

POLICY PRIMER SEPTEMBER 2021

Australia's Digital Future a nation of users or leaders?

Emerging digital technologies as a national science priority

Internationally, digital technologies are transforming the way we live, work and govern. The digital revolution is well underway, and many countries and sectors have signalled that digital futures should be a critical priority for investment, skill and capacity-building, and economic growth.

Digital technologies play a fundamental role in Australia's way of life, but we risk falling behind as a technologically driven nation unless we recognise emerging digital technology as a central and independent sector in its own right. This requires investing in research, innovation and workforce development to ensure strong expert leadership in this rapidly evolving sector.

"The best way to predict the future is to create it." Alan Kay

Overview

This policy primer has been prepared by the Australian Academy of Science and the Australian Academy of Technology and Engineering to provide a case for the Australian Government to highlight emerging digital technologies as a national science priority. It also contains advice to policymakers on how to support the national digital technology research community.

The National Academies of Science in the G20 nations* have identified digital futures as one of three foresight science priority areas for navigating critical transitions, alongside future health and the environment.¹ Likewise, the International Council of Academies of Engineering and Technological Sciences (CAETS) has also identified that data-driven decisions are essential to economic prosperity, sustainability and social wellbeing.² These examples of international expert consensus highlight the profound changes digital technologies are driving in human society and the global economy.

The fundamental role of digital technologies in Australia is evidenced by:

- the contribution of digital technologies to Australia's GDP, expected to reach \$65 billion by 2023³
- the growing demand for digitally skilled workers, expected to increase by 100,000 between 2018 and 2024²
- the rise of emerging technologies such as artificial intelligence and automation. These technologies are disrupting the workplace—eliminating, creating or reconstructing jobs—with estimates that 25–46 per cent of existing jobs could be automated by 2030⁴
- the estimated \$315 billion in gross economic value that will be generated over the coming decade by improvements to existing industries through digital technologies.⁵

This policy primer focuses on emerging digital technologies including artificial intelligence (AI), the internet of things (IoT), augmented and virtual reality, blockchain and 5G, which are transforming traditional industries such as manufacturing, agriculture, waste management, transport, finance, education and health. These digital technologies are considered 'emerging' as they are not yet at a stage where they can be considered commoditised compared with mature digital innovations such as 3D printing, mobile computing, drones or GPS.

A strong national focus on fundamental science and engineering behind emerging digital technologies will allow Australia to stay ahead of the curve in a dynamic and fast evolving landscape.

The next wave of emerging digital technologies, such as autonomous vehicles, smart micro-grids, 6G and quantum computing, will further disrupt and transform many sectors. While it is difficult to predict what future innovations might arise, a strong national focus on fundamental science and engineering behind emerging digital technologies will allow Australia to stay ahead of the curve in a dynamic and fast evolving landscape.

The applications of emerging digital technologies will continue to diversify and grow. Research and innovation in emerging digital technologies should not be artificially bound to specific application areas nor overly focus on today's needs, as doing so limits innovation potential that could otherwise create entirely new industries and jobs.

Many of Australia's international peers, including the USA, UK, France and Canada, are prioritising digital technologies as a strategy to bolster competitiveness in the emerging 'digital economy'. Australia is lagging behind its global peers, with digital innovation accounting for only 7.4 per cent of Australia's GDP compared to 11.2 per cent average across the OECD.⁴

This primer provides a clear case for the Australian Government to highlight emerging digital technologies as a national science priority. It also provides advice to policymakers on how to support the national digital technology research community, through the following key recommendations:

- 1** Elevate emerging digital technologies as a national science and innovation priority
- 2** Include research and innovation in emerging digital technologies in the 2021 Research Infrastructure Roadmap
- 3** Recognise emerging digital technologies as an independent growth sector

* G20 member nations include: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the European Union.

Emerging digital technologies

In September 2019, the Australian Academy of Science and the Australian Academy of Technology and Engineering published a strategic plan outlining Australia's potential as a digital nation.⁶ The plan reveals the critical need for Australia to capitalise on opportunities in digital technology over the coming decade and beyond.

The future of humanity is closely tied to emerging digital technologies, which will transform everything from business to health, government services and education. Digital transformations have already disrupted everyday lives. Investment in fundamental research and domestic capability to apply the science and engineering underpinning the development and implementation of these emerging digital technologies is imperative for Australia's resilience, security and prosperity.

Australians are early adopters and avid users of technology, which has been significantly accelerated by the COVID-19 pandemic.⁷ Nevertheless, emerging digital technologies continue to outpace social expectations and regulatory frameworks. A highly digitised society without expert leadership in the development of digital technologies diminishes our capacity to answer the question:

'What kind of a society do we want to be?'

Australia's digital divide continues to widen, and individuals with lower income, employment and education continue to fall behind.⁹ This challenge is likely to compound our looming shortage of digitally-skilled workers and widen existing inequalities.² Achieving digital literacy and inclusion through education and workforce development are essential for Australia to meet its commitments to the United Nations Sustainable Development Goals,¹⁰ and to ensure the development of a digitally literate, highly skilled workforce.

Emerging digital technologies have the potential to promote economic growth and societal prosperity, while simultaneously exposing us to significant threats. To critically assess the costs and benefits of these emerging technologies, Australia must maintain, and further develop, strong expert leadership in this rapidly evolving sector.

Below are described some of the most significant emerging digital technologies and their key advantages and risks:

Data, particularly **big data**, is a critical input to all emerging digital technologies. Poor quality data products and processes can have a significant negative impact on emerging digital technologies, including artificial intelligence and autonomous decision-making. The foundational nature of data, and the workforce skills required to create value from the data, underpin the success of emerging digital technologies. A large number of open questions require scientific oversight and investment into cutting edge research to provide responsible and agile value creation from data. These include data quality, data integration and

curation at scale, data infrastructure, portability, discovery and democratisation of data, data privacy and consumer rights, and efficient search and retrieval.

Artificial intelligence (AI) and machine learning have made immense progress, particularly in recognition, tracking, video and image analysis, and speech-to-text systems. Many systems are particularly successful when large machine models are trained on immense amounts of data. Outstanding performance has been demonstrated in diverse applications, from image diagnosis to predictive systems. However, many systems remain brittle, data-dependent, and far from transparent, explainable or fair, resulting in poor trust¹¹ and adoption. Creating new human-machine teams is beyond current capability.

Security of digital systems continues to be a high priority for government and business, but many organisations remain inadequately prepared to prevent, detect and respond to cyberthreats. Australia must rethink its approach to security challenges to adopt an outcome-driven strategy that incorporates digital security as a critical component of resilience. The COVID-19 pandemic has demonstrated the importance of digital systems and the need to ensure security and reliability of Australia's digital infrastructure, which plays a key role in managing other critical infrastructure such as power utilities, financial services, communication and transportation. There has been phenomenal recent growth in cloud platforms, with most leading providers based in America (Google Cloud Platform, Amazon Web Services and Microsoft Azure) and China (Alibaba).

Internet of Things (IoT) platforms, where a large number of objects can be accessed, monitored or controlled via a network connection, enable real-time communication with and between any networked object. The expansion of IoT in Australia continues, with over 16 million connected devices and more than 300 companies operating in this space nationally.¹² In Australia, IoT is expected to deliver a 2 per cent increase in productivity per year¹³ and create jobs in network design, cybersecurity, data monitoring, management and analysis.¹⁴ While the benefits of IoT are substantial, there are also risks to be addressed by further R&D, such as cybersecurity, energy efficiency of systems, and potential digital inequity and unintended harm.¹³

Quantum computing is an emerging technology which may allow us to develop faster, more efficient computers which will change the way we use and process data. Quantum computing could allow exponentially faster computation to enhance capabilities across a range of sectors, including cybersecurity, banking and financial modelling. Australia has world-class quantum computing expertise and research capabilities, supported by a rapidly emerging Australian quantum technology industry, positioning us well to capitalise on the \$86 billion global quantum industry predicted for 2040.¹⁵

Blockchain is a digital platform used to record, verify and store transactions through a network of computers, removing the need for verification by an authority such as a bank. Transactions are considered more transparent and verifiable due to the platform's decentralised nature. Blockchain can improve business processes and create efficiencies across sectors considered 'data intensive', including financial services, trade, energy, resources and healthcare. Blockchain is expected to generate annual business value of A\$4 trillion globally by 2030 and expected to create new jobs, boost economic growth and improve overall productivity.¹⁶ However, further research on blockchain applications is needed to address risks and limitations associated with confidentiality, privacy, energy efficiency and scalability.¹⁷

5G is the latest generation of mobile wireless network technology rolling out across Australia. 5G is a major digital transformation in network technology, delivering faster data transmission and more scalable and flexible connectivity. Because 5G networks have higher bandwidths and offer more reliable service, 5G can enable more services reliant on real-time, high-quality streaming or video, such as telehealth

and critical communication services. 5G is also expected to significantly boost productivity, with the potential to deliver economic gains in Australia of up to \$2000 per capita in GDP by the end of the first decade after rollout.¹⁸ Transformation introduced by 5G is expected to be accelerated with a new vision for 6G, which is becoming a major focus for industry and research worldwide.¹⁹ As 5G expands, there may be increased attack surfaces (areas or objects vulnerable to cyber attack) which will need to be better characterised as network technologies improve and roll out nationally.

Virtual reality (VR) and augmented reality (AR) are emerging technologies in which users interact with computer-generated, 3D-simulated environments. These technologies have the potential to transform gaming, tourism, education, health and manufacturing, as well as communication and everyday life. Although still emerging technologies, globally 15 per cent of businesses plan to invest in VR or AR within the next three years.²⁰ While the global market for AR and VR is growing fast, further research on risks associated with cybersecurity, privacy and data storage is needed.

Cross-sector enablement

In Australia's research and innovation landscape, digital technologies have been seen as an enabler for areas of national priority, as represented through the six industry growth centres (Advanced Manufacturing; Cybersecurity; Food and Agribusiness; Medical Technologies and Pharmaceuticals; Mining Equipment, Technology and Services; and Oil, Gas and Energy Resources).

Digital technologies are an essential enabler for almost all sectors of the economy.

Recent advancements in technology and changing industry needs have led to emerging digital technologies playing an increasingly important role in other sectors. In fact, digital technologies are an essential enabler for almost all sectors of the economy, and also independently represent a strong sector with significant growth potential.

Some key areas of application for digital technologies across other sectors include:

Future of work and learning: The changing nature of work and learning, and the transformation of today's jobs, require us to reimagine education.²¹ To protect Australia's position in a digitally empowered global workforce, we must create education systems that connect and model opportunities for learning across life and work transitions, and that support the individuals participating and contributing to our digital future.²²

Government services: Government services are significantly and rapidly transforming towards digital delivery, a process which has been accelerated by the COVID-19 pandemic. Australians are increasingly online, and expectations of government service delivery are evolving. Increasingly sophisticated digital platforms for communication, data sharing and storage, and reporting create the expectation that governments and providers deliver high-quality, secure, low cost and resilient digital services. Almost half of Australian Government investment in the digital economy in the 2021 budget is earmarked for enhancing government service delivery.²³

Logistics, transport and supply chain: Transport systems can be supported by ubiquitous connectivity, real-time traffic management and route optimisation, efficient logistical planning, semi-autonomous transport and big data integration in real time for creating safer and more efficient supply networks throughout the country.

Fintech: Numerous emerging digital technologies contribute to financial technology, such as quantum encryption, blockchain, the use of AI and big data to analyse markets, personalised pricing services, and support for rapid transactions and improving anonymity, as well as intelligence and law enforcement services. The recent emergence of companies such as AfterPay highlights the growth and leadership potential of fintech, especially within Australia's robust and flourishing finance sector.

Tourism: Increasing use of emerging digital technologies by tourism operators is allowing more customised tourism experiences. While pandemic restrictions limit international travel, virtual and augmented reality will play an increasing role in the tourism sector, allowing operators to reach a wider audience in the absence of international tourists. Artificial intelligence and fintech will continue to provide essential connectivity, advertising and customer services.²⁴

Defence and national security: Beyond cybersecurity contributions, emerging digital technologies can also provide persistent and automated surveillance, non-traditional intelligence sources, big data and data integration in real time, digitally enhanced human personnel and emergency management systems to support defence and national security.

International best practice

Australia risks falling behind as a technologically driven nation unless we recognise emerging digital technologies as a central, independent sector in its own right, warranting investment in the core aspects of research, innovation and workforce development. For Australia to keep pace with leading nations with advanced digital technology strategies, resources and capabilities, bold action by governments is urgently needed.

Internationally, numerous examples demonstrate the benefits and importance of prioritising investment in science and technology research and development, and in particular in digital technologies:

United States of America (USA): The USA is widely considered the international leader in emerging digital technologies across most identifiable measures. It is home to the vast majority of ACM Turing Awardees,²⁵ a prestigious award for contributions to the field of computer science, as well as the headquarters of world-leading technology companies such as Apple, Microsoft, Facebook and Google. This leadership has resulted from decades of sustained prioritisation and investment.

In 2019, the US Government made a series of cross-governmental investments in artificial intelligence, quantum information science, quantum computing and communications networks, demonstrating its continued and growing commitment to emerging digital technologies. These investments accompanied investments in energy, agriculture and advanced manufacturing—traditional Australian priorities. The USA's prioritisation of emerging digital technologies is well supported by subsequent budgets; for example National Science Foundation AI funding increased by 70 per cent to US\$850 million in FY2021, now making up over 10 per cent of the total National Science Foundation budget.²⁶

The focus on emerging digital technologies remains a key priority under the current US Government.²⁷ In June 2021, the United States Senate passed the *Innovation and Competition Act*²⁸ with an unprecedented show of bipartisan support.²⁹ The Act invests US\$250 billion in a comprehensive program that seeks to secure supply chains and stimulate industry in the USA. The initiative expands the US Government's role in

strategic sectors and higher education. New government offices will facilitate research and development in key areas of cutting-edge technology, from advanced energy sources to artificial intelligence and quantum computing.

United Kingdom (UK): The USA's prioritisation of science, innovation and technology is already being leveraged by the UK. The UK and US recently announced an agreement to develop a landmark science and technology partnership, which will explore areas for cooperation including research, innovation and commercialisation, and strengthen cooperation in areas such as the resilience and security of critical supply chains, battery technologies and emerging technologies.³⁰ This partnership builds on recent initiatives in the UK such as the 2020 Research and Development Roadmap and the 2021 AI Roadmap—both of which aspire to make the UK a world leader in critical emerging technologies.

These commitments accompany other UK initiatives such as the digital economy being named as one of seven cross-cutting themes of UK research and innovation,³¹ and as one of 12 priority themes of the UK's Engineering and Physical Sciences Research Council.

France: The France Europe 2020 National Research Strategy³² is France's first national strategy for research. It promotes 10 societal challenges, one of which is 'information and communication society'. These challenges are supported by five action programs, one of which involves big data. These priorities have been supported by significant government investment; for example investment in AI is expected to reach €1.5 billion by 2022.³³

Canada: The 2017 Canadian Government budget identified six key areas for its 'innovation economy' investment, with digital industries highlighted alongside advanced manufacturing, agri-food, and others.³⁴ That year, a C\$125 million Pan-Canadian Artificial Intelligence Strategy was established. Canada's Strategic Innovation Fund has invested C\$3.6 billion since 2018, supporting large-scale, transformative and collaborative projects in the knowledge economy, including streams promoting collaboration with the university and research centre ecosystem.³⁵

What action is needed

The COVID-19 pandemic has accelerated the prioritisation of emerging digital technologies in Australia, which was already underway. The Australian Government's Digital Economy Strategy³⁶ is investing \$1.2 billion into key digital capabilities, including funding for artificial intelligence and drone technologies. The Modern Manufacturing Strategy is further investing \$1.3 billion into key strategic areas of Australian manufacturing to make it more competitive, resilient and advanced. These initiatives are a welcome signal from the Australian Government that investment in emerging digital technologies is a national imperative.

In addition to these initiatives, the Australian Government must clearly recognise the importance of building scientific

capability behind the digital economy, both in investment and narrative. The national narrative and strategy for Australia's digital economy needs to address the fundamental importance of building and maintaining scientific capabilities in emerging digital technologies to drive investment and build sovereign capability and capacity.

With the wave of the global digital revolution building, Australia has a critical opportunity to institute a strategic national approach, supporting fundamental research and engineering to drive innovation in emerging digital technologies. We need a vision for innovation and research in areas of national strength and strategic priority—one that is matched by a globally competitive level of commitment and investment.

Recommendations:

If Australia is to keep pace with our international peers in digital technology capability and innovation, strong government action is needed to signal a national policy approach and provide confidence for private sector investment. In order to achieve these aims, the academies make the following recommendations:

1 Elevate emerging digital technologies as a national science and innovation priority

Elevating emerging digital technologies as a national science and innovation priority would strengthen research and development capabilities, ensure sovereign capability and industry confidence, attract global investment and catalyse Australia's technology innovation ecosystem.³⁷

2 Include research and innovation in emerging digital technologies in the 2021 Research Infrastructure Roadmap

The 2021 Research Infrastructure Roadmap will address Australia's emerging research challenges.³⁸ The roadmap is a significant opportunity to elevate the importance of building the scientific capabilities underpinning and enabling Australian innovation and development in emerging digital technologies. Government infrastructure investment initiatives must recognise the need for investment in cross-cutting emerging digital technologies, independent of particular domain areas, to achieve multi-sectoral benefits. These mechanisms should be internationally competitive and comparable with those introduced by Australia's international peers.

3 Recognise emerging digital technologies as an independent growth sector

Alongside the physical, digital and economic infrastructure needed to build research capabilities, new and existing funding and investment mechanisms should explicitly include emerging digital technology research. Australia needs to focus on driving collaboration and commercialisation opportunities in emerging digital technologies, and improving access to international markets. This can be achieved by recognising emerging digital technologies as a growth sector in its own right, and promoting it through schemes such as Innovation Connections,³⁹ a dedicated stream in the Cooperative Research Centre Projects program, and including emerging digital technologies as a cross-cutting theme across Modern Manufacturing initiatives.

Conclusion

In the words of a great pioneer of modern-day computer science, Alan Kay: “The best way to predict the future is to create it”. Australia is at a crossroads in the development of a strong digital technology economy. We have strengths in emerging digital technology research and development, but opportunities for sector growth and sovereign capability are nascent and require coordinated and strategic support. To grasp the opportunities presented by a growing emerging digital technologies sector, Australia must also strive to address the digital divide to ensure equity of access to the benefits delivered by digital technologies, and to meet the skill requirements for a future digital workforce. Australia’s emerging digital technology capabilities must receive this support in order for the nation to remain internationally competitive and ensure that scientific leadership is adequately harnessed in shaping our collective digital future.

Contributors

This briefing was prepared by members of the Australian Academy of Science’s National Committee for Information and Communication Sciences, and the Australian Academy of Technology and Engineering’s Digital Futures Forum. We are grateful for their valuable contributions.

Professor Shazia Sadiq FTSE, Chair of the National Committee for Information and Communication Sciences, Australian Academy of Science; Professor of Computer Science, University of Queensland; Digital Futures Forum, Australian Academy of Technology and Engineering

Professor Ampalavanapillai Nirmalathas, Deputy Chair of the National Committee for Information and Communication Sciences, Australian Academy of Science; Professor of Electrical and Electronic Engineering, University of Melbourne

Professor Rod Tucker OAM FAA FTSE, Observer to the National Committee for Information and Communication Sciences, Australian Academy of Science; Member of the Digital Futures Forum, Australian Academy of Technology and Engineering

Professor Benjamin Rubinstein, member of the National Committee for Information and Communication Sciences, Australian Academy of Science; Professor of Computing and Information Systems, University of Melbourne

Professor Svetha Venkatesh FAA FTSE, member of the National Committee for Information and Communication Sciences, Australian Academy of Science; Co-Director of the Applied Artificial Intelligence Institute, Deakin University

Professor Andy Koronios, member of the National Committee for Information and Communication Sciences, Australian Academy of Science; CEO and Managing Director of SmartSat CRC

Professor Deborah Bunker, member of the National Committee for Information and Communication Sciences, Australian Academy of Science; Professor of Systems and Information, University of Sydney

Professor Iain Collings, member of the National Committee for Information and Communication Sciences, Australian Academy of Science; Deputy Dean of the School of Engineering, Macquarie University

Professor Mike Miller AO FTSE, Chair of the Digital Futures Forum, Australian Academy of Technology and Engineering

Professor Mary-Anne Williams FTSE, Deputy Chair of the Digital Futures Forum, Australian Academy of Technology and Engineering; Michael J Crouch Chair for Innovation, University of New South Wales

Mr David Thodey AO FTSE, Deputy Chair of the Digital Futures Forum, Australian Academy of Technology and Engineering; Board Chair, CSIRO

Dr Craig Mudge AO FTSE, Digital Futures Forum, Australian Academy of Technology and Engineering.

Professor Glenn Wightwick FTSE, Deputy Chair of the Digital Futures Forum, Australian Academy of Technology and Engineering; Deputy Vice-Chancellor of Innovation and Enterprise, University of Technology Sydney

For further information about this work, please contact Chris Anderson, Director Science Policy at the Australian Academy of Science: Chris.Anderson@science.org.au; or the Policy Team at the Australian Academy of Technology and Engineering: AcademyPolicyTeam@atse.org.au

Cover image credit: Thomas Silkjær © This visualisation represents the full XRP cryptocurrency ledger at mid-November 2018.

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