An overarching framework for a complex digital environment

Supporting background information for:

Preparing for Australia's digital future: A strategic plan for Information and Communications Sciences, Engineering and related Technologies

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1 Introduction

Despite the amount of good work underway across Australia, we lack an overarching framework to help (metaphorically) map the terrain. A framework that encourages us to think about the digital realm as a complex and inter-connected system is proposed because:

- Digital technologies have become so pervasive that everything—from data theory to new hardware to primary school education—is now inter-linked.
    - In the best-case scenario, tackling any aspect of our digital future in isolation can be effective only in a small, and perhaps isolated, domain.
    - In a more common scenario, a new initiative can be only partially effective in a small domain because issues or barriers that were 'out of scope' were not considered.
    - In the worst case scenario, well-intentioned activities in one area can be counterproductive overall.
- New technologies, application areas and technical or societal issues arise from time to time. An inclusive, non-prescriptive framework provides an efficient way to:
    - Assess the potential impacts and flow-on effects of a change, be it a new societal driver, a new policy direction or a new technology development.
    - Identify which other technologies, applications or issues could provide useful knowledge or experience to help avoid any problems with uptake or to make it easier for existing systems to accommodate change/progress (both IT systems and socio-economic-cultural systems).

The framework developed in support of the Strategic Plan for Australia's Digital Future helps to address these points by providing a way of visualising—or at least organising for systematic consideration—the many connections between the applications of digital technology, the technologies themselves, and the many issues that the technology either faces or raises for others. This framework uses the word 'issues' in a neutral sense to describe a spectrum that ranges from 'enabling factors' through to 'barriers' which apply equally to technological as well as socio-economic issues. No firm distinction is drawn between enabling factors and barriers because of the interconnected nature of the framework—the same issue can be both an enabling factor and a barrier depending on the angle you view it from.

Each of the underpinning technologies, application areas and issues are summarised in the following sections.

1.1 Underpinning technologies

This section lists some of the many underpinning technologies rather than attempting to describe them in detail, which has been done previously. Part of the utility of the proposed framework is its ability to recognise and adopt the very large volume of work already undertaken rather than require reinterpretation or duplication. This list is not comprehensive: technologies can be added or subtracted to the framework as required.

- Machine learning and artificial intelligence
- Cybersecurity
- Automation and robotics (and Big Robotics)
- Internet of Things
- Big Data and analytics
- Data visualisation

- Broadband (high capacity communications)
- High performance computing
- Quantum computing
- Complex systems modelling
- Blockchain (and similar)
- Sensor technologies

1.2Application areas for digital technologies

Among the bewildering array of possible applications of digital technologies are:

Agritech

This can encompass, for example:

- Geolocation
- Remote monitoring and telemetry
- IoT
- Weather and climate modelling
- GWAS, HPC
- Deep learning/image recognition
- Automation and robotics
- Protected cropping
- Big data

Medtech

This can encompass, for example:

- Automation, robotic-assisted care, robotic care
- Deep learning and diagnosis
- Patient medical records
- Automation
- GWAS, big data, HPC
- Drug and vaccine design
- Epidemiology and population health
- Wearables, sensors, big data
- Social media analytics
- Remote health care

Fintech

This can encompass, for example:

- Quantum encryption
- Blockchain and similar ledgers
- Market analyses: AI and big data
- Non-traditional financial information
- Personalised pricing
- Rapid transactions
- Anonymity, intelligence, law enforcement

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METS and MinEx (together 'Mintech')

This can encompass, for example:

- Industrial automation
- Geological big data
- Data fusion, inversion, AI
- HPC
- In-field sensors, remote sensing
- Automation of exploration

Tourism and hospitality

This can encompass, for example:

- Automated reception and service
- Personalised service
- Location-sensitive information availability
- Virtual experiences (VR and AR)
- New services

Envirotech (including climate)

This can encompass, for example:

- Automation of environmental monitoring
- New and cheaper sensors, distributed networks
- Big data, non-traditional information sources, data fusion, AI
- Machine vision and object/event identification
- Earth observation satellites
- In-situ or inaccessible analyses
- Real-time, high bandwidth communication
- Real-time reporting
- Meeting international obligations

EdTech (Education)

This can encompass, for example:

- Technology in schools
- Predicting future skill sets
- Shorter attention spans
- Symbolic logic from an early age
- Higher education as a service industry
- Emerging ecosystem of education and information sources
- Pedagogic focus versus skills and capability focus
- Accelerating pace of change

Defence and security

This can encompass, for example:

- Persistent and automated surveillance

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- Blurring line between defence and national security
- Threats also undergoing a technology revolution
- Non-traditional intelligence sources
- Big data, data integration in real time
- Enhanced humans (sensing capability, information processing capacity, mobile decision support systems, mechanical assistance).
- Emergency management systems

Entertainment, social media and gaming

This can encompass, for example:

- Recreation time is 'mid-transformation'
- Music and TV already transformed to on-demand
- Social media
- Smartphone as primary browsers
- Gaming
- Navigation and driving
- IoT modifying behaviour
- AR/VR just in its infancy.
- Both driver and beneficiary of tech development (e.g. camera sensors, gaming GPUs)
- Gaming machines used in research, gaming engines used in data visualisation
- Big data, AI, personalisation, privacy

Transport and logistics

This can encompass, for example:

- Ubiquitous connectivity
- New services
- (Semi)autonomous transport (all modes)
- Efficient logistical planning
- Emergency management of whole systems
- Big data, data integration in real time
- Real-time traffic management/route optimisation

1.3Issues: enabling factors or barriers affecting the digital sectors

As previously mentioned, this framework uses the word 'issues' in a neutral sense to describe a spectrum that ranges from 'enabling factors' through to 'barriers' which apply equally to technological as well as socio-economic issues. No firm distinction is drawn between enabling factors and barriers because of the interconnected nature of the framework—the same issue can be both an enabling factor and a barrier depending on the angle you view it from.

Protocols and standards

Policy, protocols, standards and regulation can act as both enablers and barriers. Particular issues in this category include:

- Cybersecurity
- Interoperability

- Mitigation of technology lock-in and adoption of new technologies.

System resilience and robustness

Resilience and robustness can act as both enablers and barriers to technology uptake. Particular issues in this category include:

- Includes but not limited to security
- Failure modes (including the unexpected)
- Whole-of-system vulnerability
- How systems respond when they do fail
- How people respond when systems fail
- System fragility as a strong barrier to uptake
- Validation (before or after deployment)
- Hardware robustness and critical sensors

Regulation and policy

Policy settings can encourage innovation and uptake, or inhibit it. A small selection of the particular issues in this category include:

- Protection of privacy
- Income inequality
- Universality of internet access
- Net neutrality
- Business, competition, IP, innovation… policy settings.

Infrastructure (data and physical)

Infrastructure of all kinds is often a key enabler or barrier. Particular issues in this category include:

- Common platforms for data and information exchange
- Data-infrastructure for research and society
- Digitally-prepared physical infrastructure

Innovation translation

Translation of new innovation into commercial success is a current topical issue in Australia. Refer initially to:

- Innovation and Science Australia, 2016. Performance Review of the Australian Innovation, Science and Research System.
- Innovation and Science Australia, 2018. Australia 2030: Prosperity through Innovation: A plan for Australia to thrive in the global innovation race.

Equity and diversity (professional and public)

Issues relating to equity and diversity can act as both enablers and barriers to technology uptake, as well as to societal wellbeing more generally. Particular issues in this category include:

- Gender and social equity
- Economic impact of poor retention and career progression: wasted training, lost productivity.
- Benefits of diversity.

- Numerous potential drivers of income inequality.
- Avoiding a new class system based on access to information and technology

Corporate governance and investment

Issues related to corporate governance can act as both enablers and barriers, although it should be noted that failures receive public attention and success is often quiet. Particular issues in this category include:

- Research funding
- Incentives for collaboration between researchers and end-users
- Greater access to venture capital.

Ethics and privacy

Issues related to ethics and privacy can act as both enablers and barriers, although it should similarly be noted that successful management of these issues goes unnoticed by the public. Particular issues in this category include:

- Use of technology to harvest personal information
- Security of retained meta-data.
- Public awareness of and attitudes towards default privacy settings
- Attitudes differ by age and profession
- Encoding ethics into AI
- Ethics of autonomous systems engaging directly with humans
- Ethics of autonomous systems making decisions that affect humans.

Education and training

Education is Australia's existing area of strength, yet it also faces issues that could act as both barriers and enablers.

School education

Including:

- Ensuring basic capabilities in statistics and data
- Improving the quality of pre-service teacher training
- Ensuring students are competent and comfortable adopting, adapting and implementing new and existing technologies in the context of workforce changes and transformations

Vocational education and training

Including:

- Technical skills required to manage and maintain emerging digital technologies and applications

University education

Including:

- Enhancing graduate employability through internships or other mechanisms
- Aligning course design with industry needs

- Ensuring graduates are equipped with the attributes that will be required to continue participating/leading as the pace of change accelerates into the future
- Changing the expectations of both students and employers (ICS and ICT graduates may not end up employed where they thought they would be, yet bring skills that are no less useful in those other areas).
- All this must be underpinned by achieving greater diversity and gender balance in ICS and ICT higher education.

Workforce pathways and career development

Including

- Facilitating mobility between research, industry and government sectors
- Diversity and gender balance among ICS and ICT professionals
- Facilitating collaboration between universities, industry and governments.

2 A model framework

A simple model to visualise the inter-connected nature of the digital and digitally-enabled sectors is to plot enabling technologies, application areas and issues on orthogonal axes[1]. The resulting three dimensional space provides a useful framework that immediately reveals the breadth of considerations that this strategic plan attempts to address—as well as the lack of information on many of them. Interconnections within and between the technologies, applications and issues can be visualised as surfaces in this space.

[1] The axes and the position of each item on each axis are arbitrary: unconscious biases about the *x*, *y*, and *z* axes should be confronted for the sake of ignoring them.

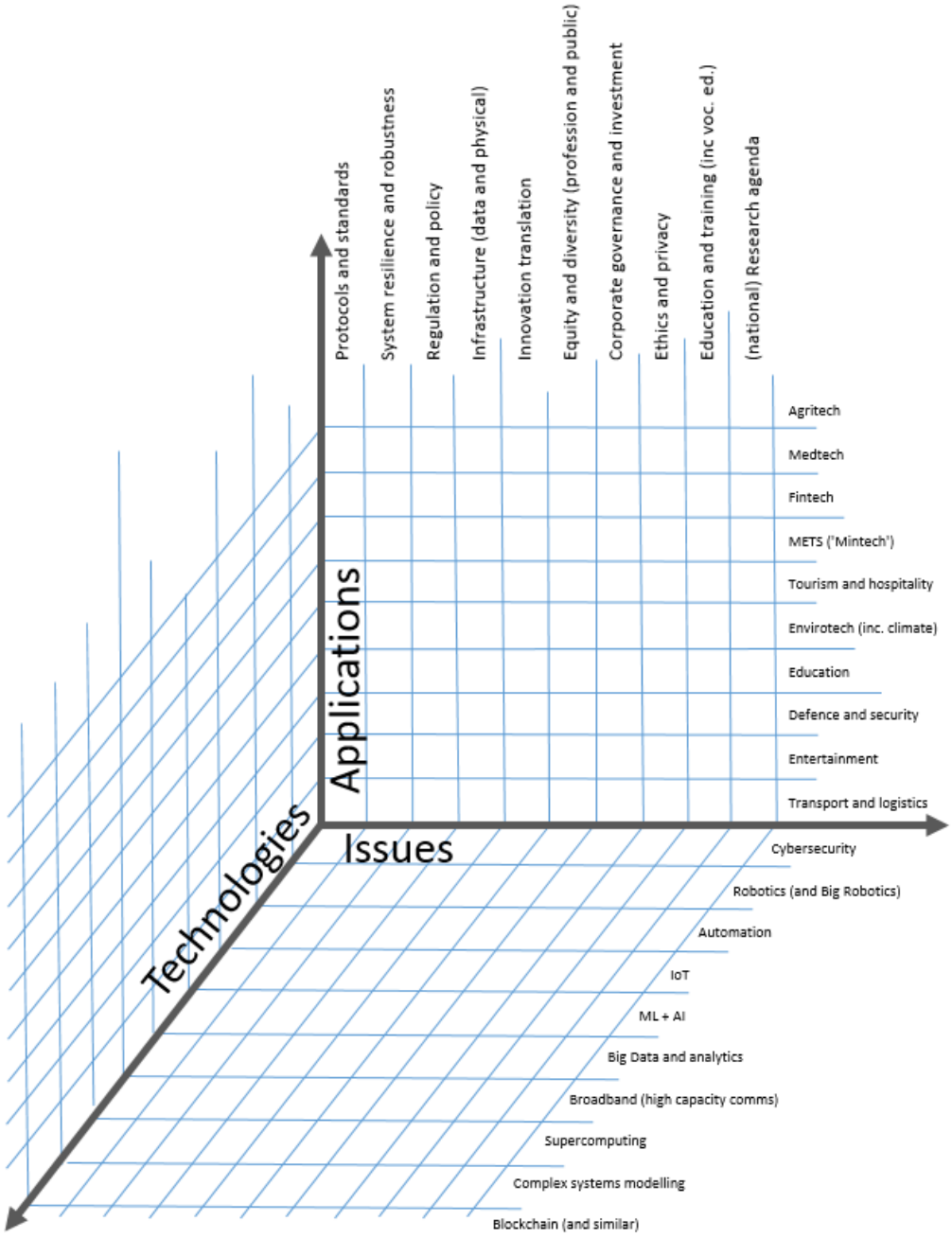

Figure 1: A model framework for considering the interconnected nature of digital technologies, their applications and their implications.

Note that the actual technologies, applications and issues provided in this example are not absolute, and can added to or subtracted from the model meet the needs of the model user.

2.1Using the framework through its 'lenses'

The integrated framework makes clear the extreme inter-connectedness of the reach of digital technologies throughout our lives and our economy, yet the complexity is difficult to convey even in 3D (or higher dimensional space, for those who can effectively conceptualise *n*-space).

For simplicity, and to assist with systematic analyses, the framework can be reduced to a series of matrices: Looking parallel to an axis—down the line corresponding to a particular application, technology or issue—yields a matrix. For example, looking parallel to the application axis from the perspective of agritech results in a matrix of technologies that may be applied in agritech and issues to consider from an agricultural perspective. Looking from the perspective of big data analytics (an enabling technology) we see a matrix of possible applications and the issues to consider. Looking from the perspective of a particular issue yields a matrix of the applications that may be affected by that issue and the technologies that could be relevant.

However, this approach should not neglect the cross-linkages between the various matrices: simplifying the model for the sake of convenient analysis can also have the side-effect of partially removing it from the complex context in which it exists (i.e. 'de-integrating' it).

2.1.1 The applications lens

Looking at the framework from the perspective of a specific application (looking parallel to the *z* axis as shown) may be useful for:

- Industry participants whose business is focussed on a particular application (e.g. a pharmaceutical company will mostly be interested in medtech) and who may wish to more effectively tackle the issues facing that application or look for other technologies that may be relevant.
- Governments, when particular industries are of political interest or to inform sector-specific policies (e.g. to help consider interplay between agricultural policy and the NBN).

2.1.2 The technology lens

Looking at the framework from the perspective of a certain technology (looking parallel to the *y* axis as shown) may be useful for:

- Researchers who are interested in shaping their research direction based on the presence (or absence) of realistic uptake pathways, or to identify possible applications and perhaps additional investors or funding sources that may not have otherwise been considered. Thinking inside the box, the framework can also help place research in context for grant applications.
- Higher education providers: curriculum development could be informed by consideration how each technology links with industry and society.
- Holders of patents for a specific technology: systematically exploring potential uses, opportunities for innovation translation, potential barriers to uptake or conflicting societal influences may improve the success rate of attempts to translate research into commercial success.

2.1.3 The enablers / issues lens

Looking at the framework from the perspective of a certain issue, be it a specific enabling factor, a barrier or even a social or political trend (looking parallel to the *x* axis as shown) may be useful for:

- Governments and policy setters who need to examine issues affecting (and affected by) digital technologies in the context of the whole sector, to help identify linkages (synergies or conflicts) with other policies, as well as any application areas that may provide key stakeholders (likely allies or opponents).

- Science communicators interested in human-centred communication: communicating the issues that matter to people and their many implications is an alternative and highly effective approach to the traditional view of science communication as filling an assumed 'knowledge deficit'.
- Economic or social assessments: the framework provides an(other) tool with which to ensure the completeness of factors considered in assessments or studies.

2.1.4 Avoiding single perspectives

Despite the obvious value of the 'lenses' in simplifying the framework to provide easier analysis from whichever perspective may interest us most, perhaps the most useful aspect is in their ability to systemically consider how others may see the digital sector. Industry participants, governments and researchers can readily use a different lens from somebody else's perspective to gain a deeper understanding of the system in which we all operate and interact. Such understanding is especially helpful when collaborating across sectors and interacting with other people or organisations that may hold different motivations, experience different pressures or have different performance indicators.

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