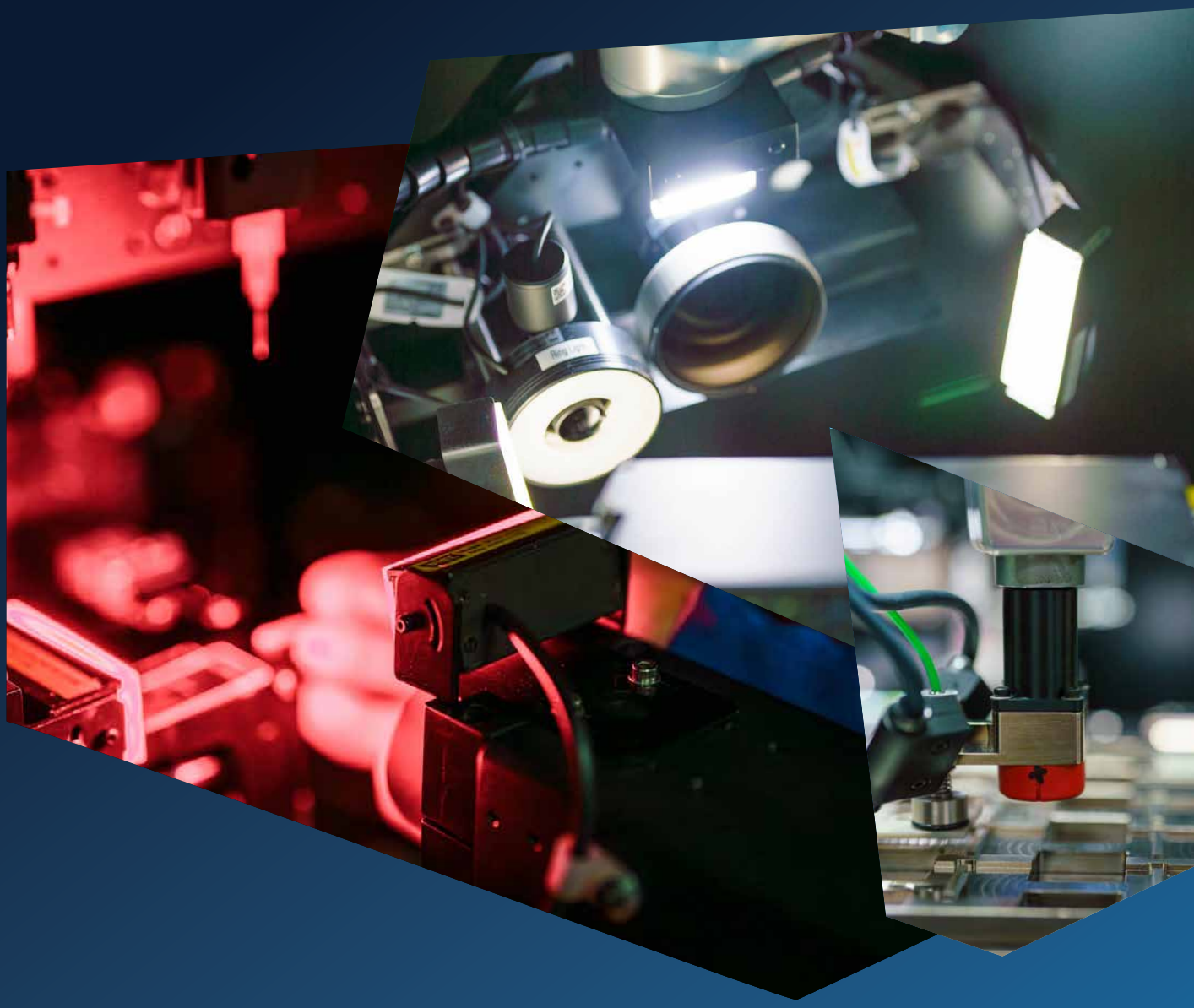
Australian Government
Department of Industry, Science and Resources

National Robotics Strategy



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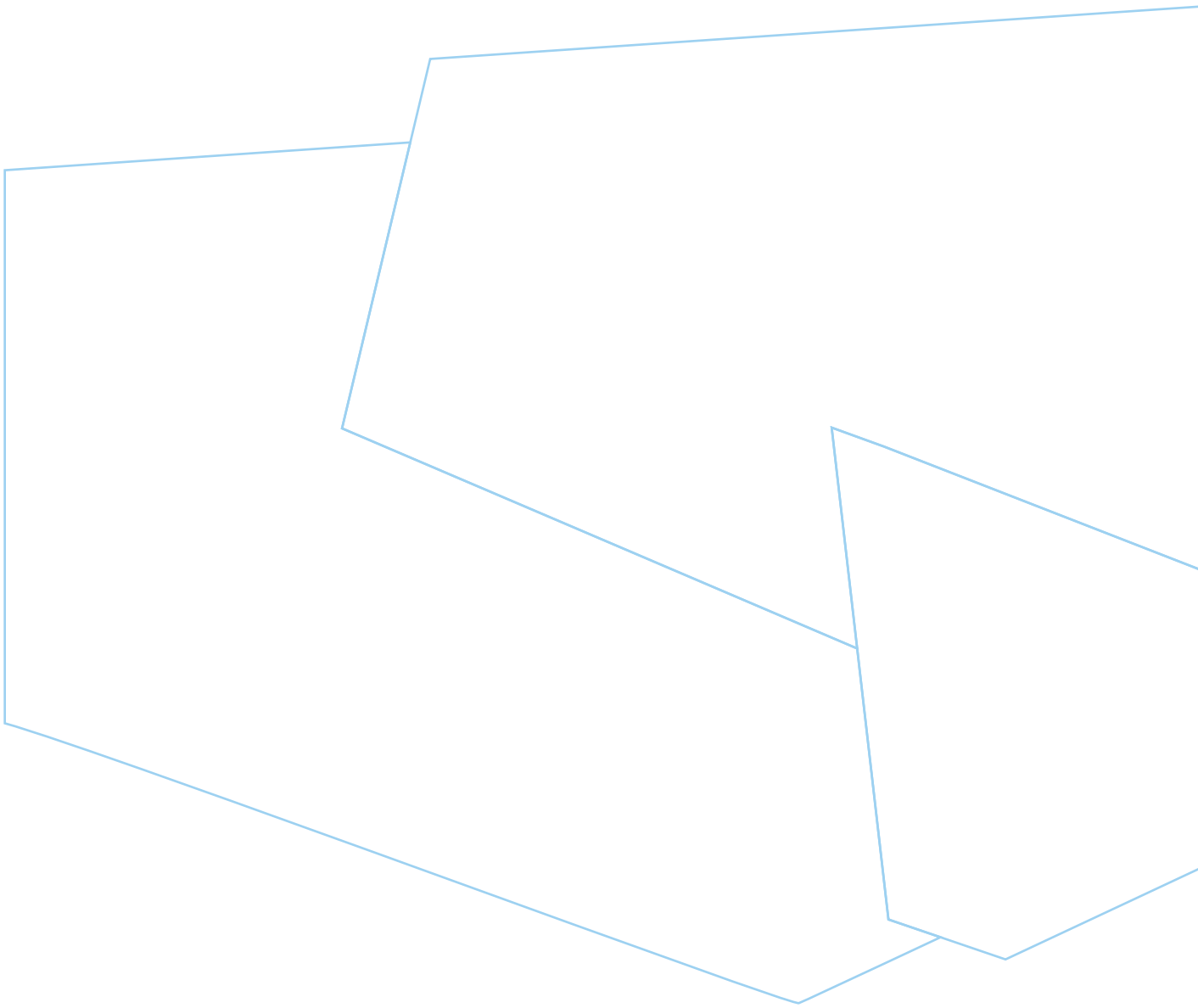

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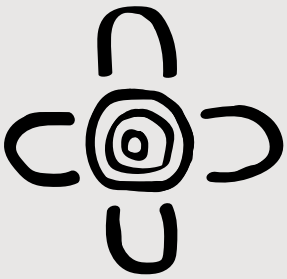


Acknowledgement of Country

Our department recognises the First Peoples of this Nation and their ongoing cultural and spiritual connections to the lands, waters, seas, skies, and communities.

We Acknowledge First Nations Peoples as the Traditional Custodians and Lore Keepers of the oldest living culture and pay respects to their Elders past and present. We extend that respect to all First Nations Peoples.

Photo caption: An autonomous robot surveying farmland.
Photo credit: SwarmFarm Robotics.

Message from the Minister for Industry and Science

Robotics and automation are critical to building a Future Made in Australia.

Around the world, countries are investing in revitalising their manufacturing base. Despite recent improvements, over the last 15 years, Australia's manufacturing industry has shrunk more than any other sector in our economy. The retirement of manufacturing assets in Australia currently outpaces investment, with capital stock depreciating by $190 million. A healthy manufacturing industry onshores supply chains, lowers production costs, and drives innovation and jobs growth.

Australia's limited uptake of robotics and automation to date is holding back Australia's manufacturing industry. We know the benefits of these technologies. Only a 1% increase in robotics can lead to a whole of economy 0.8% increase in productivity by automating high-value manufacturing and enabling production at scale.

Yet, Australia ranks 32nd globally in the adoption of industrial robots. Lifting the adoption of these technologies will allow our manufacturers to produce higher quality products in less time and make them more internationally competitive.

And it's not just in manufacturing. We're seeing robotics across our economy combat workforce shortages in sectors under pressure like agriculture, health and aged care, and emergency response. Developments in artificial intelligence allow robots to harvest crops, deploy and maintain solar panels, respond to emergencies and much more. Today robots are also supporting complex surgeries, boosting production capability in small businesses and keeping our workers safe in factories, construction sites and mines. And our aspiration should be to make more robotics and automation solutions here in Australia.

Adopting robotics and automation is about supporting workers, not replacing them. Countries investing in robotics and automation have higher manufacturing outputs alongside increased employment, growth, and job satisfaction. That's because robotics and automation can take care of the dirty, dull and dangerous activities, leaving skilled workers to focus the tasks where they can add the most value.

The National Robotics Strategy is the first of its kind in Australia. It sets a vision to develop and adopt our own robotics solutions to secure Australia's future and seize the opportunity in front of us. It highlights that the development and deployment of these technologies is supporting more rewarding, safe and dynamic jobs across our economy. It demonstrates pathways to support manufacturers upgrading and renewing capital stock. It builds on our strengths and expertise in robotics, outlining how robotics and automation can work for us, and how we can develop the right skills to build a Future Made in Australia.

I want to thank the Advisory Committee Chair, and committee members, for their efforts developing a strategy that demonstrates the immense value of robotics to our economy, if we can seize the opportunity.

The Hon Ed Husic MP
Minister for Industry and Science

Message from the Advisory Committee Chair

> The responsible adoption of robotics and automation technologies will be transformative for Australia.

The recent, rapid advances in artificial intelligence are allowing robots to perform complex tasks and solve problems in almost every industry in collaboration with people. We are seeing more sophisticated and user-friendly robots being used in Australia, making robots more practical and efficient than ever.

From addressing national challenges such as labour shortages, improving productivity and revitalising our manufacturing capabilities to providing safer and more fulfilling opportunities for workers, robotics are a critical part of our future. It will enable extraordinary new innovations in everything from medical technologies to architecture.

That's why this National Robotics Strategy is such a timely and important document. What makes it powerful is that it's been forged and formed by the views, ideas, comments and concerns of many, many Australians. We consulted extensively across the country and engaged with leading minds in robotics, technology, industry, productivity, ethics, community and workplace issues.

Every submission we received was carefully addressed, every idea weighed, every concern considered, and every recommendation made with meticulous attention to the opportunities, the risks, the context and ultimately the benefits for Australia. On behalf of the Advisory Committee, I would like to offer my sincere thanks to everybody who contributed to the strategy's development.

Australia already has enormous capabilities in robotics and automation, a deep expertise and experience accrued over decades. This strategy celebrates that, including through diverse case studies that showcase Australia's know-how, strengths and success in robotics and automation. The time to systematically and strategically build on this know-how and use the experiences of what we can learn from other countries and address the gaps and opportunities at home, is now.

It is critical for Australia's future that we get this right. The National Robotics Strategy is about creating a clear and shared vision so that we can work at pace with what is a truly transformative technology.

Professor Bronwyn Fox

CSIRO Chief Scientist, and Chair of the
National Robotics Strategy Advisory Committee

Strategy at a glance

Vision

> Australian industries are responsibly developing and using robotics and automation technologies to strengthen competitiveness, boost productivity and support local communities.

Goals and objectives

National capability

Goal: Australia has a strong, collaborative robotics and automation ecosystem that is recognised for its strengths, has a thriving domestic market and exports globally.

- Boost research and development, commercialisation and scaling up of Australian solutions targeting areas of Australian strength.
- Use government's purchasing power to grow domestic demand for robotics and automation.
- Raise the profile of Australia's robotics and automation capabilities and supply chains locally and globally.
- Leverage Australia's international partnerships and networks, as well as state and territory governments, to create new opportunities.

Increasing adoption

Goal: Australian industries are supported to integrate robotics and automation technologies into their operations in ways that benefit Australian workers and communities.

- Raise awareness of robotics and automation technologies and their benefits for critical industries, like advanced manufacturing, agriculture and mining, to support Australia's future competitiveness.
- Support and incentivise Australian businesses to adopt local robotics and automation solutions.
- Improve digital and telecommunications infrastructure underpinning robotics and automation.

Trust, inclusion and responsible development and use

Goal: Robotics and automation technologies designed and adopted in Australia are safe to use alongside Australian workers, and are secure and inclusive by design.

- Ensure regulatory and legal frameworks enabling and applying to automation technologies are fit for purpose.
- Better understand and address the social impacts of robotics and automation in critical industries.
- Promote Australia's engagement in relevant bodies for setting international standards.
- Improve safety and cyber security of robotics and automation technologies.

Skills and diversity

Goal: Australians from all backgrounds contribute to and benefit from the development and adoption of robotics and automation.

- Strengthen pathways into robotics-related careers.
- Identify ways to better promote diversity and inclusion in robotics industries.
- Monitor and plan for workforce changes and skills development alongside greater adoption of robotics and automation technologies.
- Attract skilled migrants to increase our economic prosperity and security.
- Raise awareness of the skills needed to support a technologically advanced economy.

Robotics technologies

The National Robotics Strategy uses the following definitions:[1]

Robots are machines with a degree of autonomy that can move in their physical environment or manipulate objects. All robots have 4 essential characteristics: sensing, movement, energy and autonomy.

Robotics is the science and practice of designing, manufacturing and using robots.

Autonomy is the ability to perform intended tasks based on current state and sensing, without human intervention.

Automation is the performance of actions based on a set of predefined criteria, without human intervention. Automation will be considered in the strategy where it is enabled by robots.

The field of robotics encompasses many **enabling technologies** that are used in robots, such as computer and machine vision, sensors and sensing systems, artificial intelligence (AI) and machine learning.

The term **robotics and automation technologies** is used to refer collectively to all technologies listed above.

Robots are traditionally divided into industrial and service robot types:

Industrial robots are automatically controlled, reprogrammable and multi-purpose manipulators that can move in 3 or more axes. They can be fixed in place or mobile and are used in industrial automation applications.

Service robots are robots that perform useful tasks for humans or equipment, excluding industrial automation applications.

1 For detailed technical definitions, refer to the International Organization for Standardization (2021), 'ISO 8373:2021 Robotics – Vocabulary', International Organization for Standardization website, accessed 14 August 2023.

The strategy refers to specific types of robots, including:

Field robots

Robots that operate in large, unstructured outdoor domains.

Case study: Solar Energy Robotics is a specialist division of Innovative Energy Solutions. It has developed an autonomous robot to clean solar arrays in the harsh, arid environments of remote mine sites.

The autonomous solar cleaning robots are installed directly onto solar arrays and programmed to independently remove dirt and debris from solar panels. This helps ensure the solar panels work efficiently to provide a reliable power supply to critical mine site infrastructure.

Photo caption: An autonomous solar cleaning robot clearing dust build-up from solar panels.
Photo credit: Innovative Energy Solutions.

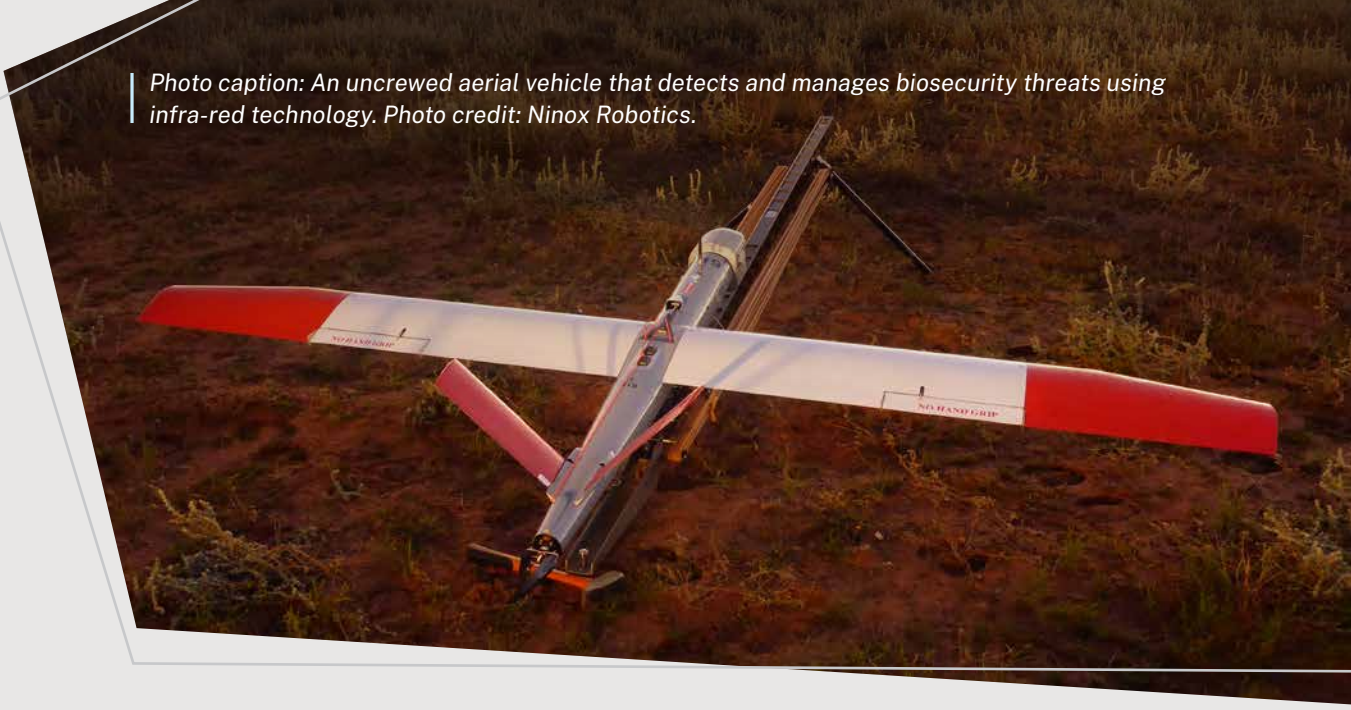


Photo caption: An uncrewed aerial vehicle that detects and manages biosecurity threats using infra-red technology. Photo credit: Ninox Robotics.

Drones

Uncrewed air, land, surface or underwater systems that can be operated remotely or autonomously.

Case study: Ninox Robotics use long-range uncrewed drones for a variety of purposes, including emergency management.

Ninox Robotics has worked with the NSW Rural Fire Service, streaming real-time video to monitor and detect environmental threats and obstructions. Using drones helps keep firefighters safe and preserve Australia's unique landscape.

Cobots

Robots designed for direct interaction with a human in a defined collaborative workspace.

Case study: Peak body Weld Australia uses a welder training system with augmented reality. The system teaches welding skills to apprentices while evaluating their performance in a hands on, interactive and controlled environment. TAFEs, high schools and registered training organisations have used the system in their own training programs.

The augmented reality system has also been integrated with a cobot. This lets an apprentice safely learn automated robotic welding skills as well as the skills to use robotics in other applications. This helps future welders gain skills and self confidence in both manual and robotic welding before moving into real world welding workshops.

Photo caption: A cobot used with augmented reality to safely simulate welding.
Photo credit: Weld Australia.

Australia's robotics opportunity

In the years ahead, national and global trends will shape the future of Australia's economy and society. These include climate change, an ageing population, geopolitical risks, labour market pressures and stagnant productivity. Robotics and automation technologies will be critical to Australia's response, as well as growing our economic diversity and building a Future Made in Australia.

Robotics and automation will transform industries and reshape work processes on a global scale, as they have already done over the preceding decades. For many years, we've used robots in mines, logistics and manufacturing assembly lines to complete tasks that need precision or are repetitive or dangerous. Advanced robotics are now changing how people engage with technology at work, improving workplace safety and creating new jobs. This will continue as robotics and automation technologies become more affordable, effective and common in workplaces throughout Australia.

Internationally, developing and adopting robotics and automation technologies has been critical for boosting productivity and raising the competitiveness of industries. Recent advancements in AI, component technologies and robotic design are improving the rate and benefits of development and adoption globally. This momentum is already visible in Australia's robotics industry. Local robotics companies were worth about $18 billion in annual revenue in 2021, up from $12 billion in 2018 (Robotics Australia Group 2022).

In Australia, productivity growth has slowed to 1.2% per year in the 20 years to 2021–22 – the lowest level in 60 years (The Treasury 2023a). The Productivity Commission's 5-yearly *Productivity Inquiry Report* and the Treasury's *Intergenerational Report* highlight the need for investment in new technologies to improve productivity (The Treasury 2023b; Productivity Commission 2023). Automation, including robotics, is predicted to increase annual productivity growth in Australia by 50% to 150%. These technologies have the potential to add a further $170–600 billion per year to GDP by 2030 (Taylor et al. 2019).

Australia has strong robotics expertise, renowned academic institutions and local capability in areas such as field robotics. Despite these strengths, the lack of a mature and well-coordinated supply chain for locally made solutions means we risk missing many of the opportunities these technologies present. Australia faces barriers in commercialising and scaling up our innovations, preventing us from taking full advantage of our leading research capability. These include the rationing of investment capital, high upfront costs needed to develop robotic solutions, limitations in our supply chains and our geographic isolation. Many Australian industries lag in adopting robotics technologies, which means many businesses are not tapping into the benefits these technologies can deliver.

Acting now to address these barriers will support revitalising Australia's economy by growing national manufacturing capabilities and help to address labour and skills shortages. Robotics and automation technologies will also play a role in supporting Australia's transition into a renewable energy superpower and net zero economy. The increased development and adoption will allow businesses to become more globally competitive, strengthen onshore supply chains and create safer work environments for Australians.

The Australian Government has already recognised the importance of revitalising sectors across our economy through critical technologies such as robotics. To support this effort, the government has the $15 billion National Reconstruction Fund (NRF). The NRF will make targeted investments to help Australia capture new, high-value market opportunities to diversify and transform our industries and strengthen our economy. A priority area for NRF investment is enabling capabilities. This concerns manufacturing technologies and products, including robotics, that support advancing Australia's industrial capability. How companies adopt robotics and automation technologies will contribute to their competitiveness across all NRF areas.

The government is also supporting industry through the Industry Growth Program (IGP). The program assists innovative small and medium-sized enterprises (SMEs) and startups in their most challenging development phase. Finally, the Future Made in Australia agenda will support investment in modernising and digitising our industries to revitalise our advanced manufacturing base and onshore supply chains.

Building on these priorities, the National Robotics Strategy establishes a shared vision, goals and objectives for Australia, informed by extensive national consultation. The strategy shows the immense potential for Australian industries throughout the economy to benefit from robotics and automation technologies. The strategy seeks to use our strengths for Australian industries are responsibly developing and using robotics and automation technologies to strengthen competitiveness, boost productivity and support local communities.

Robotics and automation at the global frontier

Germany

Germany is one of the world's major manufacturing powerhouses, partly because of its leadership in developing and adopting robotic and automation technologies. Germany's manufacturing industry has been a leader in robotics and automation for decades. It has deployed more robots than any other country in Europe and is a leading innovator in developing industrial robots (IFR 2023c). This means that German manufacturers have been able to operate domestically rather than outsourcing to overseas competitors who have lower labour costs. By innovating and incorporating new technologies, Germany has improved the cost competitiveness of its manufacturing.

Japan

Japan is a leader in robot production, producing 45% of the global supply of industrial robots (IFR 2023a). Japanese companies have been at the forefront of robotics and automation production and adoption for decades. Adopting these technologies in industrial processes has been a critical factor in Japan's economic success. Japan is also turning to robotics and automation to address barriers posed by their rapidly ageing population. While not without its issues, efforts in nursing homes have promoted more flexible work and improved staff retention.

United States

The United States is one of the world's top food producers and exporters and is a leader in adopting new technologies in agriculture. Robotics and automation have improved productivity in the sector, including through more reliable monitoring and management of natural resources. Greater control over production, distribution and storage has resulted in increased efficiencies, lower prices and reduced environmental impacts (United States Department of Agriculture 2023).

China

China has been the largest industrial robot market for nearly 10 years, and in 2022 accounted for 52% of the world's industrial robot installations (IFR 2023b). These robots, a mix of imported and locally produced technologies, are used in electronics, automotive and other manufacturing activities. This has helped China become the world's largest manufacturer, including of electric vehicles, and address trends such as skills shortages and an ageing population.

Robotics and automation in Australia

Robotics and automation technologies have the potential to generate real social, economic and environmental benefits for Australia. We have unique advantages that will allow us to capture these benefits, such as our diverse landscape, education and training system and research capabilities.

Australia has an emerging robotics and automation industry that is growing in size and influence. In 2018 and 2022, industry peak body Robotics Australia Group released 'Robotics Roadmaps' for Australia. These showed the breadth of expertise in Australia and helped raise the profile of cutting-edge Australian capabilities.

Many Australian industries have already adopted robots to work alongside humans to create safer and more productive workplaces. Robots are used in Australian underground mines, assembly lines and in dangerous settings like emergency response operations. Increasingly, medical professionals use robots to improve diagnosis, treatment and rehabilitation, as well as accuracy and patient recovery from invasive surgeries.

In agriculture, field robots support crop and livestock monitoring, and autonomous farming technologies increase crop yields and reduce pesticide use. The advanced manufacturing sector relies on automation to scale and export at a vastly increased level than what would otherwise be possible. Now, robotics and automation technologies are helping our nation transition to net zero, allowing us to install and maintain renewable energy infrastructure on a large scale.

Australia has strong research expertise and growing local capability to continue producing innovative robotic solutions. Field robotics is a particular opportunity for Australia. We have the research and development (R&D) expertise, local market and potential for high growth through global exports. In 2023, Australian research in robotics and related fields ranked in the top 10 countries globally for quality of research. We are 4th in additive manufacturing, 5th in data analytics and autonomous underwater vehicles, 6th in autonomous systems operation technology and 8th in advanced robotics (ASPI 2023). In addition, 3 Australian universities rank in the top 50 globally for robotics research publications (ASPI 2023).

Growing a sustainable robotics ecosystem will depend on the success of Australia's robotics and automation R&D and commercialising these technologies. However, researchers and startups can face barriers to commercialisation. Attracting early-stage and long-term capital are barriers because of the upfront expense of robotics and automation hardware. Australia is also not a large-scale manufacturer of many robotics components, meaning industry and developers need to import from overseas suppliers. Building Australia's domestic manufacturing capability will help address these issues by allowing access to secure, reliable and cost-effective robotics and automation technologies.

Case study: World leading Australian manufacturer using robotics and automation

Finisar Australia develops and manufactures optical switching technology to increase the bandwidth, connectivity and flexibility of optical fibre networks.

Finisar's innovative solution selects and switches light, transmitting high-speed data around the fibre network. The technology is used by multinational telecommunication companies to provide internet connectivity all over the world. Robotics and automation are essential to manufacturing this technology. Finisar uses a wide range of automation technologies, including:

- machine vision and robotic systems that accurately position optical components at a level of precision invisible to the human eye
- lasers to locate components in multiple axes
- machine learning to optimise and automatically program unique software for every unit.

Finisar research, develop and deploy their own bespoke robotics and automation technologies from their headquarters in Sydney, where they currently employ 250 staff. This results in a product that has a competitive advantage in performance, reliability and cost and protects the company's intellectual property. Using robotics and automation allows Finisar to perform advanced manufacturing in Australia, create jobs and open new export opportunities.

Photo caption: A robotic arm manufacturing optical switching technology.
Photo credit: Finisar Australia and the Department of Industry, Science and Resources.

Case study: Optimising farming through robotics

SwarmFarm Robotics uses robots to optimise agricultural processes. The company's SwarmBot robot and SwarmConnect® developer ecosystem work together to deliver better farming systems for sustainable agricultural production.

SwarmBot is an autonomous vehicle that can be used for tasks such as spraying, weeding and harvesting. SwarmConnect® is an agricultural 'app store' that lets third-party developers build applications for SwarmBot robots. The system is highly versatile and can be tailored to specific crops, farming conditions and agronomic challenges.

SwarmFarm's robots have already commercially farmed more than 2 million acres of farmland and reduced the amount of pesticides going into the environment by an estimated 1.8 million litres.

Photo caption: An autonomous vehicle spraying, weeding and harvesting crops.
Photo credit: SwarmFarm Robotics.

Case study: Australia's prize-winning performance

CSIRO's Robotics and Autonomous Systems Group is a world leader in researching and developing applied robotics. The group was one of 11 teams from around the world chosen to participate in the United States' Defense Advanced Research Projects Agency's Subterranean Challenge. The challenge explored new approaches to mapping, navigating and searching underground environments.

Australian company Emesent was also part of the CSIRO challenge team. Emesent has expertise in developing autonomous and lidar mapping with drones, including in GPS-denied environments. This lets drones collect data in challenging places for the mining, geospatial, construction and engineering industries. To navigate harsh subterranean environments during the challenge, the team combined:

- drones mounted with Emesent's Hovermap
- all-terrain ground robots from Australian company BIA5
- CSIRO's autonomy and mapping capability.

The team beat organisations such as NASA, MIT, California Institute of Technology, and Carnegie Mellon University to claim the silver medal, winning $1.3 million in prize money.

Photo caption: The BIA5 All Terrain robot mounted to an autonomous all-terrain vehicle that navigates and collects data in harsh environments. Photo credit: CSIRO.

World leading adoption of robotics and automation in Australian mining

Australia is one of the world's biggest mineral resource producers. Estimated energy exports reached a record $459 billion in 2022–23 and mineral resources made up 69% of Australian export revenue in 2021–22 (DISR 2023a). Australia's resources sector accounts for 14% of our GDP (Office of the Chief Economist 2022) and employs more than 300,000 people (ABS 2023).

The Australian resources industry is a world leader in using robotics and automation. Our mining industry has over 700 autonomous haulage trucks, with more in production (Mine 2022). Automating future mines will improve productivity and will help limit environmental impacts through reducing the scale of mining operations.

Robotics and automation play a crucial role in transitioning to low-emissions technologies. Australia has abundant reserves of critical minerals, including rare earths. These are essential inputs to clean technologies such as solar panels, wind turbines and electric vehicle batteries. Australia has joined an international grouping, the Sustainable Critical Minerals Alliance. The alliance commits us to sustainability and the highest environmental, social and governance standards for the mining and processing of critical minerals.

Many tasks can be done by automatic or remotely operated equipment such as load-haul-dump vehicles and rock breakers. Robotics and automation improve worker safety in hazardous underground environments. The Australian resources sector will continue adopting a range of robotics and automation technologies in the coming decades, including:

- smaller cooperative autonomous vehicles
- smarter sensors to detect and track ore
- better use of information to manage and optimise mining operations
- developing skills in systems integration and digital technologies for completely autonomous mines.

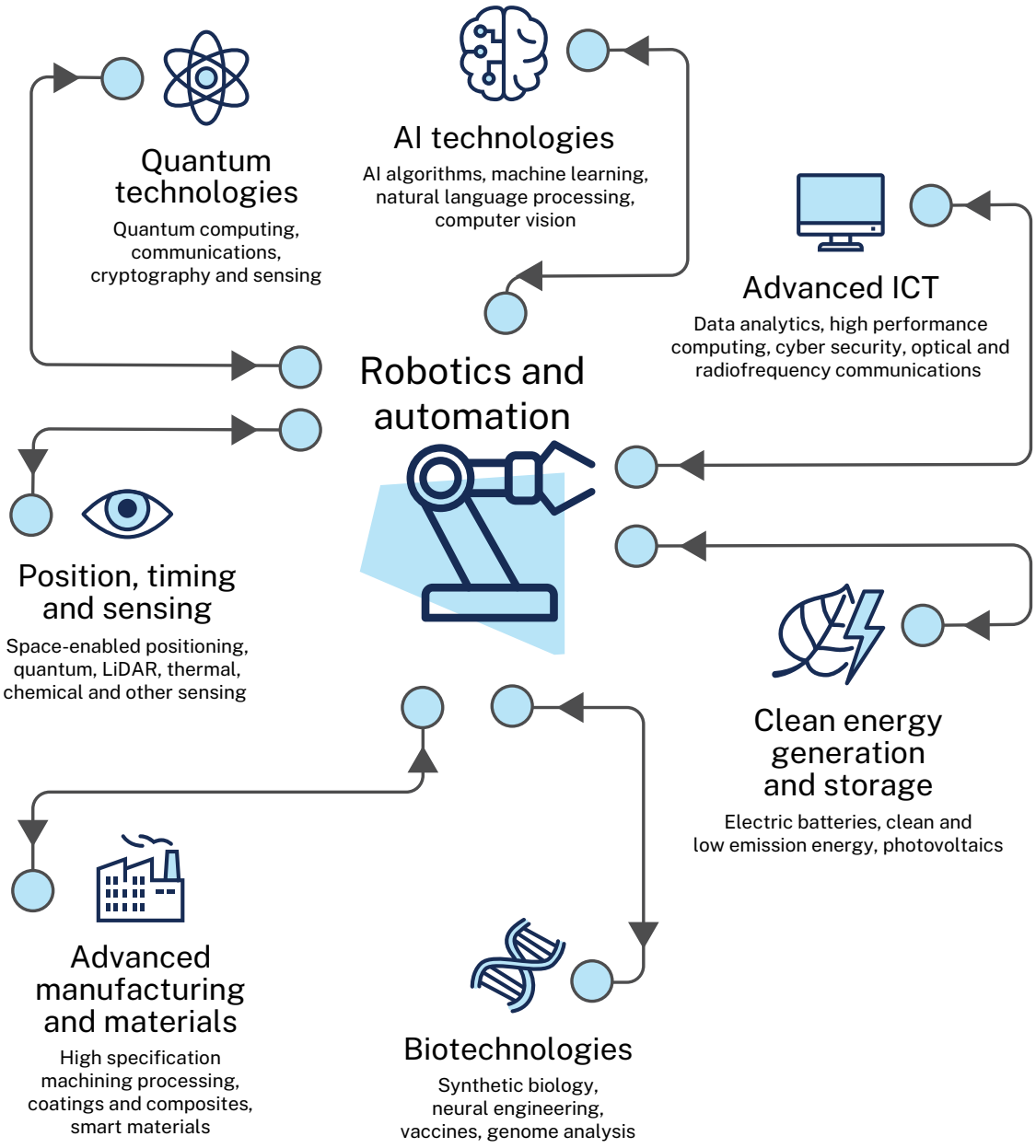
By 2030, adopting and integrating robotics and automation in the resources sector could add another $74 billion to the Australian economy. This will create new employment opportunities (AlphaBeta 2019) while supporting Australia's transition to net zero.

Robotics and critical technologies

Critical technologies are current and emerging technologies that can either enhance or pose risk to our national interest. In 2023, the Australian Government released the Critical Technologies Statement and updated the List of Critical Technologies in the National Interest. The list of technologies identifies 7 key enabling technology fields that impact Australia's national interest, including our economic prosperity, national security and social cohesion. Autonomous systems, robotics, positioning, timing and sensing is identified as one of the critical technology fields.

Critical technologies are important enablers of robotics and automation. Intelligent robots can rely on machine learning algorithms, advanced information and communications technologies such as semiconductors and radiofrequency communications. Robotics and automation technologies are also used in developing other critical technologies. For example, manufacturing semiconductors and technology to create and store clean energy both require precise robotic equipment.

Figure 1: Critical technologies in the national interest that are enabled by or used in robotics and automation.



Artificial intelligence and robotics

AI has revolutionised the capabilities of robots. It has helped create new types of robots that are more flexible, adaptable and intelligent. Through AI, robots have gained the ability to learn from data and experiences, adapt to changing situations and make decisions autonomously. The benefits have been far reaching, including improved navigation in dynamic and uncertain environments such as in mines, farms and disaster zones.

Combining AI and robotics has created situationally aware robots that can perform complex tasks across domains and work safely alongside humans. AI-enabled robots can recognise objects, faces, emotions, speech and gestures and communicate with humans and other robots. They can optimise their actions, plan their goals, cooperate with others and learn from feedback. AI is also being used to develop and optimise robots, creating safer and more efficient and precise equipment.

Advances in AI have enabled entirely new classes of robots. For example, autonomous mobile robots (AMRs) use AI to make near-real-time decisions as they navigate without assistance. AMRs are being used in many domains, including healthcare. They can deliver medication, disinfect surfaces and facilitate interaction between healthcare professionals and patients that are in different physical locations.

The possible applications of robotics are rapidly expanding thanks to generative AI, deep learning, computer vision, large language models (LLMs) and other AI technologies. For example, LLMs have the potential to enhance robotics and automation technologies by improving their learning, communication and decision-making capabilities. The exponential growth in AI applications for robotics means it is increasingly important for robotics firms to invest in AI capabilities. Governments around the world have recognised this economic imperative and are investing accordingly.

Australia has unique advantages in contributing to the AI systems that will continue to revolutionise robotics into the future. Not only is Australia a leader in AI R&D, but our companies and researchers are already actively developing robotics software solutions to address problems across a range of industries. Responsibly developing and exporting secure-by-design AI products and services for robotics presents an immense opportunity for Australia. The Australian Government's Safe and Responsible AI Agenda will ensure the design, development and deployment of AI systems in Australia in high-risk settings are safe and reliable, while the use of AI in low-risk settings can continue to be developed largely unimpeded.

Case study: Maximising the potential of robotics through AI

The University of Adelaide's Australian Institute for Machine Learning (AIML) is Australia's first facility dedicated to AI research and development. With more than 180 researchers, students and engineers, AIML performs detailed research on a range of topics such as machine learning, robotic vision and trusted autonomous systems.

AIML researchers have developed many computer vision systems and other AI-enabled solutions that have been deployed across various industries. These include:

- automated loading and unloading of shipping containers
- computer vision systems to detect material for recycling
- systems for autonomous vehicles.

AIML's research, when applied to industry problems, has led to increased productivity, product quality and workforce safety.

Photo caption: A robot interacting with a human using camera hardware and computer algorithms to process visual data. Photo credit: Australian Institute for Machine Learning.

Case study: Improving quality of life with companion robots in aged care

Andromeda Robotics uses AI and robotics technologies to design robots that improve the lives of those in need, including the elderly and children in hospitals. The company has launched a pilot project testing its AI-enabled companion robot, Abi, at an aged care facility.

Abi offers emotional support and acts as a source of entertainment, aiming to help alleviate loneliness and isolation. It uses a LLM to conduct conversations with residents at the facility, machine learning to recognise individual residents and AI to allow autonomous social interactions. Using these tools, Abi can tailor conversations based on previous interactions, and even give hugs.

Companion robots have the potential to ease labour shortages in aged care and can contribute to improved care quality, staff efficiency and overall quality of life. Through Abi, Andromeda Robotics also hopes to inspire people to think differently about the role that technology can play in critical industries.

Photo caption: Companion robot Abi providing support at an aged care facility.
Photo credit: Andromeda.

Consultation

To develop the National Robotics Strategy, the Australian Government consulted extensively across Australia with industry, academia and the wider community. Guided by the National Robotics Strategy Advisory Committee, the strategy draws on public submissions, workshops and one-on-one interviews.

The active participation of stakeholders across Australia highlighted the importance of Australia's robotics ecosystem and the need for action. We heard that for Australia to maximise the benefits from developing and adopting robotics and automation technologies, we must use our unique strengths and address a range of barriers.

Areas of opportunity

Our expertise

- Australia is a global leader in certain R&D areas, such as field robotics, collaborative robots, safe and responsible AI and computer vision. This provides a strong foundation for our local robotics ecosystem.
- Australia is a leader in adopting and using robotics in mining, emergency response and defence. We can apply these capabilities in a range of other industries.

Comparative advantages

- Australia has strengths in responsible technology, safety standards and regulation. This promotes trust, provides a competitive advantage for Australian industry and benefits our international collaboration and partnerships.
- Australia has robotic test sites, shared infrastructure and other facilities that could encourage further collaboration and coordination.
- Australia's geography offers a unique opportunity to test and prototype robotic solutions, as well as develop field robots including drones and autonomous vehicles.
- Australia's highly educated workforce can benefit from technological advances and the increased adoption of robotics and automation.

Skills

- Australian universities are internationally regarded for the quality of their robotics-related science, engineering, technology and mathematics (STEM) courses, which create world-leading robotics talent in Australia.
- Australia's robotics workforce has proven strengths in integration services, developing software and bespoke solutions for existing robotic systems.
- Australia is an attractive destination for skilled migrants, providing another method of securing a talented workforce.
- Sectors facing skills shortages, such as agriculture, construction and healthcare could benefit from the increased adoption of robotics. Robotics can lift productivity and provide fulfilling opportunities for the workforce.

Areas for development

Commercialisation

- Low levels of industry-research collaboration can limit commercialisation.
- Attracting early-stage and long-term capital can be a barrier for robotics startups due to the long lead times and capital-intensive nature of the technology.
- The costs for manufacturers upgrading or transitioning capital stock to more autonomous infrastructure can be high.
- Australia is not a large-scale manufacturer of many robotics components, forcing companies to import components when developing robotic solutions.

Awareness

- Some businesses are unaware of the benefits or return on investment of robotics and automation, limiting rates of adoption.
- Australia has limited uptake of industrial robots. The skills and infrastructure that businesses need to integrate robotics into their operations are specific to individual contexts. Adoption will need specialised training and development.
- Businesses have limited awareness of Australia's robotics and automation success stories, achievements and investment opportunities.

Trust and inclusion

- Australia's STEM workforce lacks diversity, particularly in the participation and inclusion of women and First Nations peoples.
- Negative perceptions or lack of trust may limit acceptance or use of robotics in the workforce.
- Despite Australia's strong social and governance frameworks, regulations struggle to keep pace with emerging technologies.
- Workers that will be impacted by robotics and automation need greater support to reskill and upskill. This may include job placement support, retraining programs and further education.

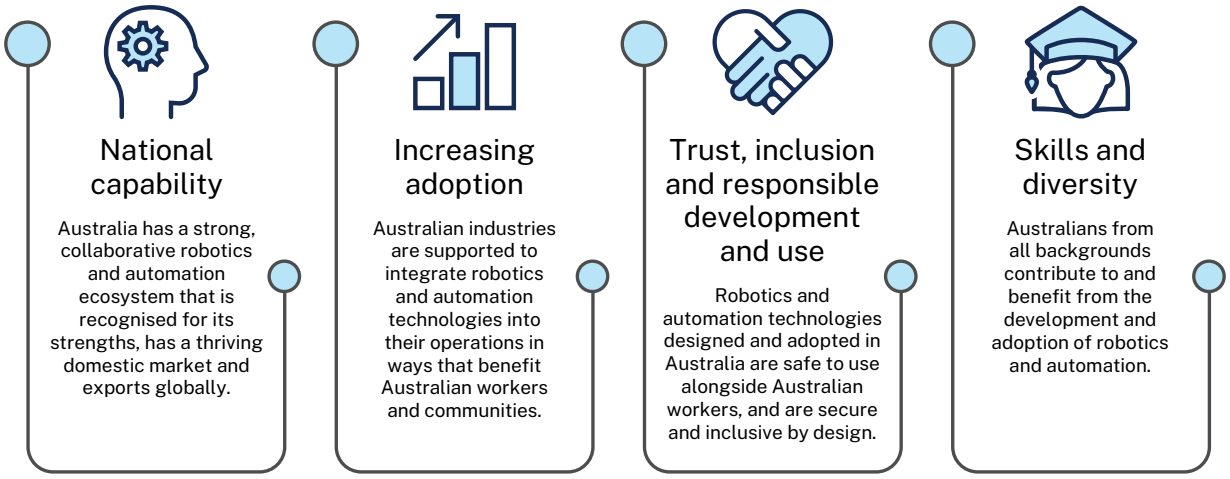
National vision

The National Robotics Strategy is a national framework to grow Australia's robotics and automation ecosystem and realise the government's vision:

> Australian industries are responsibly developing and using robotics and automation technologies to strengthen competitiveness, boost productivity and support local communities.

To achieve this vision, the strategy sets out goals and objectives organised around 4 themes that represent areas of focus. These goals and objectives call for a collaborative effort across Australia, supported by the active engagement of government, industry, researchers and the wider community. Outcomes show what success looks like, and we have proposed a series of indicators to track progress. Benchmarks will be set following the first periodic review.

Figure 2: Strategy themes and goals



Theme 1: National capability

> **Goal:** Australia has a strong, collaborative robotics and automation ecosystem that is recognised for its strengths, has a thriving domestic market and exports globally.

What we've heard

Australia is internationally renowned for our strong technical expertise and innovations. Some of our inventions are well-known and widely celebrated, such as the cochlear implant, black box flight recorder, Wi-Fi and polymer banknotes. Others go underappreciated, including some of our major achievements in robotics and automation. For example, research performed by the Australian Centre for Field Robotics (ACFR) between 1995 and 2001 produced one of the most important advances in robotics in the past 2 decades. The papers published by members of the centre on the Simultaneous Localisation and Mapping (SLAM) method are among the most highly cited in robotics world-wide. The SLAM method allows a robot to build a map of its environment while it determines its location. This innovation is vital to technologies across the globe, such as autonomous vehicles, drones, robot vacuum cleaners and virtual reality headsets.

Australia has leading academic and government robotics institutions. They produce globally competitive research and innovation, with a strong focus on field and other service robots. This expertise is partly shaped by our geography – our vast and diverse landscape is ideal for testing and deploying large or remotely operated robots. Our R&D strengths and field robotics expertise are the foundation of our current robotics industry.

Australia has a competitive advantage in developing niche and high-quality robotic systems. We excel in integrating and customising robotics and automation solutions, particularly autonomous vehicles and drones for the mining, resources and defence sectors. Australia is increasingly commercialising solutions for medical sciences and agriculture, such as robots to support health research and drones for crop and livestock monitoring. Australia's robotics industry also has strengths in:

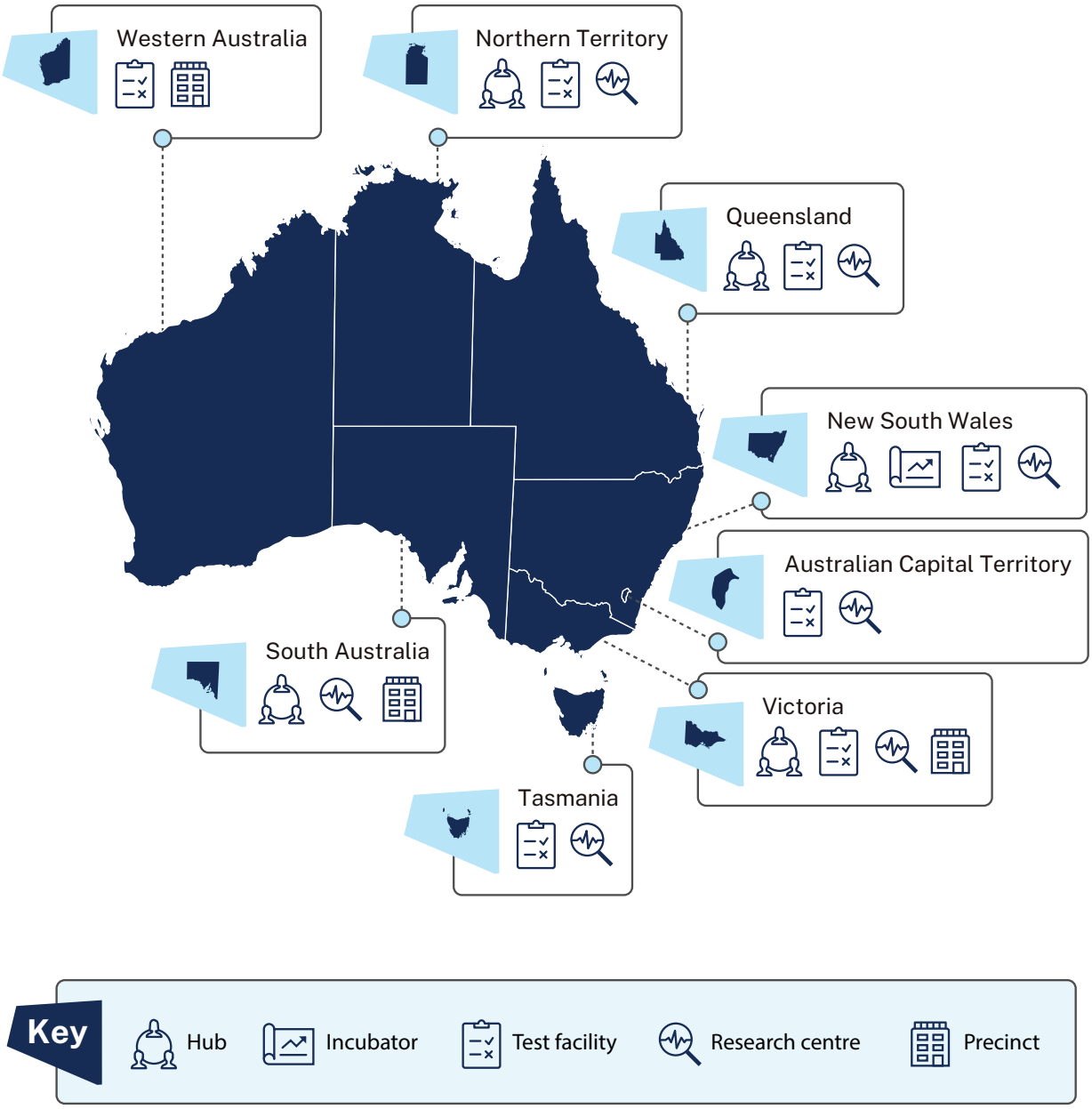
- Supplying and customising hardware for robotic platforms. This involves adding bespoke features and capabilities to existing industrial robot systems.
- Providing integration services such as analysing business processes and optimising them through robotics and automation.
- Developing software and AI technologies for robots, including computer vision and sensing technologies.

By using our strengths and investing strategically, we can build a Future Made in Australia and grow an internationally competitive robotics and automation sector. However, Australia faces barriers in commercialising and scaling up our innovations. This is partly because of the limited availability of domestic and foreign capital where investors may see robotics as a risky investment. They can also be unwilling to fund technologies which have a longer expected return on investment.

Australia's robotics and automation industry consists mostly of small companies, rather than end-to-end manufacturers of large-scale robotics solutions. These small companies tend to focus on niche areas of robotics and automation technologies or different points of the research-to-integration pipeline. Several of these companies are leading global exporters in their field.

Australia is home to many robotics facilities that offer collaborative spaces with specialised equipment, expertise and resources. These spaces bring industry, researchers and government together to collaborate and help industry development. Robotics facilities are spread throughout the country and have developed strong expertise in their areas of focus. These spaces present opportunities to further scale, improve coordination, support collaboration and bring together Australia's robotics industry.

Figure 3: Facilities in Australia supporting the robotics industry that offer collaborative spaces with specialised equipment, expertise and resources.



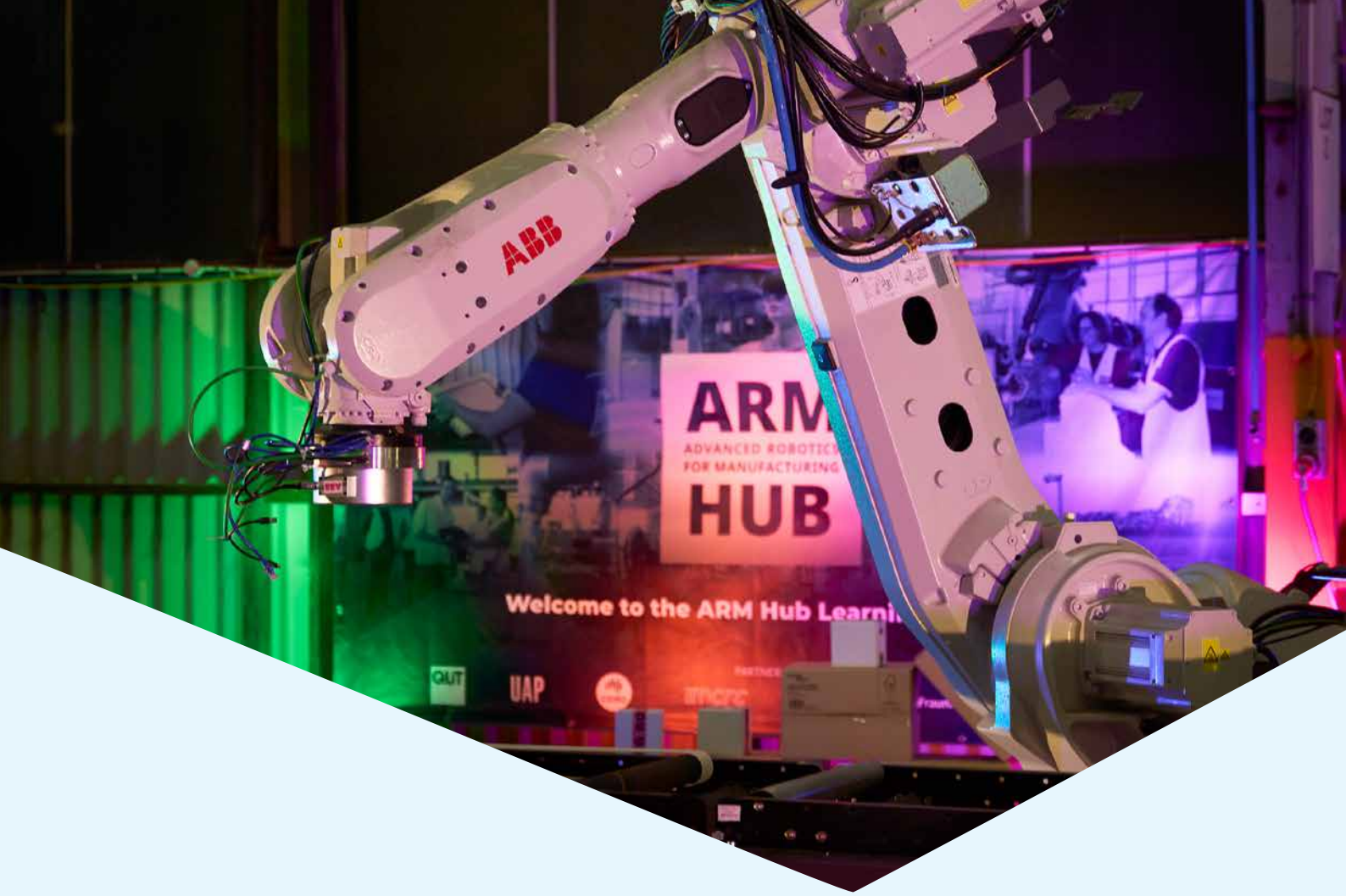
Case study: Researchers partnering with industry

The Australian Centre for Robotics (ACFR) at the University of Sydney is an established research centre, which over its 20-year history has made many major contributions to the science and technology of robotics. The ACFR's foundational research in field robotics has enabled high-impact industry collaborations including:

- automation and optimisation of mining processes from pit to port, improving safety, productivity, and reducing energy footprint
- advanced flight planning systems for commercial aviation that reduce fuel use and carbon emissions in long-haul flights
- novel designs of ground and aerial robotics for agriculture industries.

Today, the ACFR is continuing to expand into new areas. It is leading the Australian Robotic Inspection and Asset Management (ARIAM) Hub, an Industrial Transformation Research Hub with 3 university and 15 industry partners. The ACFR is also developing a robotic surgery facility in collaboration with Sydney Medical School and has conducted research in space robotics funded by the Australian Space Agency. ACFR's staff and research students have helped create many robotic startups and supported the broader Australian robotics ecosystem.

Photo caption: Staff on site at the Australian Centre for Robotics.
Photo credit: Australian Centre for Robotics.



Case study: Collaborative model fosters innovation

Located in Brisbane, the Advanced Robotics for Manufacturing (ARM) Hub uses a collaborative model to contribute to a successful and sustainable technology ecosystem. ARM Hub gives Australian manufacturers access to information, facilities and industry networks to develop and adopt robotic solutions and to source investment to implement the solutions.

The hub provides access to a network of world-leading experts in robotics, AI and design-led manufacturing. Working with in-house technical teams, they help companies use advanced manufacturing technologies, develop new products or overcome technology barriers.

Photo caption: A robotic arm at ARM Hub demonstrating potential applications of robotics in industry.
Photo credit: Advanced Robotics for Manufacturing Hub.

Case study: Robotics research protecting the Great Barrier Reef

Researchers from the Centre for Robotics at the Queensland University of Technology have developed a series of surface and submersible robots. The robots help protect the Great Barrier Reef, using computer vision and AI.

The robot's capabilities are applied to tasks such as coral reef restoration, detection and control of crown-of-thorns starfish and 3D mapping. The robots can function remotely, autonomously and in fleets, allowing researchers to quickly gather large amounts of data to help protect the reef.

Photo caption: The submersible robot, RangerBot, monitoring the Great Barrier Reef for marine pests.
Photo credit: Centre for Robotics, Queensland University of Technology.

Case study: Enhancing Defence capability through automation

The Australian Army worked with Deakin University to design and build a convoy of autonomous trucks with GPS, LIDAR, optical cameras, radar and ultrasonics.

Regular trucks were augmented with an 'autonomy stack' which mimics how a human operates the truck, including moving the steering wheel, handbrake and pedals. The convoy can operate for long periods of time in all weather conditions, reducing human driver fatigue.

Working with the National Transport Research Organisation, the Army successfully tested the convoy on public roads with other road users. The convoy followed one crewed truck, and each autonomous truck made decisions about collision avoidance in real-time. The convoy has now been transitioned into the Army's Land Mobility Program for further trials in the field.

Photo caption: An autonomous convoy of trucks being tested on an Australian highway.
Photo credit: Robotic & Autonomous Systems Implementation and Coordination Office, Australian Army Research Centre.

Case study: Navigating subsea environments with AI and robotics

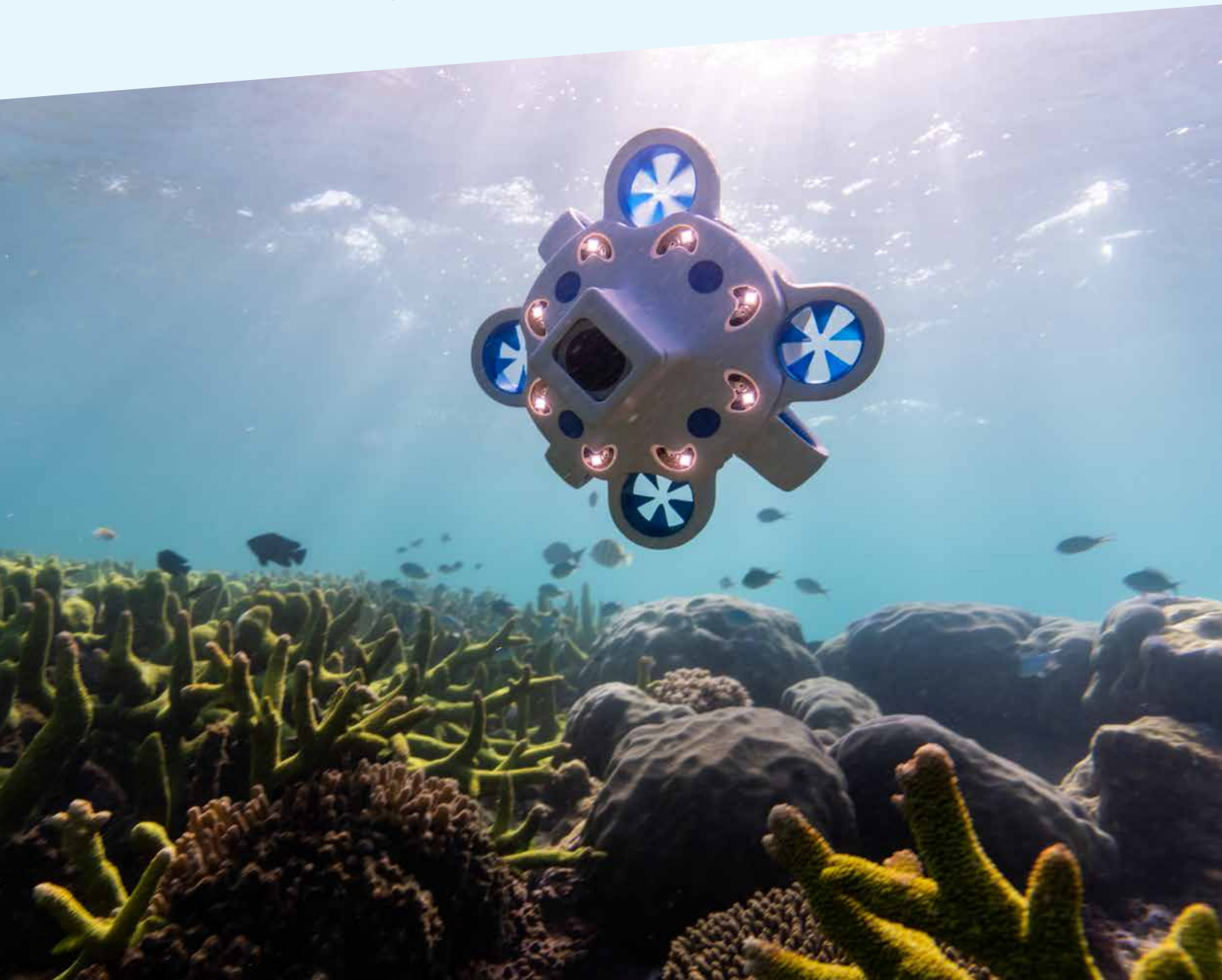
Headquartered in New South Wales, Advanced Navigation develops AI, robotics and navigation technologies. The company has sold 65,000 Australian-made solutions to over 70 countries.

Advanced Navigation opened Australia's largest subsea robotics centre in Western Australia. The high-tech manufacturing and R&D facility accelerates the production of the company's core underwater technologies, including its autonomous underwater robot, Hydrus.

Hydrus combines navigational, sonar and propulsion technologies with artificial neural network intelligence. This makes it well suited for research, survey and exploration by making data capture simple and accessible. Built on an open platform, users can load custom software and train the AI to recognise specific marine species or objects.

In 2023, Advanced Navigation partnered with the University of Technology Sydney's Tech Lab to open an AI robotics manufacturing site for autonomous systems. The site supports Australia's manufacturing capability, focusing on high-value sectors and expertise in deep technology research fields.

Photo caption: Autonomous underwater robot Hydrus surveying a marine environment.
Photo credit: Advanced Navigation.



Supporting government initiatives

The Australian Government has many initiatives underway to support industry and improve our national capability in research, development and commercialisation.

- The Future Made in Australia agenda strengthens Australia's capabilities in key industries, securing Australia's place in a changing global economic and strategic landscape and maximising the economic and industrial benefits of the move to net zero.
- The National Reconstruction Fund provides funding for projects that diversify and transform Australia's industry. As part of the $15 billion NRF, the government has announced a target investment level of $1 billion for critical technologies, which may include robotics technologies, and $1 billion for advanced manufacturing.
- The Industry Growth Program provides commercialisation and growth advice to innovative start-ups and SMEs with one or more of the 7 government identified priority areas of the Australian economy for the NRF.
  - This includes providing Industry Partner Organisation grant funding for ARM Hub, which will provide specialised sectoral advice and expertise to businesses participating in the program and complement the one-on-one Advisory Service of IGP.
- The Research and Development Tax Incentive encourages additional business investment in R&D, providing tax offsets for business expenditure on eligible R&D.
- The strategic examination of Australia's research and development system determines how we can maximise the impact of science, research, and innovation and get more value from investment in R&D.
- AusIndustry's national network of Regional Managers provides local business connections and impartial, trusted guidance tailored to businesses.
- The business.gov.au website and contact centre provide continual support, connecting businesses with information from across all levels of government.
- The Buy Australian Plan builds domestic industry capability by leveraging government procurement.
- The Australian Industry Participation policy gives Australian industry a full, fair and reasonable opportunity to compete for supply opportunities.
- The Business Research and Innovation Initiative provides SMEs with grant funding to develop innovative solutions for government policy and service delivery challenges. Australian Government agencies support the program to develop new-to-market technologies that they can negotiate to buy.
- The National Critical Minerals Strategy 2023–2030 highlights focus areas to help deliver diverse, resilient and sustainable supply chains, meet net zero ambitions, maximise the economic opportunity presented by minerals endowment, and maintain and grow sovereign capability.
- The Moon to Mars Initiative supports multiple robotics and automation technologies, including the Trailblazer rover to demonstrate robotics and remote operation on the moon.
- The AUKUS Pillar II: Advanced Capabilities technology partnership focuses on trilaterally accelerating the delivery of advanced capabilities.
- Defence's Advanced Strategic Capabilities Accelerator facilitates collaborative partnerships between Defence, industry and academia to accelerate the development and transition of innovative technologies into capability, including in the area of trusted autonomy.
- The Defence Industry Development Strategy supports reforms and capabilities to deliver the National Defence Strategy.
- The Defence Industry Development Grant provides support to SMEs for acquiring and commissioning new defence capabilities, international accreditation and certification, skills development and security posturing for suppliers, aligned with the seven Sovereign Defence Industrial Priorities.
- The Australian Trade and Investment Commission continues to support exporter journeys to new and priority markets and attract productive foreign investment to scale Australia's sovereign capabilities in the robotics sector.

- The Rural Research and Development Corporations drives innovation and productivity growth in the agriculture, fisheries and forestry sector through government and rural industry co-investment.
- The Research Translation and Commercialisation Agenda boosts collaboration between universities and industry, driving commercial returns, including:
  - The Trailblazer Universities Program, which builds new research capabilities, drives commercialisation outcomes and invests in new industry engagement opportunities.
  - The Australia's Economic Accelerator, which helps create a research ecosystem where our worldclass university research is translated and commercialised into real world innovations and productivity gains.
  - The National Industry PhD Program, which builds a bedrock of research talent skilled in university-industry collaboration.
- The National Collaborative Research Infrastructure Strategy delivers national research infrastructure to help support Australian researchers to remain internationally competitive and maximise the potential for economic benefits from scientific discoveries.

To build our national capability in robotics, the strategy has set the following objectives, outcomes and indicators of success.

Objectives

Boost research and development, commercialisation and scaling up of Australian solutions targeting areas of Australian strength

Use government's purchasing power to grow domestic demand for robotics and automation

Raise the profile of Australia's robotics and automation capabilities and supply chains locally and globally

Leverage Australia's international partnerships and networks, as well as state and territory governments, to create new opportunities

Outcomes

- Australian industry has improved access to robotics facilities that encourage collaboration, innovation and commercialisation.
- A larger, sustainable Australian robotics and automation industry that produces trusted, reliable solutions and exports globally.
- An ecosystem where researchers and industry work together to deliver innovative, world-leading commercial outcomes that address critical challenges.
- Government and industry have a deeper understanding of Australia's robotics capabilities and supply chains, helping to develop targeted actions, encourage collaboration and grow the local robotics ecosystem.
- Government purchasing power maximises local industry's robotics and automation capabilities and grows domestic demand.
- Increased access to both domestic and international markets and investment helps Australian robotics companies to scale up their innovations and grows our robotics industry.

Indicators of success

- Improved performance of Australia's robotics industry across multiple measures of business performance.
- Growth in the size of Australia's robotics industry.
- Growth in employment in Australia's robotics industry.
- Increased robotics-related R&D expenditure and patent filing activity.
- Increased number of high-quality research publications for robotics.
- Increased rates of collaboration, co-investment and commercialisation.
- Increased value of government procurement of Australian-made robotics systems.

Theme 2: Increasing adoption

> **Goal:** Australian industries are supported to integrate robotics and automation technologies into their operations in ways that benefit Australian workers and communities.

What we've heard

Robotics and automation technologies have far-reaching benefits. They will improve productivity and worker safety in many Australian industries, as well as create higher quality work for Australians. We are well positioned to increase the adoption of these technologies across the economy. Sectors that have high costs associated with upgrading business processes and infrastructure can learn from sectors who are already leading in the uptake of these technologies.

Australia is a leader in adopting whole-of-system automation solutions in mining and resources. These solutions have improved worker safety by removing risks in dangerous environments or the need to perform unsafe tasks. In other sectors, greater adoption could help address business problems by filling gaps in skills and labour, scaling production as well as improving sustainability. Stakeholders told us that companies adopting robotics have seen a range of benefits, including:

- increased labour productivity across industries
- increased scalability of production and manufacturing capability
- improved precision and reliability
- reduced operating costs
- reduced waste and environmental impact
- optimised resource management
- more employment opportunities due to increased scale of operations
- improved health and safety
- increased worker satisfaction.

Despite the benefits of robotics and automation, there are several barriers to adoption. Australian businesses need help to understand the advantages of robotics and automation. It can be difficult for organisations to find information on new technologies, including developments, trends, costs and installation time. Organisations need better visibility of how other Australian companies have adopted robotics and how this has improved their business.

There are also short-term costs and risks for companies looking to adopt robotics and automation solutions. Many businesses, particularly SMEs, are hesitant to adopt robotics because of a perceived high cost of entry. Existing business processes will need to change to realise the full benefits of adopting new technologies, and costs associated with upgrading infrastructure can be high. This often involves buying new stock, upgrading underpinning infrastructure, updating procedures and investing in training and work health and safety.

These barriers are compounded by Australian businesses often seeking international off-the-shelf solutions, rather than bespoke Australian solutions that may offer more localised support. Some businesses told us they chose international solutions because they were overwhelmed by the range of robotics and automation solutions available. Some businesses were also deterred by the perceived risks of working with a newer Australian robotics business. The availability and reliability of supporting infrastructure is also important for businesses looking to adopt these technologies. For instance, reliable internet connections and high upload speeds depend on digital infrastructure, which, if inadequate, can be a barrier to successful operations and growth.

For Australian industry, reliable access to strong, trusted domestic and international supply chains for essential materials and components is critical. Complex global supply chains can be vulnerable to disruption, resulting in unpredictable availability and costs for manufacturers. For example, industry has reported wait times of up to 36 months for some industrial robot arms. Without strong, secure and diverse supply chains, Australia faces barriers in maintaining, growing and diversifying our local manufacturing capabilities. These barriers will continue to result in businesses relying on overseas suppliers to import robotics technologies that we could supply ourselves.

Technological advances have helped address some of these barriers. Improvements made to robotics interfaces and usability, particularly in cobotics, have lowered technical barriers to adoption. Similarly, the use of digital twins – the virtual modelling of physical objects and environments – allows adopters to visualise how they can use robotics in their business by affordably simulating robotics in context.

Through increased adoption of robotics and automation, businesses can develop more productive business models, help build scale and access new markets for products. Sectors that are earlier adopters can also demonstrate to other businesses the potential use cases and commercial benefits from adopting trusted Australian solutions. These collaborative efforts can ultimately attract domestic and foreign investment for robot manufacturers and businesses who are adopting solutions, especially for manufacturers at the seed and startup stages.

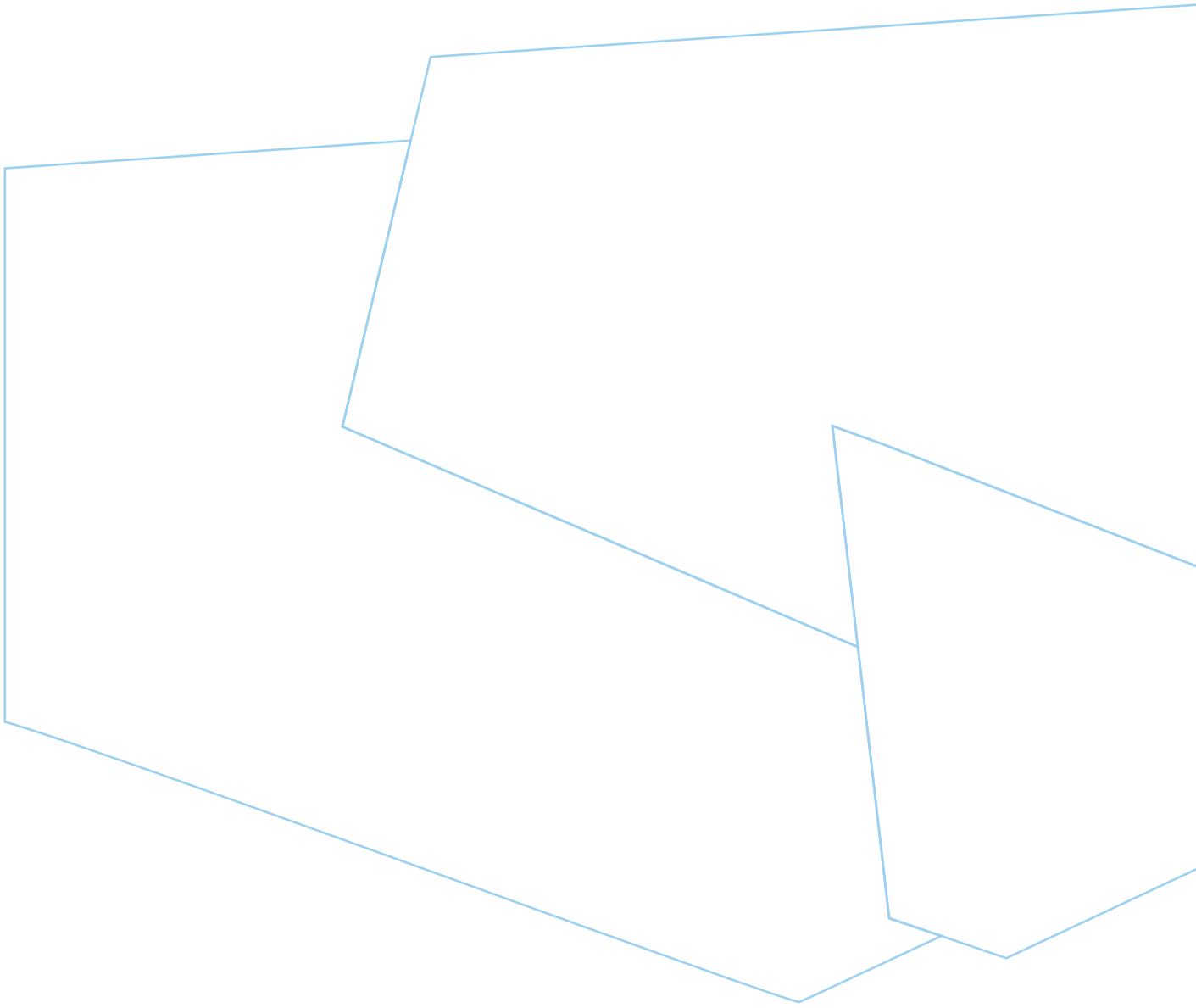


Photo caption: Lettuce grown in an autonomously controlled vertical farm.
Photo credit: Stacked Farm.

Agriculture

Robotics can help address widespread workforce shortages in the agriculture industry and help maximise yield. A range of solutions are currently being used, including:

- autonomous tractors
- fruit-picking robots
- drones for crop monitoring and precision agriculture.

Case Study: Stacked Farm, a Gold Coast-based indoor vertical farm, integrates AI, robotics and machine learning in the agricultural technology sector. The business has automated all stages of the production process on its 2,300 m^2 farm, from growing crops to packing final produce.

Stacked Farm uses end-to-end automation to address inefficiencies. By stacking their vertical crop beds using automation, the company reduces the physical footprint of the farm and the manual strain on workers. This approach is sustainable, repeatable, scalable and safe.

Construction

Robotics and automation are being used in construction for a variety of applications including autonomous earth-moving; materials handling (robotic cranes and mobile robots); structural joining (assembly); and robotic 3D concrete printing.

These applications are driven by the need to reduce costs and address skills shortages while simultaneously improving consistency, predictability, environmental sustainability and safety.

Case Study: Hadrian X is a fully autonomous bricklaying robot developed by the Australian company FBR Limited. It is designed to build structures quickly and efficiently by converting wall sketches into block data and autonomously placing blocks precisely to minimise handling and product waste.

Hadrian X can lay up to 300 large blocks or 8,000 standard bricks per hour. That means it can construct a traditional 4 bedroom, 2 bathroom home in one day, increasing productivity in construction projects. By handling repetitive bricklaying tasks, Hadrian X also reduces the risk of construction workers developing strain injuries and excess waste through precise brick placement.

Photo caption: Bricklaying robot, Hadrian X, autonomously building the walls of a house.
Photo credit: FBR Limited.

Defence

Australia is a leader in robotics technologies for defence, including niche systems for land, sea, air and harsh environments. Australia is also at the forefront of combining robotics and AI for defence purposes.

Our expertise in field robotics means Australia could lead the world in robotics applications for dynamic and harsh environments. These include defence applications, as well as in extreme weather events, mines and disaster zones.

Case Study: Boeing, supported by the Royal Australian Air Force and over 55 Australian companies, has developed and built an uncrewed aircraft called the MQ-28 Ghost Bat. This innovative autonomous aircraft is designed to work closely with crewed aircraft to support a range of missions.

Photo caption: MQ-28 Ghost Bat, an uncrewed teaming aircraft.
Photo credit: Boeing.

Health and medical science

Robots are becoming increasingly common in general hospital settings, such as transporting medical supplies and more precise medical tasks such as helping perform surgery.

Working with AI, robots can help diagnose and interact with patients. In the future, robots will be increasingly used in prosthetics and assistive technologies.

Case Study: Macquarie University Hospital has been an early investor in robotic-assisted technologies. It has a particular focus on using robotic surgery for the management of urological conditions, including prostate cancer.

The hospital also uses robotics to achieve better patient outcomes in cardiology, neurosurgery, colorectal surgery, orthopaedics and gynaecology. Research shows that certain types of robotic surgery are associated with shorter operating times and faster patient recovery.

Logistics and transport

Logistics and transport are some of the fastest growing applications for mobile robotic systems. Robots are typically used for order fulfilment, warehousing and delivery. They can increase the speed and effectiveness of supply chains and reduce errors and accidents.

Case Study: Swoop Aero is an Australian-based robotics company. Its end-to-end automated drone logistics platform gives remote and regional communities reliable access to essential healthcare supplies.

Swoop Aero operates networks in 5 countries including Malawi, Democratic Republic of the Congo and Australia, and has conducted over 27,000 flights to deliver more than 1.4 million items, including vaccines, pharmaceuticals and test kits. The on-demand deliveries have improved many communities' access to quality healthcare.

Photo caption: A drone being prepared for the delivery of critical supplies.
Photo credit: Swoop Aero.

Manufacturing

The manufacturing sector has been using robotics and automation for decades. Robots are used to do repetitive and unsafe work, as well as increase production efficiency and quality.

Case Study: Based in Geelong, Carbon Revolution is an Australian company that manufactures carbon fibre wheels for the global automotive industry.

The company uses robotics in their manufacturing process to make one-piece carbon fibre wheels that are 40% to 50% lighter than comparable aluminium wheels. These wheels can be used to reduce the weight of electric vehicles, leading to better fuel efficiency.

Photo caption: Custom designed robots automating manufacturing processes for carbon fibre wheels. Photo credit: Carbon Revolution.

Mining and resources

Robots are well established in Australia's mining and resources sector, where they can perform tasks that are highly repetitive or too dangerous for humans. Robots are commonly found in:

- utility line inspections
- autonomous vehicles including trucks and trains
- undersea and underground exploration.

In the future, robotics and automation will become increasingly important in supporting the extraction and processing of critical minerals, and allow for whole of mine automation.

Case Study: IMDEX is a global mining technology company focused on detecting and extracting minerals safely, quickly and precisely. Its semi-autonomous Blast Dog system gives mining and mineral exploration companies crucial measurement data before they start drilling and extraction. This:

- increases productivity
- supports decision-making
- improves safety
- reduces environmental impacts in the resources sector.

Photo caption: Blast Dog, a semi-autonomous system providing real-time measurement data to workers on a mining site. Photo credit: IMDEX.

Space

Australians rely on space-based technology to transmit essential data for everyday activities like weather forecasts, internet access and online banking.

Robots in space collect data remotely and go places that humans can't go. The future of robots in space could see applications such as remote monitoring and maintenance site preparation, material handling, and transport and logistics.

Case Study: The Australian Space Automation AI and Robotics Control Complex (SpAARC) is based in Perth. It is a joint initiative between the Australian Space Agency, Fugro and the Western Australian Government. SpAARC's infrastructure supports start-ups, small businesses, major international companies and researchers in developing and performing robotic activities for applications in space. These technologies allow monitoring for environmental impact and the operation of remote robotic assets that perform challenging and hazardous work.

SpAARC partners with local companies, harnessing Australia's world-leading expertise in field robots to overcome the environmental challenges of space. This has created a shared space for companies to test robotic technologies and remotely operate systems for use in space, on Earth and under the sea.

Photo caption: Mission control room at the Australian Space Automation AI and Robotics Control Complex. Photo credit: SpAARC

Case study: Enabling future growth in manufacturing

Bosch Australia Manufacturing Solutions (BAMS) was established to provide advanced automation and robotic systems to Australian manufacturers. This includes custom machine building, engineering and manufacturing solutions.

BAMS is helping 3RT convert wood waste into timber with similar physical characteristics to old-growth hardwood. The result is a low-carbon, non-toxic building material that reduces native forest depletion and helps secure global supply chains.

BAMS will supply digital production units and fully automated production cells to help 3RT improve its manufacturing efficiency. The technology can be customised and easily scaled.

3RT forecasts revenue of $44.5 million over 5 years and expects the project to create new opportunities in their workforce.

Photo caption: 3RT's robot handling hardwood, converted from renewable growth logs, on the production line built at the BAMS facility. Photo credit: Bosch Australia Manufacturing Solutions.

Supporting government initiatives

The Australian Government has a number of initiatives to support the right conditions for increased robotics adoption.

- The Future Made in Australia agenda strengthens Australia's capabilities in key industries, securing Australia's place in a changing global economic and strategic landscape and maximising the economic and industrial benefits of the move to net zero.
- The National Reconstruction Fund provides funding for projects that diversify and transform Australia's industry. As part of the $15 billion NRF, the government has announced a target investment level of $1 billion for critical technologies, which may include robotics technologies, and $1 billion for advanced manufacturing.
- The Industry Growth Program provides commercialisation and growth advice to innovative start-ups and SMEs with one or more of the 7 government identified priority areas of the Australian economy for the NRF.
  - This includes providing Industry Partner Organisation grant funding for ARM Hub, which will provide specialised sectoral advice and expertise to businesses participating in the program and complement the one-on-one Advisory Service of IGP.
- The Australian Industry Participation policy gives Australian industry a full, fair and reasonable opportunity to compete for supply opportunities.
- AusIndustry's national network of Regional Managers provides local business connections and impartial, trusted guidance tailored to businesses.
- The business.gov.au website and contact centre provide continual support, connecting businesses with information from across all levels of government.
- The Better Connectivity Plan delivers digital infrastructure, improved network connectivity and consumer awareness across regional and rural Australia.
- The TAFE Technology Fund invests $50 million to modernise IT infrastructure, workshops, laboratories, and other facilities at TAFEs across Australia.

To improve the adoption of robotics in Australia, the strategy has set the following objectives, outcomes and indicators of success.

Objectives

Raise awareness of robotics and automation technologies and their benefits for critical industries, like advanced manufacturing, agriculture and mining, to support Australia's future competitiveness

Support and incentivise Australian businesses to adopt local robotics and automation solutions

Improve digital and telecommunications infrastructure underpinning robotics and automation

Outcomes

- Increased adoption of robotics and automation throughout the economy that has helped diversify, revitalise and strengthen the competitiveness of Australian industries.
- A visible and celebrated Australian robotics ecosystem that lets Australians see the benefits of living and working with robotics and automation.
- Strengthened digital infrastructure that supports the adoption and use of robotics and automation in regional and remote locations.

Indicators of success

- Increased robot density.
- Growth in the number of new applications and uses for robotics.
- Increased uptake of Australian-made robotics solutions.
- Improved business perceptions and fewer barriers to adoption.
- Increased industry awareness of robotics solutions.

Theme 3: Trust, inclusion and responsible development and use

> **Goal:** Robotics and automation technologies designed and adopted in Australia are safe to use alongside Australian workers, and are secure and inclusive by design.

What we've heard

Robotics and automation are fast becoming part of everyday life, from fulfilling online shopping orders to improving patient health outcomes in our hospitals. The successful integration of these technologies into our society depends on their development and adoption being responsible, secure, ethical, lawful and inclusive.

Companies and industries that adopt robotics have been able to stay competitive and scale their operations, creating jobs that wouldn't otherwise exist. Without robotics and automation, Australia will struggle to remain internationally competitive and adapt to future trends like our ageing population and tight labour market. Research shows that robotics and automation often complement human labour, increasing employment and job satisfaction (OECD 2023). Robotics and automation can also reduce workplace injuries and automate routine or repetitive work, improving productivity and letting workers focus on more meaningful and rewarding tasks.

However, there is public debate on the potential impact of robotics and automation on jobs. The course of history has shown that technology can lead to structural changes in the economy. Education, targeted regulation and increasing the overall awareness of how these technologies function and benefit society will help to address concerns around employment, reliability and safety. To ensure that the development and use of robotics is responsible, we can:

- update governance frameworks to promote robotics and automation solutions that improve social wellbeing, inclusion and safety
- introduce robotics and automation into areas of the economy experiencing skills shortages
- build awareness so workers can see themselves working alongside robotics
- provide robust and flexible training systems to support workers to reskill and upskill.

To realise the opportunities and benefits from robotics and automation it's important that industry and government work together to involve users, communities and workers. By involving these groups in the design of robotics and automation solutions, we can develop them responsibly and inclusively. Australia has a record of doing this effectively, including through shared consultation on work health and safety regulations and currently in responsibly developing AI.

Given the lack of diversity in the robotics industry, communities, industry, academia and government need to bring together a range of perspectives to identify potential biases and adverse consequences. As robotics, automation and AI technologies evolve, we must work together to have the right frameworks and settings in place so everyone uses these technologies responsibly.

Promoting the safe, secure, lawful and ethical design and use of robotics and automation technologies will help protect Australia against potential risks. Fit for purpose regulatory settings and standards, as well as robust safety and cyber security arrangements can guide developers and adopters so they can adhere to best practice. For example, as cobots become more common, it is important that people and robots can work alongside each other safely and securely.

Managing cyber security, data privacy, collection, storage and use will be important to protect our industries and the wider community. Many robotics and automation technologies collect sensitive and personal data to perform their functions. They may capture information on personal identifiers, health conditions and the layout of homes or workplace environments. It is vital that Australians are aware of the potential cyber security risks robotics and automation technologies can present and mitigate these where possible. Awareness will ensure Australia adopts secure and trusted solutions to take full advantage of the opportunities that these technologies present.

Case study: Ethical protocols for drone use on Jawoyn Country

Jawoyn Traditional Owners in the Northern Territory have collaborated with CSIRO, Charles Darwin University and the University of Western Australia to develop ethical guidelines for guided, authorised drone use in Kakadu National Park.

Drones have rapidly become a vital aerial survey tool across northern Australia but need to be introduced responsibly to support First Nations data sovereignty protocols. Developing the guidelines was part of a larger project to co-design and apply healthy country indicators to monitor and manage this unique World Heritage Area.

The protocols were first applied to drones at Jarrangbarnmi, an important biocultural landscape. These protocols can guide First Nations-led innovation in the future by:

- empowering First Nations governance around how data is collected, curated and shared
- developing ethical and trusted research relationships
- enabling ongoing First Nations-led technological innovation.

Case study: Improving accessibility with robotics and automation

aKin integrates AI and robotics to create assistive technologies. The company is working with people who have spinal cord injuries to develop a robotic assistant tailored to their needs. It can sense its environment and respond to people, objects and commands, as well as modify its responses to improve patient wellbeing. The assistant will use autonomous reasoning to complete tasks such as:

- social companionship and cognitive support
- picking up items from the floor
- moving objects aside
- retrieving items from shelves
- carrying items around the house
- connecting patients to telehealth.

The robot is now in codesign and human trial phase. When complete, it will improve quality of life and sense of independence for people with spinal cord injuries.

Photo caption: An assistive robot using AI to sense its environment. Photo credit: aKin.

Supporting government initiatives

The Australian Government has several initiatives underway to build trust and ensure the use of robotics and automation is safe and responsible.

- Supporting safe and responsible AI, noting the interim government response's focus on preventing harms, clarifying and strengthening laws, working internationally and maximising the benefits of AI.
- Engagement in international technology standards setting enhances industry capacity and ensures robotics developments meet the needs of Australians.
- The 2023–2030 Australian Cyber Security Strategy sets a vision for Australia to be a world leading nation in cyber security. Cyber security is an essential component of internet-connected robotics.
- Coordinating regulatory frameworks for the emerging applications of drones ensures the use of drones is safe and respects privacy.
- Establishing a regulatory framework for the safe operation of automated vehicles on public roads.
- The National Strategy to Achieve Gender Equality guides whole of community action to make Australia one of the best countries in the world for a gender equal society.
- Fee Free TAFE supports over 355,000 student enrolments nationally, of which over 10,900 were directly in the Technology and Digital Sector.

To promote trust, inclusion and responsible development and use of robotics in Australia, the strategy has set the following objectives, outcomes and indicators of success.

Objectives

Ensure regulatory and legal frameworks enabling and applying to automation technologies are fit for purpose

Better understand and address the social impacts of robotics and automation in critical industries

Promote Australia's engagement in relevant bodies for setting international standards

Improve safety and cyber security of robotics and automation technologies

Outcomes

- Regulatory and governance frameworks promote trust and ensure robotics and automation technologies are produced and adopted responsibly.
- A deeper understanding of the social impacts of robotics and automation allow for targeted measures that enhance benefits for society and mitigate potential risks.
- Improved consultation with representative and community sector organisations builds diverse communities' capacity to integrate, adopt and engage with robotics and automation.
- International standards are widely adopted and consistent with Australia's interests.
- Robotics and automation technologies are secure and trusted by industry and the community.

Indicators of success

- Improved performance on measures of regulatory transparency and compliance.
- Reduced work-related injuries in industries adopting robotics.
- Improved performance in studies on quality of life, job satisfaction and job mobility.
- Increased energy efficiency, and reduced waste and emissions.
- Improved community perceptions of benefits from adoption.
- Improved adoption of cyber security standards to ensure robotics and automation solutions are safe and secure.

Theme 4: Skills and diversity

> **Goal:** Australians from all backgrounds contribute to and benefit from the development and adoption of robotics and automation.

What we've heard

Australia has a highly skilled and diverse population that stands to benefit from robotics and automation. These technologies can open new career opportunities and allow workers to focus on higher value and more rewarding activities. Supporting Australian workers to adapt to technological change will need ongoing education, training and reskilling. Building a diverse workforce in the robotics and automation industry will further increase the size of our talent pool and include broader perspectives, improving innovation, creativity and problem-solving.

Building sustainable education pathways

While Australia has a highly skilled workforce, the growth of our robotics and broader technology ecosystem will benefit from an increase in STEM graduates at tertiary levels. To achieve this, we need to support quality STEM education at all levels of schooling. This would include fostering digital literacy and interest in STEM for children in early learning environments and primary school.

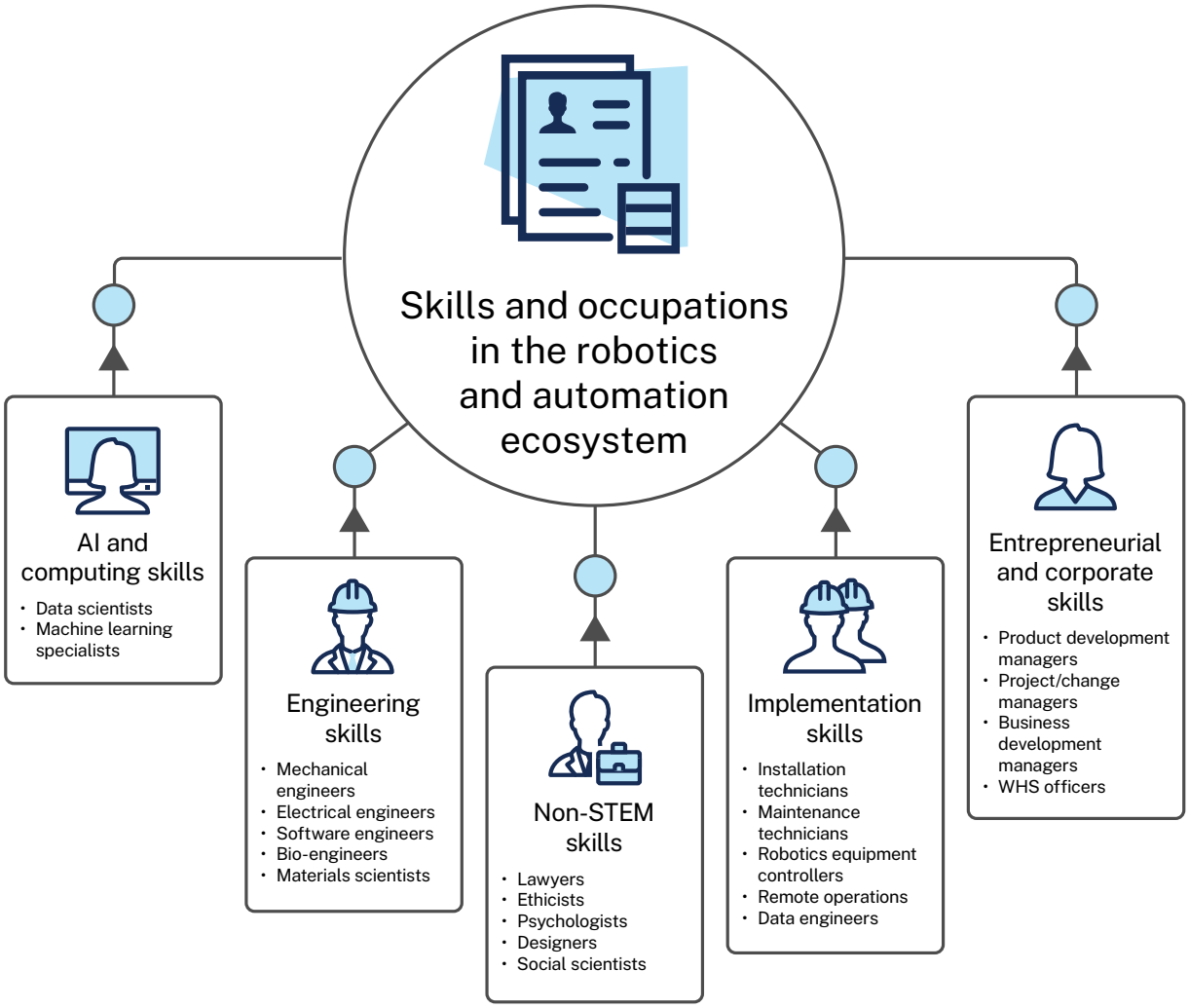
Many primary schools offer robotics as part of their curriculum as an engaging way to generate student interest in problem-solving and other STEM skills. Using robots in classrooms can help to foster critical thinking, coding, engineering, mathematics and design skills. Engaging early is important for the future robotics and automation workforce to be representative of Australia's diverse population. It is also important to provide support to schools and teachers so they have the knowledge and capacity to deliver robotics-related Australian Curriculum content.

After leaving school, pathways into robotics and automation careers are varied. There is a large list of accreditation and qualifications relevant to robotics and automation. However, understanding the skills needed and navigating the pathways through education and training and into the workforce can be difficult. This can limit the attraction to, and accessibility of, robotics and automation careers.

Some roles require undergraduate or post-graduate degrees. Australian universities are highly regarded internationally for the quality of their STEM courses. This is especially true for aeronautical engineering, bio-engineering, civil and structural engineering, computer science, electronic engineering and materials science degrees. Other roles require trade or vocational skills that students can get through on-the-job training and vocational education and training (VET) courses. TAFEs and other vocational institutions are introducing relevant courses across Australia. We have already seen an increase in the popularity of robotics-related micro-credentials, vocational courses and qualifications.

Degrees in mechatronics engineering – a hybrid of mechanical and electrical engineering – can be a direct pathway into robotics. However, STEM training and qualifications are not the only options for pursuing robotics and automation careers. Other disciplines including design, social sciences, law and ethics, play an important role in the responsible development and use of robotics and automation. Multidisciplinary robotics skills will create a workforce with diverse experiences and backgrounds that can lead to more varied perspectives and improve the quality of solutions.

Figure 4: Sample of skills and occupations in the robotics and automation ecosystem



For those already in the workforce, upskilling and reskilling pathways need to be accessible and available. Accessible pathways are vital so workers can develop the skills needed to work alongside robotics and automation technologies. Industry has an important role to play in this, alongside our education providers. Support for workers may involve training programs that focus on the skills and knowledge needed to work safely alongside robotics and automation, as well as through hands-on experience operating these technologies.

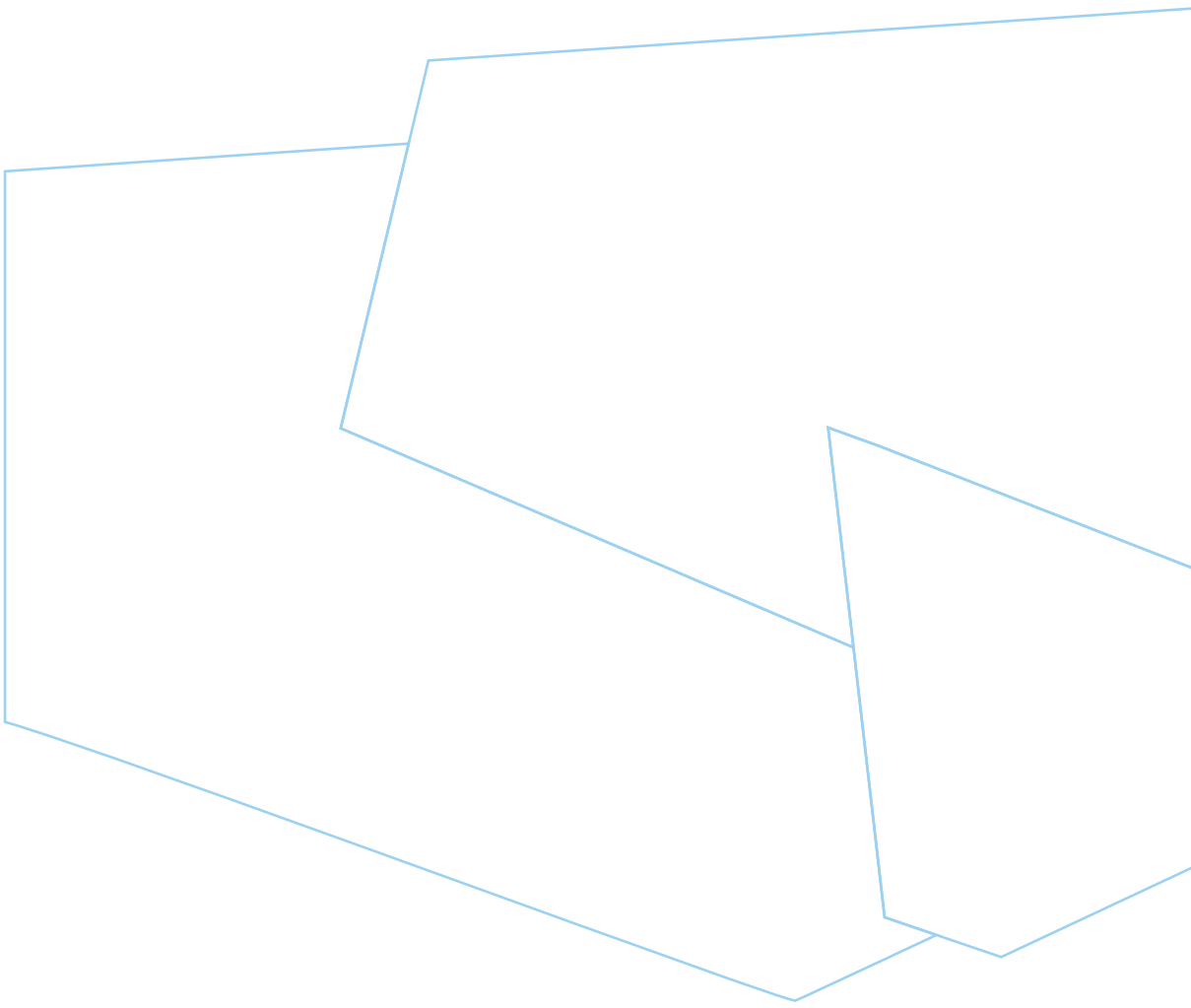
In the mining and resources sector, for example, tailored courses are available to upskill and train staff in the use of robotics specific to their industry. This approach is not only giving workers the skills they need, but also a greater understanding of the benefits of adopting robotics and automation technologies in their work. Additionally, creating a supportive environment for workers, such as through cultural awareness, inclusion and safety measures, can help ensure that no one is left behind in the transition to more automated work environments.

Attracting and retaining a diverse workforce

To improve the diversity of the robotics and automation workforce, industry, academia and government must create opportunities for under-represented groups. We can achieve this through targeted training and education programs, inclusive hiring practices and research-informed support. Marginalised groups in STEM fields include women, First Nations people, people with disability, older people, people from culturally and linguistically diverse backgrounds and LGBTIQA+ people.

A report from the Office of the Chief Scientist shows that only 0.5% of Aboriginal and Torres Strait Islander people hold a STEM degree. This compares to 5.2% of people in the wider community (Office of the Chief Scientist 2020). In 2021, the proportion of women in STEM-qualified occupations was only 15% (DISR 2023b). This trend carries into the robotics industry, where women make up somewhere between 7% and 19% of robotics engineers (Department of Defence 2023).

There are already several initiatives that support diversity in the robotics and automation industry. However, we need to do more so that the industry reflects, supports and benefits broader Australian society. Encouraging and supporting a diverse robotics workforce will help Australia combat domestic labour and skills shortages. It will also bring a range of perspectives, knowledge and understanding to the workforce. Research across industries shows that diversity in the workforce boosts innovation, creativity and problem-solving. While diverse workers should not be made primarily responsible for making their industry more inclusive, diversity in the workforce can encourage the development of inclusive and trustworthy technologies.



Case Study: Robotics labs as a practical learning environment

Australian TAFEs are working with industry to develop and offer new pathways to robotics and automation jobs and preparing Australians for the workforce of the future. Both TAFE Queensland and South Metropolitan TAFE in Western Australia (WA) deliver accredited and non-accredited programs in robotics and automation to industry and students.

In April 2018, WA's South Metropolitan TAFE and the WA Government partnered with Rio Tinto to begin the development of Australia's first dedicated qualifications in automation, which were designed to prepare West Australian students for mining jobs that utilise robotic and automation technologies.

Through their specialist training facility, the Munster Campus at South Metropolitan TAFE delivers a Certificate IV in Autonomous Control and Remote Operations and a Certificate II in Autonomous Workplace Operations to give students the capability to work alongside autonomous technologies.

In 2019, TAFE Queensland and Central Queensland University (CQUniversity) Australia were engaged by BHP Mitsubishi Alliance to form the Queensland Future Skills Partnership. The partnership has delivered 10 new microcredentials, 12 Skillsets and a Certificate II in Autonomous Technologies. These programs combined, which have been rolled out to more than 800 participants since 2021, aim to upskill the existing workforce and provide pathways for students into robotics and automation jobs of the future.

Several TAFE Queensland and CQUniversity Australia campuses deliver these and other applied technology programs through their robotics labs. Other courses offered include a Certificate IV in Industrial Automation and Control and a Diploma of Applied Technologies.

These qualifications delivered by South Metropolitan TAFE and TAFE Queensland seek to address Australia's skills shortages in robotics-related trades and occupations while providing fulfilling opportunities to Australian workers.

Case study: Sparking creativity and critical thinking through robotics workshops

The Western Australian Robotics Playoffs (WARP) engage and educate 13 to 18-year-old high school students about robotics in industry through competitions. WARP also gives the industry a chance to nurture and encourage future robotics talent. WARP is a collaboration between:

- WA's Department of Primary Industries and Regional Development
- Curtin University
- Murdoch University
- Macquarie University
- International not-for-profit organization FIRST®.

Students who participate in WARP develop skills that are vital for future careers, such as critical thinking, communication, teamwork and resilience. In 2022, students participating in WARP designed and built robots to compete in 3 on 3 basketball-style games. Agriculture and AgTech industries also attended the event to showcase automation technologies in agriculture and promote career opportunities.

Photo caption: High school students competing in the Western Australian Robotics Playoffs.
Photo credit: Western Australian Robotics Playoffs.

Case study: Attracting and retaining diverse talent in robotics careers

The Monash Nova Rover (MNR) is an award-winning student team that is designing and building the next generation of Mars and Lunar rovers. The team has 96 students with expertise in engineering, science, business, commerce, IT and design.

In 2023, the team won the Australian University Rover Challenge for the third year in row. They also placed second at the University Rover Challenge, competing against 104 teams from around the world.

MNR has created a fair and inclusive environment that helps attract and retain diverse talent in STEM. MNR proudly attribute their success and achievements to their team's diversity.

In February 2023, the MNR team launched a pink rover called 'Waratah' to spark conversations about women in STEM. Their campaign is designed to start these conversations through 3 missions:

- empower through education
- bring visibility and foster engagement
- address barriers and bias.

Photo caption: Pink rover 'Waratah' competing in the University Rover Challenge.
Photo credit: Monash University.

Case study: First Nations pathway to STEM careers

The Young Indigenous Women's STEM Academy (the Academy) supports 600 First Nations women to study and work in STEM. CSIRO delivers the Academy in partnership with CareerTrackers. The Academy is funded by the National Indigenous Australians Agency.

The Academy supports young women from Year 8 onwards. It provides a culturally safe, inclusive practice and targeted long-term support. It aims to build a generation of First Nations female leaders, role models and game-changers in STEM fields. The Academy collaborates with organisations and STEM professionals to support these young women to participate in robotics-related initiatives, including the RoboRAVE Australia competition in 2022.

RoboRAVE is a unique format in that participants can enter using any robotics platform, at any age, with any level of experience and from anywhere in the world. To compete, competitors needed to design, build and program a fully autonomous robot to complete a given task, such as:

- climbing vertical surfaces
- battling in a sumo arena
- negotiating mazes
- using vision technology to follow lines and track objects.

By supporting a team of young First Nations women to compete, the Academy gives students valuable skills in programming, designing and problem-solving. These are all qualities of successful entrepreneurship in STEM fields.

Photo caption: Students competing at RoboRAVE Australia.
Photo credit: CSIRO.

Supporting government initiatives

The Australian Government has many initiatives underway to increase skills and diversity in Australian industries. A number of these initiatives support the government's commitment to reach 1.2 million tech-related jobs by 2030.

- Supporting a thriving, skilled and diverse STEM workforce by boosting STEM programs that focus on women and science to reach more diverse cohorts.
- The National Strategy to Achieve Gender Equality guides whole of community action to make Australia one of the best countries in the world for a gender equal society.
- The Employment White Paper provides a roadmap for Australia to improve access to digital skills, promote tech adoption and grow the digital workforce. This will allow the workforce to harness the opportunities of the economic transformation associated with digitalisation and emerging technologies.
- The Australian Universities Accord pursues meaningful reform improve the quality, accessibility, affordability and sustainability of higher education.
- The National Skills Agreement expands and transforms access to the VET sector, support quality training and implement reforms to address critical skills need.
- Jobs and Skills Australia provides high quality data, analysis, and insights to better understand Australia's skills and labour shortages across the economy.
- Jobs and Skills Councils strengthen industry engagement in the VET sector including one dedicated for Finance, Technology and Business sectors with responsibility for undertaking skills and workforce planning to support and strengthen Australia's digital and technology workforce.
- The Migration Strategy simplifies visa application processes and ensures that migration programs complement the skills and capabilities of Australian workers.
- Fee Free TAFE supports over 355,000 student enrolments nationally, of which over 10,900 were directly in the Technology and Digital Sector.
- The TAFE Technology Fund invests $50 million to modernise IT infrastructure, workshops, laboratories, and other facilities at TAFEs across Australia.
- The Australian Skills Guarantee leverages government purchasing power to help address skills shortages and gender segregation in the building and construction and maintenance services and information and communications technology (ICT) sectors.
- The Building Women's Careers program expands support for women training in male-dominated industries, including in STEM.

To improve our skills and diversity in the robotics ecosystem, the strategy has set the following objectives, outcomes and indicators of success.

Objectives

Strengthen pathways into robotics-related careers

Monitor and plan for workforce changes and skills development alongside greater adoption of robotics and automation technologies

Raise awareness of the skills needed to support a technologically advanced economy

Identify ways to better promote diversity and inclusion in robotics industries

Attract skilled migrants to increase our economic prosperity and security

Outcomes

- Improved STEM and digital literacy build the skills Australians needed to develop, produce and adopt robots, and prepare for the future of work.
- Improved diversity and inclusivity in the robotics ecosystem and workplaces help address jobs and skills shortages, and improves the innovation and inclusivity of robotics and automation solutions.
- Clear pathways attract Australian and international talent to the Australian robotics industry and workforce.
- A deeper understanding of Australia's tech and robotics workforce allows for more targeted actions to boost strengths and address skills needs of the future.

Indicators of success

- Increased number of robotics-related job vacancies in Australia.
- Increased enrolments and completions in robotics-related STEM courses.
- Increased number of robotics-related STEM training and education programs.
- Increased skilled migration intake for robotics-related occupations.
- Increased diversity in STEM course enrolments and workforce participation.

References

ABS (Australian Bureau of Statistics) (2023), Detailed Labour Force Survey – August 2023, ABS website, accessed 29 November 2023.

AlphaBeta (2019), Staying ahead of the game, AlphaBeta website, accessed 20 July 2023.

ASPI (Australian Strategic Policy Institute) (2023), Critical Technology Tracker, ASPI website, accessed 16 October 2023.

Bland R, Ganesan V, Hong E and Kalanik J (2023) Trends driving automation on the farm, McKinsey & Company, accessed 16 August 2023.

Department of Defence (2023), National Robotics Strategy Discussion Paper – Submission 89, Department of Industry, Science and Resources website, accessed 13 June 2023.

DISR (Department of Industry, Science and Resources) (2023a), Resources and energy quarterly June 2023, Office of the Chief Economist, accessed 21 July 2023.

DISR (Department of Industry, Science and Resources) (2023b), STEM Equity Monitor, Department of Industry, Science and Resources website, accessed 6 April 2023.

Eggleston K, Suk Lee Y, Iizuka T (2021), Robots and labour in the service sector: evidence from nursing homes, National Bureau of Economic Research, accessed 2 May 2023.

IFR (International Federation of Robotics) (2023a), Japan is world's number one robot maker, IFR website, accessed 2 May 2023.

IFR (International Federation of Robotics) (2023b), Executive Summary – WR Industrial Robots 2023, IFR website, accessed 3 November 2023.

IFR (International Federation of Robotics) (2023c), World Robotics 2023 Report: Asia ahead of Europe and the Americas, IFR website, accessed 1 December 2023.

International Organization for Standardization (2021), ISO 8373:2021 Robotics – Vocabulary, ISO website, accessed 14 August 2023.

Mine (2022), Australia continues to dominate the use of autonomous haul trucks, Mine Magazine, Issue 117, accessed 14 December 2023.

OECD (Organisation for Economic Co-operation and Development) (2021), Making life richer, easier and healthier, OECD iLibrary, accessed 17 October 2023.

Office of the Chief Economist (December 2022), Resources and Energy Quarterly December 2022, Department of Industry, Science and Resources, accessed 29 November 2023.

Office of the Chief Scientist (2020), Australia's STEM workforce report, Office of the Chief Scientist website, accessed 6 April 2023.

Productivity Commission (2023), Advancing Prosperity, Productivity Commission website, accessed 31 October 2023.

Robotics Australia Group (2022), Robotics Roadmap for Australia 2022, Robotics Australia Group website, accessed 6 April 2023.

Taylor C, Carrigan J, Noura H, Ungur S, van Halder J and Dandona G S (2019), Australia's automation opportunity: reigniting productivity and inclusive income growth, McKinsey & Company, accessed 5 April 2023.

The Treasury (2022), Jobs + Skills Summit: Issues paper, The Treasury website, accessed 5 January 2023.

The Treasury (2023a), Productivity, The Treasury website, accessed 16 October 2023.

The Treasury (2023b), Intergenerational Report, The Treasury website, accessed 16 October 2023.

United States Department of Agriculture (2023), Agriculture Technology, United States Department of Agriculture, accessed 8 November 2023.

industry.gov.au/NationalRoboticsStrategy