The future computing needs of the Australian science sector

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Australia has no national strategy to acquire and sustain state-of-the-art high-performance computing and data (HPCD), also known as supercomputers, for research – putting the country's future prosperity and security at risk.

We currently have moderate HPCD capability in Australia, but these facilities require major upgrades every few years and have a limited overall lifecycle. Our existing supercomputers won't last beyond the end of this decade – and we need to start planning for the next generation now.

A national strategy backed by at least one exascale capability is essential to secure Australia's sovereign capability and enable science and research to meet national and regional priorities.

Key points

- Supercomputers are vital to the everyday life of Australians and the economy, impacting fields including healthcare, weather prediction, agriculture, and job creation through new technologies.
- There is no current national strategy for the next generation of research HPCD in Australia; such a strategy is necessary given the escalating needs for research and the need to keep pace with global advancements.
- Australia's research HPCD serves researchers in a variety of organisations, including universities, medical research institutes and government science agencies, including CSIRO, the Bureau of Meteorology, and Geoscience Australia, informing government decision-making and planning.
- Australia's research HPCD also bolsters our artificial intelligence (AI) capabilities. Without computing power on our own shores, Australia's AI capability relies on other nations.
- While holding potential, quantum computing and cloud computing cannot replace traditional HPCD functions for scientists in the near term and requires further development.
- Australia's stability, connectivity, and renewable energy capacity position us as an ideal host for future regional HPCD, especially an Asia-Pacific Tier-0 exascale facility.
- Securing sovereign capability depends on both investment in infrastructure and investment in software readiness programs. Similarly, the role of training, education, data management and AI is crucial to support future growth.

Australia's supercomputers are a powerful asset

Supercomputers play a crucial role in enhancing the lives of everyday Australians and boosting the economy.

Weather prediction using supercomputers allows for better preparedness and response to natural disasters.

They accelerate the discovery of **new drugs**, directly impacting patient care and treatment options.

Supercomputers may also help improve **agricultural productivity** by identifying optimal locations and species for food production to accommodate changing weather patterns, leading to increased sustainability and increased profitability.

They **save lives** – not least by tracking the evolution of COVID-19, enabling timely and evidence-based responses to the pandemic, and providing important learnings for future pandemics.

They power the discovery of **new technologies and innovations** – creating the jobs and the industries of the future for Australians.

Supercomputers power our **science agencies**, including CSIRO, the Bureau of Meteorology and Geoscience Australia, inform government decision-making and will increasingly be required to boost Australia's AI and quantum capability.

If Australia does not invest in HPCD for science, we risk falling behind in technological advancements, facing economic disadvantages, and suffering a reduction in research capabilities. Lack of investment could lead to a brain drain, national security vulnerabilities, missed international collaborations, and stagnation in innovation across various sectors, including healthcare and education.

Without substantial and strategic investment in computing, Australia's global standing in science, technology and healthcare industries will be significantly impacted.

Current HPCD landscape in Australia

Australia hosts two national (Tier-1) HPCD facilities that are accessible to researchers: NCI Australia and Pawsey Supercomputing Research Centre. These are the most powerful publicly listed computers in the country and were globally competitive upon debut. Australia also has a mix of Tier-2 and Tier-3 facilities that are hosted in individual institutions.

Additional HPCD facilities exist in Australia that are not readily available to researchers, including those operated by industry and government.

Tiers	Facilities in Australia available to researchers
Tier-0 (international or multinational facilities)	None (Tier-1 facilities maintain strong international partnerships but no completely shared international facilities)
Tier-1 (national facilities)	Gadi (NCI Australia) Setonix (Pawsey Supercomputing Research Centre)
Tier-2 (institution-based facilities)	Bunya (University of Queensland) Massive (Monash University and University of Wollongong) Ozstar (Swinburne University) Phoenix (University of Adelaide)

HPCD users go beyond researchers in universities and research organisations; they include government science agencies and government departments, industry, and international research organisations and researchers.

Capital investments in Tier-1 HPCD are currently funded by the Australian Government. However, operational funding is largely provided by the users of the facilities, including partnerships and contracts with universities, government science agencies, and industry.

Australia can currently be considered to have moderate HPCD capability – ahead of much of the southern hemisphere but falling behind progress being made in peer nations, particularly as our local supercomputers age.

Australian researchers are agile and increase ambition with each upgrade. With each upgrade to our Tier-1 facilities over the past decade, research ambition and demand have quickly matched and exceeded supply.

Both of Australia's Tier-1 facilities are oversubscribed – meaning they are unable to accommodate all of the researchers' requested amount of time to complete their work on the systems.

Demand will continue to increase.

Researchers are experiencing an increasing need for their data to be co-located with supercomputers due to the massive size of the datasets and the time it would take to transport or transmit the information if it were stored in a different location. Data storage through the commercial cloud can be useful for smaller projects, but presents significant financial barriers, and creates issues for data security and management.

To date, there has been no dedicated strategy for what comes next for HPCD in Australia. The next generation of compute requires funding that far exceeds the cost of our existing Tier-1 facilities – and the total national research infrastructure budget.

The next frontier of computing

The challenges facing Australia and the world are increasingly complex – and require more computational power to solve.

Exascale computers are computers that are capable of one exaflop or 1,000,000,000,000,000,000 (a billion billion) FLOating Point calculations (FLOPs) per second. It's a massive number that more than doubles the number of FLOPs the computers in the previous generation were capable of.

These computers are capable of analyses previously unimaginable – and at very fast speeds. These computers will be capable of the next generation of simulations – imagine being able to know how a severe weather event would impact your own property or how materials can be created to build resilient, clean energy systems.

The first exascale computer, Frontier, came online in 2022 built by the US Department of Energy. It reached 1.1 exaFLOPS, or 1,100 petaFLOPS, when it came online, making it, by official measures, the fastest supercomputer in the world. China has many powerful supercomputers that may rival Frontier, but these have not been officially benchmarked.

HPCD is also perceived to be an increasingly critical asset by governments around the world, with the USA and China having both reached exascale and other leading nations close on their heels with more computers due to come online in 2024. Many countries, including some in Europe, are already planning for post-exascale computing.

Large economies such as the USA, Japan, China and the UK have corralled the necessary investment for their exascale facilities as a national priority, guided by national strategies.

Europe offers a collective version of this strategy, in which a multi-national partnership (EuroHPC) is facilitating the development of multiple pre-exascale facilities. These are effectively multi-national Tier-0 facilities that service HPCD demands of multiple countries.

Without a strategy for Australia to meet our peer nations at the next frontier of science (and computing) – exascale and beyond – our national science system, our prosperity and our national security are all at risk.

Artificial intelligence and machine learning

The increasing investment in HPC systems is driven not only by the need to get to exascale but also by developments in artificial intelligence (AI). Computing infrastructure is a critical enabler for the development and adoption of AI tools.

This shift is driving a preference for graphics processing units (GPUs) which are engineered for concurrent applications– making GPUs more efficient in handling AI tasks than central processing units (CPUs). However, CPUs will remain preferred for many areas of research, including climate and weather. Maintaining computing capacity and advanced architectures appropriate for these different types of tasks will be essential.

Access to HPCD and software must be ensured to harness advances in AI and science.

Without computing power on our own shores, Australia's AI capability will be entirely dependent on other nations.

Cloud computing

Technologies, such as cloud computing, enrich the computing ecosystem and complement HPCD by offering on-demand resources for a range of applications. However, they are not capable of replacing the need for HPCD.

Cloud computing is useful for smaller-scale research projects but is unsuitable for large-scale research or those using sensitive data. Commercial cloud services are not financially viable for researchers with large datasets or complex requirements. Using commercial services also has risks for securing intellectual property.

The provision of computing resources by large technology companies is helpful, but this has important gaps – including instances where the data cannot leave Australian shores.

Smaller research projects with less complex and sensitive datasets can and do leverage cloud computing resources.

Quantum computing

Quantum computing holds potential as a future complement to HPCD, offering unique capabilities for certain types of complex problems. However, its practical development, integration and full realisation depend on utilising HPCD infrastructure.

Currently, quantum computing cannot replace all functions of traditional HPCD and requires further development and integration efforts before it can be considered a viable technology for Australia's computing capability.

Australia as a regional host for research infrastructure

Australia, like other leading nations, needs to urgently consider future investment in HPCD to remain competitive and provide services and benefits to all Australians. However, due to our economy's size, reaching advanced, exascale capabilities will require a well-thought-out national strategy and a regional approach that includes co-investment from regional partners.

Australia has a substantial interest in the prosperity of the countries in our region. Few countries in the region have the financial and technical capacity to invest in near-exascale and exascale HPCD. As a global and regional citizen and leader, Australia could host the next generation of HPCD capabilities for the region.

Hosting an exascale capability in Australia for the region would bring substantial economic benefits to our shores, through scientific collaboration and innovation, attracting skilled workers and the creation of new industries. An exascale capability that

is shared could be a strategic diplomatic tool, showing leadership and building trust with neighbouring countries, while fuelling regional problem solving.

Australia offers numerous advantages as a potential host for the next generation of HPCD for the region. Australia is a stable democracy with geographic separation from major geopolitical threats. Australia has excellent network connectivity to the Asia-Pacific region and established capability in HPCD.

Supercomputing uses large amounts of electricity and has the potential to contribute significant climate risk if that electricity is not renewably sourced. Both of Australia's Tier-1 HPCD facilities derive a substantial portion of their power from renewable energy, with NCI Australia currently one of just two Tier-1 research HPCD facilities globally that runs on electricity 100% derived from renewable energy.

HPCD facilities also commonly require water systems for cooling, with Pawsey utilising an innovative geothermal system developed by CSIRO for groundwater cooling that is able to manage the heat emitted by the supercomputers.

Australia has a large renewable energy capacity, alongside a national commitment and urgency to build renewable energy industries.

There is an opportunity for a Tier-0 Asia-Pacific exascale supercomputing capability to be built and hosted in Australia to support regional demand for access to exascale computing and data services – while being able to be powered by electricity from renewable sources.

Establishing an Asia-Pacific Tier-0 exascale capability in Australia would also attract related industries, investment, and expertise that bring value to the region.

Contact

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Appendix A - Roundtable participants

This brief was based on input received during the roundtable, 'The future computing needs of the science sector', held by the Australian Academy of Science on 28 November 2023. This brief does not represent the views of the following individuals who participated.

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