SECURING AUSTRALIA'S FUTURE

Technology and Australia's Future

Findings and Implications

PROJECT 5

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AUSTRALIAN ACADEMY OF THE HUMANITIES

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SECURING AUSTRALIA'S FUTURE

Funded by the Australian Research Council and conducted by the four Learned Academies through the Australian Council of Learned Academies for the Australian Chief Scientist and the Commonwealth Science Council. *Securing Australia's Future* delivers evidence-based research and interdisciplinary findings to support policy development in areas of importance to Australia's future.

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Technology and Australia's Future

ACOLA is the interface of the four Learned Academies:
Australian Academy of the Humanities
Australian Academy of Science
Academy of the Social Sciences in Australia
Australian Academy of Technological Sciences and Engineering

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Key messages

1. Technology will drive long-term economic growth

Throughout history, technology change has been the *major* source of industrial and economic growth and transformation, manifested through the transfer of ideas, products and processes from one sector, industry or firm to another. The most pervasive drivers of economic growth in modern times are **general purpose technologies** including ICT, biotechnology, advanced materials fabrication, transportation technologies, sensors and energy technologies. General purpose technologies not only facilitate efficiency and growth in existing industries, they allow combination of ideas and technologies to create entire new categories of products and services. **In order to ensure continued economic growth through technology, Australia requires ongoing investment in the organisational capacities that allow effective technology development, evaluation, adoption and adaptation.**

2. Technology will transform the workforce

Technology will change the way we work and the work we do; destroying existing jobs, creating new ones, transforming industries and internationalising labour at unprecedented levels. As with all change, technology-driven transformation will benefit some and disadvantage others across all levels of society and the economy, and on both a domestic and international scale. **In the face of changing workforce requirements and opportunities, Australia must ensure a workforce with the skills to adopt, adapt and implement new and existing technologies to a variety of ends.**

3. Australia can leverage technology change

The development, adoption and impact of technologies can be encouraged or discouraged through regulation, market mechanisms, investment or divestment, technology standards, and skills development. Technology change can be leveraged for social and economic benefit by:

- focusing on solutions to problems rather than backing specific technologies
- regulating the use or effects of technology rather than technologies themselves
- facilitating technology interoperability through standards that allow assembly of parts and mitigate technology lock-in
- ensuring rigorous evaluation of all costs and benefits in technology decisions
- investing in education and training in STEM and ICT at all levels
- ensuring a robust innovation pipeline by adequately supporting research and development.

4. Forecasting future technology developments is challenging

Accurately predicting the long-term evolution and impact of technologies is impossible. However, it is possible to forecast general technology trends and likely impacts over the short and medium term (5–15 years). Specifically, it is possible to forecast:

- the likely short-term impact of particular technologies such as sensors, autonomous systems, biotechnology and ICT
- the likely evolution and uptake of general purpose technologies
- societal factors influencing technology uptake that will persist over time.

Introduction

Advances in technology have been the dominant driver of economic growth throughout human history, and have transformed almost every facet of society. Technology drives the modern world.

Over the past century, for example, information and communication technologies (ICT) have gone from niche and specialised tools and experiments to the most general of general purpose technologies that now underpin most of the world's economic and social activity. Technology is also enabling the globalisation of products, services and culture.

The history of technology shows a pattern of growth and development that has progressed in fits and starts; mostly incremental but sometimes rapid and transformative. The early 21st century is one such period in which technology-driven transformation is impacting every industry, government function and social activity. In many cases these impacts result in direct or indirect benefits that allow greater efficiency, higher quality or entirely new products or services. At the same time however, old technologies continue to have lasting influence, and every technology change has the potential to disadvantage those invested in the status quo.

In order to ensure the greatest benefits of technology change, it is critical that Australian workers have the education and skills that will allow them to adopt, adapt and implement new and existing technologies to overcome current and future challenges.

Background and purpose

In 2012, Australia's Chief Scientist and the former Prime Minister's Science, Engineering and Innovation Council asked the Australian Council of Learned Academies to examine the implications of new technologies for Australia's social, cultural, democratic, security and economic systems.

The resulting report *Technology and Australia's Future: New technologies and their role in Australia's security, cultural, democratic, social and economic systems* was developed by leading thinkers from the sciences, humanities, social sciences, technology and engineering. It presents the key trends, drivers, opportunities and implications of technology development for Australia, reaching 18 specific findings.

This précis provides a targeted overview of the report for those involved in the development of public policy. It is intended as a companion volume to the full report, and as such does not attempt to capture the breadth and depth of its analysis and conclusions. It does however reference the report's 18 findings throughout, and presents the findings in full at the conclusion of the document.

1

Harnessing technology change for long-term economic growth

Technology is the major source of industrial and economic growth and transformation, and it will revolutionise almost every aspect of our lives over the coming decades. Some of this change is predictable but much of it is uncertain. As a consequence, Australia is faced with both opportunities that must be embraced and risks that must be managed. The balance between the two will in large part determine the extent to which technology-driven innovation succeeds or fails in delivering Australia's future social and economic prosperity.

1.1 Assessing benefits and risk, resistance and opportunity

The Australian economy has traditionally relied on commodities derived from primary industry and mining. Innovation and technology have served these sectors well. However, to ensure continued growth, Australia must proactively identify, pursue and capitalise on technology-driven innovation.

Such innovation is perceived, and in some cases actively promoted, as 'disruptive'. However, while often associated with desirable step-change in programs, services or processes, reactions to disruptive change can be mixed, with resistance from:

- those with a strong stake in existing technologies and the industries they underpin (for example, investment in electricity infrastructure)
- those with a philosophical or moral objection to the uses or implications of new technology (for instance, those who oppose genetically modified crops)

- those with significant concerns about the risks of new technology (for example, those opposed to nuclear power or concerned about radiation from transmitting devices)
- those who cannot see a place for themselves or their community in an innovation-based future (such as regional communities).

The benefits of technology-driven change are never certain, and these concerns will often be valid. However, blocking or delaying new technology on the basis of instinctive overweighting of risks relative to potential benefits can also prevent opportunities such as the development of new industries and new solutions to social challenges.

To ensure Australia's future social and economic prosperity in an increasingly connected and competitive global market, it is necessary to:

- improve the perceived fairness of the 'risk-return' trade-offs and judgements (F7–8, F10, F12)
- ensure that all of the benefits and risks of new technologies are assessed robustly and transparently (F4, F13)
- focus policy, legislative and other interventions on the effects of technologies rather than trying to regulate technologies per se (F15).

To underpin these strategies, it is essential that Australia strengthens its innovation system and its supporting policies and programs.

1.2 General purpose technologies and transformation

While much media and policy attention focuses on the latest 'breakthrough', it is in fact general purpose technologies that support the majority of innovation and incremental and transformative change in systems and processes (F14). Internal combustion, steam, electricity, early biotechnology and the internet are classic examples of general purpose technologies each of which had transformative impacts on the economy, society and culture.

Current general purpose technologies likely to have similar impacts include:

- information and communications technologies (ICTs),
- biotechnology
- advanced materials fabrication
- technologies for transport
- sensors
- energy technologies.

Two areas of innovation that offer enormous social and economic opportunities are 1) data analytics and 2) modelling and simulation (F6). Both technologies are highly mobile (they can be used anywhere) and offer benefits across multiple fields ranging from the health sector (customising services and developing new medical technologies), the design of advanced materials, new forms of transport and energy production.

General purpose technologies are discussed further in section 4.2.

1.3 Interoperability, modularity, and standards

Interoperability (the ability of different components, systems and processes to work together), modularity (the degree to which a system's components may be separated and recombined) and standards (codified specifications, methods or definitions) are primary determinants of innovation through:

- increased efficiencies
- speed diffusion of innovation across sectors
- lower costs of switching between tasks and products
- promotion of consumer choice (F16).

The shipping container and global financial messaging standards are two examples of interoperable and modular systems that have revolutionised global industry.

However, the ability to adopt, adapt or apply technology can be hampered by factors such as:

- absent or restrictive standardisation
- poor interoperability
- inconsistent, expensive, or hard-to-use information storage formats
- complicated licensing and intellectual property costs
- controlled or segmented supply chains
- trade barriers.

While standards which facilitate interoperability and market efficiency aid businesses, adoption of de facto standards too early can lock an economy into approaches that are hard to change, such as the 100 years or so it took to put a standard-gauge railway around Australia.

Governments can influence standards and interoperability by sponsoring and encouraging the development and adoption of simple, interoperable and (where possible) global standards (F16).

Finally, having multiple lightweight standards that themselves interoperate via gateway technologies (technologies that allow one system to talk to another) is a way of avoiding premature lock-in of specific technologies. The large number of simple and lightweight standards with limited scope has led to an explosion of innovation on the internet, and is a valuable approach more generally to enable innovation through the adoption and development of new technologies.

2 Developing innovation in the workplace and the workforce

Technology will change the way we work and the work we do; destroying existing jobs, creating new ones, transforming industries and internationalising labour at unprecedented levels. As with all change, technology-driven transformation will benefit some and disadvantage others across all levels of society and the economy, and on both a domestic and international scale.

In the face of changing workforce requirements and opportunities, Australia must ensure a workforce with the skills to adopt, adapt and implement new and existing technologies to a variety of ends.

2.1 Technology is destroying jobs; technology is creating jobs

Economies throughout history have operated at their labour capacity, with the majority of the working-age population engaged in the industries of the day. The changes over time in nature of the industrial base—once predominantly agricultural; increasingly industrial; and now diverse, global and increasingly service based—have been driven primarily by changes in technology.

For example, the foundation of the digital economy continues to have profound and obvious impacts. The popular photo-sharing site Instagram was sold to Facebook for about $1 billion in 2012; it had 30 million customers and employed 13 people. Kodak, which filed for bankruptcy a few months earlier, employed 145,000 people in its heyday.

A small and agile technology-based startup can cause major, long-term disruption. Airbnb may be a boon to thousands of individual homeowners with spare rooms to let, but at what cost to the hospitality industry and to those it employs? Likewise, ride-sharing company Uber is continuing to cause major disruption to long-established taxi industries.

Overall, there is a reducing need for human effort in both manual (e.g. manufacturing and construction) and computationally intensive (e.g. data analysis and system control) activities. Even more challenging, the pace of change is accelerating. By some estimates, up to 80 per cent of all jobs by 2030 could be in companies or industries that don't exist today, while around half of today's jobs could be automated within the next two decades.

As with all change, technology-driven evolution will benefit some and disadvantage others, and this redistribution of benefit will occur at the level of individuals, businesses, industries, regions, states and even nations. Existing industries and structures can wittingly or unwittingly obstruct new entrants into the market, through structural, legal and political forces.

The technology illiterate will be unable to negotiate our digitally-connected civic domains. They will have poorer access to government services, reduced job prospects and will suffer social and economic exclusion and seek support from already-stretched welfare systems (F8). Workers who lose their jobs may take time to find new jobs or leave the workforce altogether. But attempts to protect people from the differential impacts of of new technology by slowing that new technology are very unlikely to succeed. Nations that try to halt new technology will be left behind.

Alarmingly, Australia lacks critical mass in ICT skills such as programming, software development, computer engineering, data management, data mining and data analytics. This situation is certain to run the risk of slowing uptake and diffusion of new ICT, and if not addressed will reduce competitiveness and increase negative social impacts ranging from reduced employment to constrained tax revenue.

2.2 Prospering in the new economy: technology literacy, creativity and skills

The solution to the challenge of occupational dislocation is education. Technology literacy, creativity and skills are crucial for Australia to successfully adapt, adopt and support the use of technologies in current and future industries (F1). Similarly, for industries and businesses to remain competitive, they must have the skills to adopt new technology as it becomes available and adapt their businesses, and new technology, to meet specific business needs. Training students in science, technology, engineering and mathematics has the capacity to provide a broad and general ability to understand why things work, and how they might work better (F11).

Technology creation and use requires multiple actors: designers, makers, users, scientists, marketers, policymakers and enablers. Australia's education systems must both encourage high levels of scientific and technology literacy and inculcate creativity. Creativity encourages experimentation, giving people, communities and companies the necessary confidence to innovate.

People most likely to prosper in tomorrow's workforce will be protean—able to change, adapt to unfamiliar work, deploy versatile skills and learn new trades continuously as part of their working lives. The talents needed to do so are the ability to question, assimilate unfamiliar information, collaborate across teams, analyse and evaluate (F17–18). Asian countries, where disciplinary knowledge is held in high esteem, report a shift in focus towards nurturing generic skills of creativity, problem solving, collaboration and higher-order thinking.

Governments, educational institutions, industry and workplaces can help by:

- encouraging flexibility, creativity and the ability to try new things
- encouraging an increased focus on technology and engineering to complement science and mathematics training
- minimising constraints on worker mobility
- supporting the skill-development role of R&D institutions
- advocating curricula that will enable workers to adapt
- minimising highly specific training content that is focused on the old technologies employed in past jobs
- ensuring that accreditation organisations do not become change-averse gatekeepers.

Vocational training in particular will need to shift in focus from competencies that are highly specific to tightly defined job qualifications to 'vocations' or 'vocational streams' which represent groupings of similar occupations. The aim should be to foster innovative workplaces as well as innovation in the workplace (F1).

3

Leveraging technology change

The development, adoption and impact of technologies can be encouraged or discouraged through regulation, market mechanisms, investment or divestment, technology standards, and skills development. Technology change can be leveraged for social and economic benefit by:

- focusing on solutions to problems rather than backing specific technologies
- regulating the use or effects of technology rather than technologies themselves
- facilitating technology interoperability through standards that allow assembly of parts and mitigate technology lock-in
- ensuring rigorous evaluation of all costs and benefits in technology decisions
- investing in education and training in STEM and ICT at all levels
- adequately funding research and development.

3.1 A problem-based perspective

In order to foster successful innovation, policy settings must balance the need to encourage new approaches to tackling problems with the need for appropriate support and regulation of current and future technologies and their uses (F4).

One helpful way to frame this is to work 'backwards' from the problem (a social issue, security threat, an economic puzzle) in order to determine in broad or specific terms the desired end state, and develop a roadmap or hypothetical ways to solve it. This process can be enhanced by involving both innovators and end users in the process (F5).

The Australian Government has established nine national science and research priorities that identify the practical challenges facing Australia and areas in which Australia has a comparative or competitive advantage. There would be significant value in using these priority areas to frame a whole-of-government process focused on identifying and fostering opportunities for innovation.

3.2 Investing in R&D

Advanced countries around the world recognise the imperative of long-term research and development funding for economic growth. While Australia does substantially invest in research and development (R&D), it has reduced this investment over recent years[1].

The particular details of the impacts within Australia are the focus of another Securing Australia's Future report, SAF 04, which finds that 'there are significant spillovers to productivity from public sector R&D spending on research agencies and higher education'. Significantly, the report found that Australian companies and research institutions collaborate far less than in any other OECD nation thereby not stimulating innovation through collaboration.

Government *and* business R&D support is best focused on general purpose technologies because these technologies will by definition have broad and generalisable impacts that will create value in expected and unexpected ways over a sustained period of time (F14).

3.3 Leverage points

Given the underlying importance of innovation to Australia's future prosperity, governments clearly have an interest in facilitating technology change.

Governments can:

- **invest in an educated and skilled population**: able to embrace and adapt to the opportunities that new technologies provide, through supporting STEM and ICT training from at all levels of education (F1, F11)
- **focus on solutions to problems**: that appreciate the inter-relationships between technology and humanity, rather than singling out specific technologies (F5)
- **regulate the use of technology rather than technology itself**: attempting to regulate a specific technology rather than its use is likely to stifle technology progress, without tackling the underlying risks (F15)
- **mitigate negative social impacts of technology**: by strengthening safety nets, improving retraining, and assisting with the transition to alternative employment opportunities (F8)
- **require that technology evaluation is open, transparent and independent**: evaluation of new technologies should take a broad perspective and compare the new technologies to the whole-of-life benefits and costs of existing technologies (F7, F12–13)
- **facilitate interoperability**: technologies, systems and organisations can encourage standards that allow the assembly of different parts, encouraging innovation and avoiding the negative effects of technology lock-in (F16)
- **implement mechanisms that allow for explicit, efficient and adaptive experiments and trials**: to help deal with uncertainty and unforeseen (and unforeseeable) impacts (F17–18)
- **invest in research and development**: requiring research institutions to be more open with the IP they generate (F14).

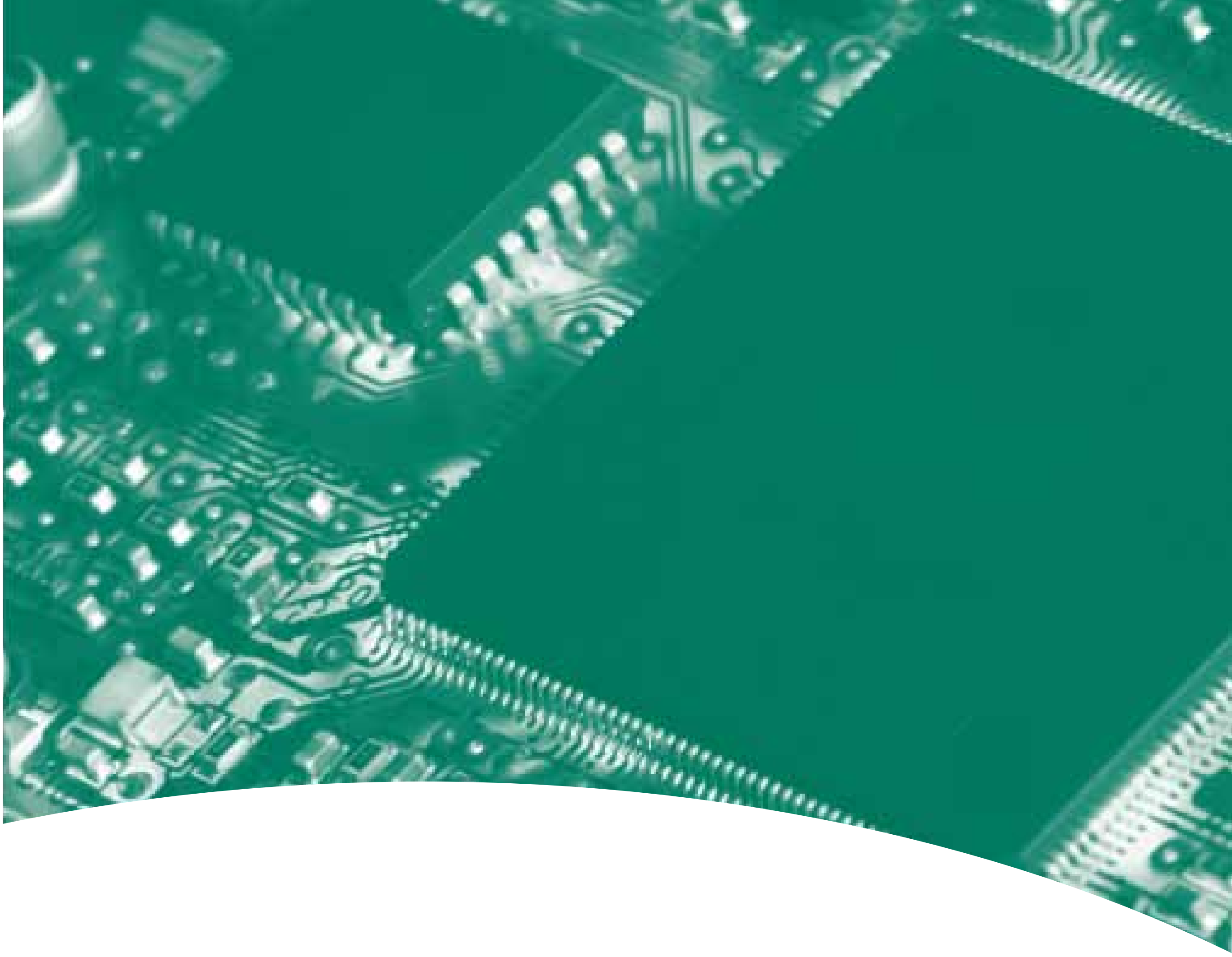
1. In 2011–12 Australian businesses invested 62% of their R&D expenditure in experimental development (using existing knowledge to create or improve products), and 32% in applied research (acquiring new knowledge with a specific application in view). Only 1% of business R&D spending went into research undertaken to acquire new knowledge without looking for long-term benefits—so-called 'pure basic research'. DIISRTE, Canberra: Department of Industry, Innovation, Science, Research and Tertiary Education (2012).

Australian companies and research institutions collaborate far less than in any other OECD nation thereby not stimulating innovation through collaboration.

4 Forecasting future technology developments and opportunities

Accurately predicting the long-term evolution and impact of technologies is impossible. However, it is possible to forecast general technology trends and likely impacts over the short and medium term. Specifically, it is possible to forecast:

- the likely short-term impact of particular technologies such as sensors, autonomous systems, biotechnology and ICT
- the likely evolution and uptake of general purpose technologies
- societal factors influencing technology uptake that will persist over time.



4.1 Short-term impact of technologies

One general purpose technology with increasing application and impact is **data analytics** (F6). This technology enables application of the scientific method to almost any system, process or application by monitoring or mining routinely collected data to provide new insights on issues ranging from causes and consequences of failure, to points of efficiency and redundancy, to prediction of new markets, supply chain requirements, or optimal maintenance schedules.

Significant impacts of data analytics are likely be seen over the short to medium term in:

- **food production**: through fine-grained monitoring and analytics of process and quality
- **soil and water**: for example in groundwater modelling and mapping
- **transport**: analysis and optimisation of national freight systems
- **energy and resources**: smart grids, energy markets, and renewables

- **manufacturing**: underpinning use of additive manufacturing, agile supply chains, materials design
- **environmental change**: monitoring, sensing, modelling
- **health**: personalised medicine, bioinformatics, ICT-enabled delivery
- **education**: through fine grained analytics to improve teaching.

Modelling and simulation is a similarly enabling category of general purpose technology. By allowing simulation of all manner of systems, engineers, researchers and policy makers will increasingly have the capacity to determine the likely consequences of different courses of action in advance of finalising a decision.

Together, data analytics and modelling and simulation offer enormous social and economic opportunities for countries which facilitate and embrace their widespread development and adoption.

Other likely areas of significant short to medium term technology impacts include:

- **computing and data technologies**: which will continue to see improvements in hardware (leading to improved data storage, transmission and processing speed) and software (increasingly sophisticated algorithms)
- **DNA sequencing and related informational biology technologies**: which will enable increasingly sophisticated personalised medicine
- **cheaper and better 3D printing**: including 3D printing of biological materials, which will change manufacturing and supply chains in a number of industries
- **renewable energy**: which will see advances in generation, storage, prediction and management technologies that will continue to result in increasingly competitive pricing and availability.

4.2 Forecasting general purpose technologies

Current and potential future general purpose technologies likely to substantially affect Australia include:

- electricity infrastructure and energy generation
- energy storage
- new forms of industrial organisation (e.g. lean production)
- nanotechnology
- biotechnology, especially genetic technologies, including GM crops
- additive manufacturing (3D printing) including bioprinting
- new materials
- waste disposal and recycling technologies
- agriculture and food technologies.

The most general and pervasive technology now, and in the foreseeable future, is ICT. Information, communications and control systems are central to almost every human activity, and there is no reason to expect that will change.

4.3 Forecasting general features of technology and technology change

Although the future impacts of particular technologies are impossible to forecast with accuracy, there are many general features of technology change that will persist. Specifically:

- **new technologies will arise from the creative recombination of existing technologies** (F3) (see *Box 2: Technology convergence)*
- **it will take significant time for new technologies to deliver broad economic impact**

Box 1. Technology trends

The greatest foreseeable impacts of technology are likely to emerge with the integration of different technologies to address challenges such as safe and efficient transport, smart electricity grids, sustainable smart cities, water resource management, automatic food quality monitoring and natural disaster management (F7).

Intelligent systems and automation: Rapid advances in natural language processing, artificial speech, vision and learning, and the rise of fast, inexpensive computing devices coupled with access to vast amounts of data will extend the reach of automation. Driverless cars, unpiloted aerial vehicles and electric vehicles offer low cost, safe and efficient means of transport. The mining industry is using driverless trucks that can operate 24/7. Increased automation can benefit agriculture, military operations such as disaster management, and border patrols.

Sensors and devices: Smaller, cheaper, more capable sensing and monitoring technology systems can, via personal devices, support group collaboration, finance management, business workflow management and electronic ticketing systems. Technologies are being developed to track collection and use of personal data, with significant implications for privacy.

Energy and resources: Energy storage technologies from small batteries to large pumped hydro systems will make it easier to predict, assess and regulate energy consumption. Other growth areas include improved large and small-scale alternative energy technology, wireless transmission, energy-scavenging technology for many consumer and monitoring applications, advanced power grid control and smart- or micro-grid technology. New primary energy generation technologies will have substantially lower carbon footprints, and will result in more efficient use of gas, oil and coal.

Advanced materials and manufacturing: Advanced material manufacturing such as 3D printing will enable fast, high quality and low cost goods manufacturing. Advanced components such as turbine blades, aerospace components and orthopaedic replacement parts are already manufactured. New uses will emerge as a result of cheaper, smaller scale consumer-friendly devices that offer site-specific, real-time, print-on-demand customised systems.

Biotechnology: Biotechnology provides solutions to diseases, climate change, fuel alternatives, food security as well as improving quality of life. Low cost DNA sequencing is impacting on the speed and volume of genetic data generation. The ability to analyse and store vast amounts of DNA data will lead to better systems for personalised medicine. New smart devices and biometric technologies will support patient monitoring and online diagnosis and treatment. Implementation of these technologies for health care will depend on open standards, public data sets, and reducing the regulatory hurdles for rapid innovation, testing, and commercial use.

- **new technologies will not completely revolutionise existing industries**. For example, not all cars will become entirely autonomous, and robots will not entirely replace the manufacturing workforce
- **new technologies will not completely 'solve' the problems they are designed to fix**: they will partially solve problems, and will also often introduce new problems (F2)
- **new technologies will come into the world in an imperfect state**: there will be failures, but often the bugs will be ironed out and the technology will eventually thrive
- **technologies will continue to change in an evolutionary manner**: some existing industries and businesses will adapt to new technologies and thrive; others will go out of business. Fast adaptation will continue to be a competitive advantage (F1)
- **small technology changes will sometimes lead to radical effects** ('architectural change'). The architecture of new technologies will shape the structure of organisations and vice versa and this will remain one of the reasons for institutional inertia in the face of technology change (F2)

- **'system innovations' enabled by new technologies will have large effects**: the technology change might be relatively small, e.g. decreasing price per byte of digital storage—but the impact can be huge, such as music shifting to online sales and storage on iPods
- **radical technology change will continue to come from many sources**: including users outside the apparent field. Examples of inventions with profound effects developed out-of-industry include the telephone (Bell, a professor of elocution) and the aeroplane (the Wright brothers, bicycle mechanics)
- **companies will continue to learn-by-doing through continuous iterative innovation, training and technology advances**: adoption will occur most rapidly where skills are most advanced and the culture is most innovative (F17–18)
- **technology inertia will continue** due to the reaction of vested interests and the need for related systems and infrastructure to adapt. At the company level there will remain substantial 'stickiness'—persisting with old technologies when superior technologies are readily available (F12–13)
- **convergence of classes of technologies will continue**: through technology interdependence, innovative combinations, new ideas, and the impact of general purpose technologies in transforming existing industries
- **divergence of classes of technologies will continue**: the flip-side of 'convergence'; technologies at one point lumped together will split into distinct technologies in the same way that hardware split with software.

Finally, **attitudes and meaning** will always play a role in how people choose to adopt and use technology (F8–10). Specifically:

- hype will persist: the impacts of new and current technologies will be overestimated in the short term and often underestimated in the long-term
- individuals and organisations will continue to place value judgements on technologies based on their perceptions of use and impact
- people will adopt and use technology in line with fashion, status and risk judgement
- where little information exists to allow assessment of the risks of a new technology, trust in institutions will become more influential.

Box 2. Technology convergence

Near-future technologies and their impacts can be forecast in terms of 'convergences'—a way of understanding the fluidity and merging of technology categories (F2–3). Examples include:

- computing power + analytics + networking = automation of brain work
- computing power + robotics = further automation of manual work
- autonomous cars + sensing + networks = accident-free, personalised public and private transport
- renewable energy sources + sensing + networking + analytics +
- extensive distributed energy sources = smart grid and renewable energy
- fast DNA sequencing + analytics = personalised medicine
- extensive sensing + analytics + networks + autonomous vehicles = safe, green, smart cities with wide scale surveillance of human activities
- nano-technology + analytics + RFID technology = automatic food quality monitoring
- meso-scale modelling and simulation + low cost high performance computing = new era in real-time decision making.

The most general and pervasive technology now, and in the foreseeable future, is ICT. Information, communications and control systems are central to almost every human activity, and there is no reason to expect that will change.

Report findings

Finding 1

Technology change is the major driver of long-term economic growth. In an environment of uncertainty, ongoing investment in the skills and organisational capacities that allow effective technology development, evaluation, adoption and adaptation will help solve social, economic and environmental challenges, leading to a prosperous and healthy future.

Finding 2

Technology and humanity shape each other. To solve Australia's social challenges, government policies and programs should understand the interrelationships between technology and humanity—solutions to complex problems will never be solely technology.

Finding 3

The way technology is categorised affects how it is imagined, evaluated, funded, adopted and used. Encouraging crossover between diverse areas and looking beyond narrow categories, sectors and disciplines for inspiration will increase opportunities for technology innovation in Australia.

Finding 4

Public policy is often based on assumptions of stability, predictability and linear progress. Policies which take into account the dynamic and multidimensional nature of technology will encourage adoption rather than protecting and favouring the status quo, allowing Australians to make better decisions to prepare for, and capture benefit from, technology change. Australia's technology future is open, not pre-determined.

Finding 5

Predicting future technology and its impact with any accuracy is extremely difficult. Recognising that general patterns of technology change will persist can help governments, businesses and communities facilitate and adapt to change. Attention should be focused upon problems that need to be solved and on helping innovators find solutions.

Finding 6

Technologies for data, especially data analytics, will play a substantial role in solving most social problems, and will augment and transform most existing technologies. In order to maximise the benefit of these technologies, Australia needs to ensure it has the advanced skills and capabilities to create and use them.

Finding 7

The value of a technology always depends on context and use. Judging technologies as intrinsically beneficial or detrimental limits the opportunities to make the best use of them. To improve the design, assessment and effectiveness of technology or any technology intervention, consider the technology in its historical, cultural, geographical, political and social contexts.

Finding 8

The adoption of any new technology in Australia will affect people differently. Costs and benefits of a technology should take into account the different impacts a technology will have on different sections of society.

Finding 9

Meanings associated with technology are deeply tied to values, beliefs, experiences and cultural setting, and as a result vary enormously. The meanings people ascribe to a technology substantially influence its adoption and use, and therefore cannot be ignored in any technology intervention.

Finding 10

Attitudes towards technology do not always reflect behaviour. Effective government policy to encourage new technologies should reflect the different reasons people have for engaging with technology.

Finding 11

Adaptability and creativity are key skills in creating, assimilating and adopting new technology. The adoption of new technology and its effective use depends on people with diverse skills playing a variety of roles. Enhancing technology literacy, including fostering skills appropriate to engaging with technology in all levels of education, can enhance Australia's ability to adopt and adapt new technologies. Promoting technology as a creative enterprise may serve to inspire a greater engagement with technology. Enhancing the tinkering aspect of STEM education at all levels (K–12, and tertiary) could create a culture that embraces technology change.

Finding 12

Technology evaluation is of central importance to technology adoption. The costs of a technology are complex to determine, context-dependent, variable, and contested. Governments can facilitate better technology evaluation by adopting international best practice and by minimising the role vested interests play in technology evaluation.

Finding 13

Cognitive biases play a major role in the evaluation of technologies, which in turn is a major determinant of adoption and use. The impacts of these biases can be substantially mitigated by adopting methods designed to counter them, including independent assessors, and readily available empirical data.

Finding 14

The difficulty of appropriating economic returns from early stage technology research and development means that substantial ongoing government investment in research is warranted. Increased investment in high quality scientific and technology research will lead to greater commercial and economic outcomes for Australia. Such research should focus on general purpose technologies, rather than particular technology winners. Having research institutions that are more willing to share their IP will create a more effective innovation system.

Finding 15

Government policy and legislation should focus on the effects due to the use of new technology, or the effects arising from new uses of technology, rather than on the technology itself in order to minimise regulatory impediments.

Finding 16

Interoperability allows the more rapid adoption of new technologies. Interoperability is facilitated by standards and gateway and platform technologies. Diffusion of technology in Australia can be aided by simple standards that lead to easier parts assembly. Adopting global standards will facilitate integration of a technology into global supply chains.

Finding 17

Accepting that failure can occur in any attempt to do something new and removing its stigma will facilitate and accelerate technology development and adoption. Training managers in business and government to acknowledge uncertainty, take risks, and deal constructively with failure will improve Australia's entrepreneurial and innovative culture.

Finding 18

The uncertainty and unpredictability inherent in the development and adoption of technology require a considered experimental approach. The adoption of the scientific method of 'test-learn-adapt' can improve Australia's ability to develop, adapt and embrace new technologies.

About Securing Australia's Future

In June 2012 the Australian Government announced *Securing Australia's Future*, a $10 million investment funded by the Australian Research Council in a series of strategic research projects. Projects are delivered to the Commonwealth Science Council by the Australian Council of Learned Academies (ACOLA) via the Office of the Chief Scientist and the Australian Chief Scientist.

Securing Australia's Future is a response to global and national changes and the opportunities and challenges of an economy in transition. Productivity and economic growth will result from: an increased understanding in how to best stimulate and support creativity, innovation and adaptability; an education system that values the pursuit of knowledge across all domains, including science, technology, engineering and mathematics; and an increased willingness to support change through effective risk management.

Six initial research topics were identified:

i. Australia's comparative advantage
ii. STEM: Country comparisons
iii. Smart engagement with Asia: leveraging language, research and culture
iv. The role of science, research and technology in lifting Australian productivity
v. New technologies and their role in our security, cultural, democratic, social and economic systems
vi. Engineering energy: unconventional gas production

Five further research topics have been identified:

vii. Australia's agricultural future
viii. Delivering sustainable urban mobility
ix. Translating research for economic and social benefit—country comparisons
x. Capabilities for Australian enterprise innovation
xi. Business diasporas in Australia: maximising people to people relationships with Asia

The Program Steering Committee responsible for the overall quality of the program, including selection of the Expert Working Groups and the peer review process, is comprised of three Fellows from each of the four Learned Academies:

Professor Michael Barber FAA FTSE (Chair)

Mr Dennis Trewin AO FASSA (Deputy Chair—Research)

Professor James Angus AO FAA

Dr John Burgess FTSE

Professor Bruce Chapman AO FASSA

Professor Ruth Fincher FASSA

Professor Paul Greenfield AO FTSE

Professor Lesley Head FAHA

Professor Peter McPhee AM FAHA FASSA

Professor Stephen Powles FAA FTSE

Dr Susan Pond AM FTSE

Professor Graeme Turner FAHA

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