Australian Government

Department of Defence

Science and Technology

Shaping Defence Science and Technology in the Aerospace Domain 2017–2027

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Shaping Defence Science and Technology in the Aerospace Domain 2017–2027 is the inaugural aerospace domain science and technology strategy. It has been jointly developed by Air Force and DST Group to inform and shape future science and technology in support of the aerospace domain. To achieve this the strategy provides guidance across six key focus areas encompassing sustainment of the current and planned force through to the development and application of novel concepts and technologies to maintain a capability edge.

The *Defence White Paper 2016* (DWP 2016) and *First Principles Review* (FPR) have set the strategic and enterprise contexts within which *Shaping Defence Science and Technology in the Aerospace Domain 2017–2027* is situated. The DWP 2016 provides for a planned force that will be more capable of conducting independent combat operations to defend Australia and protect its interests in the immediate region, whilst enhancing Australia's ability to contribute to global coalition operations. The FPR, and its associated recommendations, are reforming Defence into an integrated system that operates as a single end-to-end organisation delivering joint capabilities to the warfighter. Fundamentally, FPR seeks to embed the 'One Defence' ethos and behaviours, and encourages a more holistic enterprise view to be adopted in all endeavours.

Science and technology (S&T), as a finite and valuable enterprise-level resource, is a key enabler to both the development and implementation of DWP 2016 initiatives and the achievement of the FPR's intent of delivering joint capability to the warfighter. The collaborative manner in which *Shaping Defence Science and Technology in the Aerospace Domain 2017–2027* has been developed aligns with the intent of One Defence and seeks to deliver the integrated effects for joint outcomes envisaged within DWP 2016.

Shaping Defence Science and Technology in the Aerospace Domain 2017–2027 has been developed in parallel with the *Air Force Strategy 2017–2027* and *Air Force Operating Concept 2027*. It describes a partnership between Air Force and DST Group intended to identify and exploit S&T to support the capabilities and war fighting concepts that these documents articulate for the Air Force of the near future.

This inaugural aerospace S&T strategy has been developed by Air Force in partnership with DST Group but is intended to guide aerospace S&T across the whole of the ADF aerospace domain. The document represents long-term guidance applicable to DST Group and the broader science and technology community. Future editions will incorporate greater input from Army and Navy to ensure military aerospace domain science and technology support is considered in its entirety. More specific guidance for science and technology capabilities and shaping of the in-year aerospace program is delivered through the *Air Force Science and Technology Plan*, *Science and Technology Requirements and Priorities* documents, and *DST Group Domain Planning Guidance* documents.

Shaping Defence Science and Technology in the Aerospace Domain 2017–2027 was endorsed by Deputy Chief of Air Force and Domain Program Manager Aerospace on 25 January 2017.

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RAAF

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Working in partnership, Air Force and DST Group will identify and exploit science and technology that secures the best military aerospace capabilities for Australia.

Deputy Chief of Air Force and Aerospace Domain Program Manager DST Group

Introduction

Science & Technology (S&T) investments are crucial to a robust military capability for the aerospace domain. Recent S&T work has yielded major cost savings across aircraft types, risk reduction for major acquisition programs, and future proofing through advances in technology, such as in hypersonic flight. The aim of this strategy is to guide ongoing research in the aerospace domain that focuses the efforts of scientists and engineers working across the S&T enterprise. The strategy represents a partnership between Air Force and Defence Science and Technology Group (DST Group) to identify and take forward S&T that secures the best military aerospace capabilities for Australia; able to deliver air power and space effects within volatile, uncertain, complex, ambiguous and contested environments.

The strategy focuses on Air Force as the lead capability manager for Defence aerospace capabilities, is inclusive of Army and Navy aerospace fleets and systems, and incorporates Air Force's responsibility as the Defence Aviation Safety Authority.

The partnership between Air Force and DST Group is a critical enabler for the future Defence aerospace S&T enterprise. It recognises Air Force as a joint and globally connected service embracing innovation and the potential of emerging technologies, and DST Group as a highly regarded research organisation and the lead on interactions with academia, industry and international partners to achieve S&T outcomes that deliver future military aerospace power.

The strategy sets out the importance and role of S&T to Australian military aerospace capability. To provide long term guidance the spectrum of applicable S&T is divided into six science and technology focus areas which align with strategic guidance and the aspirations for the current, planned and future force. This is complemented by a small number of vignettes and exemplar challenges to provide greater context to the areas of research identified in the document.

A possible S&T enabled 2025 future

It's 0930 local time and the most recent piracy incident within the Asian Co-operative Security Region requires an immediate and coordinated response from the Anti-Piracy Coalition Force. AIRCDRE Wallis, as the air component commander, walks into the nearby conference room to commence the air planning group.

Utilising augmented reality provided within the conference room, AIRCDRE Wallis is able to view her virtual planning staff (both human and intelligent-agent based) together with a physical disposition of forces within the cross-domain common operations picture. Exploiting the output of the new dynamic security gateways to coordinate information across a range of access levels with coalition partners, AIRCDRE Wallis and her staff develop and refine their military response through accelerated simulation.

With the planning complete and agreed upon, AIRCDRE Wallis authorises the intelligent agent-based assistants to deconstruct the plan and download the necessary information directly to unit simulators. Unit personnel, having been alerted during the planning refinement phase are ready to commence the mission rehearsal. Meanwhile, the final information requirements are collated into the mission data pack and downloaded into the air vehicles that are on station ready for handover to the crew after the rehearsal is complete.

Satisfied that execution of the mission is underway, AIRCDRE Wallis resets the conference room to continue with the multi-department experiment that had been underway earlier this morning, and prepares to welcome the science partnership team. This new way of providing Humanitarian and Disaster Relief is going to be a real game-changer she thinks, as her virtual PA brings her up to date on the changes of the last hour.

Significant new capabilities and transformational change

Aerospace investment will see the introduction into service of a range of state-of-the-art surveillance, command-and-control and combat platforms. This includes introduction of advanced capabilities such as the F-35A Lightning II, EA-18G Growler, P-8A Poseidon, the MQ-4C Triton, and space systems including a space situational radar and space telescope. Moreover, Navy and Army are currently introducing transformational aerospace capabilities that include new helicopters, unmanned aerial systems, Landing Helicopter Dock ships and Air Warfare Destroyers, with all three services aiming to integrate these new systems and embrace carefully selected emerging technologies.

Plan Jericho, the Air Force's program to deliver a 5th generation fighting force, emphasises the need for Air Force to transform and not simply evolve. Plan Jericho has highlighted the importance of developing a future force which is agile and adaptive, truly integrated and immersed in the information age. By 2025 the Air Force aims to be a truly information age force, working jointly with Navy and Army and in close partnership with other Government agencies, as well as alliance and coalition partners.

The importance of science and technology

The ability of defence forces to maintain an enduring capability edge is being challenged by a global environment of rapidly developing and widely available technologies. Harnessing opportunities to achieve unique capability advantages and effective, evidence based, decision making through S&T is critical to enable delivery of an information age aerospace capability. This includes a force which is operationally effective; efficiently generated; and cost effectively sustained.

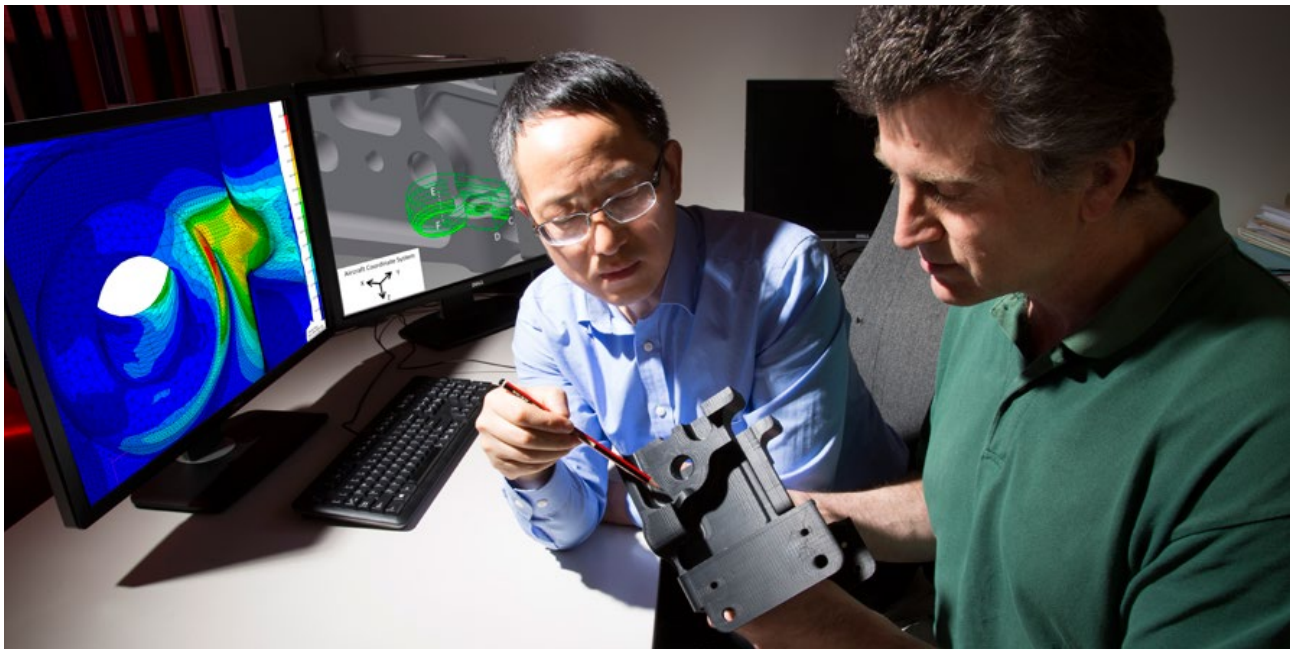
Air Force aims to achieve the most potent and agile force possible, able to operate as a truly joint and integrated capability. To fight and win in a dynamic future environment, Air Force needs to rapidly shape and adapt to situations, through strategy, concepts and tactics, involving the innovative adaptation of extant systems and the exploitation of new technologies. Air Force and DST Group must maintain a continual focus on exploiting S&T to retain a capability advantage, no matter how transient, in even the most challenging and rapidly evolving environments. The innovative use of existing technologies, novel application of new technologies, insightful development of new operating concepts and the application of advanced S&T will underpin Australian military aerospace leadership in developing and transitioning advanced capabilities. This will also ensure Defence remains well informed on S&T developments that may impact current and future capabilities.

Science and technology for Australian defence aerospace

A collaborative and flexible S&T program is an essential enabler for Air Force as the lead capability manager for the aerospace domain. A strong S&T program supports Air Force to:

- Rise to the challenges of new and complex environments.
- Build, maintain and operate a 5th generation, information enabled force.
- Be prepared for the necessary changes to be introduced by the future force.
- Facilitate the rapid harvesting of innovative technologies and concepts into new, sustained and enhanced capabilities for Defence.

While much of the current and planned aerospace technologies used by Air Force, Army and Navy are acquired overseas, it is critical that Defence has an organic and dedicated S&T support program to ensure research is applied effectively to meet Australian aerospace needs and requirements. The vital contribution to aerospace capability of Australian research organisations, including industry and academia, provides the Australian Defence Force with an independent research and technical support base that is not matched in the region.



The Air Force and DST Group strategic partnership

Achieving science and technology outcomes for the aerospace domain is underpinned by the strong partnership between Air Force and DST Group. This partnership recognises the need for a different form of strategic outlook.

Increasing worldwide investment in research and development is seeing shifts in the relative share of S&T undertaken in government, academia and the commercial sector. In addition, current research efforts are driving potential transformations in military capability, including autonomous systems, advanced materials, highly secure communications, data analytics, and advanced simulation. Working in partnership, Air Force and DST Group will steward and apply the best science and technology from across the breadth of the S&T enterprise to advance the Defence aerospace domain.

The partnership between Air Force and DST Group will employ the principle of co-design to collaboratively shape the S&T program. Through Air Force leadership on requirements and priorities, and DST Group leadership on S&T delivery and engagement with academia, industry, and international partners, a comprehensive science and technology program will be developed and actively managed. Co-design will ensure that a multi-disciplinary emphasis is brought to each area of science and technology activity.

The partnership will support ongoing, long-term research with the capacity to accelerate selected research to deliver capabilities that address rapidly emerging changes. This long term research will be complemented by faster turn-around activity to achieve immediate capability outcomes and address short term high priority tasking. This will encompass the range of aerospace capabilities and responsibilities where dedicated DST Group S&T support is essential, as well as work undertaken with academic and industry partners.

The partnership reflects the focused, yet collaborative, roles for Air Force and DST Group as the custodians of Defence aerospace S&T.

Advanced technology for issue response

Trident (the virtual Common Operating Picture integration agent) was being overloaded. Integrating the information feeds from the various embarked aviation assets, including the Boomerang autonomous VTOL UCAV, into the LHD's COP seemed to be the issue. This integration failure was also impacting the airborne exchange of information with other aviation assets, limiting the engagement and coordination options for the Commander. It was nothing to do with internal capacity of the various systems as the technical support teams from the OEMs had proven several times. If it wasn't the individual hardware, why was Trident failing?

Dr Marvin, the DST Group Aerospace combat partner, had been part of the issue response team from the start. While the OEMs had spent a few days checking the internal functions of the various systems, he had been assembling a multi-discipline team from Defence, government, industry and academia. The team included human/machine teaming, cognitive specialists, system training instructors and the necessary simulation and technical specialists.

The team was going to use the distributed Aerospace System Development (ASD) Battlelab federated with the Maritime Virtual Fleet Battlelab to replicate the mission conditions that were leading to the issue. This was the first time the ASD battlelab was being used for real world problem definition and remediation, and linking with the Maritime system was just an additional complication. The ASD battlelab had been central to developing and understanding the concepts needed for the autonomous VTOL system, but hadn't been used for VTOL since.

Australia's amphibious task force, and its embarked aerospace systems were to be Australia's on-call contribution to the ASEAN Humanitarian Response Task Force from next month. The mission competency training for the task force had to continue, and the federated battlelabs would be the nearest that they would get to the real thing. The team had 72 hours to refine a preferred solution, with modifications to be completed next week. It had to be done now because this year's force development experiment was commencing in a fortnight and the ASD battlelab was needed to simulate the legacy systems for the 2030 context.

Science and technology focus areas

To facilitate management of priorities and allocation of resources across S&T activities, research efforts need to be aligned with Defence requirements. To achieve this, six aerospace domain focus areas have been developed. These focus areas are designed to span a range of time horizons and are independent of specific phases of the Capability Life Cycle.

The six aerospace domain S&T focus areas are:

- **Decision Superiority** – To dominate an adversary's decision cycle.
- **Ensured Operational Availability** – To maximise the availability of operationally effective capabilities for missions.
- **Force Experimentation and Preparation** – To design the future force and ensure professional mastery of strategy, concepts and tactics.
- **Force Projection** – To provide military options to the Australian Government through aerospace capabilities.
- **Joint and Combined Operations** – To flexibly integrate with operational partners for synchronised awareness and effects.
- **Survivability** – To support, generate and sustain enduring operations within complex and contested environments.

The following sections expand upon each of these six focus areas and outline the vision, strategic drivers, objectives, and the areas of science and technology support.

Integrated mission rehearsal and execution

"That went well… NOT" thought SQNLDR Powers as he removed his VR headset and looked around his office. He had just been immersed in a mission rehearsal activity that was being conducted by one of his teams. While the team had functioned well there was significant room for improvement within the whole operation. That was typical of these immediate response activities – the basic planning was good, but finesse was missing. Finesse was the difference between success and failure, making mission rehearsal critical.

The EW plan had worked, and the coordination with HMAS Hobart and its Surface Action Group to achieve the missile launch was fine. The timings for the refuelling and the fall-back communications needed revision. It would be tight to make the necessary changes, but it could still be achieved.

SQNLDR Powers walked down to the No. 1 simulation debrief room and told the team what changes were needed so they could commence the virtual conferences with Headquarters and other units. Meanwhile, he would go and brief the changes to second team that would actually execute the mission. Brakes release was in 90 minutes, and the intelligence mission data would be uploaded in-flight during transit to ensure the currency of the information, given the planning and transit period.

The last anti-piracy mission had really tested the limits of the machine-augmented PED system, and this mission would do the same again. Regardless of its limitations, this new PED system was better than the previous system of launching with information that was already hours old and getting older during transit. Now with the latest data communications systems the data would be downloaded during the last phase of transit and be no more than an hour old, and the next update in work was promising even better outcomes.

Decision superiority

Vision

To dominate the adversary's decision cycle through employment of aerospace capabilities that successfully acquire, assimilate, exploit and share data and information across the joint force within contested and congested environments.

Strategic drivers

Striving to make better, faster, and more informed decisions than an adversary is not a new concept in warfare. However the increasing sophistication of modern weapon systems, and the shortened decision cycle required to defend against them, has raised the importance of achieving decision superiority. As noted in the DWP 2016, "Having situational awareness is essential to making sure our forces have decision-making superiority – knowing more about a situation and knowing sooner than an adversary so that our forces have an advantage in planning and conducting operations."

Operating environments are being increasingly shaped by information technologies with new warfighting concepts being developed to generate information effects. This is placing increasing emphasis on the collection of information and its effective exploitation. It highlights that Air Force's command, control, communication and computers capability must continue to evolve to support superior decision making. To achieve decision superiority will require integrated platforms, intelligence, surveillance and reconnaissance (ISR), full spectrum electronic warfare capabilities, and space assets to be harmonised as part of a joint capability.

Exemplar Air Force challenge
Achieve the ability for new and planned Air Force intelligence, surveillance and reconnaissance capabilities to rapidly and reliability collect, fuse and disseminate large amounts of data to sustain operations. Challenge time horizon: 5+ years

Context for delivery of science and technology support

Support will be needed to meet the challenge of acquiring, processing, fusing, protecting and distributing the necessary data and information to the elements of the joint force. This needs to be achieved across Defence in an integrated manner to support intelligence mission data (IMD) requirements, space effects, and other command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) outcomes.

The capacity for personnel to assimilate and understand the data provided by current and future systems will be severely tested and needs new and innovative approaches and tools to ensure operational imperatives of timeliness and accuracy are met.

Objectives

- To turn data into information in a dynamically contested environment.
- To develop intelligence systems that extract the best available situational awareness for the decision maker.
- To present the decision maker with timely and accurate data and information to enable trusted and repeatable decision making.
- To automate decision making where appropriate to ensure human in-the-loop decisions occur only where necessary to enhance mission outcomes.
- To understand, exploit and operate space-based capabilities while countering those of adversaries.
- To ensure integrity and distribute common (knowledge) information.
- To develop contested intelligence, surveillance and reconnaissance options.

Areas of research

- Networks
  - Agile and adaptive data networks
  - Robust, trustworthy and dynamic communication links
- Cyber analysis and mitigation
- Enabling multilevel security integration
  - Improved cryptographic tools
- × Improved processing, exploitation and dissemination of intelligence, surveillance and reconnaissance data
  - Big data analysis tools
  - Improved data correlation and fusion tools
  - Agent-based systems
- × Decision-making
  - Automated reasoning and decision support
  - Enhanced decision making tools
  - Artificial intelligence to enhance operational decisions
  - Human cognitive issues in information presentation
  - Enhanced visualisation tools
- Speed and autonomy in preparing intelligence mission data
- Persistent air and space intelligence, surveillance and reconnaissance
  - Advanced and novel sensor systems
  - Enhanced sensor and system integration
  - Integrated intelligence, surveillance and reconnaissance architectures
  - Precision geolocation; precision navigation and timing
- Protected space operations
- × Alternative solutions for decision support in contested and degraded environments

× Jericho-aligned areas of research assessed as having the highest impact (mitigation/offset) on threats and challenges, based on the global and regional operating environment.

Ensured Operational Availability

Vision

To maximise the availability of operationally effective capabilities within robust and resilient frameworks that deliver cost effective, assured and acceptable levels of safety.

Strategic drivers

Defence must husband its resources to maintain operational effectiveness and ensure that maximum capability is available to commanders at all times. In operations Defence needs to sustain a required tempo and intensity with sufficient available assets; while sustaining new state-of-the-art capabilities requires long term planning, application of advanced technologies and skilled personnel.

The introduction of new fleets of aircraft is seeing the application of specialised logistic support systems that integrate into global supply chains. This raises challenges for decision makers in drawing information from disparate systems and working to manage multiple fleets. This challenge extends to the delivery of other essential mission items, such as Intelligence Mission Data (IMD). Ensuring operational availability requires sustainment techniques to be continuously evolved to meet the changing threat environment, operational needs, and developments in new technologies.

Exemplar Air Force challenge
By exploiting emerging technologies, establish the capability to reduce sustainment costs and maintain availability across multiple aircraft fleets. Challenge Time Horizon: 3–5 years

Context for delivery of science and technology support

Science and technology supports all facets of operational availability. This includes support to the aviation safety program as an essential foundation for the generation of mission-capable platforms and systems. This encompasses support to military type certification of Defence aircraft, design and repair, and incident and accident investigation.

The airworthiness framework sets the environment in which the cost of ownership, Sovereign Industrial Capabilities, capability life-of-type, capability role changes and other logistics requirements are considered. Exploitation of novel concepts of support, logistics arrangements, repair, certification, manufacturing and materials are key areas for science and technology support.

The increased use and dependency on global fleet management and support to maintain capabilities may constrain Defence's freedom to operate. Science and technology support is required to maximise the efficiency and availability of aerospace platforms within these support frameworks. Moreover, delivery of IMD must be robustly supported, including through establishment of resilient cyber systems and networks.

Other areas of science and technology support include:

- Reducing reliance on the human through automation, autonomy, technology exploitation, crewing concepts, inspection, testing and certification efficiencies.
- Personnel optimisation – including advanced training concepts and technologies, and workforce analysis.
- Rapid rebasing in high threat environments.

Objectives

- To provide support for the conduct of military operations in an appropriately risk managed framework
- To maximise mission availability and the effectiveness of platforms, systems and people
- To understand the constraints and opportunities in intelligence mission data sufficiency and fidelity
- To maximise weapons and associated system availability and reliability
- To ensure the integrity of supply chain systems for sustainable operations
- To provide methods, techniques or solutions to support capability options dependent on platform or system life-of-type extensions

Areas of research

× Support to aviation safety for legacy and future capability systems
  – Aviation forensics and accident investigation
  – Aircraft structural integrity (fixed and rotary wing)
  – Propulsion system integrity
  – Software integrity
  – Electromagnetic effects

× Improved reliability, availability and affordability of legacy and future capability systems
  – Novel and optimised design, manufacturing and repair technologies
  – Methods and techniques for platform and systems life of type extensions and role changes
  – Automated/advanced inspection technologies
  – Enhanced prognostics and health management (PHM) systems
  – Condition-based maintenance
  – Logistics requirements modelling
  – Novel logistics concepts
  – Low observable sustainment (RF & IR)
  – Enhanced corrosion and coating models
  – Exploiting aerodynamic and flight control system performance for improved range and manoeuvre characteristics

× Human performance and training
  – Human-machine interfaces
  – Workforce pipeline analysis
  – Distributed mission training
  – Cognitive analysis
  – Virtual technologies

• Dynamic reprogramming
  – Intelligence and mission data sufficiency/fidelity
• New operational concepts and technologies to ensure capability against future operational environments
• Advanced autonomous systems

× Jericho-aligned areas of research assessed as having the highest impact (mitigation/offset) on threats and challenges, based on the global and regional operating environment.

Force Experimentation and Preparation

Vision

To design a potent and flexible military aerospace capability for Australia; and ensure professional mastery of strategy, concepts and tactics for advanced and novel aerospace capabilities

Strategic drivers

To achieve the most from state-of-the-art aerospace capabilities requires development of robust operational concepts. Systematic development of new war-fighting concepts ensures that integrated combat solutions are available that exploit innovative technologies. The Air Warfare Centre, established under Plan Jericho, is a key point of coordination for tactics and procedures development, experimentation, and support to operations.

Force experimentation and preparation encompasses a breadth of activities, including assessment of strategic options, concepts exploration, tactical innovation, mission rehearsal, and skills training. It recognises that the ADF will continue to develop future capabilities to achieve operational outcomes directed by government, will need to stay ahead by understanding technology trends, and will exploit new technologies through innovative war-fighting concepts. To realise the capabilities of a 5th generation Air Force, new methods of training, experimenting and conducting test and evaluation will be required, placing a greater emphasis on the need for Live, Virtual and Constructive (LVC) simulation capabilities. This includes:

- Increasing training and experimentation with international partners in artificial environments.
- The predictive exploration, development and trialling of force concepts.
- Utilising virtual capabilities to overcome the security limitations of exercising real systems.

These techniques will help ensure cost effective future and planned force options analysis and reduce risks in operational plans and tactics.

Exemplar Air Force challenge
With the introduction of a range of new capabilities, establish a multi-level secure and distributed training capability to develop effective tactics, techniques and procedures. Challenge time horizon: 3–5 years

Context for delivery of science and technology support

Air Force needs to design, trial, understand and evolve operational concepts and test systems to meet the demands of a rapidly evolving and complex environment. Science and technology will underpin the ability for experimentation to be supported including through LVC environments.

Professional mastery of the air, space and joint environments by Air Force personnel will require significant effort. The right person in the right job at the right time will be as important to capability delivery as the platforms, and will require the use of simulation and experimentation to achieve the necessary preparation and development.

Operations research and analysis will support the assessment of force options through capability assessments and gap analysis. This will extend to supporting concept and tactics development, and maximising the operational effectiveness of aerospace systems as part of a joint force. Science and technology will provide future technology forecasting, scenario analysis and futures assessments to safeguard against strategic shock and the impact of emerging and disruptive technologies.

Objectives

- Potential future Aerospace capabilities
  - Inform acquisition decisions
  - Develop concepts
  - Force design and testing
  - Operations
  - Logistics
- Selecting the right people
  - To exploit advanced and novel aerospace capabilities
- Training and effectiveness of teams
  - Matching the right people with systems for the future battlespace
  - Joint and coalition
  - Adaptive and comprehensive
- Speed of concept from prototyping to fielding
- Research into adversary capabilities and exploitation

Areas of research

× Live, virtual, constructive environments
  - White forces
  - Adaptive systems
  - Synthetic environments
  - Multi-layer security and whole system networking
  - Human in the loop.
  - Hardware in the loop
  - Manned/Unmanned – Teaming
  - Distributed mission training

× Experimentation and operations analysis
  - Modelling and simulation
    - Representation of Defence scenarios
    - Analysis of potential tactics and concepts of use
    - Visualisation
    - Force options comparison
    - Force mix analysis
  - Future concept exploitation
  - Future technology forecasting

- Agents/Artificial Intelligence
- Information visualisation
  - Immersive virtual and augmented reality systems

× Team effectiveness and metrics

- Future training analysis and optimisation
- Future concept exploitation through experimentation and war gaming

× Jericho-aligned areas of research assessed as having the highest impact (mitigation/offset) on threats and challenges, based on the global and regional operating environment.

Force Projection

Vision

To provide military options to the Australian Government through aerospace capabilities that deliver force projection within joint and coalition contexts.

Strategic drivers

Defence must be able to project force to meet the directions of the Australian Government. Force projection can be coercive or direct, including lethal and non-lethal options. Defence requires air power effects that exploit advanced capabilities to allow for timely operations at extended ranges. This includes long range strike as a critical element of air power projection. As noted in the DWP 2016, "The ADF must be prepared to carry out offensive strike operations against the military bases and in-transit forces of a potential adversary." Strike capabilities are being broadened to include non-kinetic options, such as electronic attack.

The achievement of force projection within the joint and combined environments draws upon the full spectrum of aerospace domain capabilities including air mobility (air to air refuelling), fixed and airborne ISR (JORN and Airborne Early Warning & Control) together with air combat capabilities operating within the contested environments.

Exemplar Air Force challenge
Achieve the capability to deliver prompt and precise kinetic effects in a future contested and denied environment. Challenge time horizon: 5+ years
Establish the capability to maintain surveillance and targeting within a contested and denied environment. Challenge time horizon: 3–5 years

Context for delivery of science and technology support

Science and technology will be applied to support Defence to operate freely across the global commons, including in contested and denied environments. To operate freely will involve, where directed, the delivery of kinetic and non-kinetic effects at long range. It will be supported and enabled by research in targeting, damage assessment and effects control/precision. This includes supporting the provision of airlift and forward basing.

Defence will support whole-of-government effects globally, and with various partners. Science and technology will be applied to support the conduct of Humanitarian Aid/Disaster Relief (HADR), including support modelling and the application of novel technologies to increase the timeliness and reach of response options

Objectives

- Have situational awareness to enable the Air Force to operate:
  - Receiving information to enable operation
  - Providing real-time information to Joint Operations Command
- Deliver integrated kinetic effects
  - Through flexible strike weapons, increased precision strike, low collateral damage capability
  - Increased reach
- Deliver integrated non-kinetic effects
  - Delivery of multi-platform electronic warfare effects
- Freedom of physical and electromagnetic movement
  - Ability to operate in a degraded state
- Achieve targeting
  - Cooperative targeting and coalition integrated fire control

- Assess effects
- Damage awareness and post-fire evaluation
- Interoperability
  - Between Defence systems and coalition systems
  - Between Defence and non-military entities
- Conduct responsive HADR

Areas of research

- Improved and timely situational awareness
  - Robust and adaptive data links, enhanced data fusion and integration
  - Space situational awareness and space operations/exploitation
  - Alternatives to space-based capabilities
- Enhanced targeting in complex environments
  - Advanced sensors for detection and tracking across full spectrum in contested and defended environments
  - Precision geolocation
  - Quantum technologies
- × Assured kinetic effects in future anti-access/area denied (A2/AD) environment
  - Stand-off strike weapons
  - Precision strike, low collateral
  - Flexible systems
  - Kinetic effect analysis tools
  - Weapons performance analysis
- × Assured non-kinetic effects in future A2/AD environment
  - Electronic warfare, including: cognitive/adaptive, force level, offensive and battle management
  - Cyber operations
  - Directed energy – laser/microwave
- Effects assessments
  - Kinetic effect efficacy and confidence
  - Damage estimation and assessment
- Improved interoperability
- Integration of proprietary systems
  - Open systems architecture and networks
  - Integrated fire control
- HADR
  - HADR combined effects and support modelling
- × Freedom of manoeuvre
  - Penetration aids to the deployment of projected force
  - High-speed airdrop and automation
  - Novel air mobility concepts
- Human factors associated with increased reach
- Improved tactics, techniques and procedures
  - Modelling and simulation
  - Operational analysis
- Additional research areas
  - Alternate to space base capabilities
  - Force mix studies
  - Hypersonics
  - Precision navigation and timing (PNT)
  - Operational analysis (OA)
  - Manned/unmanned teaming (MUM-T)
  - Unmanned aerial systems (UAS) and unmanned combat air systems (UCAS)

× Jericho-aligned areas of research assessed as having the highest impact (mitigation/offset) on threats and challenges, based on the global and regional operating environment.

Joint and Combined Operations

Vision

To flexibly integrate aerospace capabilities across multiple domains (sea, land, air, space and cyber) and with operational partners to provide synchronised awareness and effects with minimal additional resource investment.

Strategic drivers

The majority of air power missions are applied within a multi-force environment. International coalitions are often utilised to address military and humanitarian issues and Australian forces must be able to integrate and operate successfully in such environments. In addition, Australia's security hinges on a maritime strategy that requires sea, land and air forces to operate jointly to project power and control the air and sea approaches.

A key enabling air power role across the breadth of Defence missions is command and control (C2). The Air Force's C2 role has unique features that reflect the nature of the air domain and the way that Air Force personnel operate and fight. Air Force's C2 role also includes the management of military air and space operations, airspace control and Electronic Warfare Battle-space Management (EWBM). The introduction of new capabilities is driving the need for more innovative C2 to meet the demands of joint and integrated operations.

Exemplar Air Force challenge
With the introduction of next generation capabilities, establish a dynamic EW battle management system for future operations. Challenge time horizon: 1–3+ years
To maximise the effects of next generation capabilities, establish future C2 systems that automatically synthesise data from multiple sources and security domains to produce trusted real time Common Operating Pictures. Challenge time horizon: 5+ years

Context for delivery of science and technology support

The future operating environment will be dynamic, ambiguous, complex and uncertain. To fight and win in this environment will require a future force which is able to seamlessly integrate and execute joint and combined operations across Army, Navy and Air Force and team easily with coalition partners. Science and technology will be applied to develop new capabilities and techniques to address these challenges.

Future joint and combined operations will include the integration of ISR, precision strike, manoeuvre, and sustainment to achieve desired effects across all operating domains based on the ubiquitous sharing of information. This focus area will include linking information-age aerospace systems with sea and land-based weapons systems in ways that will enhance their combined effectiveness and overcome capability gaps.

Objectives

- Integrated command and control systems
- Information interoperability
- Information accuracy and timeliness
- Agile and adaptive basing and logistics
- Resilient to cyber attack
- Spectrum shaping
- Innovative operating concepts
- Support for rapid force movements over large distances
- Agile and re-programmable platforms and mission configurations

Areas of research

- × Real time, persistent and accurate information to support joint and combined operations across services and with coalition partners
  - Seamless machine to machine interoperability between command and control systems across multiple platforms, domains and with coalition partners
  - A coherent and interoperable common operating picture that spans across different C2 systems
  - Joint and combined intelligence and decision support
  - Rapid change of information protection for varying trust levels
  - Scalable and redundant communications protocol in a contested environment
  - Space operations
- × Integrated air and missile defence
- Combined sea and air operations for anti-submarine warfare (ASW)
- Joint Fires
- Air and sea surveillance
- Close air support
- Automation of joint and coalition operations planning and platform configuration
  - Automated logistics systems that support joint and combined operations
  - Automated reasoning
  - Human machine interfaces
  - Automated joint mission planning
- Data fusion
  - Information fusion over multi-level security systems
  - Robust and flexible information architecture design
- Advanced operating concepts
  - Dynamic logistics modelling and capability analysis
  - Shared and networked logistics, resources and supportability concepts
  - Flexible, agile and interoperable mission systems
- Cyber operations
- Electronic warfare battle management and communications
  - Spectrum shaping to provide near real-time allocation of band width
  - Spectrum management, electromagnetic capability and protection from unintended interference
- Soft system analysis (human factors, culture, etc.)
- × Data movement
  - Rapid and efficient movement of secure data

× Jericho-aligned areas of research assessed as having the highest impact (mitigation/offset) on threats and challenges, based on the global and regional operating environment.

Survivability

Vision

To maintain aerospace capabilities able to support, generate and sustain enduring operations within challenging, complex and contested environments.

Strategic drivers

Adversaries are now able to contest our access to space, cyber and the electromagnetic environment, impacting the ability to employ aerospace capabilities. The ability for an adversary to degrade critical enablers places a greater focus on the area of survivability, especially mission survivability.

Issues of survivability are not confined just to the aerospace platform and operating personnel. Survivability considerations encompass other supporting and enabling capabilities such as airfields/operating locations, networks and communications, through to the weapons that will be utilised. Modern platforms and weapons no longer operate in isolation but increasingly rely upon common supporting systems and networks. Disabling and/or corrupting these critical system nodes could prevent the generation of successful military missions.

Survivability in the aerospace domain includes the management of signatures and the development of improved countermeasure systems. This extends to the survivability and resilience of personnel operating in threat environments. More broadly, understanding adversary systems will provide opportunities to develop capabilities and tactics to enhance survivability.

Exemplar Air Force challenge
With the increasing reliance on space based assets, establish the capability to ensure secure, robust, distributed space operations. Challenge time horizon: 5+ years
With the increased reliance on information and data fusion for decision-support, establish timely and effective cyber defence systems. Challenge time horizon: 1–5 years

Context for delivery of science and technology support

Science and technology supports all elements of survivability, including in the areas of signatures, countermeasures, and infrastructure. This includes supporting the survivability of critical enablers including space and terrestrial networks, and ensuring their availability at air bases (fixed and/or deployed) with sufficient robustness to withstand external attack. Aerospace platforms and weapons operated by the Australian Defence Forces must be able to successfully operate within, and return from, a hostile operating environment and when damaged must be capable of quick damage assessment and adequate repair for continued operations. Science and technology has a central role in assessing vulnerabilities and improving survivability.

The ability to sustain the generation of personnel who can continue to function during periods of high operational tempo will be crucial. Personnel are, and will be for the foreseeable future, central in the operation of ADF systems and our ability to improve mental and physiological resilience prior to operations is essential for the continued generation of successful military missions. Science and technology provides crucial, evidence based, approaches necessary for achieving this goal.

Objectives

- Resilient supporting infrastructure
- Enduring critical network access
- Access to space effects
- Air vehicle/materiel survivability within the contested environment
- Personnel resilience and continued performance
- Research into the exploitation of adversary capabilities

Areas of research

- Signature measurement, management and control
  - Acoustic signatures
  - Radio frequency signatures
  - Electro-optical and infrared (EO/IR) signatures
  - Multi-spectral signatures
- On-board counter measure and defensive systems
  - Advanced directional infrared counter measures (DIRCM) – small, reliable high power lasers
  - Advanced flares and decoys
  - Countermeasures development and validation (CMD&V)
  - Electronic defence
- × Off-board support systems
  - Improved cyber-attack detection and response
  - Cyber resistant, mission assured networks
  - Agile, high assurance data networks
  - Agile, high assurance communication networks
- Infrastructure vulnerability analysis
- Rapid damage assessment, repair and manufacturing methods
- × Human performance and resilience
- Rapid Integrated mission data generation
- Ballistic protection
- Future threat Modelling and Simulation
  - Full spectrum modelling
- Ensured space operations
- Counter low observables (LO)
- × Unmanned aerial systems (UAS)
  - Unmanned combat air vehicle employment concepts
  - Counter UAS
  - Low cost mobilisation
- CBRN for aircrew

× Jericho-aligned areas of research assessed as having the highest impact (mitigation/offset) on threats and challenges, based on the global and regional operating environment.

Principles for the management of aerospace science and technology

Roles

Air Force as the lead service for the Defence aerospace domain will:

- Communicate and frame aerospace S&T focus areas, objectives, problem definitions, and challenges within the aerospace domain to DST Group.[1]
- Provide strategically aligned guidance on S&T requirements for capabilities across the capability lifecycle that is informed by the Force Design process.
- Facilitate a close working relationship between Air Force and DST Group from the senior leadership to working levels in order to embed the principle of co-design to achieve the best S&T outcomes in the aerospace domain.

DST Group as the lead agency for conducting S&T research within the aerospace domain and the lead enabler of interactions with academia, industry and international partners in the context of S&T outcomes will:

- Respond to, and help shape, aerospace focus areas, problems, objectives, challenges and future scenarios; and the application of S&T.[2]
- Be the trusted S&T advisor to Air Force in providing greater situational awareness on applicable, advanced and potentially game-changing research that could impact the aerospace domain.
- Take the lead on the exploitation of S&T within aerospace focus areas, noting that many S&T outcomes will be supported by academic and research institutions, as well as industry.
- Undertake science engagement with identified high value allies and industry.

The aerospace S&T program will be supported through co-design to ensure an ongoing dialogue between Air Force and DST Group to deliver the best possible research outcomes over the short and longer term. This dialogue will also engage the broader S&T community encompassing academia and industry to ensure that the best expertise is sourced to address S&T needs.

1 Defence, in partnership with academia and industry, will review its research priorities, their alignment with future force requirements and capacity to leverage allied partners to promote innovation (FPR Recommendation 2.21).

2 The Defence Science and Technology Organisation will strengthen partnerships with academic and research institutions to leverage knowledge and create pathways with academia and industry (FPR Recommendation 2.19)

Co-design will ensure a multi-disciplinary focus is applied not just to the strategy and aerospace S&T focus areas, but also to problem exploration and proposed solutions. Secondly, co-design behaviours will reinforce strategic engagement already present between the organisations in achieving innovative solutions and ensuring the ongoing review and rebalancing of the Aerospace S&T portfolio to support the delivery of air power and space effects as part of a joint and global force.

Principles

S&T within the aerospace domain will be viewed through the context of the partnership and based upon the following principles:

- **Strategic Alignment** – This S&T strategy and associated implementation activities will be aligned to, and guided by, the Air Force and DST Group Strategies, together with the needs of Defence's Strategic Centre.
- **User-focused prioritisation** – This strategy will guide the user-focused prioritisation of DST Group's efforts, with a focus on the effective application of S&T for the achievement of Air Power and Space effects within strategy objectives.
- **Connection between research and capability** – This strategy recognises that better connecting research to capability is critical in order to exploit advantages, some of which may be transient, to deliver air power and space effects faster and more effectively than adversaries.
- **Innovation** – Short, medium and longer term innovation will be considered in the application of S&T across each element of the Capability Life Cycle.
- **Considered application of S&T** – In connecting research to capability the application of S&T will be considered from a range of perspectives including; legal, security, implementation viability, and the expected return on investment.
- **Collaboration** – This strategy recognises that Air Force and DST Group need to work closely together in partnership rather than in an isolated customer/supplier relationship.
- **External Engagement** – This strategy recognises that required S&T capability and capacity does not reside solely in DST Group, necessitating engagement of a trusted network of government, industry and academic partners.

Key result areas

The following Key Result Areas will be used to assess the success of this strategy:

- The Air Force and DST Group partnership is able to rapidly identify and exploit S&T by using co-design methods to deliver game-changing advantages to the warfighter.
- Air Force and DST Group will realise S&T research into useable capability in a timely manner.
- The Air Force and DST Group partnership is actively managing, reporting and delivering S&T outcomes from a co-designed program of work.
- Air Force and DST Group are positioned as valued and trusted partners with their allies and within the broader S&T enterprise.

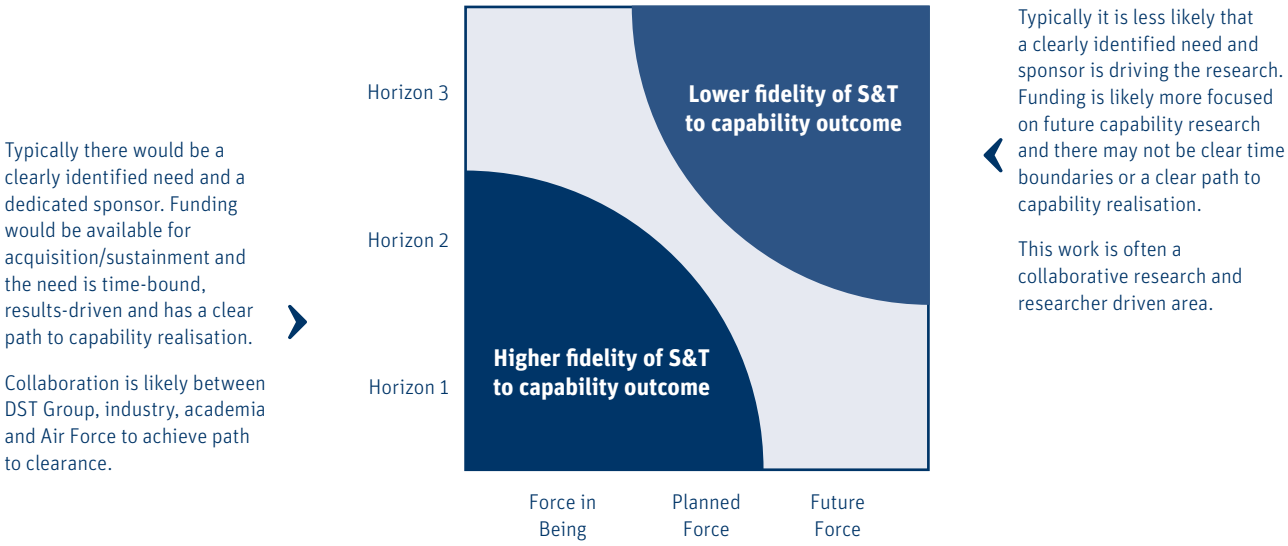
Science and technology research to capability outcomes

The Air Force and DST Group partnership supports ongoing long term research, while also enabling timely delivery of identified research at accelerated speeds to achieve enduring and transient capability outcomes. To undertake the cycle of capability generation at both the required speed and capacity must become a fundamental attribute of aerospace S&T.

To achieve research to capability outcomes, the application of S&T will be considered across the three temporal force states of the Capability Life Cycle (Force in Being, Planned Force, Future Force) in the context of the three temporal innovation horizons. The strategy will also provide for the enduring air power and space components that depend on the reliable application of established research programs; for example, the Jindalee Operational (over-the-horizon) Radar Network (JORN) and Airborne Early Warning and Control capabilities.

The application of S&T with the three temporal perspectives (Force in Being, Planned Force and Future Force) will be guided by the relative fidelity of the various science problems against the capability outcomes being pursued. This concept is illustrated in the figure below and the associated Horizon and Force State definitions.

Figure 1: Application of S&T across the three horizons of innovation within the temporal domains of the force



The three horizons of innovation

Horizon 1	Horizon 2	Horizon 3
The application of S&T in order to deliver and maintain capability against a known set of requirements.	The application of S&T which looks for opportunities to extend the current capability.	The application of S&T which is disruptive and experimental in searching for and creating new and disruptive capability.

Temporal domains of the Force State

The Force-In-Being (FIB)

Maintenance of the capability edge of the Force-In-Being is a critical requirement for Air Force as today's platforms are those deployed in response to Government direction.

The FIB is the foundation upon which the Planned Force is developed and built, and whilst the FIB may constrain the rate at which integration and networking of the Air Force can occur, it also offers opportunities to learn through considered modification of extant platforms for future capabilities.

Maintenance of the capability edge of assets is a significant aspect of FIB S&T support, with the management of airworthiness of ADF aircraft another essential FIB task.

Airworthiness and aviation safety are foundational to the ability of Air Force and Defence to prosecute operational requirements.

The Planned Force (PF)

The Planned Force encompasses those systems that are funded within the Integrated Investment Plan but are not yet introduced into service.

The PF will require S&T support to integrate extant capabilities with the new acquisitions, and provide advice to mitigate the risks inherent in the application of new technologies into an existing organisation.

The Future Force (FF)

The Future Force will be designed around new concepts of capability employment that will seek to fully exploit the potential of new and emerging technologies.

Air Force and Defence need access to forecasting and futures advice to initiate actions to prevent or reduce the strategic shock of disruptive technologies, whilst also assessing the potential for adoption of these technologies to positively impact Defence's developing Joint Force.

Definitions and acronyms

A2/AD	Anti-access/area denial
ADF	Australian Defence Force
Airworthiness	The ability of an aircraft, or other airborne equipment or system, to operate in flight and on ground without significant hazard to aircrew, ground-crew, passengers (where relevant) or to other third parties
C2	Command and Control
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CBRN	Chemical, Biological, Radiological and Nuclear
DWP 2016	Defence White Paper 2016
EA-18G Growler	Electronic warfare attack aircraft
EW	Electronic Warfare
EWBM	Electronic warfare battle management
HADR	Humanitarian assistance/disaster relief
IMD	Intelligence Mission Data
ISR	Intelligence, surveillance and reconnaissance
Joint	Activities, operations and organisations in which elements of at least two Services participate
JORN	Jindalee Operational Radar Network.
JSF	The F-35A Lightning II
LHD	Landing Helicopter Dock – amphibious assault ship
MQ-4C Triton	High altitude ISR UAS
NGTF	Next Generation Technologies Fund, announced in the *Defence White Paper 2016*
P-8A Poseidon	Maritime surveillance and response aircraft
Plan Jericho	Will provide a strategic framework for Air Force transformation, with a detailed Concept of Operations, and detailed implementation plans for the subordinate projects and tasks required to achieve the Air Force goal of fighting and winning in the information age
S&T	Science and Technology
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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For further information
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