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>
> Gavin Wearne; Director, Ports & Marine

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Words by Simon Koger

Where to begin

Australia has released its first National Climate Risk Assessment, shifting the dial on our response to climate change.

From water scarcity to extreme heat, coastal erosion to supply chain fragility, the challenges outlined in the National Climate Risk Assessment (NCRA) and the National Adaptation Plan demand that engineers act with foresight, collaboration and leadership.

Australia has a unique opportunity to play an outsized role in global decarbonisation. While our domestic emissions are only around 1 per cent of the global total, our fossil fuel exports contribute around 4.5 per cent of global emissions once burned overseas.

Transitioning to become a major exporter of renewable energy and clean technologies could flip that balance and make Australia a net positive force in the climate fight.

So where do we start? Here are five key actions engineers can take to help Australia achieve its net-zero targets.

1. Start with infrastructure and resilience

The NCRA identified 11 priority risks across seven interconnected systems, including the economy, health, natural environments and critical infrastructure.

While we can't solve all these issues at once, perhaps we could work towards a triage system and start where the impacts are most immediate, such as reducing further emissions. Then we can work towards mitigation, adaptation and building resilience.

2. Integrate adaptation and resilience

Engineers Australia's Climate Change Position Statement makes clear we need more than just mitigation; we need adaptive responses that build resilience over time.

3. Embrace hard truths of water challenges

The NCRA predicts that sea-level rise could place 1.5 million additional Australians in coastal risk zones by mid-century, while water security has been identified as a cross-system risk.

The engineering response requires both physical interventions and smarter planning.

> "The NCRA highlights that climate risks are cascading, concurrent and compounding."

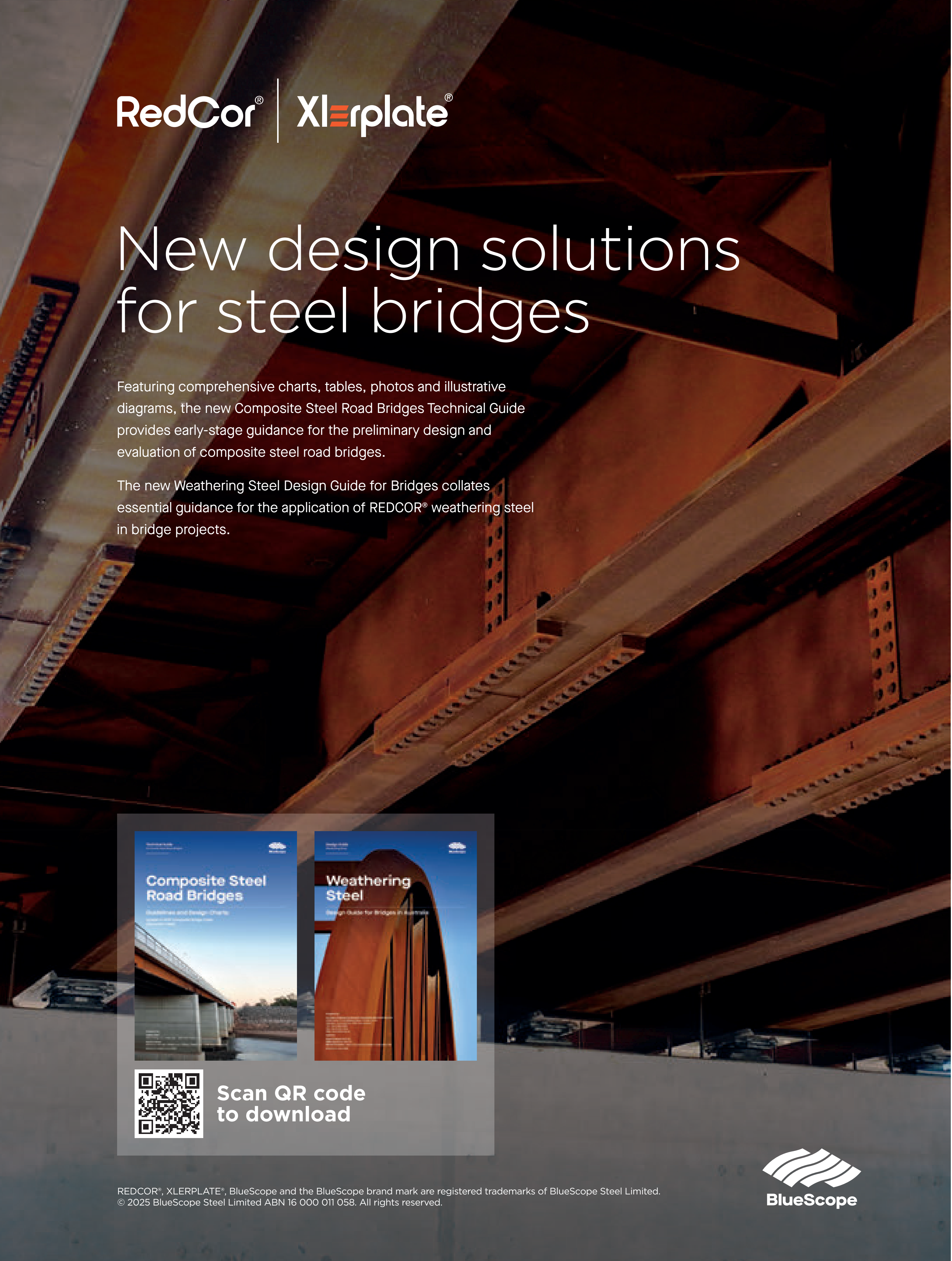
4. Build the workforce and show leadership

Delivering on net zero requires more than technical solutions; it requires people. Engineers Australia has long advocated for a National Chief Engineer role and greater engineering leadership in government.

5. Think in systems, not silos

The NCRA highlights that climate risks are cascading, concurrent and compounding. A drought disrupts agriculture, which in turn affects trade, health and social support systems.

Simon Koger is an environmental engineer and Climate Change Manager at Engineers Australia.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[Leadership]

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Integration is the engine of resilience, efficiency and sustainability.

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FROM THE NATIONAL PRESIDENT AND CEO

Engineering is integration

As 2025 draws to a close, engineers can look back on a year of extraordinary innovation, collaboration and resilience.

Engineering progress rarely comes from a single breakthrough. More often, it emerges when ideas, disciplines and technologies are brought together in ways that multiply their impact. This edition of *create* highlights how integration is becoming the defining capability of our profession, whether in energy systems, transport, manufacturing or digital infrastructure.

In this edition we look at projects with multi-decade delivery windows asking how we can deliver projects to standards that are yet to be set, integrating technologies not yet invented.

It captures the essence of integration: aligning systems, skills and foresight so that what we design now remains relevant and resilient in decades to come.

Systems that work together

Nowhere is this more evident than in the push to connect battery technologies into a national grid that is secure, reliable and adaptive. Engineers are not just solving for performance; they are weaving together considerations of safety, cybersecurity and coordination so that each part strengthens the whole.

Advances in rapid prototyping and AI-enhanced design are being folded into manufacturing workflows, accelerating productivity while linking Australian innovation with global supply chains. Transport tells the same story. From jet engines reimagined with composite materials and open-fan designs, to the extraordinary achievement of building the world's largest electric vehicle, the Incat Hull 096, here in Australia, integration is what makes ambition possible.

Integration is not an optional extra. It is the engine of resilience, efficiency and sustainability. By ensuring the parts of our world fit and function together, engineers create systems that carry society forward. That is the essence of our work, and it is what will continue to define Australian engineering in the years ahead. □

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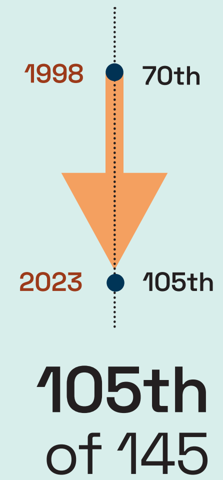
The big picture

Australia's economic complexity has dipped. Here are 13 technological trends engineers could consider to help turn the country's fortunes around.

Figure 1:
Rankings drop



Rankings plunge

Australia may boast an above-average GDP, but its economic complexity is waning.

The country is less complex than expected for its income level, according to Harvard Growth Lab's Atlas of Economic Complexity, which tracks global trade flows across markets and identifies countries' growth opportunities.

In the eight years to 2033, Australia is set to grow 1 per cent annually, ranking in the bottom half of countries globally, according to the report.

Industrial machinery, and optical and medical apparatuses are among the sectors quoted as having the highest potential for new technological investment, to drive the country's industrial diversification as part of this growth.

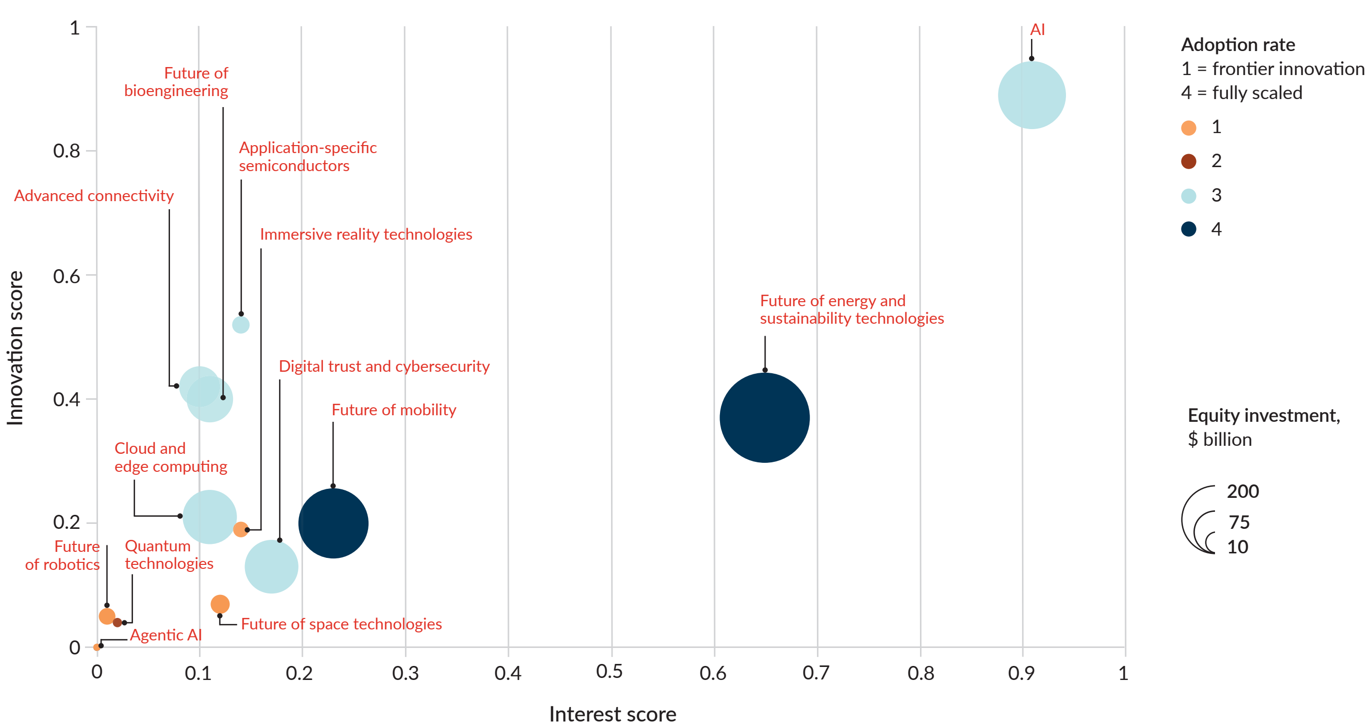
Topical tech

To turn the trough into a crest, Australian engineering companies might want to consider the 13 tech trends that matter most as we near 2026, according to the McKinsey Technology Trends Outlook 2025.

This report lists frontier technology trends deemed as having the greatest potential to transform global business. The assessments have been made based on scores for innovation (based on patents and research publications) and interest (based on news and web searches).

McKinsey also estimated the level of equity investments in relevant technologies and rated their level of adoption by organisations.

Figure 2: 13 tech trends for engineers



Growth generation

Some of the biggest jumps in innovation, investment and interest have been experienced in fields such as AI, future energy technologies and computer-related technologies such as semiconductors.

Figure 3: AI

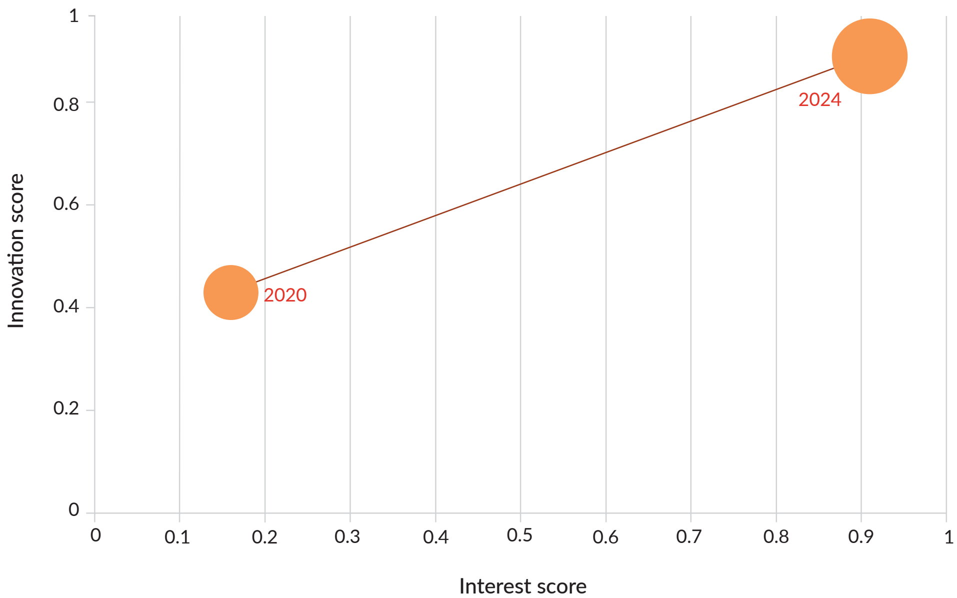
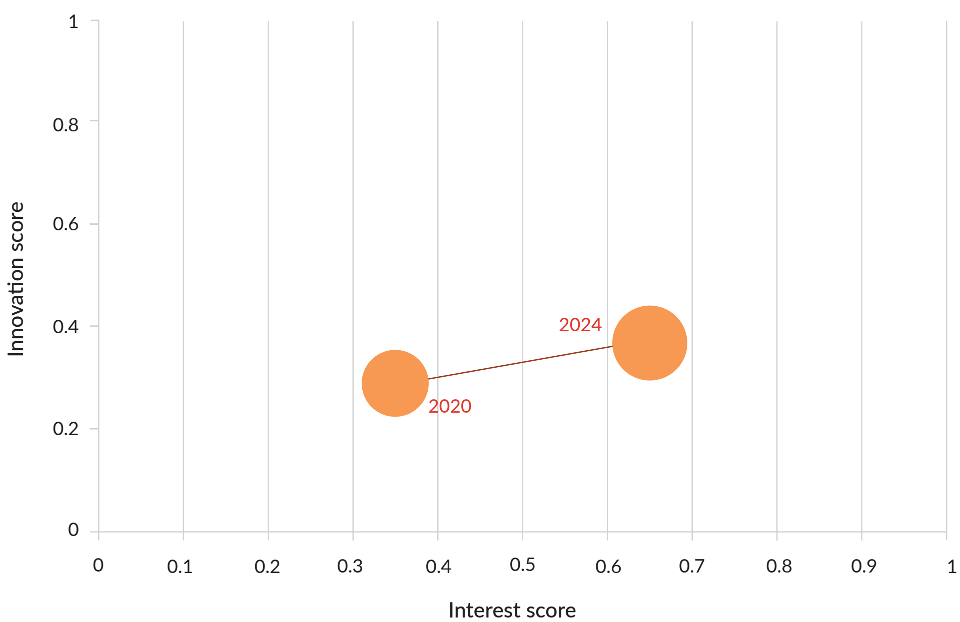


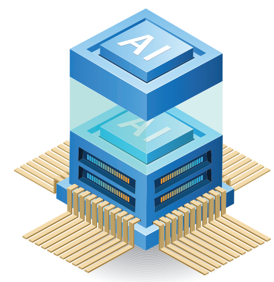
Figure 4: Future of energy technologies



ABOVE: Here's how innovation related to, and interest in the future of, energy and sustainability technologies has expanded between 2020-24. This sector encompasses all manner of innovations aimed at transforming the global energy landscape towards a more sustainable and resilient future, focusing in particular on electrification and clean molecules. Despite a dip in equity investment in this industry in 2023, it rebounded in 2024. Could this herald progress to come?

LEFT: Attracting the highest interest from both researchers and users, AI "stands out not only as a powerful technology wave on its own, but also as a foundational amplifier of the other trends", the report said.

Meanwhile, investment and interest in agentic AI, a phenomenon that has only become topical this year, is still burgeoning, with a $1.68 billion equity investment in 2024, compared to the $190.03 billion investment in AI more generally.



Action on AI

How about the Australian context? Theodoros Galanos, Generative AI Leader at Aurecon, said the best action engineers can do to make the most of new and emerging technologies such as agentic AI is to make use of them every day.

"That's how integration happens," he said. "That's how companies can integrate an AI tool in their enterprise systems, or how individuals can do so at home. Engaging with the technology every day is the essential first step."

View an interactive digital version of this article, with expanded comment from generative AI expert Theodoros Galanos of Aurecon.

SOURCES

McKinsey Technology Trends Outlook 2025, McKinsey; The Atlas of Economic Complexity, Harvard Growth Lab.

Words by Joe Ennis

Innovation nation

Australia is at a pivotal moment. What we do now will shape our place in a world economy built on technological solutions. Senator Tim Ayres, Australia's Minister for Industry and Innovation, and Minister for Science shares his vision for the nation's future success.

LEFT: Senator the Hon Tim Ayres, Australian Minister for Industry and Innovation, and Minister for Science.

IMAGE: AAP/Mick Tsikas.

> "The alternative is to sort of lean back and to become just an adopter ... and fall backwards in productivity and competitive terms."

When Tim Ayres reflects on the urgency of building Australia's future industrial capability, he tells a cautionary tale. He remembers the decline of the automotive sector in Australia, and the moment when factories closed and global manufacturers withdrew.

"What I'd observed in the years before the closure in and around the auto sector was that, though it was highly capital intensive – with lots of robotics and automation, and Australian research and design – there were enormous spillover benefits into the rest of Australian manufacturing," the federal Minister for Industry and Innovation, and Minister for Science told *create*.

When the industry moved offshore, those benefits vanished. "Imagine how much less behind we would be in EV development, hybrid car development, the battery sector and the supply chain if there was still the tens of billions of dollars' worth of development going on."

For Ayres, the collapse of automotive is more than economic history – it is a warning. Without deliberate effort, capability can be lost, leaving the nation dependent on others. The challenge now is to ensure we rebuild capabilities and take advantage of the current rapid technological advances.

Though the pace of change is rapid, it's nothing new. And with change comes opportunity.

"I've seen wave after wave of technological innovation and change make its way through the manufacturing and engineering sectors," Ayres said. "Waves of automation, robotics, laser technology – our sector has been transformed >

over the last 30 years, and this is the next wave of technology."

He is blunt about the stakes. "We can either grasp it and be confident about the role Australia can play – confident in Australian science, in Australian research and development, in Australian engineering – or we can fall behind."

Australia, he argues, starts from a position of strength. "We are rebuilding confidence in Australia, Australians and Australian engineering to be able to meet these challenges." The question is whether those strengths will be converted into lasting prosperity or allowed to dissipate as opportunities slip away.

Setting the direction

The Future Made in Australia (FMA) strategy is central to Australia's push to do the former.

"Future Made in Australia is designed to reshape and change the composition of the economy," Ayres said. "It means we're moving from mining and exporting raw materials to processing materials and moving up the value chain in new technologies. It's the largest ever Australian pro-manufacturing package, and that's what it's designed to do. It's very ambitious."

FMA identifies industries that can anchor this shift. "The policy's priority sectors include green metals, renewable hydrogen and critical minerals – industries that demand both engineering breakthroughs and large-scale investment."

Alongside FMA is the National Reconstruction Fund (NRF). "We're great at coming up with ideas, but with commercialisation, we're very poor," Ayres admitted. "The NRF aims to change this," he said, pointing to the fund's investment in PolyActiva, which is developing innovative drug delivery implants to combat glaucoma, as an example of the NRF's positive impact.

"It's the kind of thing that otherwise might have gone offshore," he said. "That IP, that research and development here in Australia, is what that fund is about – to deliver investments and co-investments that secure local manufacturing capability."

Digital infrastructure

Ayres insists digital capability must be understood as a system. "It's not just about data centres. It's about digital connectivity,

ABOVE: Tim Ayres says Australia starts from a position of strength.

"I don't want Australia to just be a quarry exporting ore to the world to be processed somewhere else. I want Australia to be extracting the maximum value. This is the moment, if we grab it."

> "There's no progress in society without engineers."

and it reaches right through to our critical minerals and our capacity in Australia to be supplying the base materials that are required for chips and for the broader compute sector."

He stresses that energy, resources and digital must work together. "I am absolutely focused on seizing the advantage. In digital infrastructure terms, Australia has an energy advantage and a proximity to big emerging markets that are big adopters of the technology themselves.

"We are a Five Eyes secure country with deep relationships with major markets and secure governance. There are a lot of reasons why Australia is a very good place for digital infrastructure development and investment."

And integration is the key. "We're very focused on getting the pathways right, sending the right investment signal."

Green metals and mining

Few sectors illustrate the stakes more than steel and aluminium. Ayres is emphatic about the opportunity.

"To secure the future of our iron ore sector and Australia's place in an uncertain world – and to lower the emissions profile of the steel sector – Australia has to play its part. And that means iron production in Australia."

The stakes are both environmental and economic. "The steel sector is an outsized contributor to global emissions, but it's foundational to the economy. So getting this right is a really significant contribution that Australia can make.

"I don't want Australia to just be a quarry exporting ore to the world to be processed somewhere else. I want Australia to be extracting the maximum value. This is the moment, if we grab it."

Hydrogen and low-carbon fuels are another focus.

"Future Made in Australia is about renewable hydrogen and low-carbon fuels as well as critical minerals. These are areas where Australia has a natural advantage and where we can lead globally."

For Ayres, engineers will play a decisive role in scaling up. "It is going to take the application of engineering skills in order to build the infrastructure, build the systems and make sure that these industries can grow at the pace required."

Engineers at the centre

Ayres is unequivocal about the role of the profession. "None of this can be achieved without engineers as experts and practitioners, and also engineering leadership."

And he emphasises partnership. "Government must play its part, but the majority of this progress is going to be made in our private sector with government support, and that means everybody needs to step up. There's a responsibility on the government to provide the leadership, but there's also a responsibility on our manufacturing and engineering firms, our university sector.

"There is a world to win, and we're only going to win if we work together."

Ayres ends with a note of urgency, but also confidence.

"Putting our shoulder behind the wheel and being confident in each other that we can make the progress" is how he describes the challenge.

For him, Australia must not repeat the mistakes of automotive manufacturing. Instead, it must seize the opportunities in AI, green metals, hydrogen and advanced manufacturing – and ensure that engineers are at the centre.

"There's no progress in society without engineers," he said. The question now is whether the profession will seize this moment and not be bystanders to a wave of change, but leaders shaping a future made in Australia. □

Economic complexity and national resilience

Australia's recent fall to 105 of 145 countries for economic complexity – sitting between Botswana and Côte D'Ivoire – is a sobering reminder of the stakes. Falling complexity, Ayres argued, is "directly linked to declining research and development intensity and declining productivity".

Leadership in technological integration is not an abstract pursuit, but a pathway to economic sovereignty, he said.

"We can be an economy that goes up the value chain in minerals production, that adopts new technologies to make sure we're big in medical technology, in advanced manufacturing, that we're driving manufacturing opportunities in the renewable economy and the energy economy."

As told to Julia Abbondanza

Professional curiosity

At just 23, Colin Sheldon FIEAust CPEng found himself chairing a regional branch meeting of Engineers Australia. Surrounded by industry veterans, he learned the value of distilling complex ideas and speaking up when it mattered.

I **grew** up in Brisbane listening to my father's stories from his work as an electrical engineer. I enjoyed maths and science from an early age, and knew I wanted a career that involved problem-solving and practical thinking.

In 2008, I began a Bachelor of Engineering (Mechanical) at the University of Queensland. During my studies I received a scholarship from the mining company Anglo American.

After graduating, I went to central Queensland and regional NSW to work across several underground and open-cut mining sites. I spent about six to seven years in those environments and valued being close to the machinery and infrastructure. I liked the chance to get hands-on and be involved right at the coal face.

I also developed an interest in how assets and systems are managed over their full life cycle. That asset management theme for critical equipment and infrastructure shaped the second half of my career to my current role at Aurecon.

Accepting leadership opportunities

During my second year in the Anglo American graduate program, I attended a couple of Engineers Australia events in Emerald. At the local AGM the chair announced they would retire and asked who would take the role. Everyone looked at me, so I put my hand up. I was 23.

That decision began a long involvement with Engineers Australia. I moved from the regional branch to the Queensland Mechanical College Branch, then was elected to the National Mechanical College Board in 2019. I have served as chair of the board since 2023. This year is my final year in that role.

My Engineers Australia involvement has helped me access opportunities to sit on university industry advisory boards and the editorial board of academic journals, act as a discipline expert for the Australian Engineering Accreditation Centre, judge and select winners of Engineers Australia's Excellence Awards and also represent Engineers Australia on committees for the World Federation of Engineering Organizations.

It has truly opened many doors and chances to get involved.

LEFT: Colin Sheldon, Aurecon.

Steeped in standards

My early involvement with Engineers Australia opened a broader view of the profession and its interface with society and industry. Through that exposure, I joined Standards Australia's technical committee ME-018 Mining Equipment.

I then took part in the Standards Australia Young Leaders Program in 2017-18, which is now called the NEXTgen program. It was an enjoyable introduction to how standards are developed, and how the national and international systems fit together.

My standards work has expanded from there. I joined committees in dependability through the International Electrotechnical Commission (IEC) and in asset management through the International Organization for Standardization (ISO).

I was selected for the IEC Young Professionals program and was later elected as a Young Professional Leader in 2021. I also joined one of Standards Australia's board committees as a NEXTGen representative.

Standards work brought me into rooms with very experienced engineers. I was often one of the youngest people at the table. While I couldn't contribute decades of technical experience, I could offer the ability to listen, synthesise detailed input >

> "I was often one of the youngest in the room. I listened, synthesised the detail and helped move the work forward."

and capture it in a way that moved the work forward.

That willingness to put my hand up and be curious made a difference to the way I learned and contributed.

Conformity assessment became an adjacent focus. I volunteered as a technical assessor with the National Association of Testing Authorities, Australia (NATA) from 2018. In 2022 I was selected to sit on its Inspection Accreditation Advisory Committee.

ABOVE: Personal resilience has been present throughout Sheldon's career.

Embracing new tech

Mechanical engineering is changing as autonomous systems, AI, battery technologies and smart manufacturing become standard aspects of design and operations.

AI and machine learning are tools that allow more scenarios and more iterations to be explored quickly. That helps with design speed and helps lift productivity. For Australia, productivity matters if we want to be competitive. The ability to deliver outcomes faster and more efficiently affects how we compare internationally.

I have seen a strong capability that sits near the leading edge of the Australian mining sector. There is still room for innovation, learning from other industries such as manufacturing, which has adopted automation to improve productivity and safety.

Sustainability and decarbonisation goals have also shaped how I think about standards. When requirements are embedded upstream, compliance stops being a choice and becomes part of how a project is conceived. Embedding expectations early helps keep attention on long-term outcomes rather than treating them as an add-on.

Role of youth

Younger engineers can play a valuable part in this shift. >

ABOVE: Standards work has put Sheldon in rooms full of experienced engineers.

> "When requirements are embedded upstream, compliance stops being a choice and becomes part of how a project is conceived."

Curiosity and initiative matter.

You may not bring 30 years of history, but you can still add value by synthesising complex details, exploring new perspectives and testing ideas that have not been considered.

I encourage emerging professionals to be willing to express what they want to achieve in a project and suggest approaches that sit outside the usual pattern. I've been able to contribute to this shift more formally through mentoring in the Australian Academy of Technological Sciences and Engineering Industry Mentoring Network in STEM program, supporting PhD students as they explore pathways beyond academia.

There is also a role for leaders to recognise how expectations are changing for young engineers.

What mattered to leaders at an earlier stage of their career may not be what matters to today's early-career engineers. Acknowledging that change and making space for it supports momentum. It can also help organisations find solutions sooner in a competitive environment where there is a race to solve problems and bring results to market.

Resilience in action

Although my work at Aurecon now looks at resilience of our ageing infrastructure, the concept of personal resilience has been present throughout my career, even if I did not label it that way at the time.

For me, it was putting my hand up before I felt fully ready, stepping into unfamiliar forums and learning by listening. It involved staying open to what other industries were doing, and asking how those ideas might transfer into mechanical systems and mining contexts.

It also involved taking part in programs such as the Standards Australia Young Leaders program and the IEC Young Professionals program, building capability piece by piece.

Looking ahead

Recently I was appointed to the Board of Professional Engineers Queensland for a term of three years. The board was established to maintain public confidence in the standard of services provided by registered professional engineers.

I remain interested in integration. New technologies work best when they are folded into mechanical systems in ways that respect how those systems already operate.

AI and machine learning help us run the numbers and test ideas quickly. Standards and accreditation help set clear expectations.

Contributing to both practice and the ecosystem around practice has been a rewarding path. It began at the coal face, continued through Engineers Australia and Standards Australia, and grew through IEC and ISO work and through NATA.

Each step added a tool or a perspective that helped with the next step.

Looking ahead, I see opportunities for Australian engineers who are prepared to be curious and deliberate. Integrating new tools such as AI will continue to open design pathways. Learning from other sectors will remain a useful habit.

Building requirements into projects early will keep attention on outcomes that last.

I started by listening to more experienced voices and writing things down carefully, and I am still on a lifelong learning journey.

This approach continues to help me contribute to work that affects how systems are designed and maintained, and how teams learn from one another. □

Emerging technologies in construction

It’s well known Australia’s construction sector needs to improve its productivity. Emerging tech such as building information modelling, AI, digital twins and unmanned aerial vehicles can cut costs, boost safety and close skills gaps – but urgent adoption is essential.

Words by Mia L Chaaya, Lucia M Sarkis and Faham Tahmasebinia

This essay is a summary of the original article, ‘Integration of Emerging Technologies with Construction Practices in Australia’, Buildings, 2025, 15(3), 396. https://doi.org/10.3390/buildings15030396

The construction industry is the fourth largest contributor to the Australian economy.[1] Despite this importance, its productivity has fallen by 1.6 per cent since 1990, while other industries have grown by 35.2 per cent.[2] This widening gap costs the nation around $47 billion every year.[3]

At the same time, vacancies for skilled workers have risen by 80 per cent since 2019, leaving the industry short by about 105,000 professionals.[3,4] Building defects add another $6.2 billion to the economic burden[6], and workplace injuries and illnesses linked to construction reduce national output by a further $28.6 billion annually.[5]

These challenges point to the urgent need for a new approach. The rapid digitisation of other industries after the COVID pandemic, coupled with the growing accessibility of artificial intelligence tools such as ChatGPT, has made clear the potential for technology to reshape construction.[7-10] Industry 4.0 theory positions digital transformation as a requirement, not an option.[7]

This study examined how emerging technologies are being used in Australia's construction sector, the barriers to wider adoption, and the steps needed to prepare the next generation of professionals.

Materials and methods

The research used a mixed-methods approach. Interviews with senior professionals provided qualitative insights, while surveys gathered quantitative data from Tier 1 and Tier 2 firms.

> "A survey of recent graduates showed low awareness of emerging technologies, particularly AI and digital twins. This mismatch suggests that universities must update curricula if they are to prepare students for the expectations of industry."

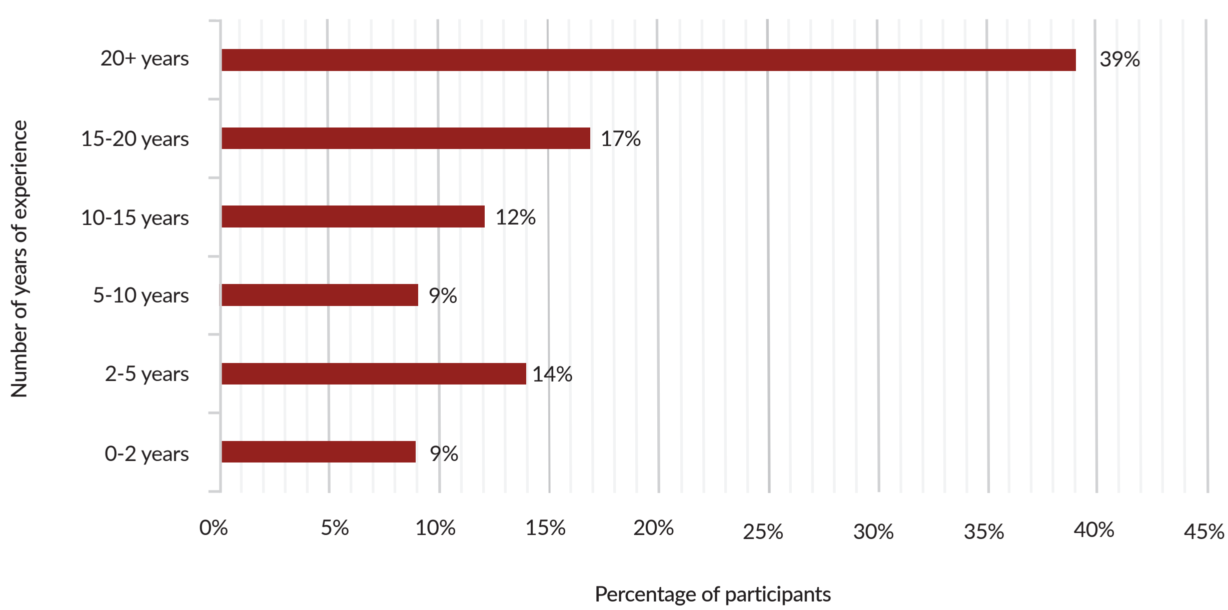
Together, these inputs helped identify both current practices and future expectations. The study also developed an evaluation tool to help companies benchmark their progress with emerging technologies and to measure how well graduates understand these tools.

Cost controls

Globally, new technologies are changing construction. They offer improvements in cost control, safety, delivery timelines and overall quality. The most relevant to Australia include:

- Building information modelling (BIM) improves collaboration and reduces rework by integrating design and construction data.[12] >

Figure 1: Survey participants' years of experience in the construction industry



- AI helps predict risks, automate design optimisation and enhance safety monitoring.[13]
- Digital twins provide real-time simulations of assets, improving lifecycle management and reducing defects.[14]
- Virtual and augmented reality (VR/AR) support training, design visualisation and faster decision-making onsite.[15]
- Sensors and connected devices monitor structural health, environmental conditions and worker safety in real time.[16]
- Unmanned aerial vehicles (UAVs) allow safer and more efficient site inspections, surveys and progress tracking.[17]

While global uptake is increasing, Australian adoption remains slow due to cultural conservatism, regulatory uncertainty and skills gaps.[18-19]

Current adoption

Among large contractors, BIM is already in wide use, but smaller firms are slower to adopt it. AI and digital twins are mostly in pilot phases. VR and AR tools are used for training and client presentations. UAVs and sensors are the most visible on-site tools, especially for inspections and monitoring.

Barriers

Survey participants identified five key challenges:

- High upfront costs for software, hardware and training
- Resistance to change in a conservative industry
- A shortage of graduates with relevant technical knowledge

Figure 2: Current importance of emerging technologies in Tier 1 firms

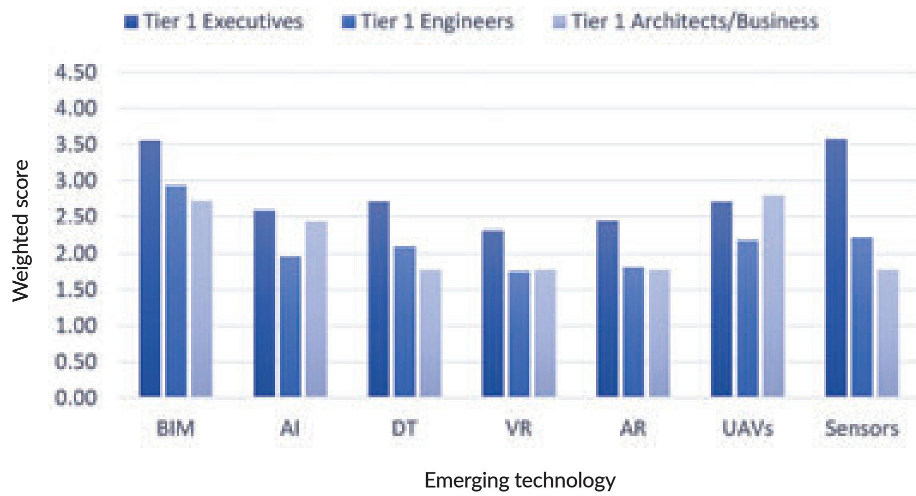
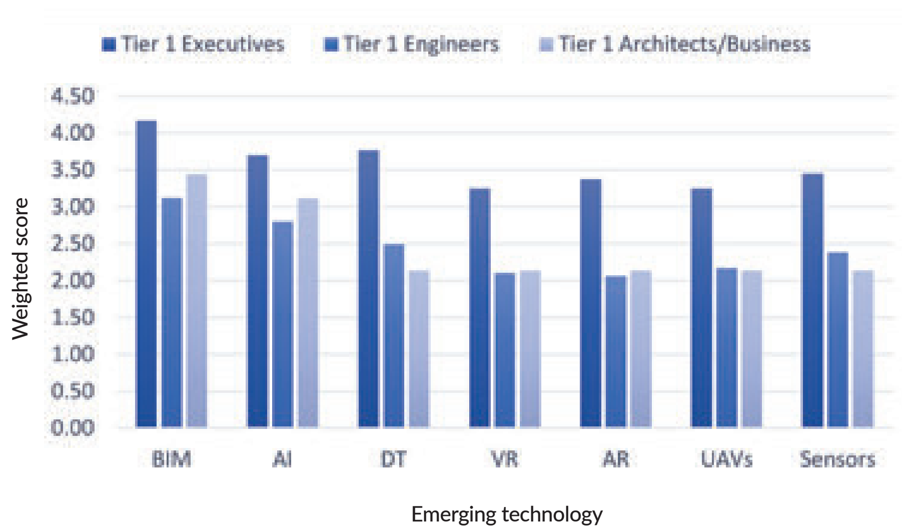


Figure 3: Importance of emerging technologies in reducing costs in Tier 1 firms – current and projected adoption levels; graduate preparedness chart



"Adopting these measures could help close the $47 billion productivity gap, improve safety outcomes and position the Australian construction sector as a global leader."

- Regulatory uncertainty about digital standards
- Industry fragmentation that slows coordinated adoption

Anticipated adoption

Tier 1 firms expect to accelerate adoption of AI, digital twins and sensors over the next five years to remain internationally competitive. Tier 2 firms are more cautious, but see UAVs becoming routine because of their proven safety and efficiency benefits.

Graduate preparedness

A survey of recent graduates showed low awareness of emerging technologies, particularly AI and digital twins. This mismatch suggests that universities must update curricula if they are to prepare students for the expectations of industry.

Discussion

The findings reveal a paradox. The sector understands the potential of new technologies, but continues to delay implementation. Industry 4.0 provides the framework for transformation, but cultural and systemic barriers remain.[7]

The pandemic demonstrated how fast other industries could move when forced to digitise.[8] In contrast, construction has been slower to act. Without change, the sector risks losing further ground as AI and automation reshape global practice.



ABOVE: Mia L Chaaya, Lucia M Sarkis and Faham Tahmasebinia.

Skills shortages add urgency. Without graduates trained in tools like BIM, AI and digital twins, firms cannot realise the benefits of innovation.

The opportunities are clear. UAVs and sensors can make worksites safer. BIM and digital twins can reduce costly defects and overruns. VR and AR can help projects stay on time by aligning stakeholders early.

Achieving these benefits requires coordinated action from industry, academia and government. Incentives, training programs and clear regulatory standards are critical.

Recommendations

This study shows that emerging technologies can help solve Australia's productivity, safety and cost challenges, but adoption is still in the early stages. The need for action is urgent.

Industry should invest in BIM, AI, digital twins and UAVs, and make them standard practice.

Universities should align engineering and construction curricula with Industry 4.0 skills.

Governments should provide funding, incentives and regulatory clarity to support transformation.

Adopting these measures could help close the $47 billion productivity gap, improve safety outcomes and position the Australian construction sector as a global leader. □

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[Ideas]

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When engineers bring automation into a project, it's not just about what the tech can do – it's about what it should do.

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Advanced manufacturing is less about what you make and more about how you make it.

BLUE-SKY THINKING

We asked three experts: When embedding tools such as AI and automation into new projects, products and systems, what do engineers need to consider to ensure ethical outcomes?

CRAIG McGRORY is Chief Transformation Officer at ACCIONA

Australia faces a huge challenge: in the next 20 years, we need to build an enormous amount of infrastructure. At present, we're doing it inefficiently. Ours is already one of the most expensive markets in the world for delivering infrastructure, so we need to find smarter ways to harness emerging technologies that drive efficiency, reduce costs and ultimately deliver better outcomes for society. In this context, adopting new technology isn't optional – it's essential.

But we must start with purpose. This isn't about chasing the latest shiny tool. The real question is: how does this help us achieve better outcomes for society? That means improving efficiency, lowering costs and strengthening governance, all while keeping sustainability at the core.

Of course, there are ethical concerns – most notably, whether technology replaces jobs. But in engineering, this isn't the issue. Right now, we simply don't have the workforce to meet Australia's infrastructure demands. Technology isn't about replacing people; it's about enabling us to do more with the skilled workforce we already have. That requires reskilling, better communication, and helping engineers develop inquiry and problem-solving skills that drive real progress. If we strike this balance, tools such as AI – and, soon, quantum computing – could become catalysts for sustainable change, rather than just another wave of technology.

We also need to confront the unintended consequences. Advanced tools demand greater power and water consumption, which is a serious concern. But ignoring them isn't an option. Instead, we must engineer more efficient solutions to mitigate their environmental impact.

Whatever efficiencies we achieve, human accountability must remain non-negotiable. AI, for example, should support decision-making, not replace it. AI's role is to gather and interrogate information, offering insights that help us make smarter, faster and more ethical choices. But the responsibility for those choices must remain firmly with the engineer.

Finally, we need to resist using these tools lazily. Superficial answers are not enough. We must demand depth, context and genuine understanding – outcomes that depend on the inquisitiveness and critical thinking that define great engineers.

"We also need to confront the unintended consequences. Advanced tools demand greater power and water consumption, which is a serious concern."

ARTIFICAL INTELLIGENCE

MATT GIJSELMAN is Director – Infrastructure Policy Advancement (APAC) at Bentley Systems

When engineers bring AI or automation into a project, it's not just about what the tech can do – it's about what it should do. Ethical outcomes do not happen by accident; they need to be designed in from the start. That means asking who benefits, who might be excluded and how decisions made by machines affect real people.

It also means recognising that we now have much of the technology we've been looking for. The challenge is no longer capability – it is culture. We need to build the leadership, incentives and institutional muscle to use these tools effectively and ethically.

Engineers play a vital role, but they can't do it alone. That is why ethical engineering demands collaboration – with communities, ethicists and other stakeholders – to ensure systems reflect a broader set of values and lived experience. Ultimately, it's about trust. If we want the public to embrace these tools, we have to show we've thought through the risks, not just the rewards.

> "It's about trust. If we want the public to embrace these tools, we have to show we've thought through the risks, not just the rewards."

RUTH LEWIS MIEAUST NER is Vice President of Standards for the IEEE Society for Social Implications of Technology, a futurist and Director of Technology Foresight Consulting

As engineers embed AI and automation into projects, products and systems, ethical responsibility must sit alongside technical excellence. Professional codes of conduct make it clear engineers are not only problem-solvers, but also custodians of technologies that shape people's lives and the environment. Designing with ethics at the forefront is about ensuring innovations contribute positively to society while avoiding foreseeable harms.

This is no small task. Generative AI, robotics and autonomous systems are transforming industries at pace. They can streamline operations, improve safety and expand human capability. Yet they can also be exploited by malicious actors, amplify bias or erode trust if they rely on inaccurate or unrepresentative data. Engineers must anticipate both intended uses and potential misuses. Protecting data provenance, ensuring accuracy and securing informed consent are critical steps in respecting those whose information underpins these systems.

Meeting these responsibilities demands an expanded engineering mindset. Beyond functionality and sustainability, practitioners need to incorporate design techniques that deliberately consider ethical, cultural and societal implications.

This means engaging with stakeholders, mapping risks and building in processes to monitor and evaluate outcomes long after deployment.

Encouragingly, global frameworks are emerging to support this shift. Standards such as ISO/IEC/IEEE 24748-7000:2022 provide structured methods for addressing ethical concerns throughout the design life cycle. By adopting these approaches, engineers can strengthen their capacity for moral reasoning and create systems that serve both innovation and integrity.

Ethical design is no longer an optional extra. It is an essential capability for shaping technologies that will define our collective future. □

On-demand webinar: Navigating the ethics of AI: building skills for responsible engineering

A tunnel boring machine being assembled on the West Gate Tunnel project in Melbourne.

Cognition shift

WORDS BY LACHLAN HAYCOCK

Large-scale infrastructure projects often span decades, yet the materials and technologies involved can become obsolete in a fraction of that time. Here's how Australian engineers are embracing modular, future-ready systems designed to embrace change.

Nobody expects the newest iPhone to reflect the latest level of technological innovation a decade after it's manufactured. For Kumar Srinivasan MIEAust, Director of Risk and Insurance at UTS, the principle is the same for long-term infrastructure projects, and the extended life cycles of these projects is the primary cause.

"Consider it in the context of the Sydney Metro," Srinivasan, who was the project's former Chief Risk Officer, told *create*. "Projects such as this typically have a life cycle of more than 10 years from inception to delivery completion and full operation. Numerous technological changes will emerge during that period.

"When we initially designed the tunnel infrastructure for some sections of the rail corridor, 4G was the prevailing technology. However, 5G had arrived by the time construction work was underway, and integrating 5G infrastructure into the tunnels at that stage wasn't easy.

"It wasn't as simple as running a different type of Ethernet cable along the tunnel wall. It was also about the contractual levers and the restrictions for engineering practice that come with that.

"Infrastructure projects must anticipate technological evolution and embed flexibility into their design and contractual frameworks to avoid potentially costly retrofits."

Considerations around the digital architecture – which may not be installed for many years after a project breaks ground – must be "baked into" the project timeline, he said.

"It's about having the ability to embrace both current technologies and what emerges in the coming years, and designing the broader infrastructure in a modular fashion. Embedding adaptability into infrastructure design isn't just a technical >

necessity. It's a strategic imperative for long-term resilience."

This means considering a project's scope according to the standards of the day, rather than the standards of when it was briefed – a tricky ask, given how much it strays into future-prediction territory, but nonetheless vital for the future viability and profitability of large-scale projects.

Ultimately, flexibility isn't just a design principle. It is also a strategic safeguard against obsolescence.

ABOVE: Kumar Srinivasan MIEAust, UTS.

BELOW: An Australian Navy frigate.

"Certain integration risks and constraints became clear to us, because what was powerful enough to run the computing in the 80s and 90s was fundamentally different to what was needed in 2007."

Inconceivable innovation

An area in which engineers are constantly grappling with the threat of technological obsolescence in long-term projects is defence manufacturing.

In her early career, Amanda Holt FIEAust CPEng, CEO of defence systems integrator SYPAQ, worked on major ship build and upgrade programs within the Australian Navy. One of her first programs of work involved the upgrading of the combat management system of navy frigates.

"That experience gave me insight into how these ships – which stay in service for 30-odd years – are incredibly expensive and complex pieces of equipment with a lead-time of decades," Holt said. "For some elements, such as the ship hull, there are opportunities for preventative and corrective maintenance throughout its lifetime. But fundamentally, large elements of the design don't change for decades.

"Then there are other elements, such as how the radars will perform and how the weapons systems will integrate, which need to be managed to ensure a ship is fit-for-purpose for decades to come – and in ways we can't even conceive of right now."

On those programs, she observed how the original design decisions made – including those around space, weight and power – inhibited or encouraged the flexibility of and the adaption of future technology in the finished product.

"Certain integration risks and constraints became clear to us, because what was powerful enough to run the computing in the 80s and 90s was fundamentally different to what was needed in 2007, when I was working on the program."

Systems engineer Professor Alex Zelinsky AO, Vice-Chancellor at the University of Newcastle, prefers to reframe the topic of rapid technological change as an opportunity for innovation, rather than a problem of future obsolescence.

"The days when a project had a single lead or hero engineer are long gone," he told *create*. "More and more we work in teams. These teams need to be flexible and agile, and come together in a way that allows new engineering solutions to be created, because we're now seeing systems of systems being built. One team might be responsible for one system, and another team for another system.

"A good example of this is the F-35 fighter jets. There are about 20 million lines of code in the software that flies those planes; they're under total software control. There are the propulsion systems, information systems and safety systems for the pilot. They're incredibly complicated, and no one person is singularly responsible for their engineering." >

CASE STUDY
Suburban Rail Loop

Planning for adaptability at project inception

Melbourne's rail network spreads its tendrils out from the CBD, with the only connections between them being other modes of transport such as bus or tram. That will change with the Suburban Rail Loop (SRL), a 90-km rail line linking the city's middle suburbs.

SRL East, the first section of the line to be delivered and the first to enter construction (in 2022), features 26 km of twin tunnels and six new underground stations. But tunnelling will only start in 2026, and that section of the line won't open until at least 2035.

That means numerous rounds of updates to rolling stock, signalling and other rail technology – not to mention upskilling of the workforce across decades – making innovation and adaptability essential.

That's why, when tunnelling does commence, an innovative ground-freezing technique will be used to build some of the safety passages between the twin tunnels, avoiding the need for ground treatment from the surface – reducing disruption to residents and roads on the surface by more than 90 per cent.

"The ground freezing technique involves pipes drilled deep underground and injected with chilled brine [salt and water]," a Suburban Rail Loop Authority spokesperson told *create*. "The brine will temporarily freeze the surrounding soil, stabilising it and making it safe for our teams to build the safety passages."

A "kit of parts" model will be used for station floors, walls, ceilings, seating, lighting, signs and fixtures, as well as the mechanical, electrical and plumbing of the SRL East stations.

"Making these station parts modular and then putting them together will save time and money, streamlining construction and reducing defects, delays and the associated costs," the spokesperson said.

The kit of parts simplifies training, construction, maintenance and replacement of elements, reducing complexity and cost, improving sustainability outcomes, and promoting effective collaboration between architects, engineers and builders.

"This model also increases worker safety as it requires offsite construction in a controlled manufacturing environment, rather than on an active construction site where multiple trades and activities occur at the same time."

AT A GLANCE

90 km
OF RAIL LINE LINKING MELBOURNE'S MIDDLE SUBURBS

26 km
TWIN TUNNELS

6
NEW UNDERGROUND STATIONS FOR SRL EAST

The former Chief Defence Scientist of Australia pointed to the country's submarine programs – both the current fleet of Collins-class craft and the future AUKUS arrangement – as another instance of incredible complexity matched with a demanding future standard.

"Submarines, some of the most complicated machines ever built, need to be built to be extremely reliable, but with redundancy built in," he said. "If one engine fails, an immediate backup is needed. The Collins-class submarines rely on a diesel engine that charges batteries so they can operate quietly underwater. All systems must be tested and assured for safety. A submarine's batteries must not catch fire and risk disaster. In future, batteries could make use of lithium due to their efficiencies, but how can we engineer components and systems to be isolated in the event of fire?

"To maximise safety and flexibility, and to ensure you have the superior solution, you need to achieve a balance between proven that have become limited over time, and innovative technology that may come with risks that are not well-understood."

Rapid refresh

The solution is relatively simple. It's about embedding integration flexibility at the earliest stage.

"When you're dealing with large and complex infrastructure, the convenience and sheer speed often causes people to have a

"To maximise safety and flexibility – and to ensure you have the superior solution – you need to achieve a balance between proven and innovative technology."

ABOVE: Sydney Metro dive track laying at Marrickville; Alex Zelinksy AO, University of Newcastle.

blinkered view of the project," Srinivasan said. "They simply aren't able to see the bigger picture, and that's where risk engineers come in.

"Integration flexibility is about ensuring that, as part of the procurement of the project, the contract is written in such a way that engineering companies can intervene and make changes without being penalised. It's

IMAGE: Sydney Metro.

not necessarily an engineering outcome – more a contractual outcome – but engineers will need to do this as part of the controls environment."

Projects such as Snowy Hydro are "really cutting-edge" in terms of the integration flexibility being shown, Srinivasan said.

"Some of the design augmentations made due to technological transitions have, in some instances, meant a reduction of up to 40 per cent of the cost of integration," he said. "They achieve this by looking at the whole life-cycle cost.

"Take an asset built to last for 100 years and ask how many times a technology change would occur in that period. If there are five technology changes, >

CASE STUDY
EastLink

Using new technology to tackle unseen challenges

Cutting-edge construction techniques were necessary on the EastLink road project in Melbourne in the 2000s.

A $400 million tunnel under the Mullum Mullum Valley was the single largest, and most challenging, element of construction, requiring a fully watertight tunnel design at all times, rather than a tunnel that allowed water in and later drained that water out.

According to a report on the project by *World Highways* magazine, "achieving water tightness involved having a circular cross-section for the tunnel and using a drainage blanket and waterproof membrane lining".

"A system using curved precast concrete floor units, sitting on temporary blocks on the membrane, allowed a flat top to be constructed so that trucks could run by. Temporary rails on each side supported two gantries in each tunnel to assist with construction including concrete pouring."

The toll road was one of the first to upgrade its tunnel ventilation system to dynamic ventilation on demand with partial portal emission.

The originally commissioned tunnel ventilation system was designed to expel 100 per cent of tunnel air through 45 m-high ventilation stacks.

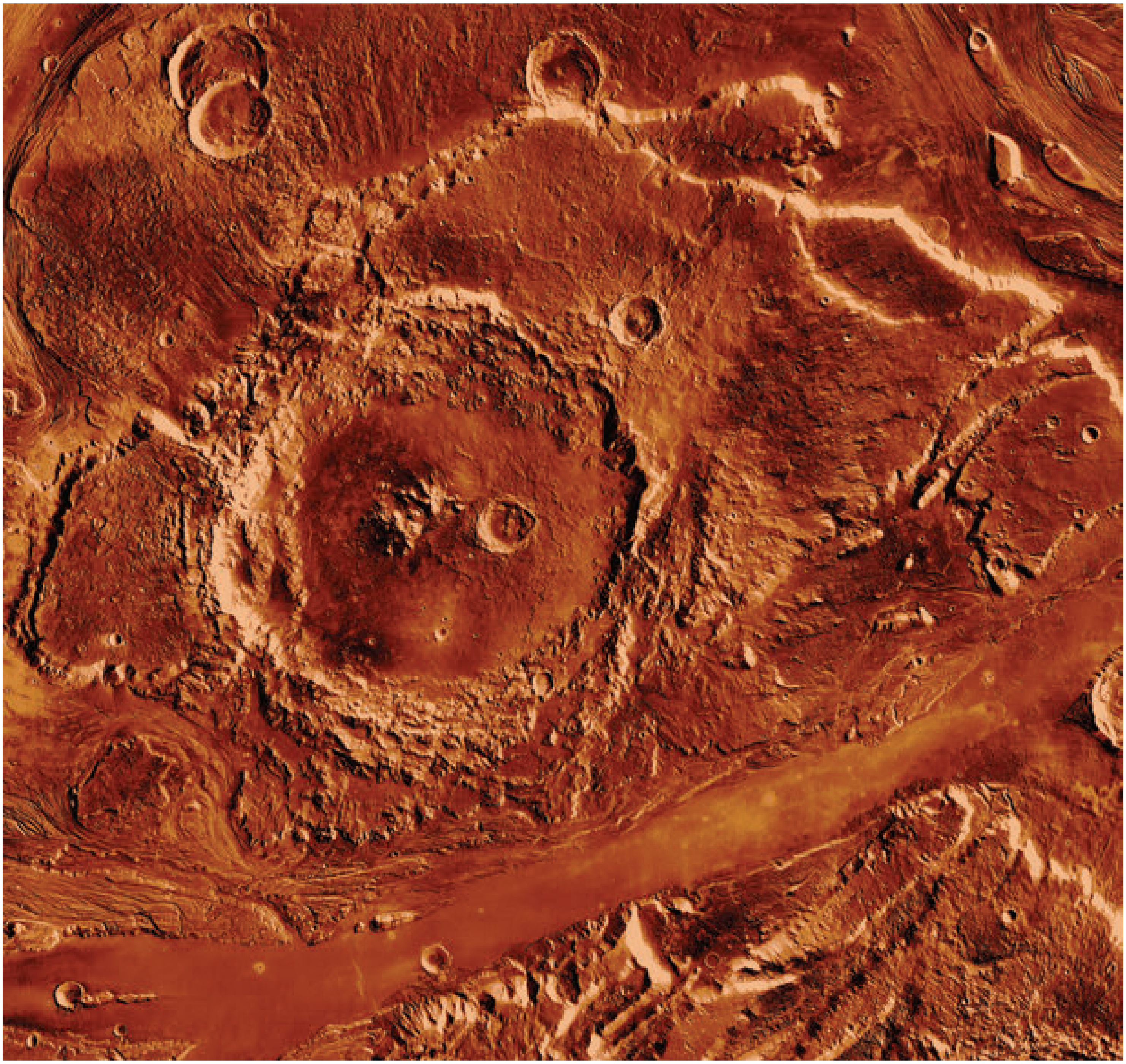
The upgraded system allowed real-time adjustment of ventilation fans based on actual tunnel conditions rather than fixed cycles, achieving a power use reduction of up to 70 per cent, and 9000 t fewer greenhouse gas emissions each year.

AT A GLANCE

TUNNEL COST
$400 million

THE UPGRADED VENTILATION BROUGHT A POWER REDUCTION OF UP TO
70%
AND
9000 t
FEWER GREENHOUSE GAS EMISSIONS EACH YEAR

BELOW: Melbourne's EastLink highway.



with each life cycle being 15-20 years, that's roughly five shifts in those 100 years. Then ask how to design things so retrofitting becomes easy."

This shift in thinking is bringing benefits beyond the financial.

"The hardest lesson anyone can learn is that they should have prevented a problem back at the planning stage," Srinivasan said. "But sometimes, the reality is that executive decision-makers won't acknowledge a mistake has been made or a better option was possible. They'll typically say their team acted in line with the information available at that point in time.

"I see that as sleeping behind the wheel."

For Holt, there's a tension between new and old-school ways of thinking.

"Previously, it seems to me, engineers sought to lock down a project and establish a clear baseline that didn't get changed unless absolutely necessary – because change costs money and introduces schedule delays," she said. "They did this rather than realise that cost blowouts and schedule delays will also emerge if bad decisions are made during the design phase.

"Take the example of battery technology. We get better power density on more or less an annual refresh cycle. Most of the battery manufacturers now have established that we don't need to redesign all of our connectors >

ABOVE:
The pace of change in robotics and drone technology is immense.

CASE STUDY
OneSKY

Integrating air traffic control systems

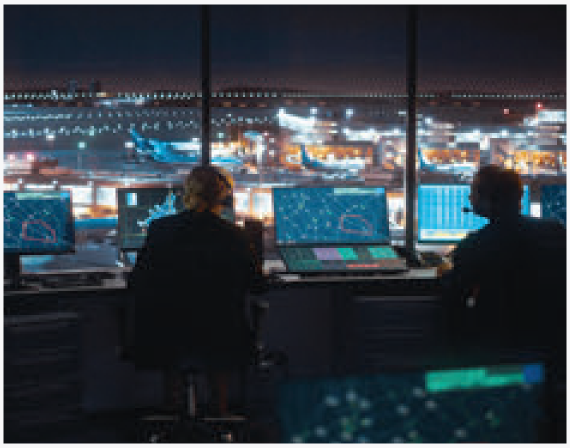
When it comes to the complex and high-risk realm of air traffic management, a system of systems approach is necessary.

A joint effort by Airservices Australia and the Department of Defence, OneSKY aims to replace discrete civilian and military air traffic control systems with a single unified system. The Civil-Military Air Traffic Management System (CMATS) will allow both civil and military air traffic controllers in Australia to access a shared view of the Australian-administered airspace.

In addition to automating air traffic control management, CMATS also integrates voice communications, record-and-replay, maintenance management and other support systems. The upgrade is intended to also benefit integration of more uncrewed systems into the country's airspace.

"One of the challenges of the OneSKY program, which is also to its benefit, is bringing the civilian and military sides of air traffic management together," SYPAQ CEO Amanda Holt said. "That's where you encounter real risks around different regulators, customers and cultures. And that's a very difficult thing to write into a specification.

ABOVE:
Amand Holt FIEAust CPEng, SYPAQ.



"What we see in a number of these step-change capabilities that are being introduced is that it's not just about writing a specification about what the software needs to do. It's about understanding the actual use case and the environment it needs to be designed for – or accepted into – and then managed through life.

"Fundamentally, this is a software system being delivered, so there will be changes to the operating system. As a result, it will require changes in cybersecurity requirements and communications. What gets delivered on day one is absolutely going to change months or years down the track."

every year, so the form factor remains essentially the same.

"The higher performance means engineers can substitute out the power cells used last year for the cells available this year. And the better power density means that drones will fly for longer, for instance – because a 5 per cent improvement in power density means a resultant improvement in endurance."

This rate of change of technology is particularly pronounced in electronics, software adaptation, AI algorithm development and even sensor processing capabilities, Holt said.

"These days, the technology refresh cycle is probably 18 months. In some disciplines, it's even faster. If we continue to take an old-school mindset, we'd spend just as long designing an engineering system to perfection, but wouldn't actually end up with componentry or elements that are particularly innovative anymore.

"We'd be designing ourselves out of relevance." □

BELOW: Constructing the new Western Sydney Airport.

"If we continue to take an old-school mindset, we'd [design] an engineering system to perfection, but wouldn't actually end up with componentry or elements that are particularly innovative anymore."

From the Chief Engineer

Words by Katherine Richards
HonFIEAust CPEng EngExec

As we embrace the challenges of designing and delivering the mega projects of the future across all sectors, it is a timely reminder for engineers to lead rather than be led by technology.

The digital DNA of our work is just as important as the physical things that we design and build.

Being a digital native, in a technical sense, is not just about applying a software tool or model to understand a problem. That was our past.

Today, as engineers we need to harness the full suite of technologies – including AI in all its forms, to help us understand our risks, our environment and our opportunities.

But amidst these changes and the adoption of new ways of working – it is equally important that we do not lose sight of the value of critical thinking and exercising engineering judgement. These are perennial values of our profession. These are the skills that we need to exercise every day to deliver the solutions that our society demands of us.

Productivity gains

As productivity slows, the digital revolution in engineering and construction has long been promised. So what's holding it back, and how do we find a way forward?

WORDS BY CHRIS SHEEDY

Over the last three decades, labour productivity in the Australian construction industry has barely budged, according to the Australian Bureau of Statistics and the Productivity Commission. Meanwhile, general market-sector industries have seen productivity increase by 64 per cent over 30 years, and manufacturing by 58 per cent, construction has languished at just 17 per cent growth.

For Martin Loosemore, a Distinguished Professor of Construction Management in the Faculty of Design and Society at the University of Technology Sydney, much of this lack of productivity growth comes down to the sector's "relative lack of investment in technology".

Studies by the American Construction Industry Institute, Loosemore said, reported that greater technology use could increase construction productivity by 30-40 per cent. Similarly, in Malaysia researchers say productivity differences between large and small construction firms were due to differences in capital intensity, or machines for labour substitution, rather than labour productivity.

And so it shouldn't be surprising that "an analysis of labour productivity in the Australian construction industry also identified technology-utilisation deficiency and a low capital-labour ratio as the main influencing factors", Loosemore said.

Eric Bugeja CPEng, chair of buildingSMART Australasia and board member of buildingSMART International, told *create* that both a cause and an outcome of this lack of digitalisation is a highly fragmented, paper-based sector that regularly suffers costly rework issues and project delays.

BY THE NUMBERS

GENERAL MARKET SECTOR INDUSTRY PRODUCTIVITY INCREASED

65%

OVER 30 YEARS

MANUFACTURING SECTOR INDUSTRY PRODUCTIVITY INCREASED

58%

OVER 30 YEARS

CONSTRUCTION INDUSTRY PRODUCTIVITY INCREASED

17%

OVER 30 YEARS

Source: Australian Bureau of Statistics (2024)

ABOVE: Martin Loosemore, UTS; Eric Bugeja, buildingSMART.

"There is no shortage of digital tools and new technologies that promise to improve every stage of project delivery, but they're not being employed," he said.

A reluctance to introduce technology is something Bugeja has witnessed over decades. As a graduate mechanical engineer, he worked in a two-person design business whose owner was keen to employ the latest technology to drive efficiencies and performance.

"Most graduates went into a big company and were told, 'This is the way we do things', but I had an opportunity to explore what was available, including 3D engineering design software. >

IMAGE: VIDA.

I used it to improve the way we designed things," he said.

"When I joined a larger engineering consultancy, I was asked to do a particular design. I opened up their 2D CAD software and thought it was ridiculous. CAD was made for drafting and not necessarily as an engineering design tool. And so I grabbed some advanced 3D software I'd used in the past and had that design done within 24 hours.

"Of course, the business said it couldn't submit that to the client because they'd allowed two weeks to do the work."

Trickle-down technology

Bugeja's tale describes a microcosm of the construction and engineering space, one in which much more could be achieved in significantly less time and by using far fewer resources. It's a productivity problem with a solution that has long been hiding in plain sight, and engineers that buy into that solution have a lot to gain.

"If we look at the future of AI, I think that will divide the market," Sandra Lang, Director of Digital Engineering at Systra, told *create*. "There are companies that are investing, and they will clearly set themselves apart from those that are not investing."

The current top-down digital leadership being demonstrated in Australia by organisations such as Transport for NSW, is a promising sign, Lang said.

"I think Australia is near the forefront when it comes to clients mandating digital requirements in their contracts. Some countries in Europe are also quite strong.

"This digital transformation has to start with government clients. The construction industry is so focused on managing risk, and digitalisation is currently considered a risk factor. The industry is so conservative, and if it doesn't have to change, it won't change."

"This digital transformation has to start with government clients. The industry is so conservative, and if it doesn't have to change, it won't change."

ABOVE: Sandra Lang, Systra; David Murphy, VIDA.

Another challenge for the sector's technological transformation comes from the supply chain, Lang said. It's all well and good for large players to have their own focus on digital transformation, but if the smaller subcontractors aren't on board, the change is not going to stick.

David Murphy, Director of Transformation and Innovation at the Victorian Infrastructure Delivery Authority (VIDA), said when the bigger organisations build their own IP in the technology space for their own competitive advantage, it often works against them.

"You can't get the scale that way," he said. "Individual company pipelines and available capital funds are rarely large enough to facilitate the investment and necessary development and support. The App Store model is a more scalable one. I think sometimes we're tying ourselves in knots to force people to work within a particular organisation's ecosystem."

For subcontractors working on different sites, Murphy said,

ABOVE: Pakenham roads upgrade, part of Victoria's Big Build.

it's the equivalent of them having to carry, and be familiar with, the operating systems of an iPhone, a Motorola phone, a Samsung phone and a Google phone, while jumping between the Telstra, Vodafone and Optus networks, just to receive phone calls.

"It's causing massive inefficiency for the supply chains and subcontractors. It's very hard to know everything about every platform in a low-margin sector.

"Success in the future will revolve around how well the best players in the ecosystem can bring interfaces together."

Overseas comparison

The State of Digital Adoption in the Construction Industry 2025 report, published by Deloitte Access Economics and Autodesk, puts Australian construction businesses in the middle ground for digital adoption, when compared globally.

> "We're not saying we don't want innovation or improvement. But we do want to control the starting point, which allows us to manage innovation and ensure there are no unintended consequences."

The report said Australian construction businesses use an average of 6.9 types of technology, such as:

- Construction management cloud software
- Mobile apps
- Data analytics
- BIM
- Smart sensors
- Construction wearables

This compares to India with 8.6 technologies, Singapore with 7.3, Malaysia and Hong Kong both with 6.3 and Japan with 2.7.

The top three benefits for construction businesses utilising technology in Australia, the report said, are:

- Improved efficiency
- Uncovering of new insights and ideas
- Increased revenue

The report said that, as an example, the company Built is currently piloting a digital project delivery tool, developed in partnership with Autodesk, to "facilitate data sharing between all stakeholders, create digital-first designs and provide real time results of potential risks and feasibility of projects".

"The pilot has led to 50 per cent faster starts onsite with 50 per cent fewer defects in the finished structures," the report said.

The top three barriers to digital adoption, on the other hand, are:

- Lack of digital skills
- Cost and uncertainty around required skills
- Limited technology budgets

More regular training, the report said, is vital in Australia as only 25 per cent of Australian construction businesses offer regular digital skills training.

Best-practice baseline

At Laing O'Rourke, a good deal of time was previously spent up front on each project deciding on the best technological and digital approaches, said Tom Mullens FIEAust CPEng EngExec, Director – Technical and Health & Safety.

More recently, Mullens and his team brought together this knowledge to develop Digital Minimum Standards for all Laing O'Rourke projects in Australia, >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setting "a new baseline for best practice".

"We want to push the boundaries of what's possible, but we also want to deliver certainty," he said. "And if you're constantly innovating, there's a high chance you'll miss something.

"We're working in regulated industries with defined outcomes on our projects, bringing together groups of specialists and working with various design partners and supply chain partners. Our approach now is to bring together all of that experience to set a baseline.

"We're not saying we don't want innovation or improvement. But we do want to control the starting point, which allows us to manage innovation and ensure there are no unintended consequences."

Laing O'Rourke's Digital Minimum Standards outline how designers are asked to develop digital models and assign required data. It also covers processes for digital design and constructability reviews, virtual build planning and the use of site technology, including how teams plan access, ensure safety and report on site activities.

"What we present outwardly gets broken down so supply chain partners only get what they need and what's relevant to their scope," Mullens said.

"One of the key conversations is the one with our designers. The model they produce has so many benefits. We use it across the physical build, but we also use it for costing our quantity take-off, our material ordering and our quality assurance. We can use it with stakeholder and community engagement and more. If it's done in a certain way, it brings significant value to a project and a client."

ABOVE: Tom Mullens, Laing O'Rourke.

BELOW: BIM technologies are changing construction.

Integrating technology

Clearly, working well with technology involves a lot more than just downloading a new app and attending a few courses.

Loosemore said that, as an increasing number of construction and engineering businesses begin to experiment with existing and emerging technologies, including BIM, augmented and virtual reality, the Internet of Things, drone data and mobile sensing, they will fail to fully capitalise on them.

That's because they will focus on the technology itself as opposed to the changes within the organisation – across knowledge, engagement and culture – needed to integrate the technology effectively.

"Technology is just a small part of the story," Loosemore said. "Recent research into successful technology implantation offers business leaders a number of important lessons."

These lessons include:

- Stay rational
  Technology is a means to an end, so don't chase shiny tools.
- Collaboration is essential
  If the supply chain isn't on board, you fail.
- There will be resistance
  People, structures, systems and cultures will need to be change-managed.
- Focus on strategy
  Look for strategic game-changers that can provide competitive advantage.
- Move incrementally
  Build on existing initiatives instead of trying to do everything at once.

Technology requires an integration strategy. Without a vision, plan and strategy, tools can become overwhelming.

Bugeja said it's important that systems are designed in such a way that they produce data in a format that is openly accessible across platforms, organisations and sectors. >

"An analysis of labour productivity in the Australian construction industry also identified technology-utilisation deficiency and a low capital-labour ratio as the main influencing factors."

"This is where the digital engineering BIM-based workflow comes in," he said. "It's all about getting all the people who are going to be involved with the project, including operating the building or the rail, or whatever it is, involved at the start.

"This allows the data backbone to be set up in a way that as the data is collected along the life cycle of a project, it simply plugs in and is not rebuilt at each handover stage."

New superpowers

When data is produced during a project then handed over on paper, or in a format that doesn't readily integrate, it remains equal to the sum of its parts. That is to say, the data is only as useful as it was decades ago.

However, Lang said, when data is collected and provided in a structured way, and combined with other tools such as sensors providing live data, its value is far greater than the sum of its parts. It offers superpowers that are not likely understood until the data comes together.

"A lot of operators still don't even understand what assets they have when a project is handed over," Lang said. "An army of people is required to fill their maintenance management system.

"But when you know what assets you have, as well as how they're operating in real time, you can start to analyse what's going on and you can do entirely new things."

Transport for NSW, for example, has real-time data from sensors being shared via its Open Data Hub for use by customers, developers, network >

ABOVE: Companies such as Autodesk put Australian construction businesses in the middle ground of digital adoption.

AVOIDING DIGITAL PITFALLS

5 lessons from the front line

Digital tools are only useful if they're deployed wisely. Don't fall into these traps.

1 DON'T CHASE SPECIFIC TECHNOLOGY
There's always a new tool on the market, said Eric Bugeja CPEng, chair of buildingSMART Australasia and board member of buildingSMART International.

2 FOCUS ON THE WORKFLOWS AND ON PROCESSES THAT CAN BE REMOVED
Transition to technology that is open and doesn't lock data away or make integration impossible.

3 CHANGE CULTURE, NOT CODE
People need to be engaged in the purpose of a piece of technology, then regularly trained in its use, said Sandra Lang, Director of Digital Engineering at Systra.

4 UNDERSTAND THE VALUE ADDED, AS WELL AS THE COST OF THE TECH
Technology has a cost, said Tom Mullens, Director – Technical and Health & Safety at Laing O'Rourke. But if utilised well, it also likely removes enormous cost from projects, and from the management and maintenance of the final product.

5 DON'T FOCUS ON THE GADGET
Think about your greatest challenges, such as sustainability, safety and productivity. Plan a holistic response then figure out how technology can help form a solution.

managers and operators. This enables apps to be developed, curated collections of data to be made available for transport-related interest groups, partnerships to be created and data stories to be told, to inform future developments.

The Open Data Hub currently has more than 53,000 active users. Prior to the databank being developed, those 53,000 users had no such opportunity to innovate.

Similarly, Victoria's Big Build, with the assistance and guidance of VIDA, is capturing vast amounts of data from various infrastructure assets, including intelligent 3D models. The VIDA Digital Engineering Process Guide, which ensures the right access to the right type of data in the centralised databank, is intended to help Victorian transport project stakeholders collaborate with the help of live, digital models, into the future.

The shift from PDF drawings to intelligent digital models has supercharged Victoria's planning capabilities, but it would not be possible without a common, shared databank.

"Many companies, in these difficult times, focus on traditional KPIs," Lang said. "When this happens, a focus on technology is one of the first things they remove from their plans, because it costs money.

"But if you look at AI and how fast things are moving, to pause innovation and digital transformation now is not the right decision. It's short-sighted if we go back to the basics and have data silos. It simply means operators spend more time looking for data.

"But if an asset owner knows their assets, they are properly maintained and managed and a lot of other offerings are built around that. The benefit goes to the end customer and the taxpayer, and that should be the goal of all engineers." □

"Success in the future will revolve around how well the best players in the ecosystem can bring interfaces together."

BELOW: Earthworks on a road infrastructure project.

Beyond backup

WORDS BY GEMMA CHILTON

The future grid won't just run on renewables – it will run on batteries. From giant grid-scale projects to the car in your driveway, the question remains: how do we make them all work together?

At about 2am on 14 December 2017, one of Australia's largest coal units – Loy Yang A3 in Victoria – tripped without warning, dumping 560 MW off the grid in seconds.

Normally, that kind of shock would leave the grid scrambling. But this time, nearly 1000 km away, the newly built Hornsdale Power Reserve in South Australia – the world's first "Tesla big battery" – came online almost instantly, injecting power before the coal plant contracted to provide backup had even responded.

At that moment, batteries revealed their big advantage: speed. Coal generators can take hours to come online, and even gas turbines need minutes to ramp. Batteries, by contrast, can deliver in milliseconds. Since then, grid-scale storage has now become part of the fabric of Australia's electricity network.

ABOVE: Professor Behrooz Bahrani, Monash University; Professor Lachlan Blackhall, ANU.

"Large-scale batteries are no longer just emergency backup," electrical engineer Professor Behrooz Bahrani, Director of the Grid Innovation Hub at Monash University, told *create*.

"They now provide essential services such as frequency regulation, peak demand management and fast responses to disturbances. Their ability to deliver these within milliseconds makes them a cornerstone of grid stability and flexibility."

In March 2025, the combined output of Australia's big batteries reached a record 1.22 GW at the evening peak, underscoring just how far the technology has come since Hornsdale put

BY THE NUMBERS

COMBINED OUTPUT OF AUSTRALIA'S BIG BATTERIES AT THE EVENING PEAK IN MARCH 2025

1.22 GW

IMAGE: Neoen.

unit in a garage: integrate storage so it strengthens, rather than destabilises, the grid.

For Professor Lachlan Blackhall FIEAust, Deputy Vice-Chancellor for Research and Innovation at the Australian National University (ANU), the rise of batteries points to a deeper systems shift.

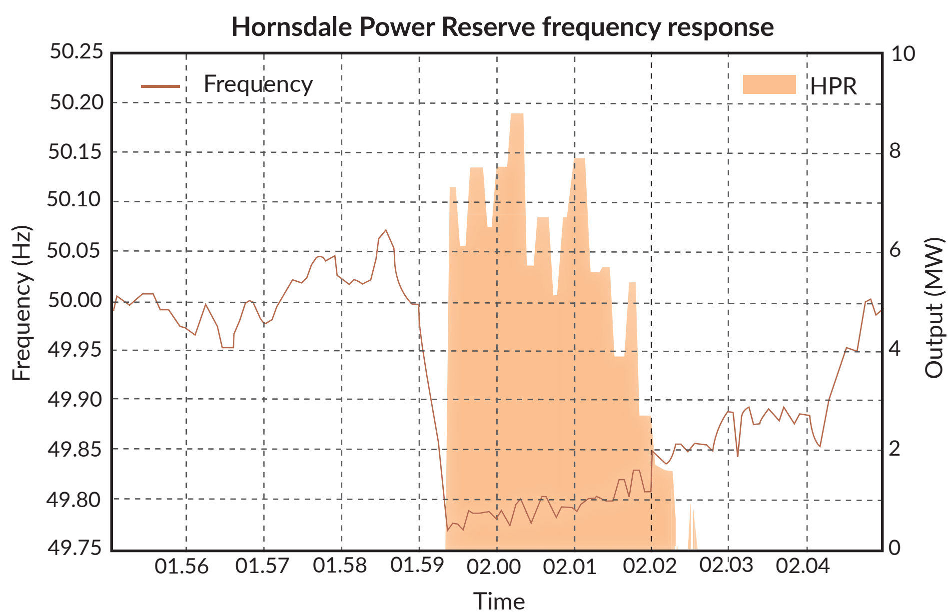
"We're moving from a centralised, fossil-fuel powered grid to a highly decentralised system with utility-scale renewables alongside millions of small generation and storage assets," he said. "This requires a fundamentally new operating paradigm."

That shift means household batteries and rooftop solar can't operate in isolation. They need orchestration – signals that help schedule when to charge, export to the grid or supply their household energy use. Without these capabilities, they risk either straining the grid or missing the chance to make it more efficient and affordable. >

batteries on the map. But as their numbers grow, the challenge is no longer whether batteries can work – it's how to make them work together.

Distributed by design

The integration puzzle is bigger than grid-scale batteries. In suburbs and towns, hundreds of thousands of household units are already in use – a number set to climb further with the federal subsidy announced in July 2025. Add a growing fleet of EVs, and the coordination challenge multiplies. For engineers, the task is the same whether it's a 300 MW utility battery or a 10 kW residential



As co-founder of Reposit Power, Blackhall helped pioneer software to aggregate household batteries into some of Australia's first virtual power plants (VPPs). Later, at ANU, he led the Battery Storage and Grid Integration Program, which trialled these ideas in practice. The 2016–19 CONSORT Bruny Island trial showed how a network of household batteries could ease pressure on the local electricity system during times of high demand.

The follow-on Evolve project (2019–21) introduced dynamic operating envelopes (DOEs) – smart software that signals how much energy homes can export or import based on real-time conditions. Unlike fixed limits, DOEs change depending on the current grid operating conditions, giving people more opportunity to use and share their energy without overloading the system.

That work seeded Elentar, a spin-out co-founded by electrical engineer Andrew Fraser, who previously worked alongside Blackhall at ANU and earlier worked on the Bruny trial at TasNetworks.

"Most batteries today are set up for the household – charge from solar during the day, discharge at night," he said. "That's good for the house, but it doesn't necessarily help the grid. In fact, it can make things worse by filling up when the system already has too much solar, and sitting empty during the evening peak."

While DOEs provide what Fraser called the "guardrails", VPPs take that orchestration even further, and can link home batteries to the market – sending signals to charge or discharge when the system needs it.

The benefits are clear at system level, Fraser said, but less obvious for households: "The economics aren't huge – often just a couple of hundred dollars a year – and if people don't trust their retailer, they're reluctant to hand over control."

Even so, coordinated storage makes the overall system more efficient and cheaper for everyone. The task now is scaling these solutions – turning research pilots into everyday practice.

Balancing act

One of the next frontiers for distributed storage is transport. A single car battery can be 10 times the size of a household unit, and as hundreds of thousands of EVs plug in over the coming decade, they could become one of the largest sources of flexible storage.

An April 2025 trial by CSIRO and Essential Energy showed how that potential could be unlocked, delivering Australia's first vehicle-to-grid solution using the Combined Charging System standard, which enables DC bidirectional charging. The project tested how EVs can store rooftop solar during the day, power homes at night and export surplus energy back to the grid.

ABOVE: **Household batteries and rooftop solar can't operate in isolation.**

Large-scale demonstrations such as Project Symphony in Western Australia are also showing what this coordination looks like in practice. There, more than 900 homes and businesses with solar, storage and controllable appliances are linked into a single operating platform, proving how distributed

> "AI and machine learning can immediately enhance predictions of demand, renewable generation and battery state-of-charge. Better predictions mean batteries can be dispatched more efficiently, reducing costs and strengthening reliability."

assets can provide many of the same services as a traditional power station – from keeping frequency steady to shaving peaks in demand.

However, elegant integration relies on more than smart hardware; it depends on being able to see what's coming. Operators need to know when the sun will dip, when demand will spike and how much charge is left across thousands of distributed batteries. That's where advanced forecasting becomes critical.

"AI and machine learning can immediately enhance predictions of demand, renewable generation and battery state-of-charge," Bahrani said. "Better predictions mean batteries can be dispatched more efficiently, reducing costs and strengthening reliability."

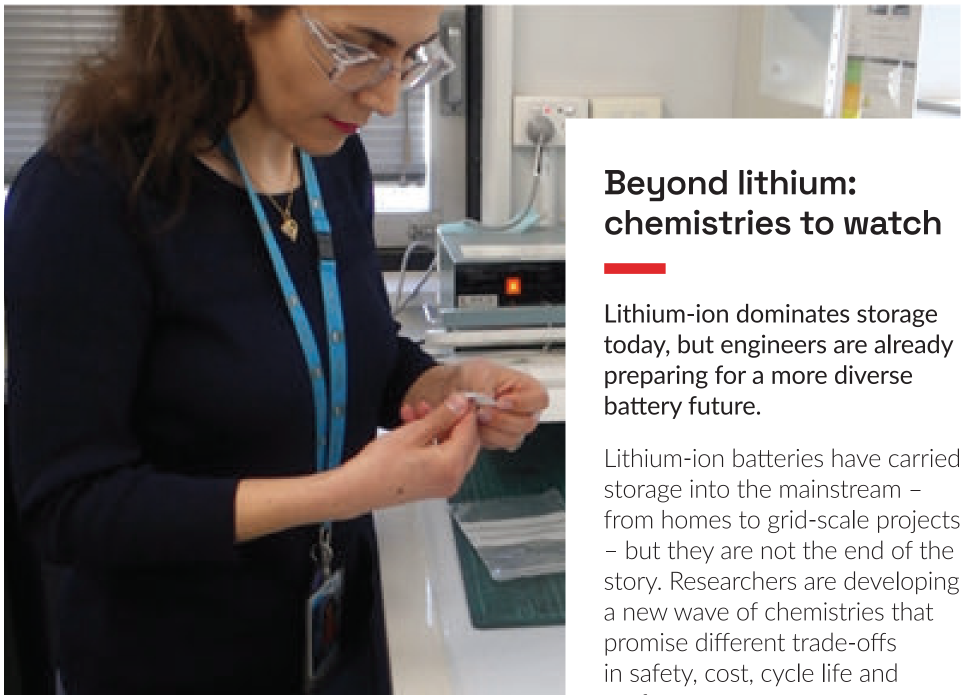
The harder part is what happens next: turning those forecasts into action across millions of individual assets. For Blackhall, this is where standards are crucial.

"Great standards are the foundation for scaling," Blackhall said. "If we want millions of energy assets integrated into the system, then integration standards have to be simple, repeatable and reliable. That's where a lot of my effort is going – building the system for scale."

The road ahead

Meanwhile, storage capacity is surging. AEMO's 2024 Integrated System Plan forecasts 22 gigawatts by 2030, much of it paired with new renewable zones. As batteries spread across the grid, questions of resilience become just as important as performance.

Lithium-ion fires, for example, are rare but behave differently to conventional blazes. It's a reminder that integration is not >



ABOVE: Dr Marzi Barghamadi, CSIRO.

Beyond lithium: chemistries to watch

Lithium-ion dominates storage today, but engineers are already preparing for a more diverse battery future.

Lithium-ion batteries have carried storage into the mainstream – from homes to grid-scale projects – but they are not the end of the story. Researchers are developing a new wave of chemistries that promise different trade-offs in safety, cost, cycle life and performance.

"Lithium-ion will continue to be the workhorse of the energy transition," Dr Marzi Barghamadi, who leads battery projects at CSIRO, said. "But no single chemistry can do everything. The future grid will need a mix."

Among the most advanced alternatives are sodium-ion batteries, which swap lithium for a far more abundant element. They can't match lithium's energy density. However, for different applications from scooters to stationary applications, they could deliver reliable and affordable storage without supply chain bottlenecks.

Other researchers are pushing solid-state designs, which replace flammable liquid electrolytes with solids. "The potential is huge," Barghamadi said. "If the cost and technical hurdles can be overcome, lithium metal solid-state batteries could double driving range while improving safety."

just about markets and software, but about how assets are designed and managed in the real world.

Another frontier is digital: "Batteries are connected assets, so protecting them from cyber threats is essential," Bahrani said.

In an April 2025 article, specialists from global battery storage company Fluence cited cases from ransomware in Queensland to coordinated strikes in Denmark as evidence that storage infrastructure is becoming a target. They argued that energy storage should now be "at the centre of the cybersecurity conversation", and for engineers to design systems with security built in from the outset.

Taken together, these risks underline the central lesson of battery integration: performance alone is not enough. Safety, security and coordination all matter if storage is to deliver on its promise.

The story of batteries is no longer about backup; it is about integration – of large and small, fast and slow, public good and private benefit. For engineers, that is both the challenge and the opportunity: to design a system where every battery, from a grid-scale Tesla Megapack to the EV in your driveway, contributes to stability rather than undermines it. ◻

"Lithium-ion will continue to be the workhorse of the energy transition. If the cost and technical hurdles can be overcome, lithium metal solid-state batteries could double driving range while improving safety."

ABOVE: **Matt Allen, Country Fire Authority; the Big Battery installation in Victoria.**

When batteries burn: fire safety lessons

Lithium-ion batteries are generally safe, but when things go wrong, they behave differently – and fire services are adapting fast.

As batteries become central to Australia's energy transition, fire authorities are confronting new and unfamiliar risks. Lithium-ion fires are rare, but when they occur, they don't behave like conventional blazes.

"Batteries are generally safe – they don't just spontaneously combust," said Matt Allen, Senior Manager of Specialist Risk and Fire Safety at Victoria's Country Fire Authority (CFA). "The bigger issue for first responders is being able to safely de-energise a battery if they turn up to a house fire not caused by the battery."

To get ahead of these challenges, the CFA has published detailed guidelines for renewable energy facilities – documents now referenced nationally and even overseas. They set out design requirements for spacing, site access, firebreaks and water supplies. The emphasis, Allen said, is on thinking about safety right from the design stage.

"Firefighter safety is the number one requirement we look at. The guidelines are built around that, as well as the safety of the community."

The 2021 fire at the Victorian Big Battery underlined what is at stake. A coolant leak in a Tesla Megapack triggered thermal runaway, destroying two [battery] units and forcing a major response. The incident, said Allen, was a turning point.

"We captured a lot of information out of that fire, and our guideline went through its biggest change because of how much we learned."

For engineers, one lesson stands out: spacing matters. Thermal runaway can escalate quickly if cells or units are packed too tightly. The CFA recommends at least three metres between large units to give firefighters room to operate and prevent one failure from cascading into many.

IMAGE: FRV.

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WORDS BY CHLOE HAVA

The digital playbook is lifting Australia's manufacturing complexity, and there are gaps yet to be filled.

Traditional manufacturing in Australia, once heavily reliant on assembly lines and mass production, has experienced decades of steady decline. Our manufacturing base shrank from 30 per cent of national employment in 1965 of less than 8 per cent in 2017 – contributing only 6 per cent to GDP.

But over the last few years, Australia's capability has pivoted from trying to compete on mass assembly to moving up the value chain into complex, knowledge-rich product and system design.

This shift aligns with the Federal Government's Future Made in Australia agenda and the National Reconstruction Fund Corporation's mandate to diversify and transform industry. These investment mechanisms are designed to grow sovereign capability in national priority areas such as defence, space, medtech and clean energy, with most value now from niche componentry.

It's a transformation engineers are leading, through additive manufacturing, rapid prototyping, AI-enhanced design and low-volume, high-mix production systems.

ABOVE: Dr Jens Goennemann, Advanced Manufacturing Growth Centre.

For competitive edge

These days, advanced manufacturing is less about what you make and more about how you make it, said Dr Jens Goennemann, Managing Director of the Advanced Manufacturing Growth Centre.

"Digital tools such as computer-aided design, digital simulation and digital twins give manufacturers a competitive edge – helping them design smarter products, cut development time and even collaborate seamlessly across borders," he told *create*. "For example, digital twins are used in aerospace to test components virtually, while local medtech firms use simulation to fast-track new devices."

To be globally competitive, Goennemann said, Australian manufacturers must focus on being better, not cheaper, with widespread adoption of these technologies playing a significant role in achieving that.

A key element to facilitating this is practical technological integration to grow at scale, said robotics engineer turned consultant Dr Michael Lucas FIEAust, founder and Principal Manufacturing Advisor at Manufacturing Catalyst.

"When people design or lay out a factory, traditionally they haven't done a lot of good thinking about it," Lucas said. "They put a production line into the space, then they try to squeeze in the next one and the next one." >

"One company I'm working with invested in a cobot because it's easily reprogrammable; they didn't need the fancy functions a bigger robot would bring."

Lucas, who provides manufacturing and material flow advice, tries to get manufacturers to consider growth early on.

"If we take a 3D scan of the space, build a good digital twin and then analyse how everything flows through the manufacturing system, we can consider if there's space to get more people, product and equipment through."

He said capturing good data was essential, but many manufacturers struggled with it.

"You can then feed that into AI-based machine learning models to predict production outcomes. One chemical company I worked with was able to predict what humidity would do to their product through a straightforward machine-learning model, and then was able to make changes to their processes."

In Lucas's view, issues can be solved with smart, simple automations that don't necessarily require an expensive, heavy-duty robot and all the difficulties that go with that.

"One company I'm working with invested in a cobot (collaborative robot) because it's easily reprogrammable; they didn't need the fancy functions a bigger robot would bring."

Prototyping the manufacturing process helped this company fine-tune its operations.

"Testing processes with their parts during assembly quickly and cheaply with cobots taught them what they needed for their future automation line, which helped bring the product to market faster," Lucas said. "They then used more advanced robotics in their manufacturing line, enabling them to scale faster as well."

Additive advances

Once confined to prototyping, 3D printing is now being industrialised, delivering certified end-use parts, compressing development cycles and de-risking production across sectors from medtech to defence.

Australian company Additive Assurance – which was recently named the top performer in an additive manufacturing challenge, led by the Applied Science Technology Research Organization of America – is providing in-situ quality assurance for metal 3D printing via AMiRIS, its externally mounted, vendor-agnostic sensing and analytics system.

"Additive Assurance leverages a lot of digital design," said the

ABOVE: Dr Michael Lucas FIEAust, Manufacturing Catalyst; Dr David Menzies, Additive Assurance.

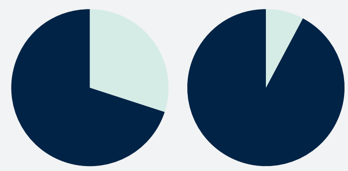
BELOW: Incat Hull 096, the world's largest electric vehicle, launching in Hobart.

BY THE NUMBERS

THE PROPORTION OF AUSTRALIAN WORKERS IN MANUFACTURING EXPERIENCED MORE THAN A

73%

DROP FROM 1965 TO 2017



30% > 8%

OF ALL WORKERS ARE EMPLOYED IN MANUFACTURING

MORE THAN

90%

OF AUSTRALIAN MANUFACTURERS EMPLOY FEWER THAN

20

PEOPLE

DESPITE THIS, CENSUS DATA SHOWS A

~60%

UPLIFT OF ENGINEERS IN MANUFACTURING, RISING FROM

39,920

IN 2016 TO

46,273

IN 2021

"This brings the information to the user in near real time to make in-formed decisions about the quality of their build, reducing the risk of poor quality, and the time for developing new products and certifying them to the applicable standards."

company's COO, materials engineer Dr David Menzies. "We develop many additional products through smart software design for digital assets and rapid prototyping using in-house capability for mechanical components."

ABOVE: Additive Assurance leverages a lot of digital design.

This process makes for a faster development cycle through transfer to manufacturing partners for final component production. "The benefit is in the fast iteration cycle," he added.

In practice, that means treating quality as a live data stream rather than a post-build report.

"AMiRIS monitors the entire build plate for every layer produced in PBF-LB," Menzies said. "We do this using an array of near infrared cameras, an automated analytical package using machine learning and an intuitive software package for monitoring, reporting and analytical purposes."

The use of machine learning dramatically reduces the time it takes to analyse each layer produced in PBF-LB.

"This brings the information to the user in near real time to make informed decisions about the quality of their build, reducing the risk of poor quality and, more importantly, the time for developing new products and certifying them to the applicable standards," Menzies said.

For small and medium-sized manufacturers, the decision often comes down to balancing risk against opportunity – especially when certification and time-to-market are on the line.

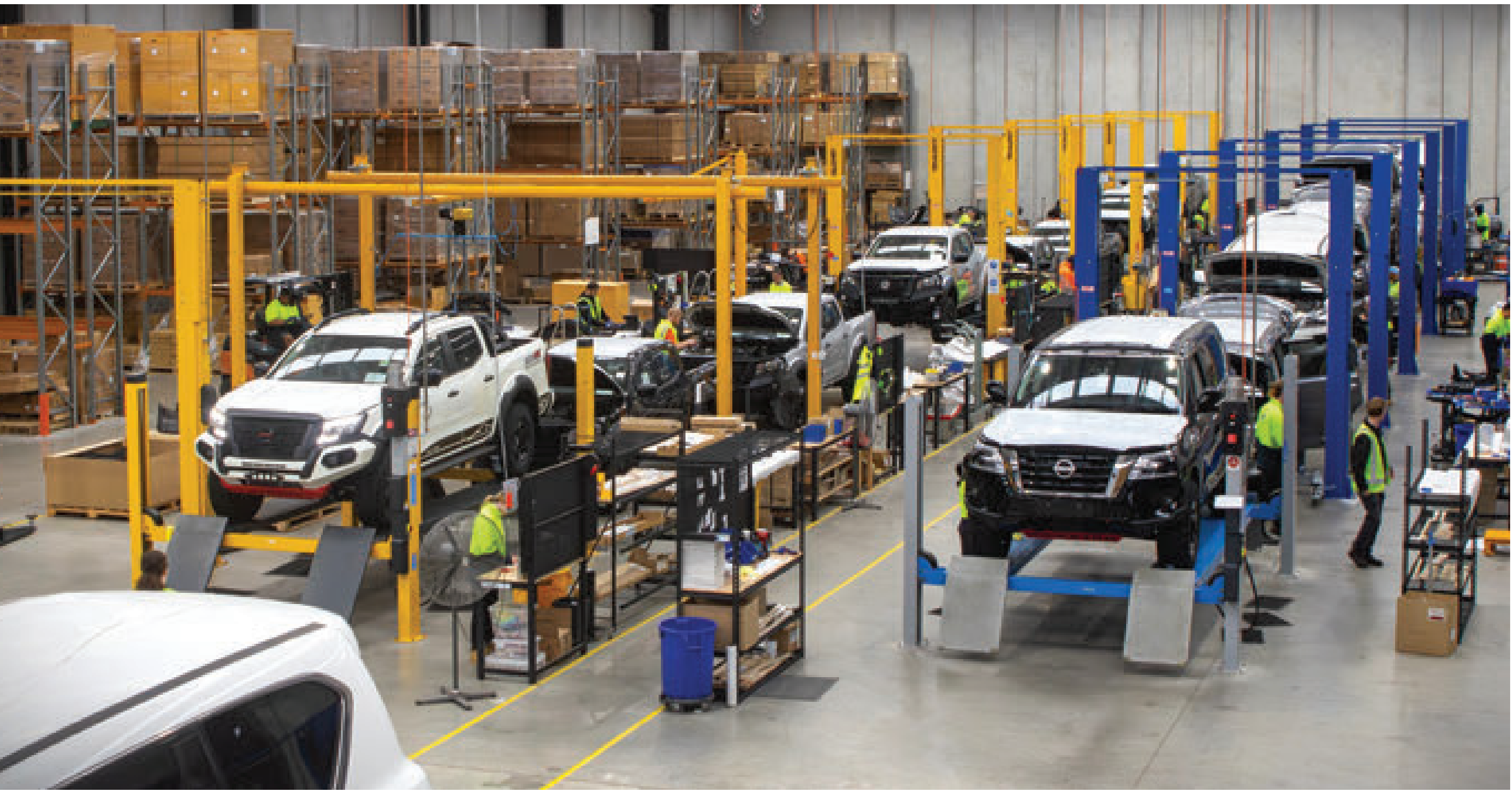
"AMiRIS users tend to understand the failures that occur in metal additive manufacturing and the subsequent cost of poor production. What is becoming a more important aspect of monitoring devices such as AMiRIS is the benefits that it brings for certification and quality assurance."

If the SME is developing its own products and requires the parts to be certified, the benefits align strongly with shorter development and certification cycles.

Secondary niche

Premcar has carved out a niche in secondary manufacturing – engineering original equipment manufacturer vehicles such as Nissan models – while expanding beyond Australia to build capability in new markets.

"We've now set up in South Africa, doing a very similar thing, and we're looking to expand into other markets, such as North America, as well," said Premcar CEO Bernard Quinn, a former Ford Performance Vehicles engineer. >



To compress programs and reduce warranty risk, the team has evolved its product-development system into a digital-first workflow that front-loads analysis and decisions.

"From an engineering point of view, we have a product development system which has evolved into a digital-based system where engineers use online forms, databases and AI to create failure mode and effects analyses," he said.

Instead of iterating through expensive physical prototypes, engineers now design parts for first-pass success with virtual testing that targets the known gate criteria.

"We design the part properly, then test it virtually – via stress, modal and frequency analysis – to give ourselves the best chance that the first prototype will pass all the tests we have to put it through," Quinn said.

Materials and methods have shifted too. 3D printing is used to accelerate learning and, where it stacks up, to supply production at meaningful volumes, cutting tooling time and cost.

"We now have two 3D printers in the business and use them to make prototype parts very quickly and efficiently at low cost," he said. "We're also starting to use 3D-printed parts in production where it's cost-effective – even at rates of around 10,000 parts a year."

Innovation specialist

Premcar now has a full-time innovation specialist who focuses on synthesising processes and systems in manufacturing, engineering and program management.

"AI and structured query language are used to integrate everything so it's more efficient and robust," Quinn said.

ABOVE: Premcar has carved out a niche in manufacturing original equipment manufacturer vehicles.

RIGHT: The Premcar helicopter design.

"We design the part properly, then test it virtually – via stress, modal and frequency analysis – to give ourselves the best chance that the first prototype will pass all the tests we have to put it through."

Looking ahead, the team sees scope for machine learning in vision-based motion studies and workflow optimisation.

"The next step, if we wanted to push efficiency further with AI, would be machine learning – for example, cameras along the manufacturing process to record how operators move, then using machine learning to alter processes to improve efficiency."

To stay future-ready, Premcar deliberately hunts variety so engineers absorb new technologies they can redeploy into core programs.

"For example, we did a helicopter design project with a full carbon-fibre monocoque. A monocoque structure doesn't have a separate frame; the carbon-fibre structure itself provides the strength. We learned a lot from that program – alternative materials, and doing stress, modal, and fatigue analysis with carbon fibre, which has completely different properties to steel and alloys."

With diesel vehicles being phased out, the team is also working with newer automotive technologies.

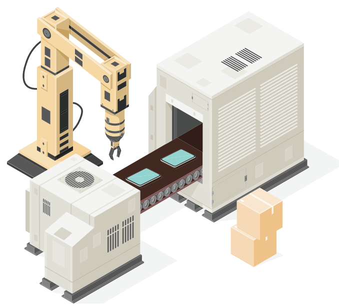
"If we only did traditional projects, we wouldn't learn," he said. "By building a catalogue of projects across EVs, hybrids, new materials and different technologies, we can apply our core engineering skills to those areas as well."

ABOVE: Bernard Quinn, Premcar.

A way to go

Despite Australia's innovation in the digital space, we continue to underperform on the sophistication and diversity of what we make and export. Recent analyses by the Harvard Growth Lab's Economic >

Where Australia ranks in making complex things



Harvard's Economic Complexity Index (ECI) tracks the diversity and sophistication of what nations make and export — a proxy for embedded know-how and value-added capability rather than sheer volume, Jens Goennemann said.

"Countries that possess the capability to add value, for example, to their commodities are more complex compared to those that export iron ore and coal, and have it processed or burned in other countries," he said. "Australia exports a lot of iron, dirt and, along with it all, embedded carbon dioxide – placing us at a shameful yet deserved 105th place on the ECI."

Australia is trailing far behind manufacturing leaders Germany, South Korea and Singapore, as well as mid-table players Chile and the United Arab Emirates.

"Germany is a manufacturing powerhouse, and that strength is underpinned by what they call the Mittelstand – mid-sized businesses that make parts or intermediate goods," Goennemann said. "About 75 per cent of the world's trade is in such unfinished goods."

Germany's Fraunhofer model, which has been in operation for more than 73 years, shows how long-lived, applied research crowds in private capital and lifts industrial capability.

"Funding is tripartite: one-third industry, one-third government, one-third academia," Goennemann said. "Academia helps to improve a commercial idea, and government and industry underwrite a large pool of funds."

This continuity of programs and policies underpins growth and signals to private markets that manufacturing is a critical national capability. And as a result, capital equity and institutional lenders back it.

The broader and more capable a country's industrial base, the faster it can also pivot under shock – whether that be supply disruptions or pandemics – turning ideas into certified products, jobs and exports. That breadth underpins resilience and sovereign capability.

"Countries such as Australia that rank low on complexity are easy to beat when a cheaper source appears," Goennemann said. "We can't compete on cost; we have to compete on value to be globally competitive."

In a nutshell, here's what it will take for Australia to move up the ranks:

Scale the "missing middle"
Back the most capable SMEs to become mid-sized manufacturers through long-lived, industry-led programs.

Add value onshore
Process, assemble and certify resources here so more value and capability stay local, and Australia is harder to substitute in global supply chains.

Invest in applied commercialisation
Emulate durable tripartite models that translate R&D into certified, tradeable products and crowd-in private finance.

Policy certainty that unlocks finance
Continuity of programs and clear signals reduce risk and draw in banks and institutional lenders to fund equipment, skills and export growth.

Capability is also for shock response
A broad base of capable makers can pivot when supply chains choke. "Manufacturing capability is a long play," Goennemann said. "But not one top-tier economy lacks it."

Complexity Index (ECI) puts Australia in the bottom third globally, between Botswana and Côte d'Ivoire, fuelling debate about the urgency of moving up the value chain.

"Some of Australia's manufacturers are highly capable. But most of them remain small due to limited access to growth capital in their size bracket, which restricts them from investing in technology, equipment, skills and growth," Goennemann said.

"With more than 90 per cent of Australian manufacturers employing fewer than 20 people, our lack of scale hurts our competitiveness. Unlocking growth opportunities for our most capable firms is critical to lifting competitiveness and driving transformation."

Seven steps

In Goennemann's view, companies need to span the seven steps of manufacturing – R&D and design, to logistics, production, distribution, sales and service – to retain value.

"Companies such as ResMed, RØDE and DroneShield show how leveraging the full value chain creates resilience and global competitiveness," he said.

Manufacturing along the seven-step value chain is also a major job creator, providing opportunities for all skill levels, from professionals to skilled trades.

"Manufacturing and engineering are symbiotic. Manufacturers rely on engineers across all seven stages of the process, while engineers need a strong local industry to provide meaningful roles and retain talent in Australia," Goennemann said. "These roles provide engineers with diverse career pathways and are more diverse, attracting around 30 per cent more female participation than traditional production roles."

But the challenge now is scaling small manufacturers so they can deliver the high-value, complex products the world needs.

"This will require backing our manufacturers and empowering them to harness and further invest in our skilled workforce and natural resources to drive prosperity and growth at home while exporting to the world."

However, a major barrier to this process is access to capital. Too many small-sized manufacturers can't secure funding that matches their growth abilities, limiting them from adopting technology, scaling and competing globally.

Shifting policy

The other challenge is unpredictable policy. Constant shifts in policy or a lack of incentives create uncertainty, making it hard for manufacturers to plan and invest.

"Clear, stable, long-term policy settings are essential to give Australian manufacturers the confidence to innovate, scale and compete internationally," Goennemann said.

While the Future Made in Australia policy is a good start, initiatives must be right-sized and agile to match the overwhelmingly SME-based nature of Australia's manufacturing industry he said.

"Get funding into the hands of capable manufacturers quickly, in practical, digestible amounts, through industry-led programs and I'll show you how manufacturing can thrive." □

ABOVE: Predominantly Australian-owned DroneShield provides AI-powered counter-drone solutions.

> "Manufacturing and engineering are symbiotic: manufacturers rely on engineers across all seven stages of the process, while engineers need a strong local industry to provide meaningful roles and retain talent in Australia."

IMAGE: Droneshield.

Automatic for the people

WORDS BY JONATHAN BRADLEY

On a continent where the tyranny of distance is a day-to-day reality, autonomous approaches underpin the operation of mining, agriculture, transport and more.

The International Space Station soars through skies at an average low-orbit height of 400 km. As human operations go, that's impressively remote – but it's nothing compared to a remote iron ore operation in the distant north of Western Australia.

There, resource extraction machines trundle along under the supervision of advisors sitting in an operations centre in Perth, more than 1000 km away.

"In Western Australia, we are the largest iron ore producer in the world," said Michelle Keegan, who finished up her term as the director of the Australian Remote Operations for Space and Earth (AROSE) consortium in April.

"We mine four times more iron ore than 20 years ago at the beginning of the iron ore boom, and we weren't able to get there without being able to automate the equipment.

"Moving billions of tonnes of iron ore today is done with automated trucks and automated drills – and Rio Tinto has automated trains."

Some of the country's biggest economic operations, then, are carried out with little human involvement at all – and many of the humans who are involved sit at a lonely remove from the earth-hauling and machine-scraping action.

For some industries in Australia, thanks to the hardships imposed by distance and harsh terrain, autonomous systems aren't a hope for the space-age future; they're a very real part of day-to-day life.

Country to city

Rio Tinto's automated train, a system named AutoHaul, has shuttled iron ore from the Pilbara to coastal port facilities about 800 km away for the past seven years. But in a very different environment, on the opposite side of the country, the cargo comes in the form of the urban commuter.

ABOVE: Michelle Keegan, Atrico; Kate Ford CPEng, Sydney Metro; Rio Tinto's AutoHaul.

Opening in the northwestern suburbs in 2019 and extending into the city from 2024, the Sydney Metro network demonstrated that driverless trains could operate equally well in a bustling metropolis as they could crossing the desert.

Among public transportation specialists, trains are rated according to their level of autonomy, beginning with GoA0, which contains no level of

> "If you look at different case studies around remote operations, a lot of people would say it's important to improve safety – but it's very important to give consistency in outcomes and operations."

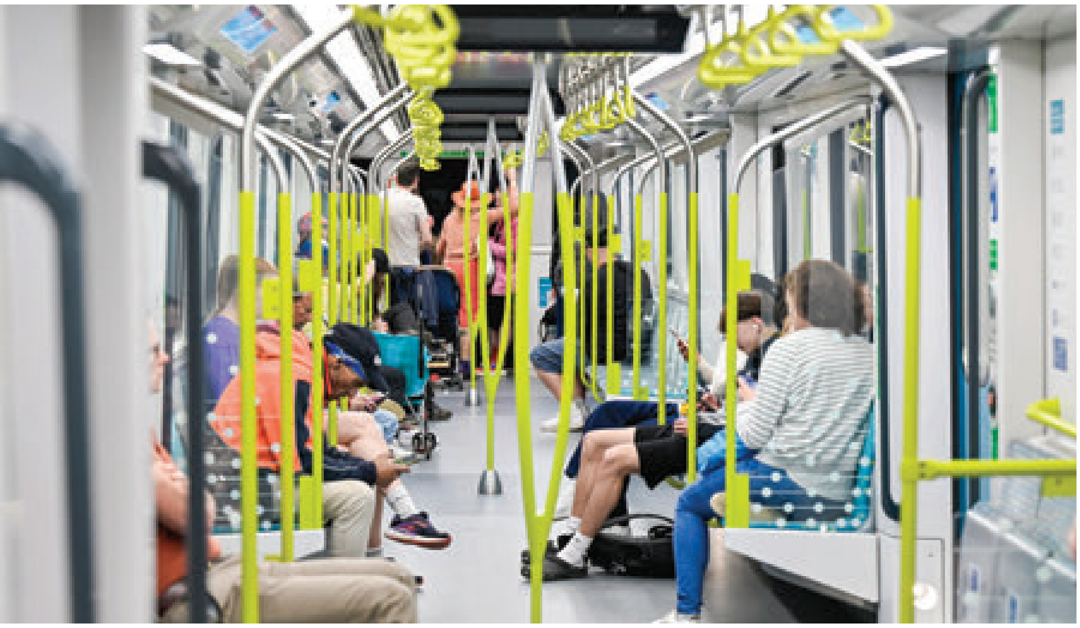
autonomy whatsoever. Sydney Metro trains are rated GoA4, the highest grade.

"GoA4 indicates that it is a fully automated driverless system," said Kate Ford CPEng, the Trains, Systems, Operation and Maintenance Delivery Director for Southwest at Sydney Metro.

"With GoA3, you have a driver on board who would drive to a speed profile, and the system would automatically brake to stop at a station, but the driver could control doors opening and closing, or train departures. Whereas in a GoA4 system, everything is automated."

The benefits of such an approach can be seen immediately, Ford said.

"One of them is about repeatability – human interactions with systems drive small, minute differences," she >



said. “With an autonomous system, every train behaves in the same way, which means you can be more efficient on braking from an energy perspective. We've got regenerative braking in the city because it's repeatable.”

The autonomous approach also increases the safety and reliability of the Sydney Metro, a particularly important attribute for a system that sees trains leaving a station every four minutes during peak hour.

Removing humans from the decision-making tasks surrounding arrival and departure – or opening and closing carriage doors – allows the system to operate identically each time, without delay or disruption.

“The flip side is obviously that it requires far more testing. You have to do far more assurance on all of the systems that feed in to ensure repeatability can happen safely.”

Similarly, Keegan explained, the repeatability facilitated by automation has meant miners can maintain production with a limited available workforce, or ensure that their machines don’t overcut or undercut a seam.

“At the beginning of the [iron ore] boom in 2005, there was an exponential demand for steel, which meant that, if we were to continue to maintain our share of iron ore production, we had to do something different to be able to grow,” Keegan said. “If you look at different case studies around remote operations, a lot of people would say it's important to improve safety – but it's very important to give consistency in outcomes and operations.”

ABOVE: Interior of an autonomous Sydney Metro train; Dr Salah Sukkarieh, Australian Centre for Robotics.

Robots on the range

Reliability, consistency, safety: the operations around Australia that use autonomous systems look very different and service a broad range of industries, but they’re all designed to take advantage of these common goals.

For more than a decade, Dr Salah Sukkarieh, Professor of Robotics and Intelligent Systems at the University of Sydney’s Australian Centre for Robotics, has worked on perfecting agricultural robots that help farmers with such tasks as weeding, spraying pesticides, and monitoring and moving livestock.

His experience extends beyond that; he’s worked on intelligent robotic platforms for aerospace, ports, environmental monitoring, disaster response, mining and more.

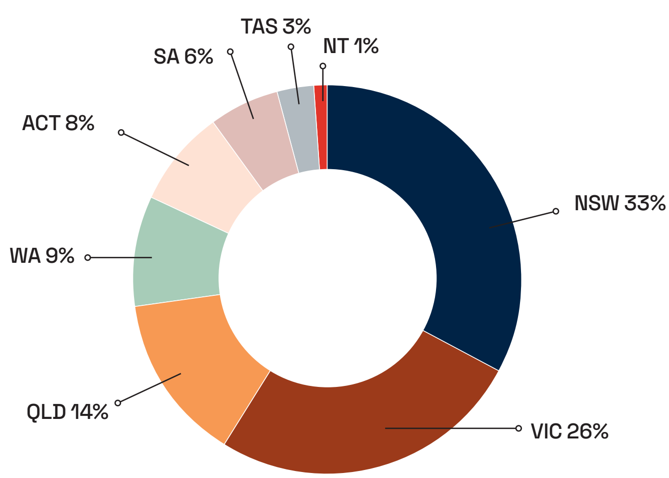
Regardless of the domain in which he’s operating, Sukkarieh approaches the task of designing and working an autonomous system in much the same way each time.

“You sit there, and you define the same type of requirements and activities,” he said. “I'll be looking at an environmental axis, I'll be looking at a human-involvement axis, and I'll be looking at a complexity-to-the-task axis.

“Along those three axes, you ask: What is it about the

IMAGE: Sydney Metro.

Research into robotics and autonomous systems (by number of publications) by state and territory, 2018-22



Source: Department of Industry, Science and Resources.

environment? What is it about the tasks? How much human involvement does there need to be? That frames the choices about what you might do with an autonomous system."

When Sukkarieh first began working with robotics, while researching for his PhD, systems were less developed and required resourceful cross-disciplinary knowledge application. He brought together understanding of electronics, sensors, platforms and algorithms – and, eventually, experience with the domains in which his robots would operate, such as horticulture.

Today, the field has matured, and robotics can be used as an enabler rather than approached as a platform.

Someone who specialises in the AI aspect of a system, for instance, might not need in-depth knowledge of the robot that is operating their algorithm.

"If you're a roboticist, you look at the fundamental requirements of what the autonomous system will need to do, or be like or act like, or perform or operate in. That changes the way you design the solution," Sukkarieh said.

"If you focus more broadly on intelligence systems, you're looking at that overall picture. Does the AI need to work in real time or is it OK offline? Do the sensors need to capture a lot of information or need to process that information in real time? Does the platform work in very rugged terrain – in which case it'll need other sensors that tell me how its attitude is going, its position, its velocity."

Placing the system's requirements at the forefront leads to further questions. Is the primary goal of the platform information-gathering, or is it important for it to interact with its environment? >

ABOVE: Dr Sue Keay, Robotics Australia Group.

BELOW: An autonomous system in agriculture.

"Australia had to get very good at developing technologies that help us overcome remote distances and all of the requirements to service the huge amounts of infrastructure that we have."

IMAGE: University of Sydney.

WHO'S IN CHARGE?

Autonomous systems might be able to remove humans from their day-to-day functioning, but does that liberate the engineers from the responsibility to ensure they're safe and socially responsible?

Dr Sue Keay, chair of Robotics Australia Group, is unequivocal in her answer to that question.

"They actually take principal responsibility," she said. "The designers of these systems can't remain isolated from the consequences of those designs.

I know that it would be more convenient to hope it's someone else's problem, but it isn't."

Keay recommends designers and regulators of newer technologies, such as AI, look to the robotics industry as an ethical guide.

"Right from the design point, robots have to be built with safety in mind, and then they have to meet certain standards before you're able to sell them," she said. "Once they're implemented, you have to do functional safety checks to make sure they're actually working towards their intended purpose, regardless of the environment they've been put in."

Following similar guidelines for AI could not only see responsible use and development of the technology, she said. It could also offer social permission for its wider implementation.

"If you were to apply the same rigour for non-physical AI, we could probably develop the regulations that are required to make people feel comfortable with AI being deployed more broadly across the Australian economy."

And while machine learning is not a new feature of autonomous systems, the increasing sophistication of AI is expanding their potential. Faster and more accurate algorithms offer the potential for systems to be engaged in reasoning tasks, rather than preset activities.

Sukkarieh describes the thought process an agricultural robot could go through today, all without a farmer's input: "It might rain in three hours; harvesting will happen tomorrow; irrigation was switched on at 6:00 o'clock; pests in block A; therefore, I will spray block C."

Interoperability is another factor that is growing in importance for autonomous systems, according to Colin Sheldon FIEAust CPEng, Manager, Asset Management and Performance at Aurecon and chair of Engineers Australia's Mechanical College.

ABOVE: Colin Sheldon, FIEAust CPEng, Aurecon.

"Interoperability is going to keep developing and make it easier to interface, and that starts to democratise autonomous system development," he said.

"There's always been an argument for IP and proprietary-access systems, but it's becoming more of an understanding from original [equipment manufacturers] and other manufacturers that this is coming, so they need to align with the standards, and develop their outputs and inputs so they work with other systems."

Made for Australia

From Sukkarieh's perspective, it's no surprise autonomous systems have flourished in Australia.

"We've led the world in many ways," he said. "It's a large land, and it's very much focused on primary industries. Nobody wants to work out in the middle of nowhere, and the weather conditions are challenging.

"If you had to say what the factors are that allow autonomy to flourish if you decide to go down that path, Australia has those right conditions."

According to Dr Sue Keay, the founder and chair of Robotics Australia Group, the country has always had a great reputation in the realm of field robotics, which is concerned with robust systems that typically work outdoors in unstructured environments.

"The good news for Australia is that we specialise where robotics needs to be," she said. "Australia had to get very good at developing technologies that help us overcome remote distances and all of the requirements to service the huge amounts of infrastructure that we have."

That has meant developing technologies that can operate in remote areas without being

IMAGE: Wisk Aero.

Aerial taxis

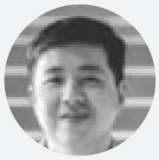
As the 2032 Brisbane Olympic Games draw closer, officials in South East Queensland are turning to the skies to ease the sprawling region's congestion problems.

In 2022, the South East Queensland Council of Mayors signed a partnership with Wisk Aero, a fully owned subsidiary of Boeing dedicated to electric vertical take-off and landing (eVTOL) flight – or aerial taxis.

Dr Kai Li Lim, of the University Queensland's Dow Centre for Sustainable Engineering Innovation, said the plans are far from fantasy.

"[The technology] is moving quickly enough for us to see a really feasible implementation by the Brisbane Olympics," he said.

"It will most likely be marketed as a premium product that caters to the more affluent folks, and then after that – once you get market traction and scale – you can make it more affordable."



ABOVE: Dr Kai Li Lim, UQ.

LEFT: Wisk Aero's eVTOL concept.

While eVTOLs can be operated autonomously like a drone, Lim expects that, at first, they will have human pilots.

"This is more of a regulatory and safety issue than a technological issue, because the technology is quite established," he said. "Once you start to put passengers in the vehicle, the stakes are a lot higher, and that's why you want to have a human inside there."

Instead, technological challenges revolve around creating more energy-efficient batteries that don't add too much weight to the payload. The taxis would also need supporting infrastructure.

"Building vertiports, for example, and having the right grid capacity," Lim said. "Especially when talking about urban areas, how do you secure land for the vertiports? Then, before selecting them, you have to look into electrical grid capacity, because even if you're talking about a few eVTOLs, you're talking about megawatts of power."

Although it will be important for the government to oversee any new aerial transportation modes, Lim is optimistic that the regulators will get it right, particularly considering eVTOLs are much quieter than helicopters, the most comparable vehicle.

"There has been a lot of consultation and discussion in relation to how we're going to regulate eVTOLs in the country," he said. "We have always been a more risk-averse country when it comes to our policies, and we do put safety first, so it's just having those mechanisms to ensure that these services can be rolled out.

energy intensive – preferably relying on long-life batteries – and creating systems that can operate in communications-denied environments.

"These are all things fairly unique to the Australian context that have been important for Australian roboticists to solve for," Keay said.

"Fortuitously, that happens to be the direction robotics is heading in, now that we're moving towards self-driving cars, and humanoid robots that need to be able to operate in unstructured environments and behave reliably and effectively."

Sheldon notes that the immense task of managing complexity and risk makes autonomous solutions particularly attractive, especially for mining.

"In terms of the scale of the equipment and potential related incidents, there's a lot of time spent managing the safety of the person operating the equipment," he said.

A helping hand

As autonomous systems become increasingly sophisticated, Sukkarieh is noticing that the range of industries to which they can be applied is expanding.

"As technology advances, it also gets cheaper in various forms, which opens up more solutions to industries that originally couldn't afford it," he said. "Mining probably helped facilitate a lot of the knowledge and technology that went into agriculture, and now I think there is potential in environmental monitoring [because] it's very similar to agriculture."

"We are at a huge inflection point with robotics, automation and AI. The next five years are going to be super-exciting."

Keegan says the future of autonomous systems is "up to our imagination" and expects these newer sectors to feed ideas back into some of the more established industries.

"What's exciting is that there are other non-traditional players thinking about this and challenging the norms," she said. "If we think particularly about the copper sector and the fact that we need to be able to learn how to mine much deeper and do that in a safe way, it's up to us to design that future operation and make it real."

That means new technologies, new approaches and perhaps even closer integration between the mining and space sectors.

"We are at a huge inflection point with robotics, automation and AI," Keegan said.

"The next five years are going to be super-exciting." □

Projects

76
Battery-electric prowess
Australian engineers have reimagined what a high-speed ferry can be.

80
Fantastic engineering
Will the revolutionary potential of open fans become an aviation reality?

84
Not a bridge, but a legacy
A customised cable-hoisting system helped raise the world's largest aerial gantry.

Changing currents

Built in Tasmania, on the banks of the Derwent, the largest, most complex all-electric vehicle ever developed promises to inspire a new era in marine electrification.

WORDS BY JOE ENNIS

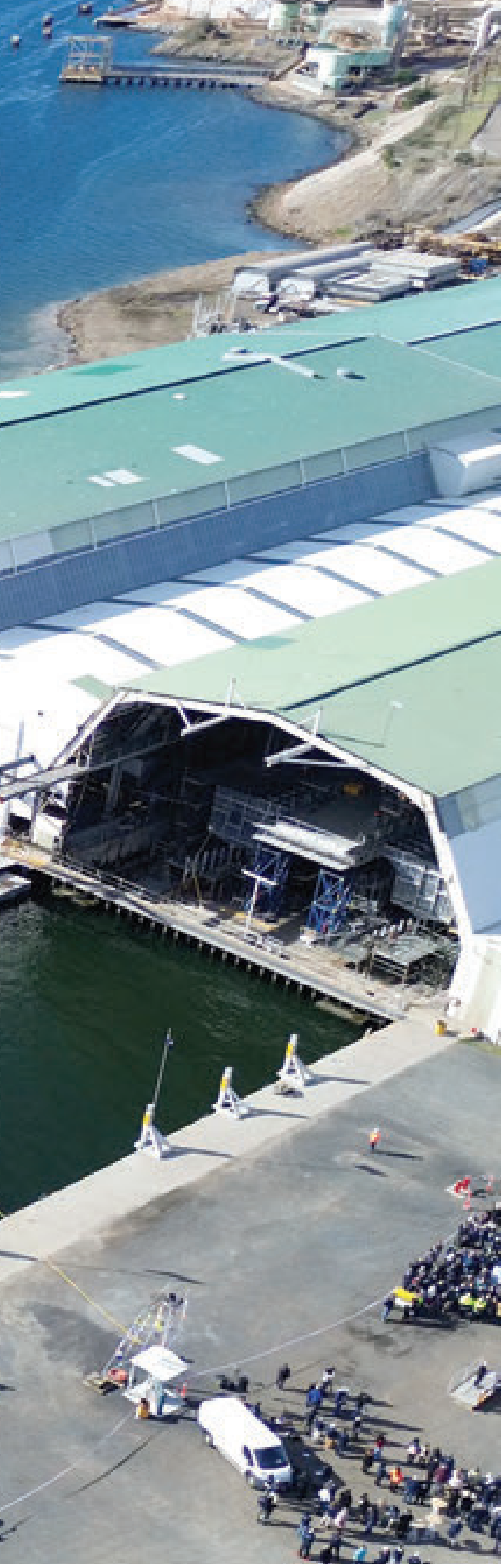
ABOVE: The Hull 096 ferry, commissioned by Buquebus.

Back in May 2025, crowds lined the Hobart waterfront, craning for a glimpse, as a shiny new passenger ferry slipped gracefully into the water. But this was no ordinary vessel. This was Hull 096 – the latest commission of Hobart-based Incat, long-time builders of lightweight, high-speed aluminium catamarans.

It's also the world's largest battery-electric ship.

At 130 m long, Hull 096 is, as Incat CEO Stephen Casey declared, "the largest electric vehicle of any kind ever built, and one of the most significant single export items in Australia's manufacturing history".

Where four dual-fuel LNG engines might normally thunder away, the ship hums silently on pure battery power. In dispensing with combustion altogether, Incat's engineers have reimagined what a high-speed ferry can be – clean, quiet and uncompromisingly modern.



Commissioned by South American ferry giant Buquebus, Hull 096 will carry 2100 passengers and 225 vehicles across the River Plate, between Buenos Aires in Argentina and Colonia in Uruguay, turning a workhorse commuter route into a showcase for maritime innovation.

Why battery-electric?

The decision to move from LNG to battery power was as much philosophical as it was technical. Ferries, vital to urban mobility worldwide, are too often synonymous with diesel smoke and engine roar.

"Incat and Buquebus have a shared vision," Casey said. "The decision to move from an LNG-powered design to a fully battery-electric vessel was driven by the opportunity to lead the industry towards net-zero emissions."

And this extends beyond the vessel's powertrain, as "100 per cent of the energy consumed in its construction comes from renewable sources".

The benefits ripple far beyond carbon reduction: zero exhaust emissions on the water, a gentler acoustic footprint, and a markedly more pleasant ride for passengers and waterfront communities alike.

This leap was enabled by major advances in energy-storage technology. Incat chose Dolphin NxtGen battery modules from Norwegian energy innovator Corvus Energy: compact, lightweight, efficient. The result: an energy-storage system of more than 5000 modules, tipping the scales at over 250 t and delivering an eye-watering 40 MWh of capacity – four times larger than any other maritime installation.

To keep speed and efficiency in harmony, the lightweight aluminium >

"At Incat, we're not just building a ship. We're building the future of sustainable transport, right here in Tasmania."

AT A GLANCE

OVERALL LENGTH
130 m

BEAM WIDTH
32.4 m

PASSENGER CAPACITY
2100
PEOPLE

VEHICLE CAPACITY
225
CARS

ENERGY STORAGE CAPACITY
≈43 MWh
(5016 MODULES)

BATTERY WEIGHT
>250 t

PROPULSION
8
PERMANENT-MAGNET MOTORS DRIVING WÄRTSILÄ WXJ1100 WATERJETS DELIVERING A COMBINED
24,000 hp

SERVICE SPEED
≈25 kn
(46 km/h)

37.5 kn
AT 100% POWER

RECHARGE TIME
60-90 min
USING AUTOMATED TOWERS

hull aims for hydrodynamic grace, slicing through the water with minimal drag to reach a 25 kn service speed.

Scale and systems

Housing 250 t of batteries in an aluminium catamaran was a feat of engineering sleight-of-hand. Engineers had to balance weight distribution, reinforce structures and fine-tune stability, all without sacrificing speed.

Powering this leviathan is an eight-motor symphony: permanent-magnet electric motors driving Wärtsilä WXJ1100 waterjets. Delivering approximately 24,000 hp, this setup marries muscle with efficiency. The waterjets themselves were engineered to be "tens of tonnes lighter than on previous Incat installations", a saving that helped offset the mass of the batteries.

As Wärtsilä notes, this configuration delivers "low weight, a shallow draft and excellent manoeuvrability – critical characteristics when docking at busy urban terminals".

Efficiency and charging

Despite all its grandeur, Hull 096 is a model of operational precision. At 25 kn, it makes the Buenos Aires-Colonia run in about 75 minutes. Rapid turnaround is enabled by automated charging towers at each terminal, topping up the batteries in just 60-90 minutes.

The entire ecosystem, from the energy-management brain and power-conversion muscle to the DC hub, shore-charging kit and ProTouch propulsion controls, comes via Wärtsilä, a company betting heavily on an electrified maritime future.

"Ferries play a vital role in meeting the growing demand for environmentally sustainable transport options, with ship electrification a key solution for enabling the sector to transition towards net zero emissions," Wärtsilä Marine President Roger Holm told the *Tasmanian Times*.

Safety, of course, is paramount. Incat, Corvus and Wärtsilä devised rigorous protections: fire-resistant enclosures, advanced ventilation, thermal-runaway isolation and constant system monitoring, all built to withstand the punishing realities of marine life.

Regulatory approvals spanned multiple jurisdictions, with Hull 096's blueprint likely to influence future battery-electric ship standards worldwide.

A turning point

For Casey, Hull 096 is far more than an engineering milestone. "It is the first fully-electric vessel of its size in the region, the largest battery installation ever fitted to a ship, and a testament to what can be achieved through collaboration, innovation and vision."

With battery technology evolving and charging networks expanding, the knowledge gleaned from Hull 096 will feed into a new generation of electric craft – faster, sleeker and capable of longer voyages.

ABOVE: Stephen Casey, Incat.

Incat sees it as proof that zero-emission ferries are not just a green dream, but a commercially sound reality.

Another contract

"At Incat, we're not just building a ship. We're building the future of sustainable transport, right here in Tasmania," Casey said.

It's also a masterclass in integrated design; aligning hull form, energy storage, propulsion and infrastructure into a coherent, commercially viable whole.

And the story doesn't end here. In July 2025, Incat revealed it had won the contract to design and build two battery-electric ferries

"[Hull 096 is] the largest electric vehicle of any kind ever built, and one of the most significant single export items in Australia's manufacturing history."

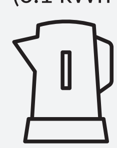
Power in perspective

43 MWh is enough to:

CHARGE
717
EVs (60 kWh battery)

DRIVE THAT EV
239,000 km
(6 times around Earth)

BOIL
430,000
kettles
(0.1 kWh each)



for Danish operator Molslinjen. Slightly shorter at 129 m, these vessels will carry about 45 MWh of batteries and hit speeds above 40 kn on the bustling Kattegat route.

Incat Chairman Robert Clifford calls the project another "turning point not just for Incat but for the global maritime industry", noting it will spawn a new class of high-speed, low-emission ships. The expansion is also an economic boon for Tasmania, with Incat's Prince of Wales Bay facility set to double both its capacity and its workforce.

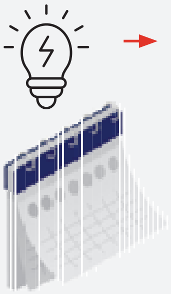
High-speed, all-electric shipping is no longer a distant aspiration. It's here, it's humming and it's built in Tasmania. □

ABOVE: The ferry under construction in Tasmania.

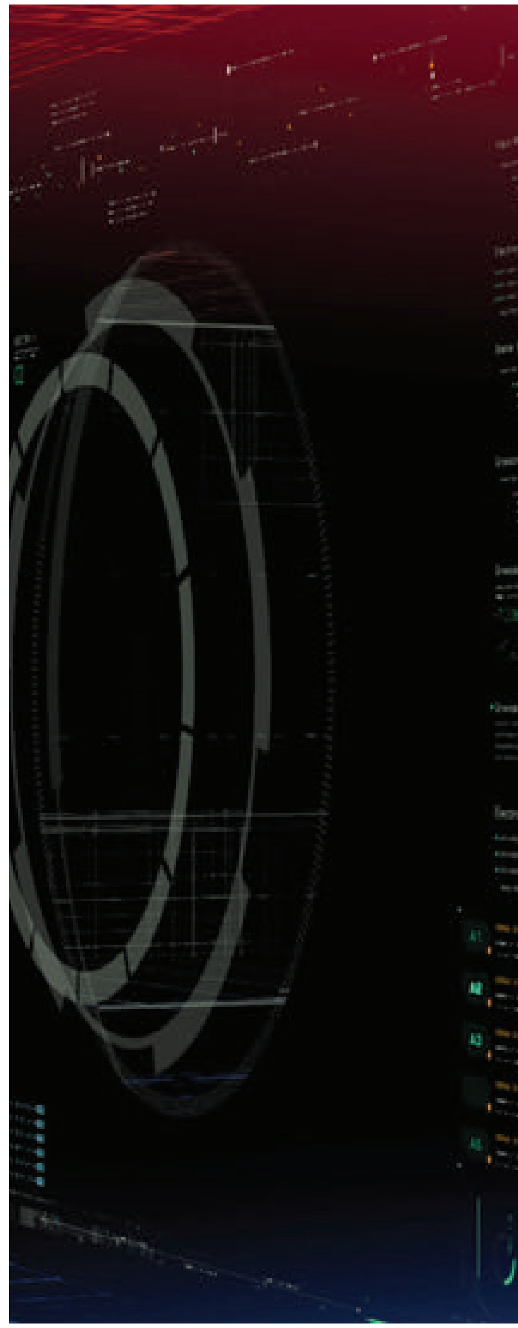
RUN YOUR TV FOR
49 years
non-stop (100 W TV)

POWER YOUR ENTIRE HOME FOR
~7.9 years
(15 kWh/day)

BAKE BREAD FOR
17,200
oven-hours
(2.5 kW oven)



LIGHT
10,000
LED bulbs (10 W) for
18 days



Blades of glory

The ambition is embedded in the name: the Revolutionary Innovation for Sustainable Engines program. It isn't aiming to be just another aircraft engine upgrade; it's going for broke as a breakthrough for aviation technology.

WORDS BY LARISSA FOSTER

CFM International is a joint venture between GE Aerospace and Safran Aircraft Engines, and its Revolutionary Innovation for Sustainable Engines (RISE) program is an advanced technology demonstrator that has already achieved numerous breakthroughs in the quest to propel the next generation of aircraft. Weaving open-fan aerodynamics with advanced materials, 3D printing and fuel flexibility, RISE's novel open-fan engine design promises greater efficiency while significantly reducing emissions.

Since the program was unveiled in 2021, the global efforts of 2000 engineers and a network of partners such as NASA and the US Department of Energy's National Laboratories have put CFM on track for ground and flight tests this decade.

As Executive Director of the CFM RISE program at GE Aerospace, Alex Simpson, told *create*: "If you really want to do something different, you have to do some things differently."

ABOVE: Alex Simpson, GE Aerospace.

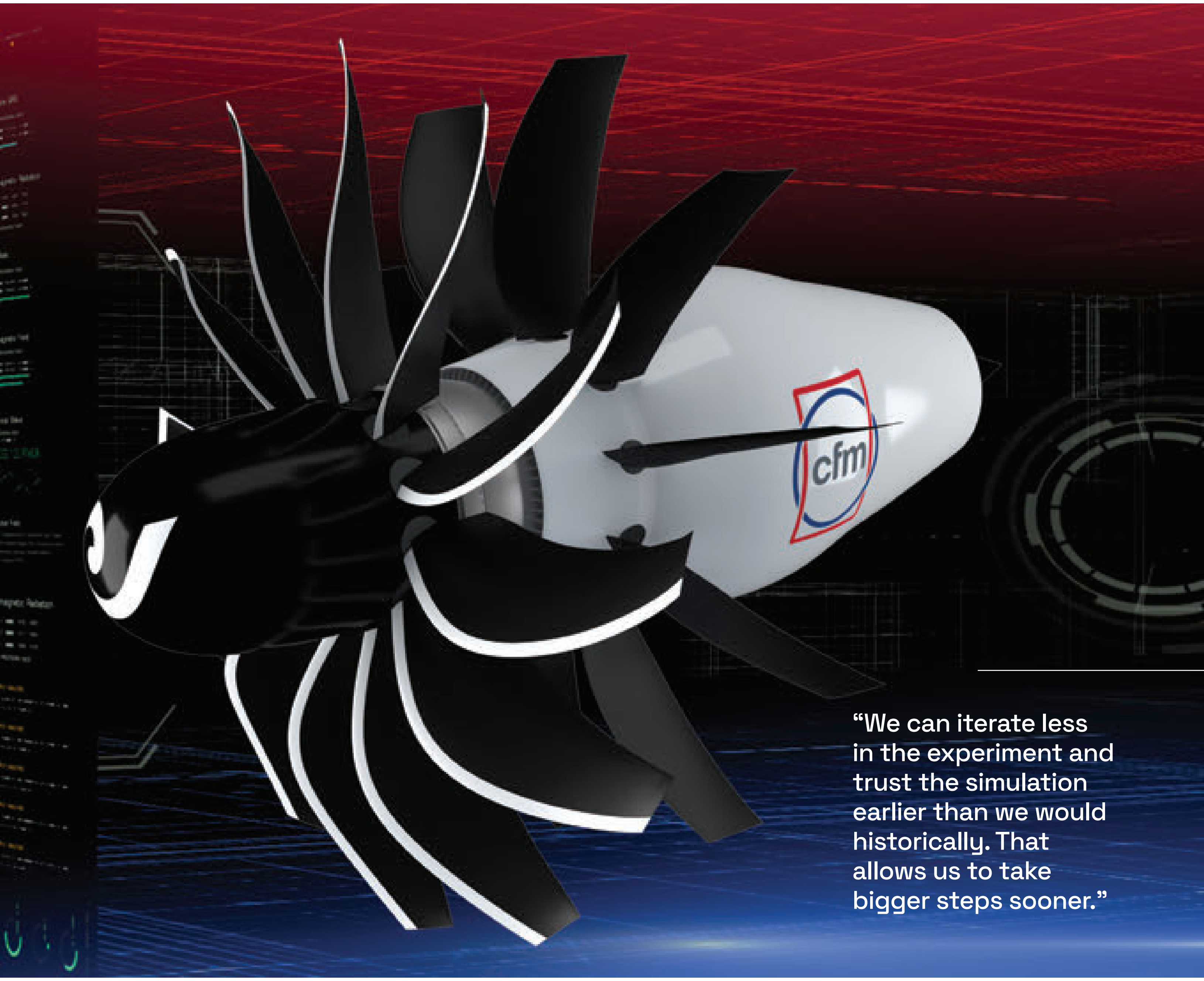
Propulsive efficiency

The innovative heart of the RISE program is its novel open-fan architecture. This new jet-engine design removes the traditional engine duct. Freeing the blades in this way allows for a larger fan size with less drag, to improve fuel efficiency and reduce carbon emissions.

Considered alone, the open fan (or "propfan") concept is hardly new. But the duct-free experimental engines GE Aerospace and Safran produced in the 1980s, while demonstrating the fuel efficiency of the concept, were bulky, heavy and unbearably loud. The single-stage open-fan engine, by contrast, is on track to achieve a bypass ratio more than five times greater than the most advanced ducted engines, which are reaching the limits of their propulsive efficiency.

"If you look at the history of commercial aerospace, what we've done is steadily grow the size of the fan to help with propulsive efficiency. And it turns out you can do only so much when you hold on to having a duct," Simpson said. "You reach a point where that trade between the efficiency you're gaining by increasing the fan size, and the weight and drag of the duct balance, each other out.

"To go any further, you have to take a big step – removing the duct."



> “We can iterate less in the experiment and trust the simulation earlier than we would historically. That allows us to take bigger steps sooner.”

ABOVE: GE Aerospace's open-fan concept.

Conceptual leap

The RISE program has put the open-bladed fan at the centre of reimagining aviation with the help of significant advances in technology and computing. Its conceptual leap makes the open rotor engines of last century seem like museum pieces by comparison – and it has been achieved almost counter-intuitively by simplifying the architecture.

“The one we flew back in the 1980s was a counter-rotating open rotor with two rotating blade rows, which is both heavy and complicated,” Simpson said. “Because our design capability has progressed so much, we can go from two rotating fan blade rows to one with a stationary outlet guide vane.”

A key advantage of the open fan is that this stationary guide vane behind the main fan blade allows a fan – one already unducted and extremely efficient – to fly at the same speed as today's narrow-body engines and aircraft.

“It is, in many ways, a very significant step forward.”

Advanced computing has enabled the CFM RISE team to analyse aerodynamics at an extreme level of fidelity to produce >

a fan that's markedly more efficient aerodynamically – and a lot quieter – than its predecessors.

"The design capability we have today in terms of supercomputing, and the fidelity of the design tools we have, are orders of magnitude more capable than they were previously," Simpson said. "It's allowing us to explore the physics in much finer detail than we've been able to up to this point. It's hard to overestimate just how significant a step up that is in terms of capability."

Next-gen materials

Adding to the supercomputing expertise are the breakthroughs in composite technology GE Aerospace has been making since before the 1990s. Advancements in materials and manufacturing help enhance the engine's performance and reduce its production costs.

Rather than being made of metal, the fan is equipped with carbon-fibre composite blades that are lighter, stronger and more durable than jet engines, with the blades made from all-metal alloys.

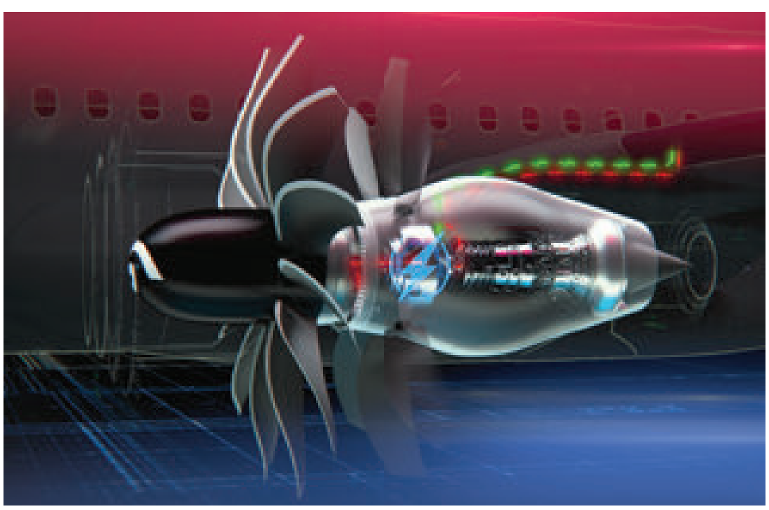
"It turns out that having a very large fan requires it to be very light – and a composite fan blade is key to drawing on that field of experience. We can now have an open-fan engine with a much better aerodynamic and acoustic design, with a light composite blade that sets you up for success on the architecture.

"Only GE Aerospace and CFM have that capability."

As well as the open-fan design and carbon-fibre composite fan blades, the RISE project is reimagining the materials at the core of the engine. The open fan's compact core, which houses the compression and combustion modules, is comprised of ceramic matrix composites (CMCs). Lighter than steel yet capable of withstanding extremely high temperatures, CMCs present a groundbreaking material for the hot section of a commercial aircraft engine.

"This material fundamentally has a great temperature capability and is lighter than metals, so we can use it as a replacement for components where it is appropriate to be weight-saving and give additional thermal capability. If you can cut down the amount of cooling needed, you're being more efficient."

Furthermore, the core is being designed and tested for



ABOVE: A render of the concept being implemented, unrepresentative of any defined future aircraft configuration.

LEFT: Visualising the open-fan design.

BY THE NUMBERS

THE RISE ENGINE OFFERS A

20%

REDUCTION IN FUEL CONSUMPTION AND CARBON DIOXIDE EMISSIONS COMPARED TO OTHER ENGINES

MORE THAN

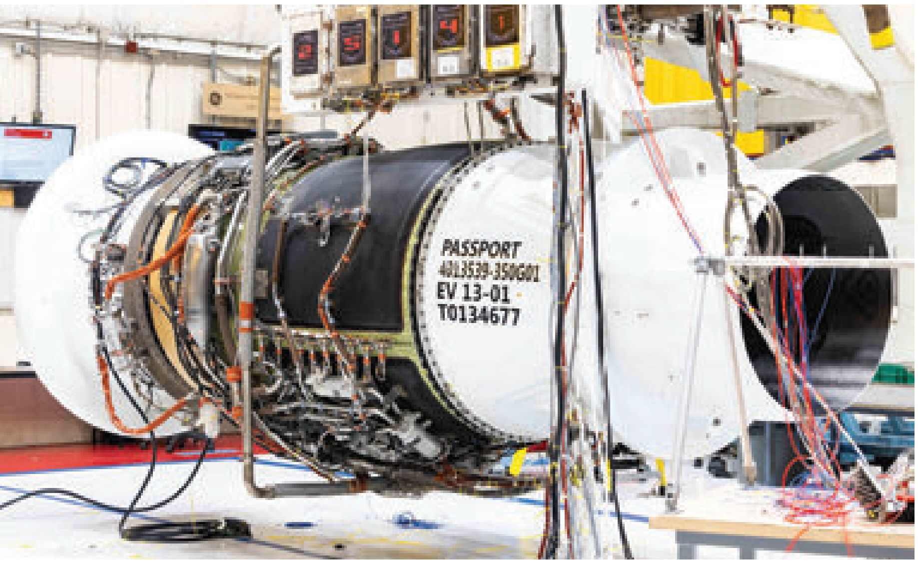
2000

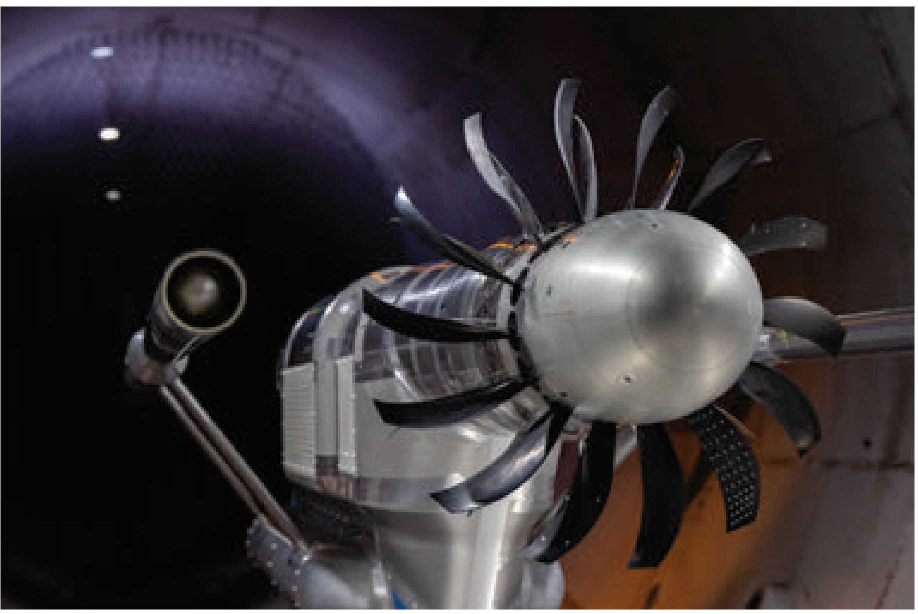
ENGINEERS ARE WORKING ON THE PROGRAM

THE COMPANY HAS MADE

275 million

COMPOSITE FAN BLADE FLIGHT HOURS SINCE 1995





ABOVE: GE Aerospace technologies have been developed across decades.

compatibility with alternative, next-generation fuels, including unblended sustainable aviation fuel. This has the same chemical composition as common jet fuel, but, instead of being made from fossil-based sources, it comes from renewable sources.

CFM also continues to advance hydrogen-combustion technology. The integration of hybrid-electric technology in the RISE program is another key pursuit: GE Aerospace is currently developing a hybrid-electric system, including projects in partnership with NASA, that will further reduce the dependence on liquid fuels.

Simpson noted that the composite fan, CMCs and fuel alternatives reflect advancements in materials and manufacturing pioneered by GE Aerospace and Safran across years of research and development.

"It's an example of how long-range this business is. We develop these technologies over decades."

From lab to flight deck

Essential to the RISE program is the pursuit of a reduction in fuel consumption and carbon dioxide emissions by more than 20 per cent compared to today's most efficient engines, towards a target of net zero by 2050. The global aviation industry currently accounts for about 2 per cent of global carbon emissions, a figure that will likely increase as commercial aviation expands.

"It's ambitious, and historically a significant step for a single generation," Simpson said. "Typically, in the previous generations we've done 15 per cent, so a 20 per cent fuel burn goal over today's state-of-the-art engines is a big deal."

Trust in simulation

So will the revolutionary potential of open fans become an aviation reality? The fidelity of supercomputing simulations and extensive wind-tunnel testing to date suggests the commercial launch of open-fan technology is a matter of when, not if.

US National Laboratories has been a crucial partner in this pursuit. Its supercomputing has changed the nature of testing and simulation to advance open-fan design and capabilities.

"We can iterate less in the experiment and trust the simulation earlier than we would historically. That allows us to take bigger steps sooner," said Simpson. "Setting up an experiment is an extraordinarily involved and labour-intensive task, so if you can trust a simulation in these more complex spaces, it can save you a lot of time. It's very exciting as an engineer to see so many technology maturations coming along as per plan.

"I don't have a lot of big risks that I'm still overly concerned about at this point. I think we have the engineering challenges well in hand, and I think we've got the right architecture to get us to where we want to go." □

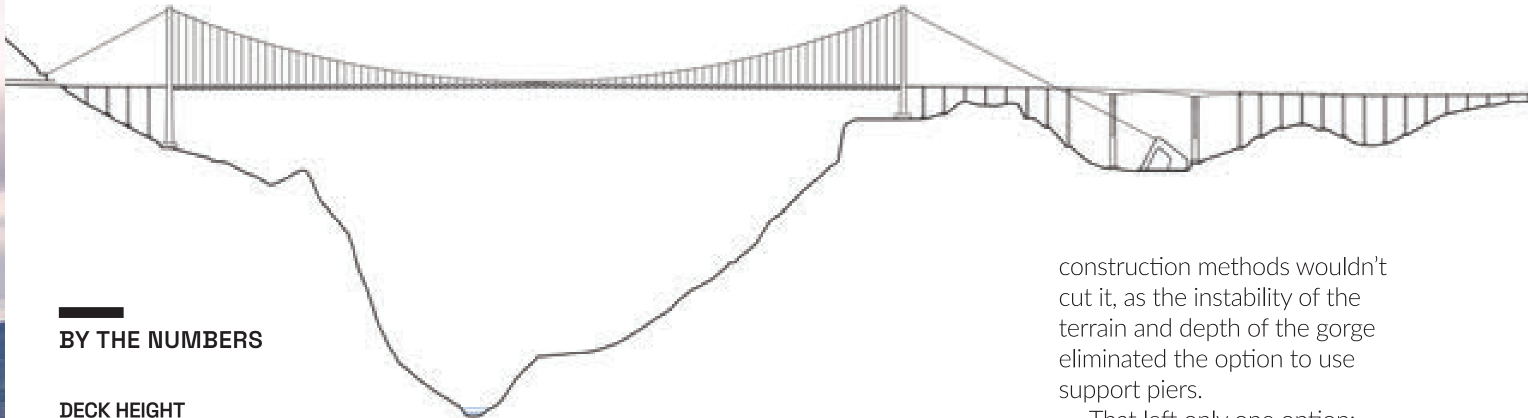
Grand designs

WORDS BY JOE ENNIS

China's Huajiang Grand Canyon Bridge is a feat of extreme engineering that has resulted in the world's highest bridge platform.

Despite being riddled with deep river gorges and limestone karst valleys, where vertical drops of several hundred metres are common, the remote Guizhou province, one of China's least developed, has become a focal point for the country's economic expansion.

In order to open up the resource-rich region, which boasts abundant open space for renewables and rivers suitable for hydro power, China has embarked on such a road and bridge-building blitz that, remarkably, the province is now home to all of the world's 10 highest bridges.



BY THE NUMBERS

DECK HEIGHT
625 m
ABOVE CANYON FLOOR

MAIN SPAN
1420 m

TOTAL LENGTH
2890 m

TOWER HEIGHTS
262 m
AND
205 m

STEEL TRUSS WEIGHT
22,000 t

ESTIMATED COST
US$28 million

LOADING TESTED TO
3300 t

TRAVEL TIME REDUCTION FROM
5 hrs TO 1 hr

“This bridge demanded everything – technical knowledge, persistence and courage. The reward is not just a bridge, but a legacy.”

The most spectacular of these is the Huajiang Grand Canyon Bridge. Modestly billed as a solution to a commuting problem, reducing hours-long detours to a casual two-minute crossing, this convenience comes off the back of some spectacular engineering.

Faced with some of the most extreme geographical and geological challenges, even by Chinese standards, engineers knew conventional bridge construction methods wouldn’t cut it, as the instability of the terrain and depth of the gorge eliminated the option to use support piers.

That left only one option: a suspension bridge spanning nearly 1.5 km, with its deck soaring 625 m above the river.

By comparison, the Sydney Harbour Bridge span is less than half that length, and its deck is just 49 m above water.

ABOVE: Mapping the bridge’s elevation.

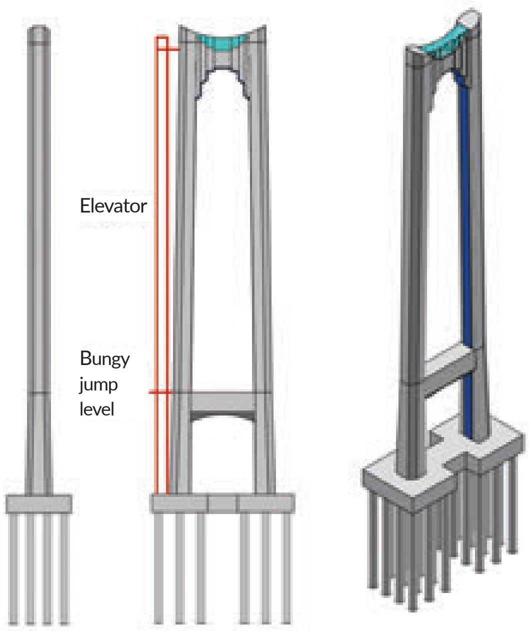
BELOW: The completed bridge officially opened on 28 September 2025.

High winds

For this project, engineers settled on a single-span suspension bridge with a steel truss deck. The truss depth, at close to 8 m, is stiffened to provide resistance against the high winds that sweep through the canyon.

The finished bridge measures 2890 m in total length, with a 1420 m main span, carried between two towers, 262 m on the north side and 205 m on the south. At this scale, “we couldn’t rely on conventional cranes”, said senior engineer Wu Chaoming. >

“Seeing the truss rise above the gorge gave us a sense of achievement, not just because of the structure, but because we knew we had addressed risks most projects never face.”



ABOVE LEFT: Huajiang west tower and elevator.

ABOVE RIGHT The bridge's truss lineup.

So engineers developed a customised cable-hoisting system which became the world’s largest aerial gantry. This system spans the valley via four steel track ropes, each designed for more than 8000 kN of tension.

“The hoisting system became our lifeline,” Wu said, “moving girders weighing over 200 t safely into place, while controlling sway, wind gusts and thermal expansion.”

Millimetre precision

The valley creates a natural wind tunnel, with typical sustained crosswinds of more than 70 km/h and gusts of up to 160 km/h. Engineers designed the structure to accommodate wind-induced movement, with monitoring systems helping control lateral sway and torsional rotation. The truss deck is made from 93 modular sections weighing more than 22,000 t in total. As with many Chinese high bridges, these sections were prefabricated offsite and hoisted across the valley into place.

The hoisting system integrated trolleys, winches and real-time monitoring to send 200 t sections running on a pair of aerial rails between towers. This precise monitoring allowed the sections to be placed with millimetre precision.

Temperatures range from 30°C in summer to −20°C in winter, creating stress cycles in steel cables and expansion joints And although Guizhou is not China’s most active seismic zone, earthquakes are still a common occurrence. The risks were many and high.

“Seeing the truss rise above the gorge gave us a sense of achievement, not just because of the structure, but because we knew we had addressed risks most projects never face,” chief engineer Li Zhao said.

Testing the load

Earlier this year, the all-important staged load test was conducted when 96 trucks weighing 30 t each were driven slowly across the deck to ensure safety and performance.

LEFT: Dismantling the scaffolding.

An array of more than 400 sensors embedded in the structure monitored deflections, stresses and vibrations, giving engineers an immediate view of how the structure performed under heavy load.

Project manager Wu Zhaoming described the event as "the final exam before the bridge opens. For us, it was the moment theory became reality."

Time-saving templates

Though Huajiang Grand Canyon Bridge is unique in the scale of its challenges, China has been able to deliver so many record-breaking bridges in such a short time due to its emphasis on standardisation and prefabrication. Engineers have developed a suite of tried-and-tested suspension and cable-stayed bridge templates. Core elements such as tower geometry, cable anchoring systems and stiffened steel truss decks are reused and adjusted for local topography.

This approach reduces design risk, streamlines fabrication and allows contractors to mobilise equipment and skilled labour more quickly.

It's also an iterative process where lessons learned on one project can be applied almost immediately to the next. The result is an industrialised process where high-deck bridges across Guizhou's gorges can be delivered faster and more reliably. □

Pushing beyond norms

Bridge historian and highestbridges.com curator Eric Sakowski has spent two decades documenting the rise of China's super-high bridges. For him, Huajiang is as notable for what it represents as for the numbers on the page.

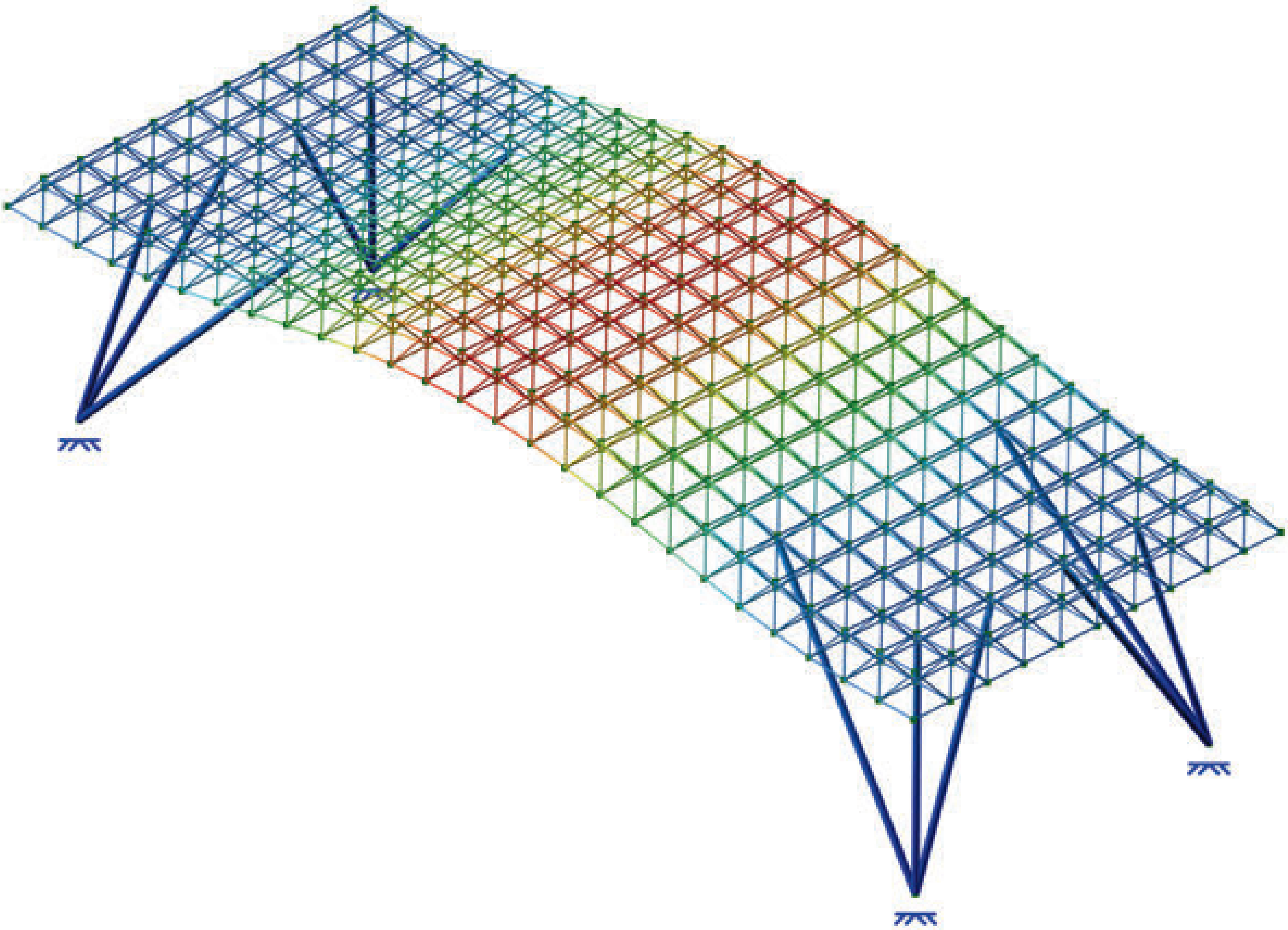
"For smaller bridges, standard templates have sped up construction," he told *create*. "But Huajiang belongs in a new category where engineers deliberately push beyond norms."

Though processes and protocols may be shared, "these are not cookie-cutter designs".

He points to other projects that show this culture of experimentation:

- **Lugu Lake Bridge** *(Sichuan)*
  The largest A-frame suspension design attempted, with main cables spreading 25 m apart at midspan and converging to just 4.3 m at the towers.
- **Litanghe Bridge** *(Sichuan)*
  The world's longest-span towerless suspension bridge, with cables anchored directly into mountain tunnels and no access road on one slope. Equipment is ferried by gondola ropeway.
- **Wujiang Mozhai Bridge** *(Chongqing)*
  Opened in 2023, with the world's tallest extradosed span on concrete piers 216 m high, second only to France's Millau Viaduct.

"Most of these crossings could have been built more conservatively," Sakowski noted. "But expressway developers are embracing unusual forms. In Huajiang's case, the tower tops are the real signature – those layered, bowtie-shaped crossbeams wouldn't look out of place on the Golden Gate. It's a reminder that aesthetics are still part of the equation."



[Experience]

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High-wire act
The continuous power provided by catenary connections could transform open-pit mining and road freight.

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Alarming structural flaws led to South Korea's worst peacetime disaster.

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DISASTER

Breaking point

Words by Julie Nguyen

When five floors of a department store in Seoul's Gangnam District collapsed, it constituted South Korea's worst peacetime disaster.

It began with a months-old crack. Then another. Then, on the morning of 29 June 1995, in the heart of Seoul's upscale Gangnam District, hairline fractures snaked across the ceilings of the top floor of the busy Sampoong Department Store.

At first, managers cordoned off the floor. The situation was manageable. But by midday, those cracks had widened to up to 10 cm across.

Customers reported hearing several loud bangs from the top floors as the vibration of heavy air conditioning units on the roof radiated through the cracks. Just one day before, a worker heard a strange noise, which was later revealed to have been the sound

BELOW: The aftermath of the collapse.

of a reinforcing steel bar slipping through concrete.

Still, management ignored the advice of onsite engineers and refused to issue evacuation orders. They switched off the humming air conditioners, moved merchandise down to the basement and closed off the fourth floor.

At 5:57pm, time ran out. In just 20 seconds, the entire south wing of the store crumbled in an avalanche of concrete and steel. In total, 502 people were killed (including six whose bodies were never found) and nearly 1000 were injured.

Following investigations into the disaster's cause and mass public outcry, two people were sentenced for criminal negligence, corruption and accidental homicide convictions, and multiple city officials were charged with bribery.

Latent errors

In the immediate aftermath, the cause of the disaster was unclear. The investigation committee suspected a gas leak as the most likely reason. However, scenes of the rubble showed the building hadn't thrown debris outwardly as with an explosion; it had compacted downwards like a stack of cards. With gas ruled out, attention turned to the building's construction.

The Sampoong Department Store, consisting of five upper floors and four basement levels, with an atrium connecting the north and south wings, was made of reinforced concrete and built as a flat slab construction. Using this technique, concrete columns bear the load of the floor slab above, doing away with the need for cross-beams when the load is calculated accurately.

BELOW: The department centre prior to disaster.

In an article published in *Forensic Science International*, Tae Won Park, from the Department of Architectural Engineering at Dankook University, wrote: "[Sampoong Department Store] had the structure that collapse of one pillar support led to breakdown of an entire structure in a moment. Therefore, such [a] structure requires a precise design and construction."

However, the final design was not as precise as it needed to be, as frequent changes to its function and design, and construction deficiencies, put the building at risk of catastrophic failure and were ultimately to blame for the disaster.

The first cause originated in the building's planning stage when owner Lee Joon converted the initial plans for a four-floor residential building to a commercial shopping centre.

According to approved drawings, the unplanned-for fifth floor would be a rollerskate rink, a decision made to bypass zoning regulations that restricted the number of trading floors a department store could have. Joon remodelled the top floor, again, to a food court. >

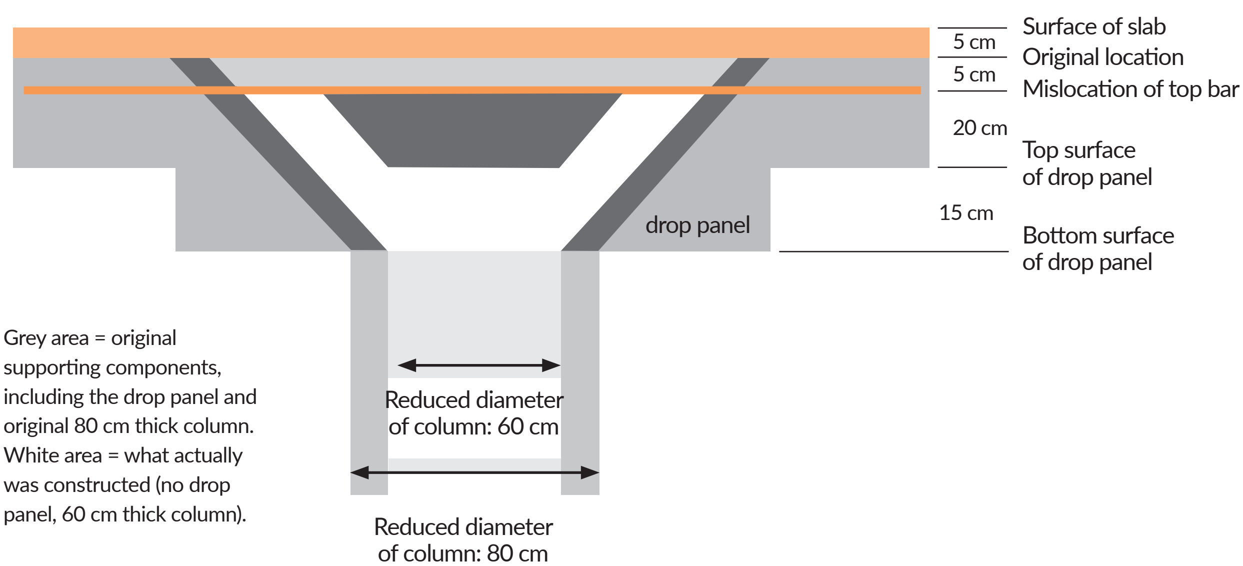


Figure 1: A visual representation of the joint between the slab and column

This had major ramifications. Heavy kitchen appliances were installed, new wall partitionings were added, and hot water pipes were run along the reinforcing bars in the upper floor slabs. Park found only 40 per cent of the original flexural strength was retained.

While this construction flaw was not enough to precipitate the building's collapse, it contributed to structural weakness which was compounded by the omission of drop panels identified in at least one column on the fifth floor.

"In [a] flat slab structure, [a] drop panel plays [the] role as a beam in frame slab structures that consists of pillar and beam," Park wrote. "Consequently, no construction of [the] drop panel could be a direct factor to [the] collapse of [the] building."

The combination of the mislocation of the reinforcing top bars, undersized diameters of the top columns and the lack of a supporting drop panel severely compromised the structure's ability to counteract the high shear forces being directly applied to the concrete columns, which were additionally excessive to those assumed by the original design engineer. Each of these would reduce its safety factor, investigations concluded.

ABOVE: The building's south wing collapsed within 20 seconds.

Critical point

Despite these alarming structural flaws and construction deficiencies, the department building stood for five years. The final blow was the installation of air conditioning units on the rooftop in 1993.

Three cooling towers, weighing a combined 45 t, were originally placed towards the residential end of the roof. Residential complaints of noise eventually led to their relocation on the other side. However, rather than carefully lifting or disassembling them into smaller units to minimise structural damage, they were placed on rollers and dragged across the roof.

Importantly, they were moved directly over a column in the fifth floor; column 5E, which investigations found to be the originating point of collapse when the fifth floor slab around it gave way to punching shear force.

Over the next two years, each time the air conditioning units clicked on, vibrations would gradually widen cracks around the column, and by the morning of the disaster, it overloaded, culminating in the department store's progressive collapse.

Crackdown

Construction of the building began in 1987, in the middle of South Korea's infrastructure boom and one year before

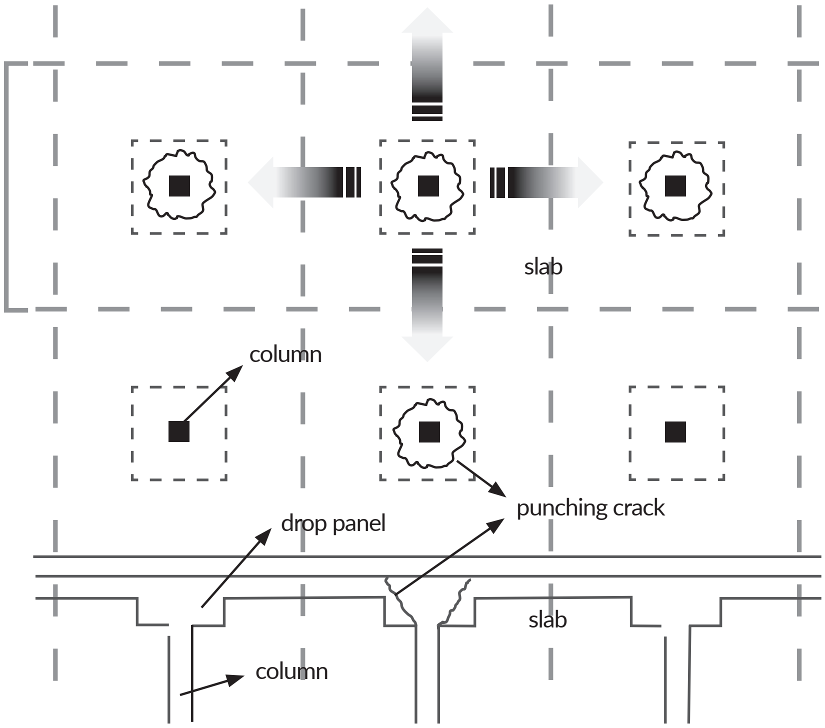


Figure 2: Start point of progressive collapse

Seoul would host its first Olympic Games.

Against this backdrop of major socioeconomic growth, court investigations found evidence of corruption among local planning officials, including accepting bribes to approve frequent design changes, which enabled Sampoong's owner to circumvent safety provisions. Perfunctory inspections sandpapered over the early warning signs, with cracks already observed in April 1995.

This was summarised by the chairman of a special investigation committee organised by the government: "The accident was the result of poor management caused by a lack of construction [and] building inspection, maintenance and management, and a lack of supervision from the administrative office."

The response to the collapse also revealed gaps in emergency rescue protocols; namely, a lack of a command and control system to coordinate the response across emergency personnel, inadequate rescue equipment and a delay in rescue. As a result, new disaster management laws were created, including:

- The establishment of the Disaster Control Act on 18 July 1995. This strengthened emergency infrastructure around response, recovery and relief following human-caused disasters at the national and local government level.
- The creation of the National 119 Rescue Service on 19 October 1995, provisioning rescue resources directly to major national accidents. □

ABOVE: This diagram shows the slab with the columns below, and the shear forces that punched through the columns into the columns below.

DIAGRAM: Adapted from Tae Won Park, *Forensic Science International.*

Access references for this story.

LEARNING FROM HISTORY

The Sampoong Department Store disaster represented one deadly incident in a series of 1990s disasters with their origins in South Korea's period of rapid development in the 1980s.

On 21 October 1994, a section of Seongsu Bridge, a major cantilever bridge that ran over Seoul's Han River, connecting the northern Seongdong District to the southern Gangnam District, cracked during morning rush hour. The 48 m long section of the 1.2 km bridge brought down six cars and one bus, killing 32 people and injuring 17.

The direct cause of the disaster was identified as poor welding of the vertical members connecting the suspension truss to the anchor truss. Equally, inadequate maintenance was to blame as the load on the busy bridge increased due to overloaded trucks crossing from a nearby cement plant. The bridge had been designed with 18 t vehicles in mind, but some of the trucks weighed as much as 24 t. Had thorough safety checks been conducted, it's likely a collapse wouldn't have occurred.

Following the investigation, then-president Kim Young-sam called for the revision of construction laws to extend the maintenance and safety management periods of buildings, and stronger prevention measures around poor construction. One key result was the creation of the Special Act on the Safety Control of Public Structures, mandating that structures 10 years and older undergo regular inspections by non-government experts. Seven months later, the Sampoong Department Store collapsed.

THE LOOK BACK

Catenary power

Catenary power – the overhead wires that supply energy to countless trains and trams – is fundamental to transport, and now there are some big visions to take it off the rails.

Words by James Chalmers

ABOVE: ABB's eMine Trolley System enables vehicles to run on an electric trolley assist line instead of using diesel fuel.

IMAGE: ABB.

While electric cars, buses and trucks have recently become a common sight on Australian streets, it is far from the first time.

In fact, 80 years ago, a visitor to almost any major city would have encountered frequent trolleybuses, their tyre-clad wheels powered by overhead electric wires. Clean, quiet and efficient, trolleybuses were killed off by their inflexibility – tethered to the grid, they couldn't navigate around a simple traffic snarl – and faltering economics.

By the 1960s, diesel engines and fuel were cheap enough for transport authorities to accept the noise and fumes, wiping out the trolleybus networks.

Today, however, the principle behind the trolleybus is making an engineered comeback. Faced with the immense challenge of decarbonising heavy transport, engineers are looking back to direct electrification to power some of our heaviest vehicles.

High-wire act

Nowhere is the challenge greater than in open-pit mining, where haul trucks burn vast quantities of diesel pulling loads up long ramps. These sites, with their fixed, high-energy routes, have become the perfect incubator for reinventing catenary technology.

The first step was the diesel-trolley hybrid. Trucks connect to overhead lines on the most demanding, energy-intensive uphill segments, dramatically cutting fuel use.

Collahuasi copper mine in Chile, for example, installed catenary power on a 1 km section of ramp. The four 365 t Liebherr trucks have more than doubled their uphill speed – from 11 to 25 km/h – while diesel consumption and carbon dioxide emissions on that segment have fallen 98 per cent.

This "bridge" technology is being advanced by manufacturers such as Komatsu, whose Power Agnostic haul truck platform was first deployed at Sweden's Aitik mine in July this year. Its modular architecture allows a mine to start with a diesel-trolley system and later transition to battery-electric or hydrogen power without replacing the entire vehicle.

The next evolution is the battery-electric trolley, which uses the catenary not just for propulsion, but for dynamic charging. The truck is fully electric, and the overhead line recharges its batteries while in motion, cutting downtime. Hitachi Construction Machinery and ABB are trialling this approach.

Innovative engineering is also tackling the primary drawback of traditional catenaries: the fixed, costly infrastructure. Instead of a 15 m-tall overhead mast system, Liebherr's Power Rail concept uses a side-mounted conducting rail just a third the height, making it faster and easier to install and relocate.

Hitting the highway

Worldwide, road freight is a major emissions source. In Australia, heavy trucks are responsible for more than two-fifths of all transport emissions. The fact that heavy road freight is normally concentrated on major arterial routes has made it an attractive target for catenary power.

Germany has been leading the direct electrification of trucking, building multiple short stretches of “eHighways” since 2017.

There, Professor Alan McKinnon of Hamburg’s Kühne Logistics University, estimates 60 per cent of heavy truck carbon dioxide emissions occur on just 2 per cent of the road network, while almost 90 per cent of freight trucks cover fewer than 50 km or less after leaving the highway. In German and Swedish trials by Siemens and Scania, trucks use a small on-board battery for the first and last miles.

While eHighway trucks require significantly more infrastructure than traditional trucks or even battery-electric trucks, they bring other advantages.

One is their efficiency, thanks to minimising conversion losses. The German government estimates eHighway trucks have a well-to-wheel efficiency of 77 per cent, compared to 62 per cent for battery-electric trucks and 29 per cent for hydrogen fuel-cell trucks. Traditional diesel trucks average 20-25 per cent.

With no need for heavy, long-range batteries, eHighway trucks are also lighter. This means they can carry more goods – making their efficiency even higher. By lessening dependence on batteries, they also reduce the high energy and resource costs of manufacturing batteries. Lastly, the continuous power also eliminates refuelling or recharging stops.

Despite the high upfront costs of investing in catenary infrastructure, one major German study estimated that electrifying between one-third to half of Germany’s autobahn network would be the cheapest way to decarbonise road freight.

Other studies have arrived at similar conclusions. For example, Cambridge University’s Centre for Sustainable Road Freight concluded that “overhead catenaries and compatible [heavy goods vehicles] are the most energy-efficient and cost-effective solution to fully decarbonise the UK’s road freight network”.

“The investments in pantograph electric vehicles would pay back the vehicle operators in 18 months (through lower energy costs) and the electrification infrastructure could pay back its investors in 15 years (through electricity sales),” the authors argued in the 2020 paper.

Shifting roadblocks

Despite the clear technical advantages, the path to adoption is fraught with challenges. The most significant is the classic chicken-and-egg problem: haulage companies won’t invest in catenary-capable trucks without the infrastructure, and governments or private entities won’t fund expensive infrastructure without a fleet of vehicles ready to use it.

Further, social and political acceptance remains low. Research in Germany reveals that while industry actors are open to the technology, the public has a poor understanding of it, and local residents are concerned about visual impact and safety.

For Australia, these developments are profoundly relevant. Our economy relies on road freight and resources – two areas where this technology shows promise. Australian mines are trialling trolley-assist haul trucks and loaders as part of their electrification. But eHighways look like being a longer haul. They could potentially help decarbonise vital freight arteries such as the Hume, Pacific, and Bruce highways, but the tyranny of our distances make it challenging. □

LEFT: Germany has led the way in trucking electrification.

Different approaches

Overhead wires and pantographs aren’t the only way of directly electrifying road transport.

Catenary systems using overhead power lines, and trucks equipped with pantographs. This approach is familiar from trams and trains, and is by far the most widespread and advanced.

Wireless induction systems use coils installed under the asphalt, which transmit power into the vehicle without direct contact. The same technology is used for charging electric toothbrushes, and increasingly for mobile phones and other devices.

Electric rails in the road, where a movable arm extends from the truck to the rail. This system operates like a slot car track.

Events

NOVEMBER 2025 to DECEMBER 2027

2025

10-14
NOV 2025
Australasian Tunneling Conference 2025

Location: *Perth*
Website: *atc2025.com.au*
Join leading professionals, engineers and innovators for five days of keynotes, cutting-edge technical sessions and in-depth discussions on the latest advancements and challenges in the underground industry.
Register now

25-28
NOV 2025
Hydrology and Water Resources Symposium 2025

Location: *Canberra*
Website: *hwrs2025.com.au*
Experts and policymakers from Australia and the Asia-Pacific will explore the state of current hydrology and water knowledges that can inform decision-making amid climate challenges.
Register now

13 Nov 2025
Engineers Australia Excellence Awards gala dinner

Location: *Sydney*
Website: *engaus.org/excellenceawards*
Recognise the people and projects redefining what's possible in Australian engineering. The gala dinner is the national celebration of innovation and excellence. Indulge in premium hospitality, inspiring company and a night like no other. This is the room you want to be in.
Register now

2026

27-30
APR 2026
Systems Engineering Test and Evaluation Conference (SETE)

Location: *Sydney*
Website: *clems.eventsair.com/sete26/*
Connect with experts and advance complex capability practices as you share your knowledge and contribute to the conversation at SETE 2026. Explore AI, data engineering and simulation in systems design, testing and optimisation.
Call for abstracts

13-18
SEP 2026
35th Congress of the International Council of the Aeronautical Sciences

Location: *Sydney*
Website: *icas2026.com*
Gathering global aerospace leaders, this premier forum highlights the latest research, emerging technologies, sustainability practices and next-generation aviation. Share your insights and help shape the future of aerospace by submitting an abstract.
Abstracts close 10 January 2026

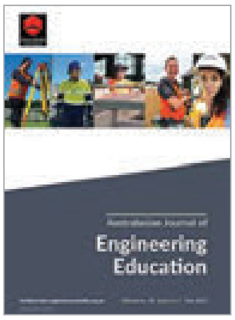
2027

27-02
NOV-DEC 2027
Asian Pacific Confederation of Chemical Engineers Congress 2027

Location: *Sydney*
Website: *apcche27.com*
Save the date for this landmark conference which will bring together leaders in chemical engineering, innovation and research across the Asia-Pacific. Register your interest for program updates, early bird offers and key announcements.
Register your interest

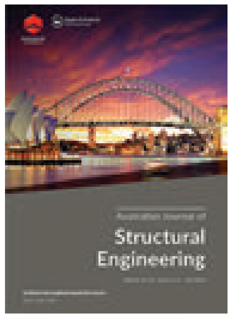
Resources

JOURNALS



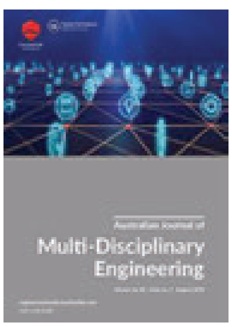
EDUCATION
Engineering students' perceptions of problem and project-based learning: comparing online and traditional face-to-face environments

This paper investigates and compares students' perceptions of a problem and project-based learning modules delivered through face-to-face and online environments in sequential years.
bit.ly/47epMde



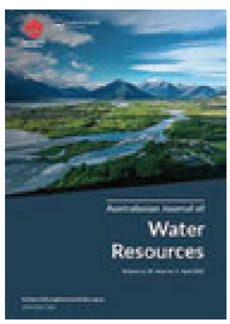
STRUCTURAL
Comparative analysis of cup-headed and hex-headed bolts: current industry practice and structural capacity

This study aims to compare cup-headed bolts and hex-headed bolts in terms of their practical applications and structural capacity in timber post-to-beam connections through a combination of industry surveys and experimental testing.
bit.ly/3JvUMeU



MULTI-DISCIPLINE
Stakeholder engagement in large infrastructure projects

This paper is concerned with the dynamic nature of stakeholder relationships related to large infrastructure projects.
bit.ly/4mzolLi



WATER
Adaptive clustering regression model for forecasting water quality index

This paper proposes an adaptive clustering regression model to enhance water-quality index prediction.
bit.ly/45AABVR

RESOURCE RECOMMENDATIONS

Ingenious perspective
Expand your thinking on the engineering profession with an international lens. Stories published by *Ingenia*, the publication of the UK Royal Academy of Engineering, range across structural engineering, mechanical engineering, robotics, environment and more.
ingenia.org.uk

Field guide
Looking for your next read? Authored by the creator of video series Practical Engineering, *Engineering in Plain Sight* is an illustrated field guide to the world of engineering, exploring the simple yet effective mechanisms behind the built environment.
practical.engineering/book

Papers galore
Engineers Australia's publication library boasts resources to fuel your learning. One recent addition? A basic primer for the role and potential of batteries.
engineersaustralia.org.au/resources/publication-library

Engineers Australia members have access to a plethora of technical journals free of charge.

THE LESSON LEARNED

Kym Murphy FIEAust CPEng EngExec

Early in her career, Kym Murphy made mistakes that were hard to miss – including a set of skewed culverts still visible today. But those missteps became formative lessons in accountability.

As told to Joe Ennis

I still laugh, and sometimes cringe, when I think about the skewed precast culverts we installed on the Roma-Taroom Road.

You can still see them today, poking out like misaligned Lego blocks. They were meant to make things easier for the drainage crew. Instead, they became a very visible lesson in thinking things through.

Back in the late 1990s, I was a young civil engineer managing a 7.3 km greenfield deviation to upgrade a section of a 150-km key freight route that was predominantly unsealed. It was a big project, working across tough blade-ploughed country, incorporating earthworks, safety improvements and major drainage works. I was leading a young team, many of us new to large-scale earthworks.

I'd never worked with scrapers before, so I leaned into learning on the job. Cycle times, cut-and-fill balancing, haul distances – all new. We set the project up and it was going well. The crews were hitting performance targets, but something didn't add up. We were ticking all the boxes on paper. But we just weren't shifting enough material.

KEY LESSONS

01
It's okay not to know. Lean into learning and ask for help.

02
Don't be afraid to stop and reassess, even when it's unpopular.

03
Excellence is not perfection. Own your mistakes and grow from them.

I made the unpopular call to stop production. That gave us space to figure out the issue. Turns out, I hadn't accounted for the difference between bank or cut cubic metres, loose and compacted volumes. A small oversight, but it meant we had under-allocated how many scraper loads of material we needed to shift to build and compact the embankment. Just a couple of numbers, but they had a major impact.

That wasn't my only misstep. To reduce the labour intensity of installing numerous drainage culverts and keep ahead of earthworks production, I ordered precast headwalls, forgetting they're made perpendicular to the pipe. On a skewed alignment, that meant every culvert headwall stuck out at awkward angles. Higgledy-piggledy is the best way to describe it. We made it safe, but it's still there. It still makes people laugh. And maybe it still teaches new engineers what not to do.

What stayed with me wasn't just the technical learnings. It was the importance of vulnerability, of owning your mistakes. Excellence isn't perfection; it's being the best version of yourself in everything you do. It's about being accountable and creating the kind of space where people can fail safely and learn from it.

That's the environment I had that supported my professional growth – and that's the environment I now try to foster within my teams. □

Kym Murphy FIEAust CPEng EngExec is Director, Infrastructure Management and Delivery, Queensland Department of Transport and Main Roads, and a member of the Engineers Australia College of Leadership and Management.