance usage. This study has laid the foundation for further research effort.

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d. Health technologies

A research effort has been commissioned with the Australian Centre for Field Robotics at the University of Sydney to explore the feasibility of developing a 'smart' deployable capability for enhancing medical support of casualties at the tactical edge. This research effort aims to arrive at an enhanced understanding of current state-of-the-art health technologies for casualty stabilisation as well as monitoring, diagnosis and treatment that could assist with battle casualties at the point of injury. Other areas of research include the potential role of autonomous technologies and the ways that relevant health technologies may be employed in practice in a tactical setting.

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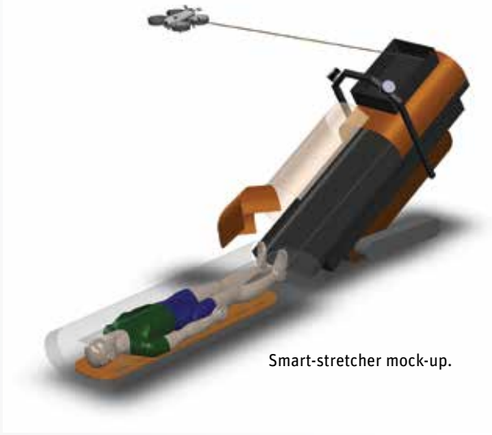

Smart-stretcher mock-up.

e. Power and energy

A study was completed on military-off-the-shelf power and energy (P&E) interconnectivity that examined the ability of platform and field-based power and energy systems (including future and legacy kinds) to interconnect with each other. While examining potential interconnectivity, the study also noted P&E architecture issues Army might need to consider to effectively integrate soldier, platform and field-based systems.

Fuel savings achievable through the employment of hybrid power systems have also been examined. This work established that even the simple replacement of legacy diesel generators with modern generators equipped with smart electronic control and load-following capacity can lead to significant fuel savings. Additionally, a study was completed on power options for dismounted combatants that concluded there was a need for a better integration of wireless charging devices with vehicles and deployed infrastructure in order to facilitate seamless charging of soldier-borne electronic devices.

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7. Creating and shaping the future

a. Army Coastal, Littoral, Estuarine and Riverine Capability Needs analysis

Through the Army Experimental Framework (AEF), DST conducted the ADF Coastal, Littoral, Estuarine and Riverine (CLEAR) Capability Needs analysis. The study delivered evidence and insights on capability needs and the military utility of alternative CLEAR capability systems and fleet solutions in support of a deployed combat brigade. The analytical campaign employed user workshops and a limited objective experiment along with combat simulation and operations analysis methods to examine four themes of the CLEAR capability: Riverine Patrol, Coastal Manoeuvre, Logistics-over-the-Shore and Force Protection. The study articulated the impact of critical extant CLEAR capabilities reaching life-of-type, and defined how CLEAR capabilities can combine with the Australian Amphibious Force to deliver a unified amphibious capability. The study sponsor, LTCOL Dan Conners, commented that the study "… feeds directly into the joint capability needs narrative, nested within the strategic guidance."

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b. Limited objective experiment for C3&ISR 2030 concept development

Through Army's Limited Objective Experiment 2-15, DST developed a causal model of the future operational Combat Brigade Headquarters (CB HQ) in order to determine the individual and combined impact on operations of the C3 and ISR functions for different organisational, conceptual and technology-enabled futures. LOE 2-15 involved wargaming within a 2030 scenario with CB HQ subject matter experts to populate the model as well as provide insights into how technology enablers could contribute to their CB HQ functions and what structural, procedural or technology changes could improve warfighting outcomes in 2030. The study supports Army's future C3 & ISR functional concepts, which underpin Army's Future Land Operating Concept 2030 and inform future Army capability requirements beyond the current Defence Investment Plan.

From the point of view of the sponsor, the campaign exceeded expectations. It delivered a causal decision-aiding model that combined existing evidence and expert opinion to inform C3 and ISR aspects of future land operating concepts; it highlighted key areas of concern (centralised control, operations with degraded networking, robust concept design) for the effectiveness of C3 and ISR in a future degraded and contested environment; and it provided a modelling framework that could be reused to inform future and follow-on concept studies.

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c. Building on Army Initiatives studies

The Building on Army Initiatives process was supported by a series of Land Analytical Decision Support (LADS) studies (LADS 1-16, LADS 2-16 and LADS 4-16) that provided red teaming support to question and identify all assumptions and associated issues and establish whether there was evidence to support and justify the assumptions and arguments.

LADS 1-16 provided red teaming support in two distinct areas: questioning assumptions in the brigade and battlegroup constructs put forward in the Building on Army Initiatives process, and questioning the assumptions in the Second Division (2 DIV) transformation process. This red teaming support took the form of structured workshops and surveys to identify the assumptions underpinning arguments followed by a check of deep key assumptions. The outputs were a briefing pack assembled to assist LTCOL Nick Bosio's briefing of the Chief of Army's Senior Advisory Committee and the *Support to 2 DIV Transformation Project with Red Teaming* Client Report.

LADS 2-16 involved training Army Headquarters staff in the red teaming toolkit of methods and assisting them to run their own structured workshops to red team various proposals for the generation of pre-landing forces.

LADS 4-16 investigated the issues in generating enabler mass, addressing the question of how the Army as part of a joint integrated total force manages its force weight and balance across its full range of tasks, functions and responsibilities. The work involved a number of structured workshops and surveys with input primarily from 6, 16 and 17 Brigades. This was a successful project that resulted in the production of the client report, *Generating Enabler Mass in the Australian Army,* and a briefing pack to assist LTCOL Matt Patching and LTCOL Meegan Olding give a briefing to the Chief of Army's Senior Advisory Committee on this issue.

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d. Manned-unmanned teaming

The Manned-Unmanned Teaming (MUM-T) LADS study (LADS 2-16) employed a range of methods including: a scan of MUM-T concepts and use-cases; a scan of currently available unmanned aerial and ground systems; and a seminar wargame exploring tactical employment of unmanned technologies for light infantry. The outcomes of the seminar wargame showed that the majority of issues resulted from the size of the area of operations (relative to the size of the experimental force (EXFOR), the presence of complex terrain and the combat team's lack of organic ISR. This resulted in blue team forces being dispersed, with limited ability to detect threats. From a consideration of size, weight and operational need (based on issues identified during the baseline wargame), participants selected a range of unmanned capabilities for use in the MUM-T wargame. Based on mitigation of risk for this scenario, the EXFOR syndicate placed a high priority on the micro-unmanned aerial vehicle (UAV) and unmanned ground system (UGS) over other systems. This is consistent with the findings from other MUM-T programs that found utility in an organic very small UAV capability for infantry at the section level. The area denial system would have had a major impact; however, it is not clear whether current technologies could generate the desired effect or if they could be inserted with the combat team in this scenario. Other MUM-T programs found high utility in unmanned ground vehicles (UGV) for extending small unit operation without external support, but this was not found to be an issue in the wargame due to the 24-hour timeframe and static defensive nature of the scenario.

The scan of current unmanned systems showed that there are commercially available UGS, UGV and UAV that could meet the requirements identified in the wargame. The ideas generated here could help inform a planned future trial of unmanned systems. Other MUM-T programs have demonstrated the utility of trials and live exercises for developing concepts and identifying issues; it is therefore recommended that Army conducts such a trial. The study outcomes also emphasised the limitations and constraints of using MUM-T including factors such as autonomy and control, mobility, endurance, noise and signature, operator workload and training, sustainability and survivability. These issues provide some technological challenges for industry to address.

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e. Evaluation of the command and control functional concepts related to a reinforced combat brigade

How does a reinforced combat brigade headquarters formulate, update and disseminate a commander's intent? The LADS 6-15 study answered this question using a multi-method investigation involving qualitative data collection techniques through surveys and structured brainstorming workshops, quantitative analysis methods and visualisation techniques. Out of this work, we were able to develop the 'I-cubed' framework that brings together the commander's intent, information themes and battlefield image. This bottom-up approach identified four reports as the four critical nodes on the causal map of the reinforced combat brigade headquarters.

An inquiry-based demand-pull search for information was undertaken using three established frameworks for modes of information exchange. These are: the pipeline, transmitting information according to a set order and established format; the alarm, signalling the occurrence of one or more exceptional threats; and the tree, a serious incident causing a complete change in the image of the battlefield. Even as operational tempo rose, there was no change in the mode of information exchange for a given category – the only change was the speed at which the information was transferred. These four reports, themselves dependent on others, represent the key cues that any commander seeking to make decisions under bounded rationality could first look to, while embodying the critical outputs to be maintained in any reduced or attrited headquarters. This work was reported in the DST paper, *Land Analytical Decision Support Study: Evaluation of the Command and Control Functional Concepts Related to a Reinforced Combat Brigade,* and the observations from EX HAMEL 2016 were separately reported in another DST paper, *Compiling, Adapting and Sharing the Commander's Image and Intent*.

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f. Determining key issues within the ADF's ability to lead a combined joint task force

The Army Experimentation Headline 2016 analytical campaign involved a series of iterative activities designed to determine the priority issues in joint capability in the 2025–2030 timeframe that will shape or impact the ADF's ability to lead a combined joint task force conducting operations in the near region up to combat level of complexity. This analysis was seeded by an initial elicitation of issues collected from senior officers across the ADF. Subsequent activities were refined and added to this initial list of issues before they were themed and grouped. The Headline 16 Steering Group (HMSP-A, COMD 1 DIV and HFD) directed the following areas be the focus of the capstone event (the Headline Experiment 2016):

- Force projection: inter and intra-theatre lift,
- Sustainment, and
- Command, control, communications, computers, intelligence, surveillance and reconnaissance (information collection, sharing and analysis).

The information collected during the campaign was used to develop twenty DST discussion papers that formed the foundation of a number of ADF issues papers, which were then red teamed by an ADF O7 panel before being presented to a two-star forum.

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Glossary – S&T highlights from the Land Domain

ADF	Australian Defence Force
AMLE	Army Modernisation Lines of Effort
ASLAV	Australian light armoured vehicle
C3	command, control and communications
CASG	Capability Acquisition and Sustainment Group
CERDEC	Communications-Electronics Research, Development & Engineering Center
CIOG	Chief Information Officer Group
CLEAR	coastal, littoral, estuarine and riverine
DST	Defence Science and Technology Group
Dstl	Defence Science and Technology Laboratory
EW	electronic warfare
EXFOR	experimental force
GL	Group Leader
ISR	intelligence, reconnaissance and surveillance
LADS	Land Analytical Decision Support
LASAGNE	Layered Approach to Service Architectures for a Global Networked Environment
MSTC	major science and technology capabilities
PA	Project Agreement
RDECOM	Research, Development and Engineering Command
RF	radio frequency
RL	Research Leader
S&T	science and technology
SATCOM	satellite communications
SIGINT	signals intelligence
SOER	Special Operations Engineering Regiment
SPAWAR	Space and Naval Warfare Systems Command
SRI	Strategic Research Initiative
STANAG	NATO Standardization Agreement
TARDEC	Tank Automotive Research, Development and Engineering Center
TORVICE	Trusted Operation of Remote Vehicles in Contested Environments
TTCP	The Technical Cooperation Program
UAS	unmanned aircraft systems
UGS	unmanned ground system
UGV	unmanned ground vehicle

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