List of critical technologies in the national interest

The technologies on this list are current and emerging technologies that have been identified as having a significant impact on our national interest (economic prosperity, national security and social cohesion). Many of the technologies on the list have implications for defence and security, but also often have broader applications.

- Advanced materials and manufacturing
- AI, computing and communications
- Biotechnology, gene technology and vaccines
- Energy and environment
- Quantum
- Sensing, timing and navigation
- Transportation, robotics and space

List of critical technologies in the national interest

Many technologies on this List have implications for defence and security.

Advanced materials and manufacturing

Additive manufacturing (incl. 3D printing)

Manufacturing physical objects by depositing materials layer by layer according to a digital blueprint or 3D model. Additive manufacturing systems use a variety of techniques to print objects in various sizes (from nanoscale to room-sized) and materials (including plastics, ceramics and metals). **Applications** for additive manufacturing include rapid prototyping and making custom or small quantity components.

Advanced composite materials

New materials created by combining two or more materials with different properties, without dissolving or blending them into each other. Advanced composite materials have strength, stiffness, or toughness greater than the base materials alone. **Examples** include carbon-fibre-reinforced plastics and laminated materials. Applications include vehicle protection, signature reducing materials, construction materials and wind turbine components.

Advanced explosives and energetic materials

Materials with large amounts of stored or potential energy that can produce an explosion. **Applications** for advanced explosives and energetic materials include mining, civil engineering, manufacturing and defence.

Advanced magnets and superconductors

Advanced magnets are strong permanent magnets that require no or few critical minerals. **Applications** for advanced magnets include scientific research, smartphones, data storage, health care, power generation and electric motors.

Superconductors are materials that have no electrical resistance, ideally at room temperature and pressure. **Applications** for superconductors include creating strong magnetic fields for medical imaging, transferring electricity without loss, and hardware for quantum computers.

Advanced protection

Clothing and equipment to protect defence, law enforcement and public safety personnel and defence platforms from physical injury and/or chemical or biological hazards. **Examples** include helmets, fire-retardant fabrics, respirators, and body armour.

Continuous flow chemical synthesis

Systems that produce fine chemicals and pharmaceuticals using continuous-flow processes, rather than batches. Compared to batch chemistry, flow chemistry can make fine chemicals and pharmaceuticals faster, more consistently and with less waste products. **Applications** for continuous flow chemical synthesis include rapid analysis of chemical reactions, and manufacturing industrial chemicals, agrichemicals and pharmaceuticals.

Coatings

Substances applied to the surface of an object to add a useful property. **Examples** include anti-biofouling coatings that prevent plants or animals growing on ships or buildings, super-hydrophobic coatings that repel water from solar panels or reduce drag on the hulls of ships, electromagnetic absorbing coatings that make airplanes and ships less visible to radar systems, thermal coatings that reduce heat loss and increase energy efficiency, and anti-corrosion coatings that prevent rust.

Critical minerals extraction and processing

Systems and processes to extract and process critical minerals safely, efficiently and sustainably. Australia has an abundance of critical minerals and has the opportunity to be a global leader in the ethical and environmentally responsible supply of key critical minerals. **Applications** for critical minerals extraction and processing include mining, concentrating minerals, and manufacturing battery-grade chemicals.

High-specification machining processes

Systems and devices that can cut and shape raw materials into complex and highly precise components. **Examples** include computer numerical control (CNC) mills, CNC lathes, electron discharge machining, precision laser cutting and welding, and water jet cutting. Applications for high-specification machining processes include making aerospace parts, and making components for other manufacturing devices.

Nanoscale materials and manufacturing

Materials with essential features measuring less than 100 nanometres and technologies for their manufacture. **Applications** for nanoscale materials include, paint, pharmaceuticals, wastewater treatment, data storage, communications, semiconductors, capturing carbon dioxide, and nanoscale tracking markers for critical materials.

Novel metamaterials

New synthetic materials that have properties that do not occur naturally, such as the ability to bend light or radio waves backwards. **Applications** for novel metamaterials include energy capture and storage, radio antennae, and adaptive camouflage.

Smart materials

Materials that have properties that change in response to external action. **Examples** include shape-memory alloys that change shape when heated and self-healing materials that automatically repair themselves when damaged. Applications for smart materials include clothing, body armour, building materials and consumer electronics.

AI, computing and communications

Advanced data analytics

Systems, processes and techniques for analysing large volumes of data (i.e. 'big data') and providing useful and timely insights, usually with limited human intervention. **Applications** for advanced data analytics include medical diagnosis and treatment, acoustic analytics, regulatory compliance, insurance, climate monitoring, infrastructure forecasting and planning, and national security.

Advanced integrated circuit design and fabrication

Systems and processes to design sophisticated integrated circuits and manufacturing processes to fabricate integrated circuits using process nodes below 10 nanometres. **Examples** include systems-on-chip (SoC), field programmable gate arrays (FPGAs), stacked memory on chip and specialised microprocessors for defence industry.

Advanced optical communications

Devices and systems that use light to transfer information over optical fibre or free space (i.e. air or the vacuum of space) and use laser technologies, adaptive optics and optical routing to transfer information faster, more reliably, more efficiently and/or using less energy. **Applications** for advanced optical communications include high-speed earth-satellite communications, short-range visible light communications (i.e. 'Li-Fi'), narrow-beam laser communications and multi-gigabit broadband and corporate networks.

Advanced radiofrequency communications (incl. 5G and 6G)

Devices and systems that use radio waves to transfer information over free space (i.e. air or the vacuum of space) and use novel modulation techniques, advanced antenna designs and beamforming technologies to transfer information faster, more reliably, more efficiently and/or using less energy. **Applications** for advanced radiofrequency communications include communications satellites, cellular networks (e.g. 5G and 6G), wireless local area networks (e.g. Wi-Fi), short-range wireless communication (e.g. Bluetooth), sensor networks, connected vehicles, implantable medical devices and mobile voice and data services for public safety and defence.

Artificial intelligence (AI) algorithms and hardware accelerators

Artificial intelligence (AI) algorithms are computer algorithms that perform tasks normally requiring human intelligence. **Applications** for artificial intelligence algorithms include personal and workplace virtual assistants, process automation, virtual and augmented reality, creating more realistic video game environments and characters, public transport planning and optimisation, crop and livestock management, and defence.

Artificial intelligence hardware accelerators are computer hardware optimised and purpose built to run artificial intelligence algorithms faster, more precisely or using less energy than is possible using non-optimised general-purpose computer hardware. **Applications** for artificial intelligence hardware accelerators include processing on board smartphones, portable virtual and augmented reality systems, and low power internet of things (IoT) sensors.

Distributed ledgers

Digital systems for recording transactions, contracts and other information across multiple systems or locations. Distributed consensus mechanisms eliminate the need for a central authority to maintain the ledger, making transactions and stored records less susceptible to cyber-attacks or fraud. Blockchain is an example of a distributed ledger, with the digital currency Bitcoin utilising blockchain as its ledger for financial transactions. **Applications** for distributed ledgers include cryptocurrencies, verification of supply chains such as for product provenance and emissions monitoring and verification, tracking recoverable and recyclable product content, land records, and share trading.

High performance computing

Computer systems that exceed the performance capabilities of consumer devices (i.e. widely available desktop and laptop computers) by an order of magnitude. High performance computers—such as supercomputers—can process large volumes of data and/or perform complex calculations that are impossible or impractical using consumer devices. **Applications** for high performance computing include climate modelling, computational chemistry and high quality computer graphics for film and television.

Machine learning (incl. neural networks and deep learning)

Computer algorithms that automatically learn or improve using data and/or experience. Machine learning is a type of artificial intelligence. **Applications** for machine learning include computer vision, facial recognition, cybersecurity, media creation, virtual and augmented reality systems, media manipulation (e.g. deepfakes), content recommendation systems, and search engines.

Natural language processing (incl. speech and text recognition and analysis)

Systems that enable computers to recognise, understand and use written and/or spoken language in the same ways that people use language to communicate with each other. Natural language processing is a type of artificial intelligence. **Applications** for natural language processing include predictive text, language translation, virtual assistants and chat bots, summarising long documents, sentiment analysis, and making technologies more accessible and inclusive.

Protective Cyber Security Technologies

Systems, algorithms and hardware that are designed to enable a cyber security benefit. **Applications** for cyber security technologies include but are not limited to; operational technology security, trust and authentication infrastructures, protection of aggregated data sets, protection of AI systems and supply chain security.

Biotechnology, gene technology and vaccines

Biological manufacturing

Processes that use living cells to make useful chemicals or materials. **Examples** include fermentation products, biologic medicines such as antibodies and enzyme replacement therapies, and enzymes for environmental remediation and recycling plastics.

Biomaterials

Natural or synthetic materials that can safely interact with biological systems (e.g. the human body) to support medical treatment or diagnosis. **Applications** for biomaterials include medical implants, such as artificial joints and heart valves, scaffolds to promote bone and tissue regrowth, biosensors and targeted drug delivery systems.

Genetic engineering

Tools and techniques for directly modifying one or more of an organism's genes. Existing techniques include CRISPR gene editing and molecular cloning. **Applications** for genetic engineering include making crops that are more nutritious or require less water or pesticides, treating genetic diseases by replacing faulty genes with working copies and cell therapies that treat diseases by extracting, modifying and reimplanting patients' own cells.

Genome and genetic sequencing and analysis (Next Generation Sequencing)

Tools and techniques for quickly sequencing (i.e. 'reading') the genetic material of human beings, other living organisms and viruses, and for analysing and understanding the functions of those sequences. **Applications** for genomics and genetic sequencing and analysis include identifying the genes associated with particular diseases or biological functions, identifying new communicable diseases, crop and livestock breeding and predicting how effective drugs will be for different patients.

Nanobiotechnology

Devices, tools and techniques that use the special properties of nanostructures to monitor or modify living organisms. **Applications** for nanobiotechnology include more targeted pesticides, biosensors that can detect and count flu viruses, and bioactive nanocapsules that can deliver drugs to where they are needed and nowhere else, reducing side effects and enabling more doctors to use more powerful drugs.

Nanoscale robotics

Nanoscale machines made from components like DNA. **Applications** for nanoscale robotics include targeted drug delivery, identifying cancer cells and moving molecules to assemble drugs or other nanoscale robots.

Neural engineering

Systems and devices that directly monitor, or interact with, the brain or nervous system. **Applications** for neural engineering include biofeedback monitoring, sensory prosthetics and devices to supplement or replace damaged nerves.

Novel antibiotics and antivirals

Systems for identifying or designing new types of antibiotic and antiviral drugs that can treat bacterial and viral infections in humans and animals safely and effectively. New antibiotic and antiviral drugs must be continually developed and tested to ensure there are drugs available to treat both new infectious diseases and existing bacterial and viral diseases that become resistant to existing drugs. **Examples** include drugs to treat Methicillin-resistant Staphylococcus aureus (MRSA) and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

Nuclear medicine and radiotherapy

Nuclear medicine uses radioactive substances to diagnose or treat diseases. **Applications** for nuclear medicine include imaging internal organs and tissues, viewing biological processes and using radiopharmaceuticals to treat cancers and other diseases.

Radiotherapy uses ionizing radiation to treat diseases by damaging the DNA in targeted cells, killing those cells. **Applications** for radiotherapy include treating some types of cancer and treating other diseases caused by overactive cells.

Synthetic biology

Designing and constructing biological systems and devices that have useful functions not found in nature. **Applications** for synthetic biology include creating microorganisms that can clean-up environmental pollutants and recycle plastics, manufacturing animal-free meat and dairy products, and biological computers.

Vaccines and medical countermeasures

Tools and techniques to quickly develop and manufacture vaccines, drugs, biologic products and devices used to diagnose and treat emerging infectious diseases and medical conditions caused by exposure to harmful chemical, biological, radiological, or nuclear substances. **Applications** for vaccines and medical countermeasures include public health emergencies, industrial accidents and defence.

Energy and environment

Biofuels

Solid, liquid or gas fuels produced from biological or organic sources. **Examples** include biogas and biodiesel derived from plant biomass, and bioethanol from crops such as corn and sugar cane.

Directed energy technologies

Systems and devices that transfer energy between two points in free space. **Applications** for directed energy technologies include powering consumer electronics, recharging electric vehicles, powering aerial drones, ground-space energy transfer, wireless sensor networks and internet of things devices, and advanced weapons.

Electric batteries

Devices that produce electricity from stored electrochemical energy and tolerate multiple charge and discharge cycles. Electric batteries utilise various materials and chemistries (e.g. lithium-ion (Li-ion), nickel metal hydride battery (Ni-MH)) and form factors (e.g. flow batteries for stationary grid storage, polymer electrolytes for vehicles and personal devices). **Applications** for electric batteries include electrified road and air transport, smartphones and personal electronic devices, medical devices and grid energy storage.

Hydrogen and ammonia for power

Sustainable production, storage, distribution and use of hydrogen (H2) and ammonia (NH3) for heat and electricity generation. Hydrogen and ammonia are potential low or zero emission, zero-carbon alternatives to fossil fuels and electric batteries. **Applications** for hydrogen and ammonia include energy storage and as a fuel source for aviation and marine transport, long distance road transport and heating.

Nuclear energy

Electricity generation using the energy released when the core of an atom (called the atomic nucleus) splits into two or more lighter atomic nuclei. **Applications** include energy production for self-contained and/or remote uses, such as space travel, submarines, scientific research and medical isotope production.

Nuclear waste management and recycling

Processes to safely dispose of, or reuse or reprocess for useful purposes, radioactive waste products from medical, industrial and research practices. **Examples** include converting radioactive liquid waste into synthetic rock to minimise leeching, and reprocessing spent radioactive fuel for use in long-life, low-power batteries. Applications include environmental protection and extending the useful life of nuclear material.

Photovoltaics

Devices that convert solar energy into electricity using layers of semiconductor materials. **Applications** for photovoltaics include low-emissions power stations, rooftop solar power, spacecraft and personal electronics.

Supercapacitors

Electrochemical devices that can store large amounts of energy in small volumes. Supercapacitors store less energy and for shorter durations than rechargeable batteries (hours or days, rather than months or years), but can accept and deliver charge much faster than rechargeable batteries, and tolerate many more charge and discharge cycles than rechargeable batteries before performance degrades. **Applications** for supercapacitors include regenerative braking, smartphones and personal electronic devices, grid energy storage and defence.

Quantum

Post-quantum cryptography

Mathematical techniques for ensuring that information stays private, or is authentic, that resist attacks by both quantum and non-quantum (i.e. classical) computers. The leading application for post-quantum cryptography is securing online communications against attacks using quantum computers. Because quantum computers can efficiently solve the 'hard' mathematical problems we currently rely on to protect online communications, Australia needs post-quantum cryptography to ensure communications stay secure once quantum computers are available.

Quantum communications (incl. quantum key distribution)

Devices and systems that communicate quantum information at a distance, including cryptographic keys. **Applications** for quantum communications include transferring information between quantum computers and sharing cryptographic keys (which are like secret passwords) between distant people in a way that means it is impossible for anyone else to copy.

Quantum computing

Computer systems and algorithms that depend directly on quantum mechanical properties and effects to perform computations. Quantum computers can solve particular types of problems much faster than existing 'classical' computers, including problems that are not practical to solve using even the most powerful classical computers imaginable. **Applications** for quantum computing accurately simulating chemical and biological processes, revealing secret communications, machine learning and efficiently optimising very complex systems.

Quantum sensors

Devices that depend directly on quantum mechanical properties and effects for high precision and high sensitivity measurements. **Applications** for quantum sensors include enhanced imaging, passive navigation, remote sensing, quantum radar, and threat detection for defence.

Sensing, timing and navigation

Advanced imaging systems

Imaging systems with significantly enhanced capabilities, such as increased resolution, increased sensitivity, smaller devices, faster image capture or otherwise novel and useful capabilities. **Applications** for advanced imaging systems include healthcare, creative industries, surveillance, and scientific research.

Atomic clocks

Devices that keep time by measuring the frequency of radiation emitted or absorbed by particular atoms. Atomic clocks are the most accurate timekeeping devices known and are used (directly or indirectly) for tasks where measuring time with precision and consistency is essential. **Applications** for atomic clocks include active and passive navigation systems, processing financial transactions and synchronising telecommunications networks.

Gravitational-force sensors

Devices that detect minute changes in Earth's gravitational field. **Applications** for gravitational-force sensors include passive navigation enhancement and detecting mineral deposits, concealed tunnels and other subsurface features that create tiny variations in Earth's gravitational field.

Inertial navigation systems

Systems and devices that can calculate the position of an object relative to a reference point without using any external references. **Applications** for high precision inertial navigation systems include replacing or augmenting other navigation systems that require external references—like GPS—in places where external signals can be blocked or corrupted; e.g. underground or in cities with narrow streets and tall buildings.

Magnetic field sensors

Devices that can detect and measure the strength and/or direction of magnetic fields. **Applications** for magnetic field sensors include passive navigation, imaging for health, metallurgy, scientific research and threat detection for defence.

Miniature sensors

Miniature devices (generally smaller than 10 mm3) that can detect and record or communicate changes in their environment, such as temperature, radiation, vibration, light, chemicals or moisture. **Applications** for miniature sensors include 'smart dust' wireless sensor networks to monitor environmental conditions in agriculture or near possible sources of pollution.

Multispectral and hyperspectral imaging sensors

Multispectral imaging sensors capture data across several discrete ranges across the electromagnetic spectrum, such as red, green, blue and near infrared light; hyperspectral imaging sensors further this approach by capturing hundreds of much smaller ranges across the electromagnetic spectrum. **Applications** for multispectral and hyperspectral imaging sensors include healthcare, defence, agriculture, manufacturing, measuring soil carbon content for carbon sequestration, and machine vision for autonomous vehicles and robots.

Photonic sensors

Devices that use light to detect changes in the environment or in materials. **Applications** for photonic sensors are broad, ranging from mainstream photography, through to sensors for environments where electrical or chemical based sensors are impractical or unreliable, such as laser-based gas sensors to detect explosive materials or flexible photonic sensors embedded inside the human body to monitor bodily processes.

Radar

Systems that listen for radio waves and microwaves reflected off objects and surfaces—such as people, buildings, aircraft and mountains—to 'see' how far away and how fast those objects are moving. Active radar systems send their own radio signals to reflect off objects; passive radar systems listen for radio signals sent by targets or reflections of signals already present in the environment (e.g. television signals). **Applications** for radar include weather forecasting, situational awareness, connected and autonomous vehicles, virtual and augmented reality systems, and defence.

Satellite positioning and navigation

Networks of satellites that broadcast precise time signals and other information, which Earth-based devices can use to calculate their location and for navigation. Advanced systems enable greater location accuracy and faster location finding, and greater resistance to unintentional signal interference and intentional jamming or spoofing. **Applications** for satellite positioning and navigation include consumer and commercial transport, construction and surveying, tracking valuable goods, and defence.

Scalable and sustainable sensor networks

Sensor devices and systems than can be cost-effectively deployed in large numbers and over large areas to monitor physical conditions and communicate findings to one or more locations. **Applications** for scalable and sustainable sensor networks include smart electricity grids, intelligent transportation systems and smart homes.

Sonar and acoustic sensors

Systems that listen for soundwaves created by, or reflected off, objects—such as boats, submarines, fish and underwater mountains—to identify those objects and/or 'see' how far away and how fast those objects are moving. **Applications** for sonar and acoustic sensors include monitoring marine wildlife, and threat detection, identification and targeting for defence.

Transportation, robotics and space

Advanced aircraft engines (incl. hypersonics)

Engine technologies that enable greater speed, range, and fuel-efficiency for aerial vehicles. **Examples** include hypersonic technologies such as ramjet and scramjet engines that allow aircraft and weapons to travel beyond Mach 5 (i.e. flying more than five times the speed of sound).

Advanced robotics

Robots capable of performing complex manual tasks usually performed by humans, including by teaming with humans and/or self-assembling to adapt to new or changed environments. **Applications** for advanced robotics include industry and manufacturing, defence and public safety, and healthcare and household tasks.

Autonomous systems operation technology

Self-governing machines that can independently perform tasks under limited direction or guidance by a human operator. **Applications** for autonomous systems operation technology include passenger and freight transport, un-crewed underwater vehicles, industrial robots, public safety and defence.

Drones, swarming and collaborative robots

Un-crewed air, ground, surface and underwater vehicles and robots that can achieve goals with limited or no human direction, or collaborate to achieve common goals in a self-organising swarm. **Applications** for drones, swarming and collaborative robots include public safety, environmental monitoring, agriculture, logistics, and defence.

Small satellites

Satellites with relatively low mass and size, usually mass under 500 kg and no larger than a domestic refrigerator or washing machine. **Applications** for small satellites include lower-cost earth observation constellations and wide area communications networks.

Space launch systems (incl. launch vehicles and supporting infrastructure)

Systems to transport payloads—such as satellites or spacecraft—from the surface of the Earth to space safely, reliably and cost-effectively. **Applications** for space launch systems include launching defence, commercial, and scientific and research payloads into earth orbit.