Australian Government
Department of Defence
Science and Technology

Shaping Defence Science and Technology in the Land Domain 2016–2036

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Shaping Defence Science and Technology in the Land Domain 2016–2036 is the inaugural Defence Land Science and Technology (S&T) strategy. The Army Modernisation Lines of Effort (AMLE), found within the Army Modernisation Plan 2015, provide the definitive statement of long term modernisation imperatives in the Land Domain. The AMLE, as currently described, are capability and outcomes focussed, with an inherent S&T flavour to them. This document serves as a companion to the Army Modernisation Plan, and articulates the S&T capabilities required to implement the modernisation strategy more explicitly. Some text from the Army Modernisation Plan is borrowed here to set the context. For a fuller account of Army's strategic intent beyond S&T, the reader should refer back to the Plan.

This document also looks to S&T requirements aimed at sustaining the current force. It sets out all needs, ranging from operations support and current force sustainment activities to far-future needs, and thus articulates all S&T needs in the Land Domain. Custodianship of the Defence S&T Capability is DST Group's primary responsibility. This document should be used to inform and shape future science and technology capabilities.

This document represents long-term guidance for S&T capability development, and is applicable beyond purely DST Group internal capability. Guidance to prioritise and shape the in-year program is delivered through the Science and Technology Requirements and Priorities documents and the DST Group Domain Planning Guidance documents.

Shaping Defence Science and Technology in the Land Domain 2016–2036 was endorsed by HMSP-A and DPM-L on 23 August 2016.

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Introduction

Scientific and technical support is applied to current Defence operations, investigates future technologies for Defence application, and ensures Australia is a smart buyer and user of Defence equipment. In addition, it develops new Defence capabilities and enhances existing capabilities by increasing performance, adaptability, security and safety, and reducing the cost of ownership of Defence assets.

The Army manages the future focussed parts of its modernisation program within a set of thematic subsystems known as Army Modernisation Lines of Effort (AMLE). The AMLE serve as a useful framework to articulate Army's science and technology (S&T) needs. The AMLE take the form of an environmental scan, vision, narrative and roadmap, which are published annually in detail in the Army Modernisation Plan. These are the consistent products across all AMLE, developed after extensive consultation with other services, departments and agencies. They provide an understanding of key decision points, conditions or triggers that support modernisation initiatives.

The redesigned Capability Lifecycle arising out of the First Principles Review of Defence is managed through a set of 40 programs, 9 of which are managed by Chief of Army. These are important to refer to in work that DST Group undertakes in support of acquisition and sustainment, but do not cover the totality of future S&T needs beyond the Integrated Investment Plan funding horizon. This document takes the AMLE construct as providing useful headings to organise the totality of S&T support for Land, and will be organised into Focus Areas aligned with AMLE and future needs. Capability Programs may be mapped to these Focus Areas, and future iterations of this document may review the Focus Area headings that have been chosen and potentially adjust alignment with Programs.

In addition, DST Group is investing into Strategic Research Initiatives (SRI) to build capabilities that address emerging threats and exploit anticipated long-term technology trends. This has been recently bolstered in the Defence White Paper by the announcement of a Next Generation Technology Fund (NGTF). The elements of the SRI program that are applicable to Land S&T are also articulated within the Focus Areas in this document, and may be informed and guided by the AMLE Roadmaps. Elements of future capability that Army would seek to be supported by NGTF are highlighted throughout the document.

It should be highlighted that the Army is structured along the lines of the regular force, as well as a Special Operations Command (SOCOMD). Special Operations in particular has equities across the different Defence Domains, however it is functionally under Army command. As such, S&T needs that support Special Operations capabilities are covered in this document. SOCOMD also plans to update a more specific Special Operations S&T plan, as part of its Special Operations Program Strategy, which will be released shortly.

There is an expectation that the Chief of Army will by default look to DST Group to service its S&T needs. In some cases, DST Group may not have the capacity or necessary S&T capability to provide what is needed, and then, in line with the First Principles Review, DST Group can assist Army in finding other sources of S&T support, including R&D partnering with DST Group. This could include Australian academia, industry, or collaboration and burden sharing with our international allies.

Future Land Operating Environment – Direction and Challenges

Emergent Themes

In examining the individual AMLE, a number of recurring modernisation themes have been identified. These themes have broad applicability across the Army and the reader is encouraged to refer back to these when examining the detail below. These themes provide a high-level overview of what is important to Army, and the priorities articulated throughout this document relate directly back to them. This is a recognition that there are no clear boundaries across the various Focus Areas, and considerable interdependencies exist:

a. *Optimising the human-system interaction.* This includes tailoring the individual to the future operating environment and tailoring the systems to the individual. The combined effects of big data and new technologies (including increased networking) are likely to increase information processing and analysis demands placed upon human decision-makers. Continuous periods of high operational tempo and the use of heavy and complex equipment are expected to increase physical and cognitive demands and stress. Personnel will need to operate in a high technology and information rich environment and will need to be resilient in order to survive in a wide range of operating scenarios and circumstances.

b. *Enhancing the Army's capability through modernising mission command.* The proliferation of new digital technologies provides a significant opportunity for improved information exchange, smart exploitation of multi-source tactical and strategic data, support systems for decentralised decision-making, and creation of novel capabilities through the interoperation and collaboration of mission systems. Future forces will likely be highly dependent on pervasive networks, especially in a dense urban operating environment.

c. *Developing and testing operational concepts and force structure to ensure they are best suited to meet the demands of the future operating environment.* In order to remain a capable force in the future operating environment and be able to capitalise from technology insertions, Army must adapt organisationally. An approach is required to draw assumptions about the future operating environment that support both consistency and contestability of capability proposals.

d. *Counter adversary use of readily available commercial technologies.* It is expected that in the future operating environment adversaries will increasingly have access to and exploit commercially available high technology items and/or will create disruptions through re-configuration and confluence of low-cost technologies.

e. *Increased reliance on remotely controlled, automatic and autonomous systems.* This includes automation and autonomy in physical as well as digital systems. There is a need for Army to understand the capability and quality of performance that automated and autonomous systems afford and how to integrate such systems in order to maximise capability and reduce human presence where possible.

Other emerging themes include the need for command and control and wider C4I integration across combat service support (CSS) and intelligence, surveillance and reconnaissance (ISR); common simulation environments; architecture-based capability design and employment of Commonwealth-endorsed open standards across modernisation activities; force protection against a growing range of threats; more agile and less vulnerable supply of battlefield power and energy; and the institutionalisation of knowledge capture and training.

Defence White Paper 2016

A Changing Force Structure and Significant New Capabilities

The coming years will see a number of significant capabilities being developed and introduced into service, among them the future Soldier Combat System, Protected Mobility Vehicles (light) and other transportation, the Combat Reconnaissance Vehicle, the Infantry Fighting Vehicle, the maturisation of the digitised battlespace, new Long Range Joint Fires systems, and new surveillance and space systems. The following (indicative) diagram shows consistent delivery into service throughout the next fifteen years, and an increasingly interoperable Joint Force. To realise these capabilities, significant effort in analysing future needs and defining and developing these capabilities will be required. Once developed, a deep understanding of the capabilities will be required to ensure maximised operational effectiveness.

Land Operations in a Contested Urban Environment

The Future Land Warfare Report highlights the likelihood that Australian Land Forces will have to be ready to engage in a contested urban environment and in littoral areas against lethal threats. This is the logical conclusion from a convergence of mega-trends, including the rise of megacities, a highly connected population, the proliferation of highly lethal weapons systems, and an increasing constrained and resource-poor future. Operating in such environments will pose a whole range of new challenges in command, control & communications (C3), force protection and situational understanding. Land forces must be well-integrated with the Joint Force to assist in meeting these challenges.

AMLE / Focus Areas

The rest of this document outlines the Land Force's military objectives and capability needs, along with supporting research areas, in the current 6 Focus Areas: Force Projection and Application; Human Performance; Force Protection; Command Control and Communications; Situational Understanding; and Combat Service Support. It also outlines one more Focus Area that is not currently intrinsic to the AMLE, that of Creating and Shaping the Future Force. This important area serves an integrating function across the different modernisation lines of effort.

In deriving the research areas listed in the following pages, consideration has been given to blending extant capability research needs, support to operations, the need for emerging S&T capabilities identified through the AMLE and the Integrated Investment Program, as well as future (conceptual) requirements. Much of the required work articulated in this document will be leveraged from S&T work in Joint, Maritime, Aerospace and Intelligence domains. The reader is encouraged to refer to these companion documents to the Land S&T Strategy, all to be released in 2016. In combination, they serve to articulate all Defence S&T needs.

Science & Technology Focus Areas

Force Projection and Application

Overpopulation, sprawling urbanisation, increased resource scarcity, exponential inter-connectivity and the proliferation of advanced technologies are fundamentally reshaping future land operating environments. Demographic and economic pressures are providing further fuel to age-old ethno-sectarian, nationalistic and religious hatreds. Rapid proliferation of advanced technologies is enabling increasingly elusive, determined and capable non-state actors – while making possible impressive modernisation gains for assertive state-based competitors determined to challenge the global rules-based order. Significant growth is evident in a range of disruptive technologies; from theatre anti-access/area denial capabilities and long-range precision weapons – to next generation anti-armour missiles, armed unmanned aerial systems (UAS), advanced counter-network capabilities and the manipulation of social media.

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.

Vision

Ensure the joint combined arms team of the future is a robust, adaptive and potent *medium weight* force – optimised for sustained close combat in crowded, contested, connected, and lethal operating environments. The evolution of the Combined Arms Fighting System will focus on a wide range of lethality, mobility, survivability, command and control, situational awareness and sustainability augmentations.

Science and Technology Support

A fully mature Combined Arms Fighting System is the Land Force of the future, and presents a significant integration challenge. S&T support is required to inform complex capability design, integration and acquisition decisions to come. Focus is required on open, adaptive and evolvable digital architectures and 'system of systems' technologies, aviation safety and operational effectiveness, counter-unmanned threat technologies, advanced mission systems, directed energy and novel energy weapons, the teaming of man and machine, and the exploration of robotics and trusted autonomous/semi-autonomous technologies. The range of new technologies in digital evolvability, novel weapons and autonomous systems and teaming will require considerable support from NGTF, and a strong partnership is emerging with US Army RDECOM in exploring these technologies.

The White Paper also provides for an extended-range missile system that can provide persistent, scalable and discriminating fires to, and is able to interoperate with, the Joint Task Force of the future. S&T support is also required to enhance the force projection, engagement systems and the tactical agility of Special Operations Forces.

Priorities		
Understand the major threats to the Combined Arms Fighting System anticipated out to 2030, and help to determine the most promising solutions	Develop an open, evolvable and adaptable Land Force system of systems architecture and implementation path to best support sustained land operations in uncertain, complex and contested future operating environments	Determine how best to leverage unmanned systems/sensors/robotics for 'manned-unmanned' synergies out to 2030, and thus transform to the next paradigm in land warfare

Force Projection and Application

Military objective/capability

Close Combat Modernisation

- Develop next generation infantry fighting vehicle and main battle tank capabilities
- Prepare Force for contested urban environments
- Enhance the force projection, engagement systems and the tactical agility of Special Operations Forces
- Manned-unmanned teaming as the next paradigm in land warfare

Combat Support Modernisation

- Develop next generation combat reconnaissance vehicles
- Mature fires digitisation and integration
- Next generation munitions – autonomous, loiter, programmable, scalable, discriminating
- Unmanned ground robotics for breaching / demolition

Land-based Cross-domain Activities

- Long range fires and land-based maritime strike
- Ground-based air and missile defence
- Mitigate emerging threats with novel weapons systems
- Develop armed unmanned aerial systems
- Enable growth, mission configurability and context awareness of digitised joint land combat systems
- Integrate with Joint capabilities – Growler, Joint Strike Fighter, Air Warfare Destroyer, submarine

Army's Aviation Capability

- Airworthy aircraft and safety
- Operational effectiveness and survivability
- Operations in degraded visual environments

Army's Future Amphibious Capability

- Integration of advanced land force capabilities in support of the Amphibious Force
- Enduring rotary wing Force Generation
- Develop Joint coastal, littoral, estuarine and riverine capabilities and beach access systems

Research areas

Support to acquisition decisions, and improve tactics, techniques and procedures

- Exercise and operations analysis
- Modelling and simulation
- Concept exploration and evaluation through experimentation and wargaming
- Advice on system performance, operational effectiveness and potential improvements
- Helicopter-ship operations

Architectures and networks

- Open, adaptable and evolvable common vehicle architectures and standards
- Open network architectures and integration
- Vehicle systems self-management
- Vehicle sub-system integration and risks

Weapons and mission systems and effects

- Explosives, ballistics and unguided weapons systems
- Weapons performance analysis
- Advanced combat and mission systems
- Novel weapon technology intelligence and forecasts
- High-energy laser physics, directed energy and microwave weapons
- Advanced seeking, detection, tracking, control and engagement systems
- Integration of Joint sensors and effectors

Structural integrity of aircraft & accident investigations

- Ultimate strength of intact and damaged structures
- Through life structural assessments
- Failure mechanisms and analysis
- Corrosion mechanisms and protective systems
- Forensic materials analysis
- Flight dynamics modelling

Unmanned systems

- Autonomous technologies and artificial intelligence
- Unmanned aerial control technologies
- Ground robotics
- Manned-unmanned teaming concept analysis

Human Performance

The enduring nature of war as a primarily human endeavour provides the philosophical foundation for placing human performance at the forefront of Army's modernisation program. *The pervasiveness of human performance within all Land Force capabilities dictates that the human must remain central to the development of all other lines of effort.* The primacy of soldiers over equipment, structures and systems, distinguishes Army from the other Services, and is characteristic of its intent to 'equip the operator', rather than 'operate the equipment'.

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.

Vision

Our people, as individuals and teams, repeatedly outsmart, outperform and outlast a lethal, agile, adaptable and well-connected adversary.

Science and Technology Support

Human Performance is seen as critical to future Land Force success. S&T support in Human Performance will aim to:

- Cognitively and physically prepare our people to operate against a lethal, agile, adaptable and well-connected adversary;
- Cognitively and physically augment our people and their supporting systems to outperform and protect against a lethal, agile, adaptable and well-connected adversary;
- Build capable and cohesive teams to best support and optimise human performance.

DST Group is partnering with numerous top universities to deliver these outcomes, as part of a new investment by Army, the Human Performance Research Network. NGTF is needed to further bolster this investment, and grow the S&T capabilities required to deliver an enduring Human Performance edge for the ADF. We are also partnering strongly within the five-eyes research community, particularly with US Army RDECOM and Defence R&D Canada on aspects of survivability and human systems performance.

Priorities	
Develop a cognitive edge augmented by autonomous decision support systems, and enhanced resilience to operational deployments	Select, train and equip personnel to be physically resilient members of high performing teams

Human Performance

Military objective/capability	Research areas
Cognitively prepare and augment individuals and teams • Effective decision making • Cognitive adaption and resilience • Form effective teams • Emerging information systems design • Mitigate performance decrements • Exploit wearables for cognitive performance • Team with autonomous systems	**Cognitive sciences** • Cognitive selection and training for performance and resilience • Psychological state monitoring • Immersive and adaptive training systems • Ergogenic aids for cognitive performance • Ergonomics for cognitive augmentation • Night vision and hybrid vision • Human teaming with autonomous systems
Physically prepare and augment individuals and teams • Physical performance and resilience • Adapt to challenging environments • Develop load-sharing technologies • Advance clothing, equipment and platforms • Exploit wearables for physical performance	**Human-centred physical sciences** • Physical selection and training for performance and resilience • Physiological state monitoring • Assistive technologies (load sharing, exoskeletons, etc.) • Ergogenic aids for physical performance • Soldier system integration and design standards
Improve warfighter feeding and nutrition • Optimise nutrition and feeding systems • Exploit emerging food and drug technologies • Improve food selection behaviour	**Food and nutrition sciences** • Mission adaptive nutrition • Shelf stable food processing • Packaging and logistics • Improved nutritional behaviour • Enhanced digestion
Advance the repair and rehabilitation of soldiers • Improved physical rehabilitation • Mediate psychological effects of service • Exploit emerging medical biotechnologies	**Medical sciences** • Health and wellbeing data management • Management science • Personalised medicine • Biomarker correlates for injury and illness
Make Army's teams and organisation more adaptive • Build team and organisational resilience • Increase professional mastery • Improve perceptions and behaviours	**Social sciences** • Leadership and talent management • Linguistic and cultural development & tools • Organisational culture measures and interventions

Force Protection

Future conflict is likely to see Australian land forces operating in an increasingly crowded, largely urban littoral environment against adversaries which are harder to detect, and yet possess greater levels of connectivity and lethality, than those in Australia's recent military history. Force protection will remain a key consideration in future deployments as it preserves the fighting power of the force and, in doing so, maintains the commander's freedom of manoeuvre to conduct operations against the enemy, in support of allied forces, or in aid of the local population. Force protection is also an important aspect of fulfilling the Army's moral obligation to its soldiers.

Future land forces need to be structured, trained and equipped with integrated passive, reactive and proactive force protection measures which allow it 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.

Vision

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Science and Technology Support

Protection of our forces is of paramount importance. It involves S&T ranging from CBRNE defence, understanding weapons systems and their effects, and advanced physical and active protection approaches including modular systems, novel armour and materials. DST Group is forging a strong partnership in particular with the Defence Science and Technology Laboratory in the UK to explore the emerging active protection technologies for vehicles that will need to be integrated in the future Land fleet. Opportunities exist to expand this collaboration to include US RDECOM, and will require NGTF support. Scope to expand this interaction to more holistic integrated survivability research over the coming years will also be explored.

Defence has also forged a strong partnership with the five-eyes partner countries through the CBR Memorandum of Understanding, which spans the full range of technologies for CBR defence. NGTF is needed to support Australia's contribution to international efforts to produce medical countermeasure products to protect against the wide range of threats. NGTF is also needed to harness the diverse expertise Australia has in novel and advanced materials research to support future protective solutions.

Force Protection also requires detailed knowledge, measurement and mitigation of signatures and their associated sensor systems, and various methods of counter-surveillance and deception to counter threats. The integration of the many approaches and systems is required, supported through modelling, simulation and analysis. Finally, protection against electronic and cyber attack is also critical, though since the technology areas significantly overlap, this is covered in detail in the C3 Focus Area later in this document.

Priorities		
Understand and mitigate the next generation of CBRNE threats, including improvised and high-end military threats	Develop novel protection systems, including armour systems and modularised active protection systems, deception systems, and the reduction of exposure to threats from autonomous systems	Counter-surveillance for vehicles (moving and static) across the hyper-visual, electromagnetic and audible spectrums

Force Protection

Military objective/capability	Research areas
CBRNE Defence • Reinforced Combat Brigade is able to survive and fight in a CBRNE environment • Strategic counter-CBRNE functions provided by SOCOMD • Reduce force exposure with autonomous detection and electromagnetic countermeasures to improvised explosive threats	**CBRNE Defence sciences** • CBRNE detection, protective ensembles, contamination control, and forensic exploitation • Medical countermeasures and trauma management • CBRNE hazard assessment and modelling **Improvised threat countermeasures** • Improvised threat characterisation • Advanced force protection electronic countermeasure techniques and systems
Physical Protection • Develop next-generation integrated soldier combat system • Develop next-generation mounted and protected capability with a survivability growth path • Develop modular and scalable protective solutions including active systems that operate across multiple platforms • Adapt Land Force distribution and disposition to mitigate against emerging threats	**Weapon systems and effects** • Seekers, propulsion and control • Modularised and open architecture active protective systems **Soldier, vehicle, aircraft and infrastructure survivability** • Blast and ballistic protection appliqués • Ballistic, blast, fragmentation, fire protection assessment and assurance • Advanced multirole armours and protection materials, including fabrication technology • Armour life-of-type • Mission modelling, simulation and analysis • Integrated survivability simulation and modelling
Counter-surveillance and Deception • Integrated battlegroup signature management systems, including decoy systems • Counter to a high degree the full spectrum of contemporary and future surveillance techniques • Enable full range of military manoeuvre	**Signature measurement, management and control:** • Radar, visible, infrared, electromagnetic, acoustic **Sensor systems** • Integrated signature modelling • Electro-optical sensing including hyperspectral • Autonomous sensing platforms and systems • Integrated threat warning and situational awareness
Electronic Warfare (EW) / Cyber • The deployed Land Force is able to detect threats and deny adversary electronic and cyber attack • Degrade an adversary's offensive and exploitation capability through disrupting electromagnetic spectrum system control	See Command, Control & Communications Focus Area

Command, Control and Communications (C3)

Land forces will operate in a contested, degraded or denied Electromagnetic Spectrum (EMS) domain affected by civil, commercial and protagonist actors. Increases in technology, connectivity and the use of digital networks will see an increase in electronic warfare and cyber threats. The volume of information flows, and the level of trust in the information, will present unique challenges to the decision maker. The Army must develop an ability to defend critical networks and operate during conditions of network denial or degradation, with resilience to cognitive, electronic warfare and cyber attack.

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.

Vision

Commanders achieve decision superiority across the full spectrum of military operations optimised by a coherent and intuitive network of sensors, Soldiers, platforms and agile command posts, with the necessary planning and execution Network Operational tools.

Science and Technology Support

The digitisation of the Land Force has profound impacts on the way it operates and applies C2. S&T support is needed to explore the best options for system-level optimisation, deliver protected satellite and radio communications, develop advanced electronic warfare (EW) techniques and systems, provide cyber defence, find ways of operating in austere and contested cyber-EW environments, and develop capability advantage from the convergence of cyber, EW and signals intelligence (SIGINT) systems.

In supporting C3, it is particularly important to leverage Joint S&T capabilities. DST Group partners with US Army RDECOM, US AFRL and US Navy SPAWAR (for Marines) in researching survivable communications networks; and US Army RDECOM, the Naval Air Warfare Centre and Defence R&D Canada in researching advanced techniques for optimisation and distributed EW battle management. Significant SRI investment is involved in this work. Work in cyber defence crosses Whole-of-Government needs, and also draws on the expertise of various international intelligence partners. One new innovative and promising approach to survivable communications is distributed beamforming. Looking further forward, quantum technologies offer a new paradigm in enabling secure and communications, and will be critical in cyber security and precision navigation and timing. NGTF will be needed to support new initiatives such as distributed beamforming, and maintaining the current edge that the Australian quantum research community has in this highly competitive field.

Priorities		
Land Forces must be fully integrated into the Joint network environment, to deliver the fully Joint Task Force, and the risks inherent in this digitisation transformation must be managed	Practical methods of defending Army C3 against electronic warfare and cyber attack need to be developed. C3 has to be enhanced through smart technology and self-protection and self-healing mechanisms that mitigate the risks associated with operating in a contested and information-degraded environment	A resilient command and control system, including tools to enhance and withstand attacks on the cognitive capacity of the decision maker

Command, Control and Communications

Military objective/capability

Command and Control (C2)

- HQ optimised to leverage digitisation
- Decision makers are cognitively enhanced and enabled to comprehend and adopt a faster decision cycle than the adversary

Communications and Networking

- Converged battle management systems – C2 / Fires / Joint / ISR
- Information is globally accessible and advanced management allows tailored processing to suit context
- Digitisation exploitation and diversification, with resilience, self-adaptation and redundancy, including
  - communications systems
  - positioning, navigation and timing
  - sensor-effector systems

Cyber & Electronic Warfare (EW)

- Enhance tactical mission systems resilience to cyber and EW attack
- Integrate defensive cyber and EW systems into a joint architecture
- Global operational assurance of technology and information to rapidly mitigate compromise
- Cyberspace operations are conducted with integrity, trust and assurance
- Develop capabilities to achieve tactical cyber-EW effects

Research areas

System level optimisation

- Command and control concepts and capabilities
- Automated reasoning and decision support
- EW battle management technologies enabling improved C2 in cyber and electromagnetic domains, including denied / degraded environments
- Information flow modelling and analysis
- Coalition interoperability

Protected satellite and radio communications networks

- Dynamic networking, optimisation & compression
- Distributed beamforming
- Low probability of intercept / detection communications
- Communication range extension
- Autonomous agents for network resilience
- Secure quantum key distribution

EM interference suppression and avoidance

- Electromagnetic environmental effects compatibility
- Time division multiple access timing methods
- Frequency filtering and active signal cancellation

Tactical cyber-EW systems and effects

- Adaptive and cognitive cyber-EW systems
- Quantum and electromagnetic technologies for sensing, positioning, navigation and timing
- Precision geolocation
- Multi-function apertures and architectures
- Multi-channel broadband sensors and effectors
- Integrated threat warning and situational awareness

Cyber vulnerability analysis and mitigation

- Cyber mission assurance
- Automated vulnerability discovery and analysis
- Trustworthy systems
- Cryptographic tools, quantum encryption

Convergence of EW, communications, SIGINT and cyber

- Multi-role systems
- Data correlation and fusion methodologies
- Information integration and display

Situational Understanding

Key challenges of the future operating environment include the impact of state and non-state actors with access to emerging disruptive technology, the ability to maintain the dominant narrative, and the incorporation of systems and processes which rapidly disseminate understanding across the tactical, operational and strategic domains. Additionally, knowledge management, system integration and advanced analytics underline the importance of assets which can be configured to more effectively operate across the collective, joint, coalition and interagency spaces.

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.

Vision

Situational Understanding enables decision superiority: Future Land Force operations are founded upon situational understanding provided by an operationalised Joint Interagency Intergovernmental Multinational Enterprise. Every soldier is informed through understanding patterns of behaviour, constraints and opportunities of geography, topography, cultures, environment and forces that allow us to direct, misdirect, predict, and pre-empt.

Science and Technology Support

S&T support is needed across the breadth of technologies supporting Situational Understanding, and relies heavily on systems, architectures and technologies being developed for the Joint environment:

- Sensing technologies: Advanced sensing systems, including the phenomenology of the various sensor technologies and the processing / integration of those sensor systems needs to be understood.
- Tactical integration: Effective incorporation of deployable intelligence information management systems is critical to the achievement of tactical C2 within the mobile networked Land Domain.
- Information integration: As the Army becomes more digitally focussed and equipped, it will be of paramount importance to ensure effective integration across the multi-intelligence domains.
- Experimentation: Development of the Army to a digitised force will be undertaken iteratively and incrementally. It is crucial to use experimentation as a learning approach to inform iterations.

DST Group SRI supports work in advanced sensing and information architectures. NGTF funds are needed to drive development of critical advanced analytics technologies that are urgently needed to complement the ADF's investment in sensing, and further strengthen our partnerships with technology leaders in the international intelligence community. Quantum computing also looms on the horizon as a game-changing technology for information security and processing.

Priorities		
Integration of ISR into the Joint domain with coalition interoperability, and resilience to degraded and contested environments, while achieving information dominance over our adversaries	Development of an ISR enterprise, with advanced analytics, intelligence fusion and efficient dissemination of information as a focus	Development of novel sensor systems and supporting capabilities to operate within complex and contested environments, particularly the urban-littoral

Situational Understanding

Military objective/capability	Research areas
Sensing • Timely awareness through manned-unmanned teaming with ISR assets • Persistent active, semi-active and passive autonomous multi-sensing systems • Tactical – strategic sensing integration • Robust sensing in complex, hostile and degraded environments where reach currently does not extend	**Sensor systems** • Integrated signature modelling • Electro-optical sensing including hyperspectral • Passive radar **Intelligence systems** • Geospatial systems • Biometric systems • Unmanned sensing platforms and systems • Space-based systems
Process and Analysis • Deployable intelligence information management systems and information assurance • Advanced analytics allows tailored processing to suit context • Understand, influence and shape the adversary • Reduce analyst workload through user aware / context based automated information fusion	**Advanced computing systems** • Cognitive computing • Big data technologies and architectures, distributed cloud technologies • Neuromorphic and quantum computing **Analytics and fusion** • Data mining and deep machine learning • Language technologies, speech recognition • Image analysis and processing • Sensor data fusion and high level information fusion • Automated reasoning and decision support **Social sciences** • Social network modelling • Social psychology and influence techniques
Integration and Awareness • Enterprise ISR architectures integrated in the Joint domain and with battle management systems • Deployed systems dynamically contribute to or draw from strategic systems as necessary to maintain understanding, and control / influence surroundings	**Integrated ISR architectures and systems** • Open architectures and standards • Scalable networks **Human-machine interface and cognition** • Visual analytics • Information integration and display • Human knowledge elicitation and capture

Combat Service Support

Sensors for various purposes with a range of sophistication and functions are increasingly becoming a standard part of technology design, and to a lesser extent, health-state monitoring. For Combat Service Support (CSS), the use of sensors as part of asset tracking systems can offer benefits in enhancing situational awareness, and monitoring of supply chains and equipment health. Biosensors in wearable and implantable form offer health-state monitoring capabilities in the longer-term. The health area has seen advances in neurological research, injury prevention systems, portable diagnostics and treatment of complex injuries.

Autonomous and remotely controlled robotic systems have gained popularity as potential human replacements for tasks that are 'dull, dirty and dangerous'. Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs) have potential applications in supply, distribution and evacuation roles. At the same time, advances in prosthetics and exoskeletons are offering better options for replacement of human function.

In the field of power technologies, power generation has long included consideration of alternative energy sources, with continuing advances in hydrogen generation, biomass/waste-to fuel conversion, solar cells, concentrated solar power, and use of wind energy. Energy storage research has seen improvements to the cost-efficiency of lithium-ion batteries and exploration of alternative materials for batteries and supercapacitors. Direct Current microgrids are also gaining popularity as a more efficient way of managing the local distribution of electricity.

Across the functional areas of CSS advanced logistic information systems, embedded sensors, pervasive visibility and decision support are seen as key enablers for a robust control framework. This control framework creating distributed situational awareness acts as a basis for effective CSS planning and execution.

Vision

To ensure Army possesses CSS capabilities that enhance its operational reach, combat endurance and freedom of manoeuvre. CSS modernisation will be achieved through the exploitation of proven technologies and emergent logistic systems and encompasses delivery of CSS to the deployed land forces.

Science and Technology Support

The proliferation of advanced technologies in logistic supply chains provides an imperative for the Land Force to modernise. S&T support will be required in decision support methods, distribution technologies, maintenance technologies, human health technologies, and power and energy systems, particularly for deployed forces. NGTF will be needed to harness the expertise of the Australian R&D community in novel and emerging power and energy systems, including storage and distribution systems particularly for dismounted soldiers. We are also able to partner with US Army RDECOM on power distribution systems and the US Naval Research Labs on ultra-thin, flexible solar panels, as well as more broadly with our five-eyes partners.

Priorities	
Modernisation of power and energy management, storage and distribution systems to drastically reduce burden on the soldier, and enable longer-duration, more self-sufficient missions	Rapid modernisation of distribution systems through the embracing of automated and autonomous technologies that reduce personnel threat exposure and provide a step-change in efficiency

Combat Service Support

Military objective/capability	Research areas
CSS Control and Force Design • Deployable CSS information systems • Sense and respond technology for CSS • CSS systems integration with wider networked information systems • CSS force elements organised for operations and adapted for garrison	**Logistic decision support methods** • Logistic information flow modelling and analysis • Big data technologies and architectures, distributed cloud technologies • Design and assessment methods for CSS force structures • Modelling and decision support for CSS force design
Distribution • Semi-autonomous routine replenishment • Semi-autonomous casualty evacuation • Enhanced load carrying for Army aviation	**Distribution technologies** • Automated and autonomous logistic systems • Supply chain design • Human-systems integration • Additive manufacturing and repair technologies
Maintenance • Development of architecture for maintenance information management and decision support • Sustainable operations and maintenance productivity • Predictive maintenance in CSS	**Maintenance technologies** • Advanced sensor systems for asset tracking and health state monitoring • Logistic data mining and statistical analysis • System health and usage monitoring systems • Condition based maintenance • Design for maintainability
Health Services • Enhanced patient care through fusion of health data and analysis capability • Expert systems support to non health-professionals • Advanced surgical capabilities • Semi-autonomous initial assessment and treatment of Battle Casualties	**Health technologies** • Telemedicine research and simulation-based health training • Health/diagnosis expert systems • E-health and data management • Robotic augmentation / human teaming • Life preservation and advanced prevention and treatment technologies
Field Services • Deployable energy infrastructure systems • Improved energy security and geographical freedom for provision of energy • Reduced burden and weight on the soldier through integrated power solutions	**Power and energy** • Power and energy systems architectures and integration • Power and energy systems modelling and optimisation • Advanced energy storage and power distribution technologies • Novel and emerging power generation and harvesting technologies • Power and energy management technologies

Creating and Shaping the Future Force

The ADF will continue to develop future capabilities to achieve the operational outcomes directed by government. As a forward looking organisation in a rapidly evolving technological environment it will seek to stay ahead of potential adversaries through the identification, exploitation, and assessment of emerging/disruptive technologies. The Focus Areas described in this document provide a path forward to achieve this. There is also a need to consider the design of the whole force, address the Focus Areas interactions and whole of force impacts and issues, and conduct analysis of the potential far future to modify future operating concepts as needed. This is the ultimate strategic foresighting that drives, adapts and integrates the rest of the modernisation and force design process.

This work is focussed towards three key areas for future proofing the Land Force:

- Shaping the Future Land Force;
- Innovating the conduct of Ground Manoeuvre; and
- Optimising Decisive Close Combat (this last area having a strong relationship with Force Projection and Application).

It is through these three perspectives that Land Force is able to understand the advances within the individual Focus Areas and their impact on the operational effectiveness of the force as a whole; enabling force design to be conducted holistically.

Science and Technology Support

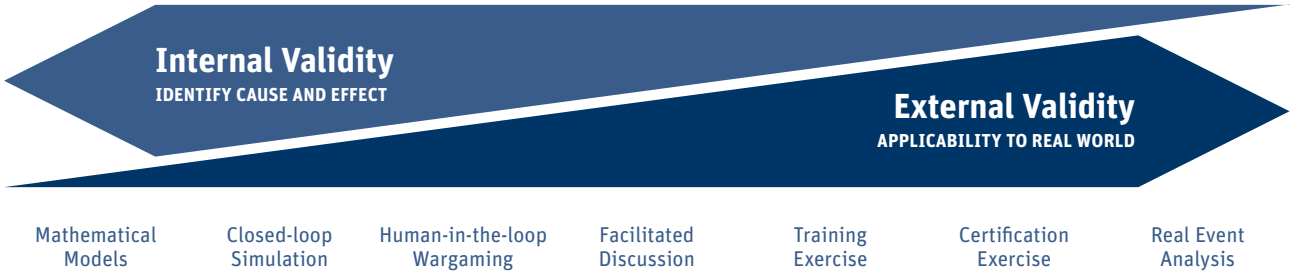
Operations research, analysis and experimentation support the exploration and evaluation of possible futures and determine their likely impacts. This work is done in close cooperation with the Focus Areas considering the three main aspects of force design: concepts, major systems and force structures; at all times considering them in the context of Army's unit of action, the Reinforced Combat Brigade; providing objective evidence for capability decisions and to maximise operational effectiveness of future Land capabilities. Key areas of S&T support rest in Combat Simulation and Modelling as well as Land Force Red Teaming. As similar organisations, and with Land Forces that have considerable commonality, we will aim to partner particularly with UK Defence Science and Technolgy Laboratory on capability studies beneficial to both nations. We also benefit from close interaction with US Center for Army Analysis and TRADOC in accessing leading simulation capabilities.

The irreducible uncertainty of the future makes it necessary to use preparatory scenario methods to test and improve the robustness, adaptability and plasticity of future land-related operating concepts in plausible environments and against the potential shocks of emerging and disruptive technologies.

Priorities	
Scientific analysis and defendable evidence to support capability decisions and maximise operational effectiveness along the lines of shaping the future land force, innovating ground manoeuvre and optimising decisive close combat	Technology foresighting, forecasting and preparatory scenario methods to mitigate against the strategic shock of emerging and disruptive technologies

Creating and Shaping the Future Force

Military objective/capability	Research areas
Development of the Whole Army to meet operational outcomes as directed by government within an uncertain future • Impact of emerging and disrupting technologies on the Land Force • Backcasting from future concepts to Army in Being • Design possible future forces • Future focussed concepts and capability	• Land Force Red teaming • Preparatory scenario analysis • Concept analysis • Horizon scanning • Technology foresighting • Judgement based operations research • Force design analysis • Military experimentation • Backcasting
Innovating future ground manoeuvre for future missions • Brigade and Battle Group manoeuvre options for the future • Assessing the impact of enablers to ground manoeuvre effectiveness • Integration of enablers into Brigade and Battle Group operations	• Concept mapping and analysis • Systems dynamic modelling • Bayesian modelling • Combat simulation and modelling • Military experimentation • Forecasting • System process modelling • Judgement based operations research
Optimising Decisive Close Combat within possible future environments • Understand the contributions of elements of the close combat ecosystem • Capability decisions based on objective evidence	• Combat simulation and modelling • Capability needs, options development and analysis • Close combat studies • Combined arms team modelling and analysis • Military experimentation • Data analytics • Statistical analysis • Forecasting • Optimisation



Definitions and Acronyms

ADF	Australian Defence Force
AFRL	US Air Force Research Laboratories
AMLE	Army Modernisation Line of Effort
Airworthiness is a concept, the application of which defines the condition of an aircraft and supplies the basis for judgement of the suitability for flight of that aircraft in that it has been designed, constructed, maintained and operated to approved standards and limitations, by competent and authorised individuals, who are acting as members of an approved organisation and whose work is both certified as correct and accepted on behalf of Defence. DI(G) OPS 02–2	
C2 / C3	Command and Control / Communications
CBRNE	Chemical, Biological, Radiological, Nuclear and Explosives
CIED	Counter Improvised Explosive Device
CSS	Combat Service Support
EW	Electronic Warfare
EA-18G Growler	electronic warfare attack aircraft
ISR	Intelligence, surveillance and reconnaissance
Joint	Activities, operations and organisations in which elements of at least two Services participate.
JSF	The F-35 Joint Strike Fighter
LHD	Landing Helicopter Dock – amphibious assault ship
LOE	Line of effort
NGTF	Next Generation Technologies Fund, announced in the 2016 Defence White Paper
PMV-L	Protected Mobility Vehicle – Light (as delivered by Land 121 Phase 4)
POE	Primary Operating Environment
S&T	Science and Technology
SIGINT	Signals intelligence
SOCOMD	Special Operations Command
SRI	Strategic Research Initiatives, investments in future technologies made by DST Group
Survivability (system)	The capability of a system to avoid or withstand a hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission.
UAV / UAS	Unmanned Aerial Vehicle / System
US Army RDECOM	The US Army's Research Development and Engineering Command, that oversees the majority of the laboratories working to support US Land Forces.
US Army TRADOC	The US Army's Training and Doctine Command
US Navy SPAWAR	The US Navy's Space and Naval Warfare Systems Command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For further information
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