ENGINEERS
AUSTRALIA

create

Engineering. Making Life Happen.

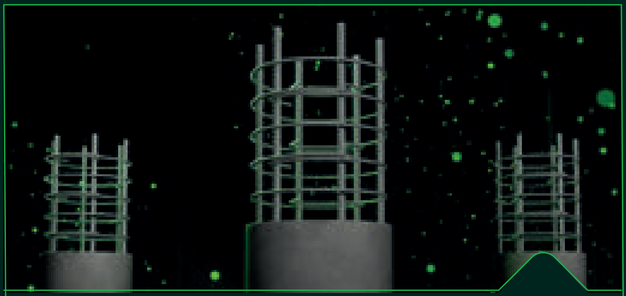
It's complicated

What it takes to engineer the most complex machines ever made

create VOL 12 | NO.1 | FEBRUARY 2026

ENGINEERS AUSTRALIA

Uses up to 16.7% less raw material than our standard 500N reinforcing steel and made from 100% scrap metal.



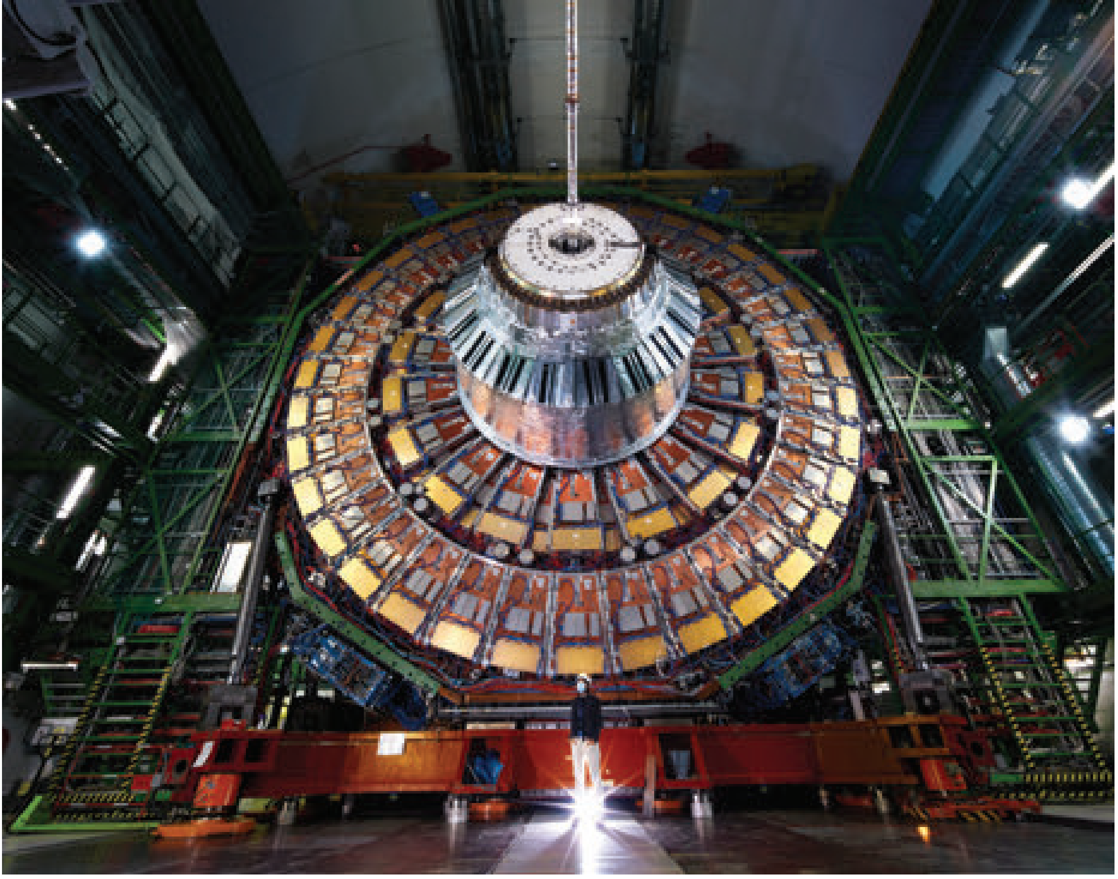
Delivering a lower embodied carbon solution when used in place of our equivalent load capacity standard 500N reinforcing steel.

Confidence from third-party certification from GECA (SSPv1.0i-2019) and meets Australian Standard AS/NZS 4671.

SENSE SOLUTIONS

Delivered by InfraBuild

Contents



PROJECTS

EXPERIENCE

ENGINEERS
AUSTRALIA

Engineers Australia
Phone: 1300 653 113
Website: *engineersaustralia.org.au*

For subscription enquiries, please contact the Engineers Australia Member Services team:
contact@engineersaustralia.org.au

For advertising enquiries, please contact Sudip S Gupta, Advertising Sales and Partnerships Manager:
ssgupta@engineersaustralia.org.au

LOCATIONS:

Adelaide
Level 11,
108 King William Street
Adelaide SA 5000

Brisbane
Level 9,
340 Adelaide Street
Brisbane QLD 4000

Canberra
Level 1,
11 National Circuit
Barton ACT 2600

Darwin
9 Cavenagh Street
Darwin NT 0800

Hobart
Level 5,
188 Collins Street
Hobart Tasmania 7000

Melbourne
Level 26,
181 William Street
Melbourne Victoria 3000

Newcastle
Suite 3, Tonella Commercial Centre
125 Bull Street
Newcastle West NSW 2302

Perth
Level 10, Allendale Square
77 St Georges Terrace
Perth WA 6000

Sydney
Mezzanine Level
44 Market Street
Sydney NSW 2000

.Mahlab

Editorial Director: James Chalmers
Commissioning Editor: Joe Ennis joe@mahlab.co
Production Editor: Lachlan Haycock
Creative Director: Gareth Allsopp
Art Director: Caryn Isemann

CONTRIBUTORS:
Julia Abbondanza, Jonathan Bradley, Larissa Foster, Elle Hardy,
Chloe Hava, Karen Jamal, Sian Powell, Daniel Salas, Chris Sheedy

Level 3, 727 George St, Haymarket, NSW 2000
www.mahlab.co

Printed by: IVE **Mailed by:** D&D Mailing **ISSN 2205-5983**

Engineers Australia is committed to sustainability
This publication has been printed using paper sourced from sustainable forests as certified by PEFC, an international non-profit, non-governmental organisation promoting sustainable forest management globally. With more than 300 million ha of certified forests, PEFC is the world's largest forest certification system.

Words by Joe Ennis

Member-centric, future-focused

As Engineers Australia's new National President and Board Chair, electronics engineer and technologist Tom Goerke FIEAust CPEng EngExec sees an exciting opportunity – and an obligation.

An optimist by instinct, Tom Goerke believes engineers are uniquely placed to shape Australia's future – provided the profession is willing to evolve alongside technological, social and economic change.

"Engineers have always been problem-solvers," he told *create*. "What's changed is the speed and scale of the challenges we address. That makes this an incredibly important moment for engineering."

Goerke acknowledges the strong foundation laid by his predecessor, Dr Raj Aseervatham. "What I'm inheriting is an organisation with momentum, a clear strategy and an appetite for change. My focus is helping Engineers Australia deliver on that strategy in ways that are meaningful for members and valuable for the nation."

Central to Goerke's agenda is a sharper, more data-driven understanding of the organisation's diverse 140,000-strong membership. He sees digital transformation as a critical enabler – not technology for its own sake, but a way to better understand what members need.

"We want to be genuinely member-centric," he said. "That means listening carefully, learning from data and feedback, and tailoring how we support engineers.

"History shows us that technology doesn't remove opportunity – it reshapes it."

"This deeper understanding will allow Engineers Australia to deliver more personalised services, clearer pathways and stronger advocacy on behalf of the profession."

Emerging technologies

Goerke brings a long-standing engagement with emerging technology, including AI. Rather than viewing digital disruption as a threat, he sees it as an amplifier of engineering capability.

"History shows us that technology doesn't remove opportunity – it reshapes it. Our job as engineers is to engage with these tools critically, ethically and creatively, not to fear them."

That perspective is informing Engineers Australia's work on AI and digitalisation, and its role in helping members understand changes to engineering practice, productivity and professional expectations.

Perhaps Goerke's strongest focus is on the future pipeline of engineers and the need to evolve engineering education in step with industry. An adjunct professor at Curtin University, he sees Engineers Australia as a critical catalyst between universities, industry and government.

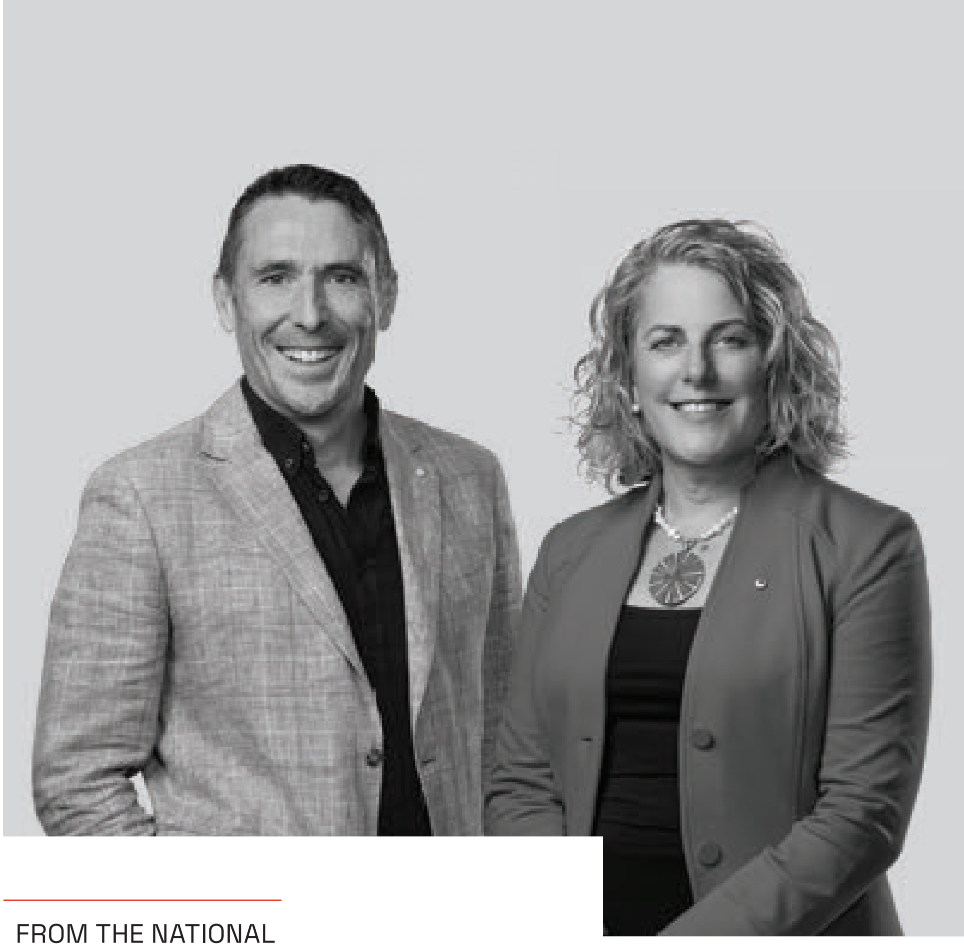
"We have a responsibility to help evolve education models so graduates are better prepared for modern practice.

"I'd like to see Engineers Australia use data insights proactively – working with universities, industry and government to help shape curricula, promote industry-integrated learning models and support faster adaptation as needed."

Optimistic about both the profession and Australia's capacity to innovate, he believes engineers will be central to solving challenges ranging from the energy transition to digital transformation and national productivity.

"There is so much positive work happening right now. Engineers are behind it – often out of the spotlight. My goal is to help ensure their contributions are understood, supported and amplified." □

[Leadership]



FROM THE NATIONAL PRESIDENT AND CEO

Led by purpose

The new year is underway, and Engineers Australia is delighted to welcome new National President and Board Chair Tom Goerke FIEAust CPEng EngExec, who brings a wealth of experience to the role.

Tom Goerke's career began as an electronics design engineer and has since spanned systems engineering, telecommunications, startups, and the design and operation of major innovation centres across Australia and overseas. He has worked with global operators and leading international ICT vendors, built and scaled new technology ventures, and now runs a technology advisory firm.

Goerke is also an adjunct professor, bringing real-world engineering practice into universities. This issue of *create* explores how this breadth of experience informs his perspective on where the profession needs to head next.

The theme of this edition is complexity. Engineering has always been about solving the world's intricate challenges, and in 2026 we face national and global issues that demand the expertise, innovation and vision of engineers.

create analyses the myriad of engineering requirements for some of the country's major climate and technology challenges – and its big-ticket projects such as the 2032 Brisbane Olympics and Paralympics. Underpinning success in these complex environments is the strategies of the multidisciplinary teams tasked with bringing them to life. *create* talks to engineers who are transforming complicated problems into smart solutions, drawing on expertise from within the profession and beyond.

This year, Engineers Australia is pleased to be a Local Event Supporter of the FORMULA 1 QATAR AIRWAYS AUSTRALIAN GRAND PRIX.

Formula 1 is often presented through the lens of its drivers, but the sport is fundamentally an engineering achievement. Every lap is the outcome of thousands of engineering decisions across aerodynamics, materials, data, software, energy systems, safety and operations. While the drivers are the public face of the competition, it is the engineers behind the scenes who continuously redefine the limits of performance and safety. Our presence at Albert Park will highlight Formula 1 as a live demonstration of the depth of engineering expertise required to sustain the sport.

Smart systems engineering for sustainable networks is the focus of World Engineering Day on Wednesday 4 March. From the upkeep of miniature cities in Antarctica to the creation of a robotic solar panel installation machine, *create* meets the engineers behind the designs.

We also reflect on how the profession can assist in some of Australia's pressing challenges – including the R&D brain drain, boosting STEM representation among our policy makers, and the role of socially responsible AI.

With the new year comes the opportunity for knowledge sharing and purpose-backed decision-making. The success of many of Australia's key projects will require the skills of our profession in doing what engineers do best – finding solutions to complex challenges and improving our quality of life. □

Tom Goerke
FIEAust CPEng EngExec
National President and Board Chair
nationalpresident@engineersaustralia.org.au

Romilly Madew AO
FTSE HonFIEAust EngExec
Chief Executive Officer
ceo@engineersaustralia.org.au

The big picture

Engineers continue to push the limits of possibility and innovation.
And with extreme innovation comes immense complexity.

Parts of a whole

Engineers are helping to drive an exponential leap forward in innovation by embracing interconnected systems. And often, the greater the innovation, the greater the complexity of the system.

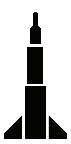
This is true simply at a numbers level. The parts in many large-scale machines, in aeroplanes and rockets for example, can reach into the millions.

Here are four examples of objects comprised of an incredible number of individual parts.

BOEING 787 DREAMLINER

2.3 million individual parts

The craft relies on a complex international supply chain that sources parts from countries such as the UK and Japan.



SATURN V ROCKET

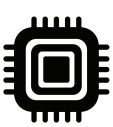
5 million individual parts

The Saturn V was considered the most complex machine ever during construction.

LARGE HADRON COLLIDER

Millions of components

The compact muon solenoid detector alone has 9.3 million silicon microstrip sensors.



INTEGRATED CIRCUIT

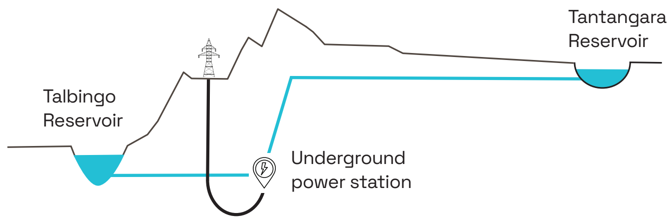
Billions of microscopic transistors and memory sites

A computer chip vastly outnumbers the parts in a mechanical assembly such as an aeroplane.

Unrivalled enterprise

In Australia, this engineering complexity also extends to major infrastructure projects. Take **Snowy 2.0**, the country's largest hydropower project, for example.

Talbingo Reservoir



BY THE NUMBERS

27 km

OF WATERWAY TUNNELS

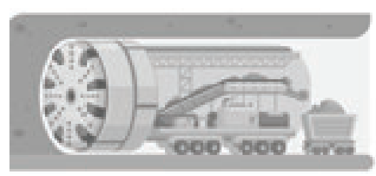
4

TUNNEL BORING MACHINES WILL BE USED

THE POWER STATION COMPLEX WILL BE LOCATED

800 m

UNDERGROUND



ROCK BOLTS

15-20 m

LONG WILL BE DRILLED INTO THE ROCK AT THE TOP AND SIDES OF EACH CAVERN

2

MAIN CAVERNS

MACHINE HALL

240 M LONG X 50 M HIGH X 30 M WIDE

TRANSFORMER HALL

200 M LONG X 50 M HIGH X 20 M WIDE

IMAGE: Snowy 2.0.

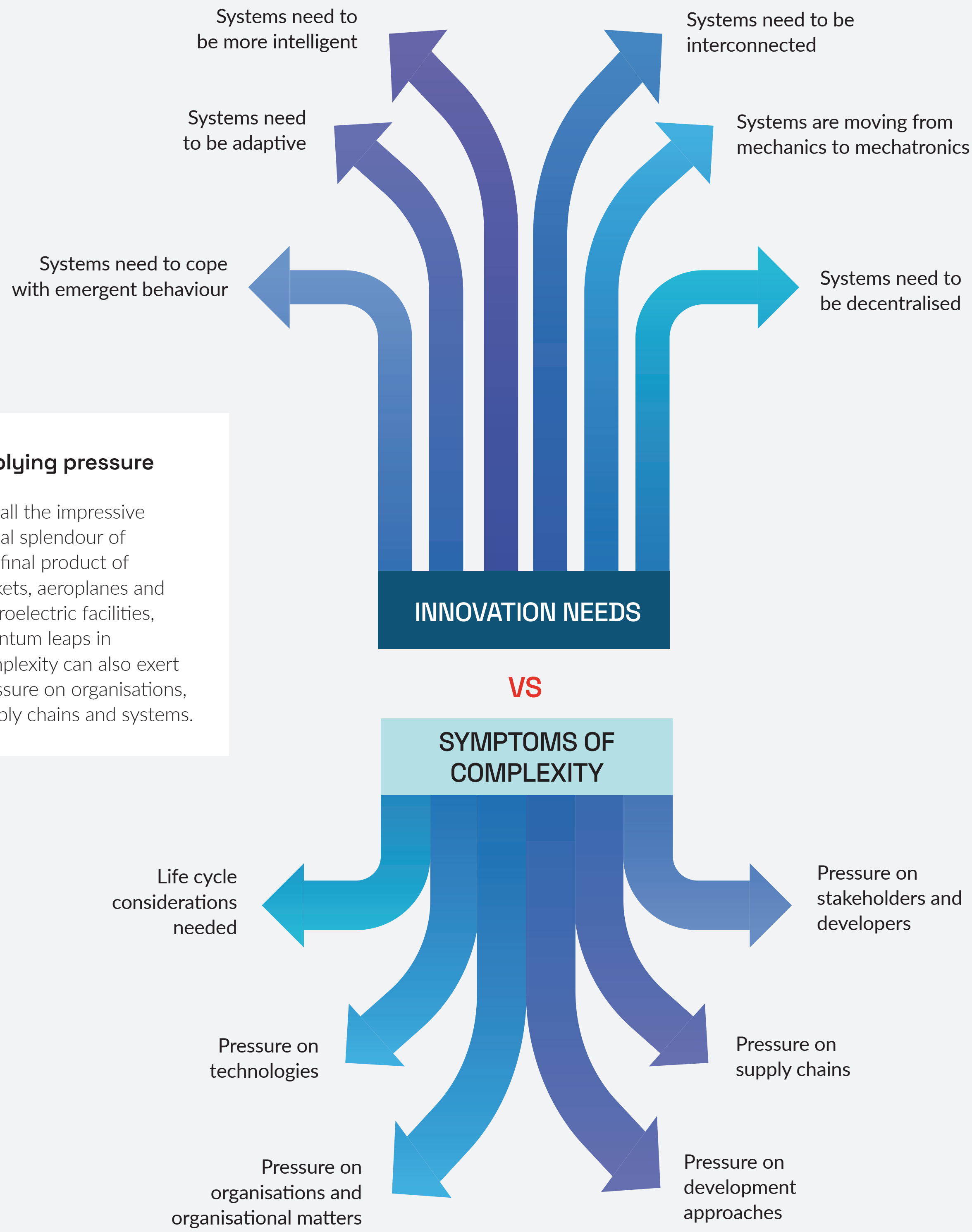


Diagram adapted from Garza Morales (2023).

Applying pressure

For all the impressive visual splendour of the final product of rockets, aeroplanes and hydroelectric facilities, quantum leaps in complexity can also exert pressure on organisations, supply chains and systems.

SOURCE
Garza Morales, GA et al., 2023, Engineering complexity beyond the surface: discerning the viewpoints, the drivers, and the challenges, Research in Engineering Design

"We must deploy the full $15 billion, and we must do it wisely. If we can crowd in three times that from private and international partners, that's $60 billion flowing into Australia's industrial base."

IMAGE: Dylan Coker.

Words by Joe Ennis

Capitalising on complexity

Australia's industrial future depends on its ability to do more than extract and export. The $15 billion National Reconstruction Fund is charged with rebuilding the country's capacity to manufacture technologies and materials at scale.

LEFT: Mary Manning, National Reconstruction Fund.

Despite its fair share of innovations, Australia is famous for its struggles translating world-leading ideas into commercial realities. Established in 2023, the National Reconstruction Fund (NRF) aims to change that reputation by investing in industrial capability to diversify and transform Australia's economy.

With more than a thousand applicants for funding to date, someone with experience in rigorous governance and with a commercial, future-focused mindset is vital to guide investment decisions in the national interest.

That's Chief Investment Officer Mary Manning, a veteran fund manager with decades of private sector experience who has stepped into the government space for the first time. That breadth and depth of experience matters when the goal is to turn ambition into sovereign industrial capability.

For Manning, the NRF is more than another investment fund. It's an opportunity to shape Australia's industrial story.

"It's about building capability," she told *create*. "We can actually help the country make things again."

The NRF invests across seven priority sectors: renewables; enabling capabilities; defence; transport; resources; agriculture, forestry and fisheries; and medical science. These are known internally by the acronym REDTRAM."

Though the idea is simple – using government investment to prime the innovation pump – the execution is much more complex. The NRF can invest across both debt and equity, from senior secured lending to early-stage venture capital requiring a critical eye sensitive to long-term outcomes. >

The goal is to develop sovereign capability by ensuring Australia can produce and scale critical technologies on its own terms.

Taking intelligent risks

Backing innovation means embracing uncertainty. For Manning and her team, that means balancing commercial returns with national interest.

"We're a commercial fund, not a grant program," she said. "We have a return benchmark – the five-year government bond rate plus 300 basis points – so every deal must stand on its own merits."

But risk, she said, isn't a deterrent; it's part of the design. "The National Reconstruction Fund Corporation Act 2023 identifies areas where we can take higher risk."

These areas include national security, new and emerging technologies and industries, and projects with longer-term horizons. "Private investors often can't go there because their funds are shorter-dated. That's where we step in."

What you end up with is a diverse portfolio in terms of industry, but also across the risk spectrum. Some projects are low-volatility industrial expansions; others, such as quantum computing or hypersonic flight, may take a decade to commercialise.

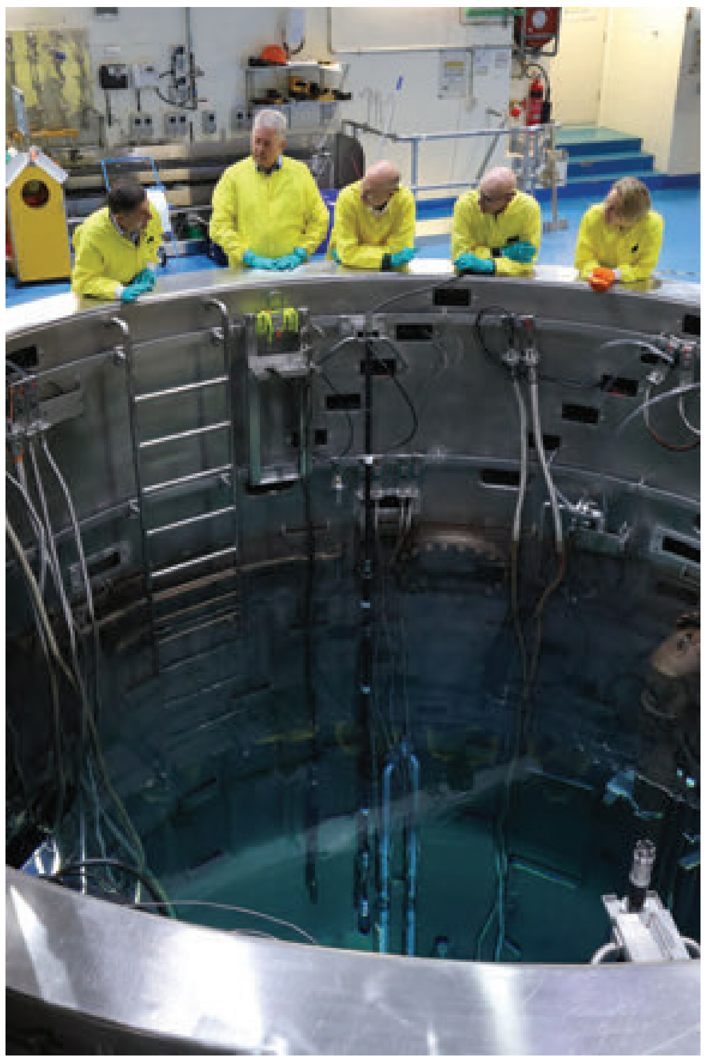
"It's about constructing a portfolio that works as a whole. Some investments will outperform. Others won't make it. But together, they move Australia forward."

Collaboration by design

Amid the broad scope and intertwining complexities, collaboration is a core priority.

Again, "collaboration is written into the Act", she said. "We must collaborate with other Specialist Investment Vehicles – Clean Energy Finance Corporation, Northern Australia Infrastructure Facility, Export Finance Australia, Future Fund and Australian Renewable Energy. We share intelligence, compare deal flow and coordinate impact."

And that cooperation extends beyond government. "The NRF wasn't set up to



ABOVE: The NRFC team touring the Australian Automation and Robotics Precinct in Western Australia in June 2025.

RIGHT: NRFC CEO David Gall and CIO Mary Manning inspecting the OPAL Multipurpose Reactor at ANSTO's Lucas Heights facility in Sydney in September 2025.

crowd out private capital. It's here to crowd it in. For every dollar we invest, we aim to bring in at least one dollar from the private sector."

Sometimes that crowding-in effect goes global. "Foreign direct investment matters just as much. If international partners co-invest, we expand the whole pie rather than just reshuffle slices."

It's an approach Manning says is uniquely Australian in spirit – pragmatic, networked and open. "The NRF can be the anchor investor that gives others confidence to join in."

Making the big decisions

With thousands of decisions required, systems are everything. Behind the scenes, Manning has built an investment process designed to rigorously interrogate applications.

"We've had more than a thousand proposals. Only a handful make it through. So we start with two simple questions: 'Can we?' and 'Should we?'"

"Can we?" is a legal test. The project must fit within the NRF Act, one of the seven sectors and be primarily Australian-based. "Should we?" is the real debate. "That's where we weigh the investment thesis against the risks."

Each proposal passes through multiple phases of due diligence, from a one-page "phase zero" summary to full-scale 50-page investment papers for board approval.

"It's a tightly engineered process. We actually have an engineer on the team who designed our investment decision funnel – what goes in, what comes out and all the decision gates in between."

So far, 16 investments have made it through that funnel. Among them are projects that reflect both the ambition and diversity of the fund.

One early-stage investment supports Hypersonix, a hydrogen-powered aircraft company developing scramjet engines that can reach Mach 5 speeds without emitting carbon dioxide.

"It's high-risk, high-potential and 100 per cent Australian engineering," Manning said.

At the other end of the spectrum is Arafura Rare Earths, developer of the Nolans Project, north of Alice Springs.

"Our $200 million equity investment helps unlock the critical minerals that feed wind turbines and batteries. It's a complex project with over a billion in debt and a billion in equity, but the impact on jobs, regional development and supply-chain resilience is enormous."

The contrast between a small hydrogen startup and a billion-dollar mining operation shows how broad the NRF's remit truly is.

"That breadth and depth is what makes the work so intellectually rewarding. It's rare to have a $15 billion multi-asset fund investing from Series A venture capital to large-scale infrastructure."

> "It's a tightly engineered process. We actually have an engineer on the team who designed our investment decision funnel – what goes in, what comes out and all the decision gates in between."

Seven disciplines

Collaboration isn't just an external priority, but also an internal necessity.

"For every proposal, we bring together people from seven disciplines – investment, finance, legal, environmental-social-governance, impact, technical and risk," Manning said. "That can make things more complex, but it also leads to better decisions. You're constantly learning from people who know different things than you do."

That cross-functional model, she believes, mirrors the way engineering teams work – multidisciplinary, iterative and evidence-driven.

Understanding complexity is vital. "It doesn't have to be chaotic. Handled properly, it leads to stronger outcomes."

Having $15 billion to spend is one thing, but making sure Australia gets value for money is vital and likely to be heavily scrutinised. It's a fact not lost on Manning.

"We must deploy the full $15 billion, and we must do it wisely. If we can crowd in three times that from private and international partners, that's $60 billion flowing into Australia's industrial base."

Her priorities are clear: sovereign capability, regional development, job creation and supply-chain resilience, all underpinned by commercial discipline.

"If we get that right, the NRF will have helped rebuild Australia's capacity to make things. That's how you turn complexity into capability." □

Editor's note: All facts and figures are accurate as of 25 November 2025.

Building an innovative engineering culture

When this engineer joined a Perth start-up, he found a multidisciplinary company committed to a positive culture and premium solutions.

In 2017, when Tony Daniel heard that Craig Bloxham and Tony Comerford were launching a consultancy, he knew he wanted to be a part of their vision.

"I was aligned with their approach on a cultural level," he recalled.

"We're a very good fit together and I believed they could actually do it. What they proposed was a different offering to the market that could help solve people's problems."

Daniel's commitment to that ideal saw him join Agilitus as one of the company's earliest foundation team members and, eight years on, he has grown with the company to become a member of its executive leadership team responsible for nurturing and managing its biggest clients.

Agilitus, for its part, has transformed from a start-up with a handful of employees working together out of a small room in Perth to a national firm of more than 460 employees providing engineering, design, advisory and project delivery services. With more than 100 clients across the resources, energy and industrial sectors, its top 10 projects in one year alone delivered $35 billion of capital value, and it has overseen more than 50 decarbonisation strategies and projects.

Daniel is proud to have been a part of a journey that's seen the business diversify its client base, expand its capabilities and increase the size of its team, all while maintaining its core values and culture.

"Seeing new people come into the business and bring their approach to the work has been great," Daniel said.

"The diversity in our office and the spectrum of what we can offer is quite extraordinary. We have the ability to support each other and learn from each other, so there's a lot of collaboration."

Growing with the company

Today, Daniel is Agilitus' Regional Manager of WA Operations.

"This encompasses everything from an operational perspective within the business; all the projects and our core disciplines report to me," he said.

"It's quite an exciting role to be honest and I'm really enjoying it. It gives me the best opportunity to engage and foster talent, making sure our original culture we developed is consistent and filters through to everything we do now."

"And because we're on a growth trajectory, this philosophy is a priority for every new person joining the business and every client we work alongside."

LEFT: Tony Daniel, Agilitus

A core strength of Agilitus is its repeat clientele, primarily because of the effort it has put into maintaining a strong culture, Daniel believes.

"We approach each project challenge carefully, placing the best skilled people who align with project needs," he said.

"This is all done while considering how we mitigate risks, and refining a best for project solution, which considers the entire lifecycle of the project and the immediate outcomes required."

"We listen to really analyse a client's problem so we can own our assessment and mitigate any risk. That way we can be confident about moving down an innovative path that delivers potentially increased cost savings or added value. We challenge convention, particularly when we know it will deliver superior results. It's a mindset."

All for one

The commitment shown by Agilitus employees like Daniel reflects some of its distinct qualities as a growing business with a national footprint.

Most significantly, Agilitus is entirely employee-owned, ensuring the team is highly engaged in its clients' success.

"When we say shared success, it really is shared, because our business is 100 per cent employee owned. We reward loyalty, high performance, and cultural fit," Daniel said.

"We're all personally invested in the success of our business and its projects."

The company also boasts a low employee turnover rate and engages a large proportion of full-time employees.

"When you join Agilitus, we work hard on providing a long-term career path for you. We'd like to think when you join us; we'll work together until you retire. We're big enough to do important projects and small enough to really care about our people and clients," Daniel said.

" When we say shared success, it really is shared, because our business is 100 per cent employee-owned. We reward loyalty, high performance and cultural fit. Anyone in a leadership position has that investment and they've shown that they're committed to how we approach things and what our goals are. We're all personally invested in the success of our business and its projects. "

Tony Daniel, Regional Manager, Western Australia

For instance, when one of Agilitus' largest clients began facing significant production implications due to fatigue and vibration issues with their large crushing stations, the traditional solution would have been to demolish the structures and rebuild them.

"We were able to come in as a last resort and challenge ourselves to think outside the box and develop a solution that had never been tried on that scale or in the industry before," Daniel said.

"We took the client through the potential risk, which enabled them to bring their stakeholders on the journey, where they could understand how we would mitigate those risks. We developed a solution, shock-tested it, implemented it, and then replicated it on another site."

"Our team is here for the long term and, as a result, we align together on what we're trying to achieve and where we want to be in the short, medium, and long term. We're good at celebrating our people and our successes, as well as identifying where people need support. It's about being set up to achieve your greatest success."

Daniel is just one of the many instances of Agilitus' ability to recognise talent and help develop it to ensure their people have the best chance to succeed. It's the kind of working environment that keeps engineers excited about the future.

"Our vision is ambitious and long term," Daniel said. "We all see ourselves as part of Agilitus for a long time."

IMAGE: Andrew Wilson.

"We ensure that everything people need to live and work safely, in one of the harshest environments on earth, continues to function."

As told to Julia Abbondanza

"Engineering took me to the end of the world"

Simple tasks take extraordinary effort when you're engineering at the South Pole, according to Sara Pearce MIEAust CPEng NER, Director of Engineering at the Australian Antarctic Division.

I **have** always known, almost instinctively, I wanted to be an engineer. My love of design began with architecture. As a kid, I would spend hours flicking through big glossy coffee-table books from the library about architecture, completely absorbed by the lines of tall buildings and the elegance of form and structure.

I was fascinated by technical drawing too. My older brother took it at school. I would watch him sketch plans and think, "I want to do that." But I soon realised something that has shaped my entire career: not every project needs an architect, but every project needs an engineer. That understanding changed everything, and I have never looked back.

After finishing high school, I took a slightly unconventional path, starting with a Diploma of Structural Engineering at TAFE before heading to university. I also took a gap year to teach English in China, an experience which taught me a lot about independence and adaptability – and that I was decidedly not destined to be a teacher.

ABOVE: Sara Pearce's work is "unlike anything else".

LEFT: Pearce in Hobart.

When I returned to Sydney, I completed my engineering degree at UTS in 2005 and began my career at a design and construct company. What began as a graduate role became a 15-year journey at the same company, something that is quite rare now. I started as a design engineer, then became a project engineer, project manager, construction manager and eventually a design manager.

That continuity gave me something invaluable: the ability to see the entire life cycle of a project from the first line on paper to the moment it stands on its own. It's >

ultimately what prepared me for the role I have today.

Sydney to South Pole

My first encounter with Antarctica happened by chance.

One morning I was getting ready for work when I saw a segment on TV that asked, "Are you crazy enough to take on a job in Antarctica?" I had already worked in nearly every state and territory in Australia, so I thought maybe I was crazy enough.

I looked up the Australian Antarctic Division's website and applied for a summer expeditioner role as an engineering services supervisor. It was incredibly competitive, but somehow I got through on my first try.

In 2017 and 2018 I spent my first summer at Davis Station. My employer at the time gave me unpaid leave to go, so I did not have to quit my job, which was an incredible opportunity.

I was away for six months, including training in Hobart and a two-week sea voyage each way aboard the *Aurora Australis*.

I will never forget waking up that first morning as we arrived at the edge of the sea ice. The ship had docked in its exact coordinates, as it always did, and everything outside my cabin window was blinding white and impossibly still. I remember thinking it couldn't possibly be real.

When I stepped off the helicopter that took us from ship to shore, a flight that lasted about 45 seconds, it felt like stepping onto another planet. I turned to a crew member and asked them to pass a message to my boss back in Australia, thanking him for choosing me.

That moment sealed my connection to Antarctica forever.

> "Simple tasks took extraordinary effort. Materials had to be staged carefully, some kept warm, others unpacked from shipping containers during rare good-weather days."

BELOW: Mawson research station.

Miniature cities

Today I am the Director of Engineering at the Australian Antarctic Division. It is a relatively new role created to highlight the importance of engineering in the division's operations. The work we do is unlike anything else.

The Australian Antarctic Program operates three Antarctic stations – Casey, Davis and Mawson – and one sub-Antarctic station on Macquarie Island. Each one functions as a miniature city. We produce water, generate electricity, maintain heating and lighting systems, and ensure that everything people need to live and work safely, in one of the harshest environments on earth, continues to function all year round.

Take water, for example. At Davis Station we do not have a natural supply of fresh water. Instead, we use a hypersaline lake and a reverse osmosis unit to produce it. The catch is that the system only runs for about eight to 12 weeks a year.

That means we have one chance to make enough water for the entire year. If something breaks, it's up to us to fix it before the window closes.

Keeping that water from freezing is another challenge. We use insulated tanks with internal heating loops that circulate warm water to maintain temperature.

It is the kind of detail most people would never think about, but down there it is the difference between survival and shutdown.

The land in winter

Last year, I returned from a full winter in Antarctica, something few people experience. I spent the summer of 2023 and 2024 at Mawson Station, where we began work on the long-awaited Mawson bollard project. The goal was to build a new mooring point for our research vessel.

It was a logistical ballet. We had to move a drilling rig across the sea ice to reach the site before it melted, leave it there for months, and then return when the weather warmed up to drill into rock that had not been touched in 40 years. The work was not glamorous, but it was deeply satisfying.

After that summer I moved to Davis Station to manage a renovation project. We converted shared rooms into single-occupancy quarters and upgraded part of a building that also housed our communications hub. It was like being a part of an Antarctic edition of *The Block*.

Simple tasks took extraordinary effort. Materials had to be staged carefully, some kept warm, others unpacked from shipping containers during rare good-weather days. We would have 12 people line up to carry sheets of plasterboard, one by one, through the building because nothing could be left outside. It was slow, precise and highly collaborative. That is exactly what Antarctic work demands.

RIGHT: Pearce inside the wind turbine at Mawson Station.

Lessons in inclusion

In Antarctica, leadership must be collaborative. Everyone has a role to play, whether they are an engineer, a chef or a communications technician. You quickly learn that solving problems is not about hierarchy; it is about bringing the right people together and staying open to different perspectives.

That approach builds resilience. When things go wrong, and they always do, you need people who can adapt and pivot. In an environment where mistakes can mean losing water, power or heat, there is no room for ego.

As a woman in engineering, I have also seen the industry evolve dramatically over the past two decades. When I started, it was still heavily male-dominated. Today there is more representation, but not as much as there should be. I sometimes wonder if the glass ceiling still exists, or if it is partly a mindset. For years women hesitated to apply for roles unless they ticked every box, and that thinking can still hold us back.

My generation of women sits in an interesting position. We grew up without social media and have had to adapt to a rapidly digital world. That makes us a bridge between two very different ways of working and thinking. I see that as a strength, allowing us to empathise with both sides and lead with perspective.

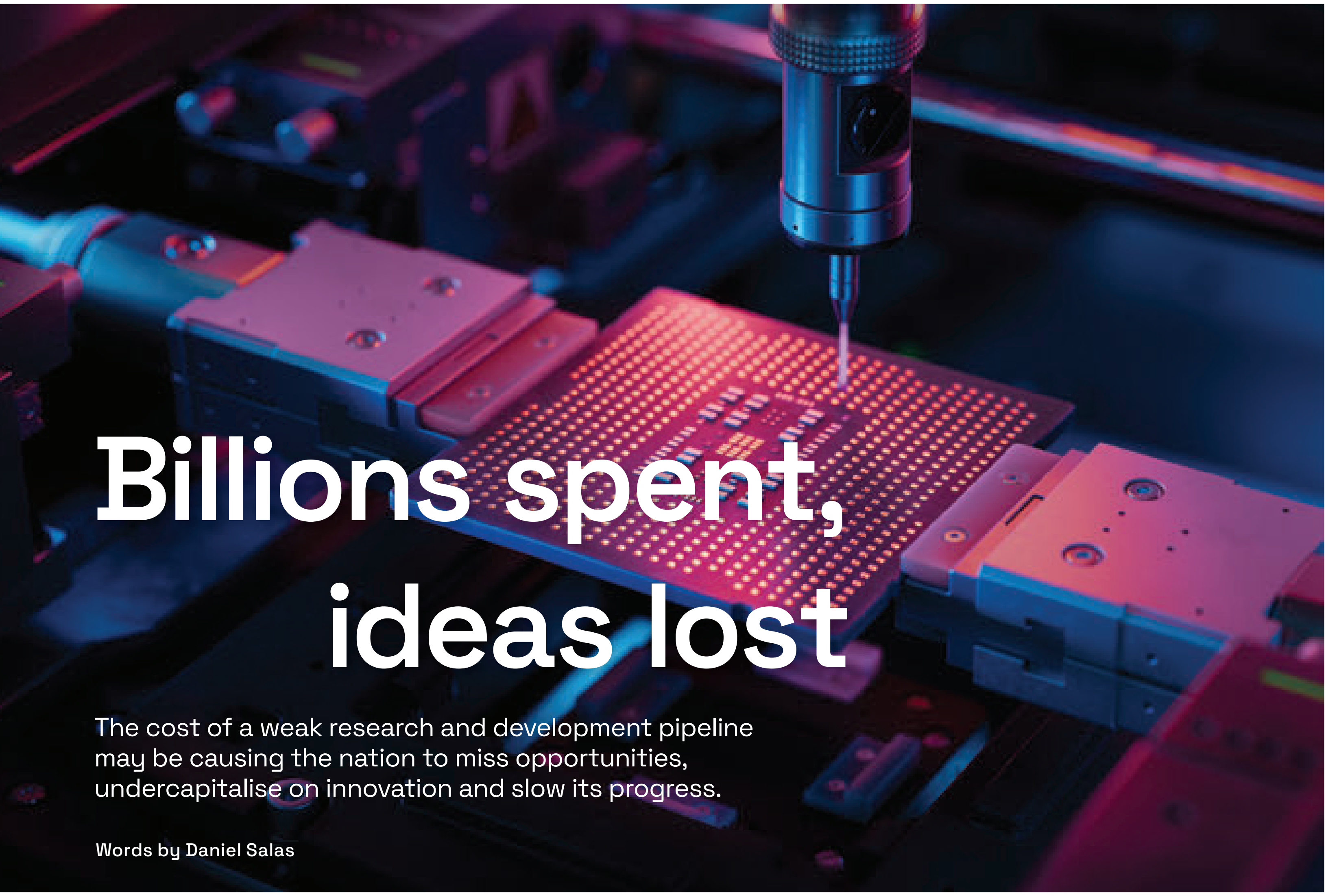
> “There is something grounding about knowing that every pipe, wire and beam you oversee directly affects someone’s ability to live and work.”

Finding courage

Working in Antarctica changes you. It teaches patience, humility and the beauty of purpose-built design. There is something grounding about knowing that every pipe, wire and beam you oversee directly affects someone’s ability to live and work in an environment most people will only ever see on a map.

If I could give one piece of advice to young engineers, it would be to follow your passion. The world needs engineers who care deeply about what they do. When you love the work, you will find the courage to take on challenges that might seem impossible.

Antarctica gets under your skin in a way that’s hard to explain. For me, it’s a reminder of what is possible when human determination meets the power of nature. ◻



Billions spent, ideas lost

The cost of a weak research and development pipeline may be causing the nation to miss opportunities, undercapitalise on innovation and slow its progress.

Words by Daniel Salas

Engineers are indispensable to Australian research and development. Almost one-third of the engineering workforce is employed in R&D-intensive sectors such as manufacturing or professional, scientific and technical services. Of Australia's total business spend on R&D, half is engineering-related.

With the Australian Government's Strategic Examination of R&D (SERD) aiming to harness existing strengths and maximise investment, it is time to assess the landscape and explore how engineers can continue to advance the national interest.

Discussion about Australia's R&D capabilities often returns to the same contrast: our strength in discovery research versus our persistent struggles in commercialisation.

It is well documented that Australia excels in research, producing 3.4 per cent of the world's published output, despite representing only 0.33 per cent of the global population.[1] In the face of this achievement, we still struggle commercialising these ideas.

The World Intellectual Property Organization's 2025 Global Innovation Index ranks Australia 16th for innovation inputs (up two places from the previous year), but only 27th for outputs (up three places).[2]

This challenge is hardly new. Engineers Australia's 2022 Commercialisation of Engineering Innovation paper highlighted the same weakness, echoing findings from the Department of Industry, Science and Resources, and Group of Eight universities.[3] The consensus is clear: the innovation pipeline is underpowered. The cost is missed opportunities, undercapitalised ideas and a growing sense that we are falling behind.

Private sector pressure

Across government, industry and the professions, calls are mounting to address Australia's decline in R&D investment. Gross expenditure on R&D

(GERD) sits at just 1.68 per cent of GDP, a steady decline from its 2.24 per cent high in 2009, and well below the OECD average of 2.7 per cent. With both spending declining and persistent challenges in commercialising innovations, many argue we should aim for at least 3 per cent.

Doing so would require an additional $23.1 billion annually. With a tight commonwealth budget, much of this $20-plus billion gap will need to come from the private sector.

Australia's push to lift R&D intensity is further complicated by its reliance on just three industry divisions – professional, scientific and technical services; manufacturing; and financial and insurance services – which account for nearly 73 per cent of total R&D investment.[10] The SERD discussion paper notes that global manufacturing intensity and R&D intensity are closely correlated. Australia's business R&D intensity is less than half that of peer countries, and manufacturing contributes only 6 per cent of industry Gross Value Added compared to 17 per cent in comparator nations.[4] In this context, much of policymakers' hope rests on a comparatively smaller industrial base than those of peer economies.

Approaches to addressing these challenges differ. The Australian Industry Group cautions that additional funding alone may not improve outcomes without addressing structural weaknesses, while the Australian Academy of Science proposes an R&D levy to force all business to review their commitment to R&D.[6]

Strategic response

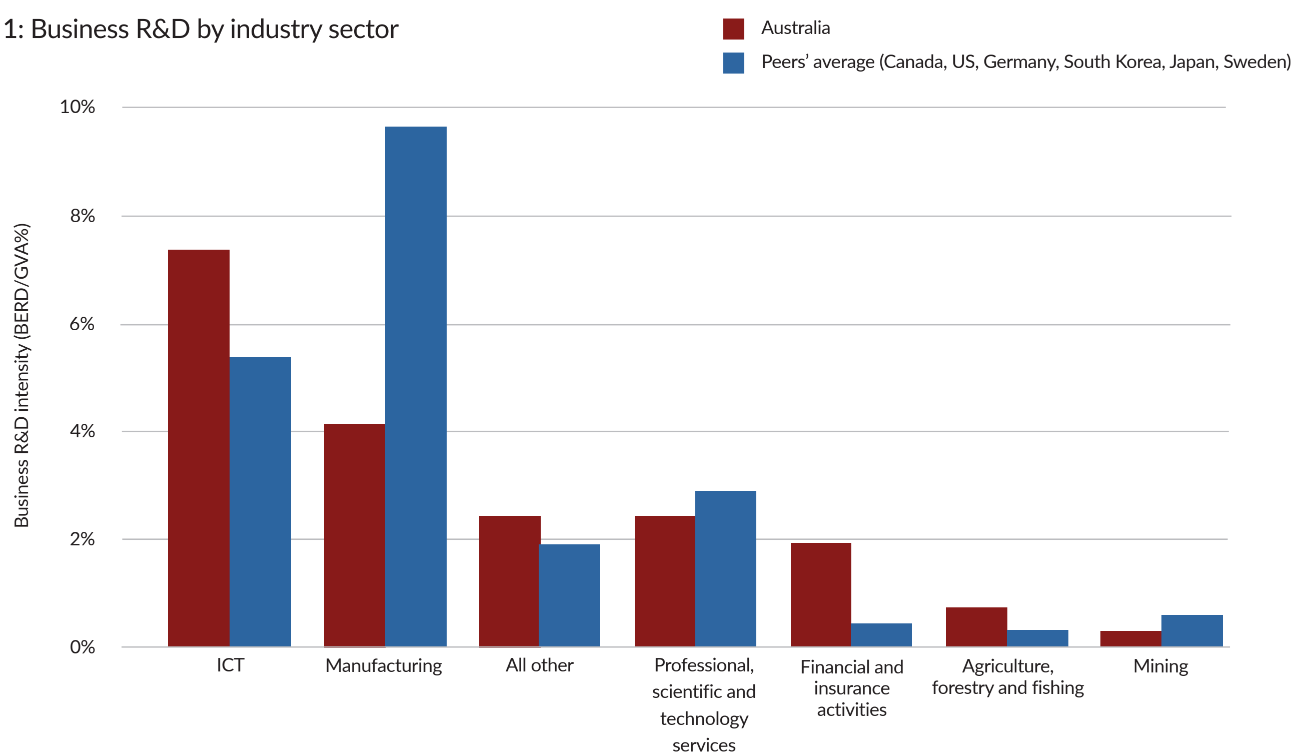
Recognising the importance of lifting R&D intensity and reversing steady declines in expenditure, in December 2024 the government convened an independent expert panel to review Australia's R&D system. Chaired by Tesla and Blackbird Ventures chair Robyn Denholm, the panel also includes former Chief Scientist Ian Chubb, surgeon and researcher Professor Fiona Wood AM, and LaunchVic CEO Dr Kate Cornick.

In February 2025, the panel opened public consultations in response to its discussion paper. Engineers Australia's submission touched on refining our commercialisation skills pipeline, businesses' access to R&D incentives and support, and improving government procurement.

Through September 2025, six thematic papers were released. They covered the panel's overarching objectives of maximising investment value, >

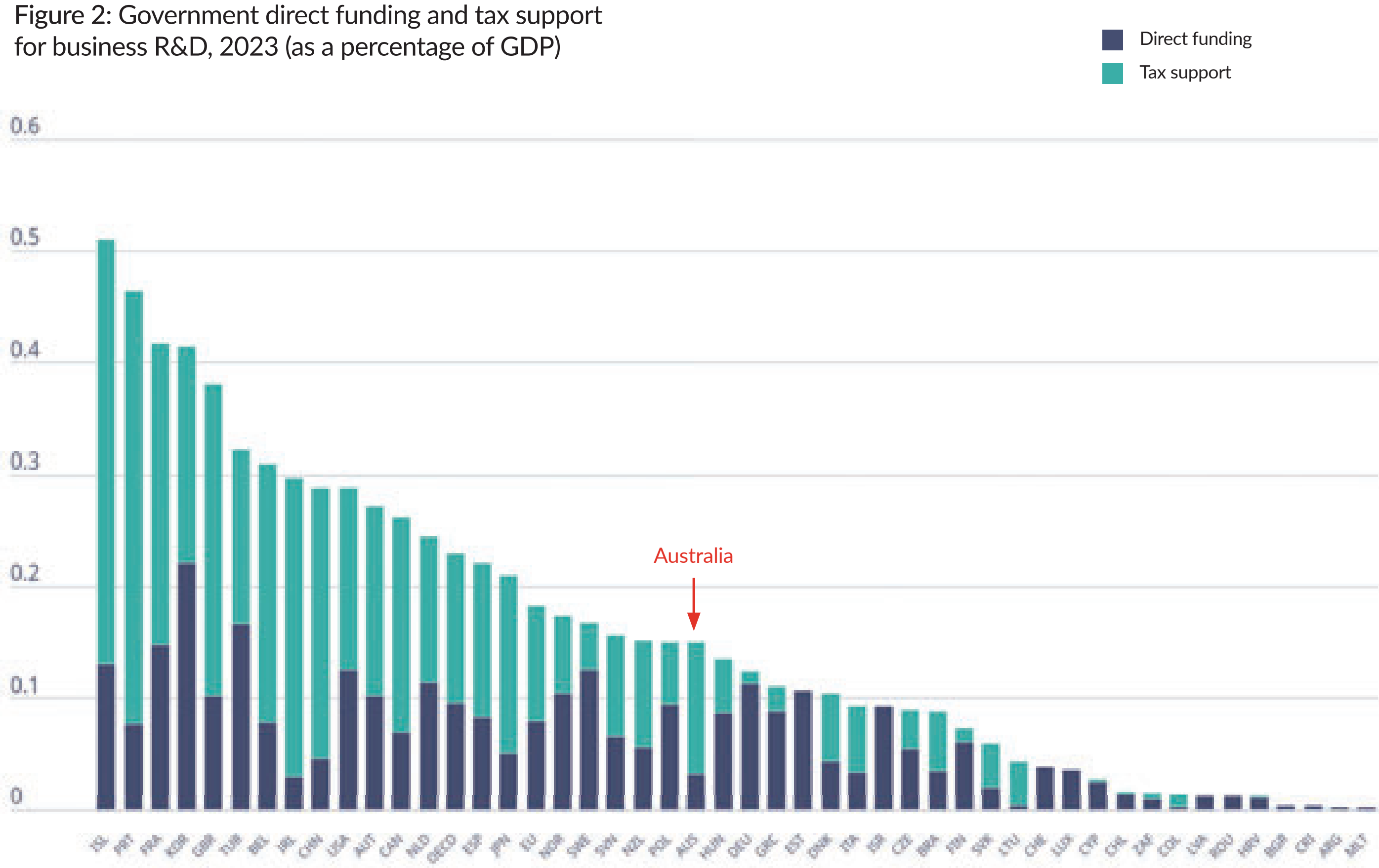
> "Australia's R&D support system may not be fit for purpose, or coordinated sufficiently. Reform is needed to better reflect the structure of our economy."

Figure 1: Business R&D by industry sector



Source: OECD Analytical Business Enterprise R&D, 2020-21; ABS Research and Experimental Development, Businesses, 2021-22

Figure 2: Government direct funding and tax support for business R&D, 2023 (as a percentage of GDP)



strengthening linkages, supporting national priorities, increased R&D investment, and ultimately uplifting Australia's R&D intensity and performance.

The SERD panel delivered its final report of recommendations in December.

Navigating the streams

The Australian R&D ecosystem is marred by a system of funding sources often acknowledged as unnecessarily complex. The first issues paper released by the SERD acknowledges this challenge and notes the likely inefficiencies and duplications that would arise among Australia's 215 individual R&D funding streams.

The message in these issues papers is clear: Australia's R&D support system may not be fit for purpose, or coordinated sufficiently. Reform is needed to better reflect the structure of our economy and better support small and medium enterprises (SMEs) to scale their innovations.

Scaling up

A central challenge in reaching the 3 per cent GERD may lie in the structure of Australia's economy, with a small share of manufacturing, fewer middle-sized companies and the government's financial support settings.

Our economy is dominated by microbusinesses, with 94 per cent of firms employing between one and nine people. In countries such as Germany, Canada and the United States, the share is far lower – around 62-67 per cent.[5] SMEs are also responsible for 55 per cent of overall business expenditure in R&D.

The Australian Government's financial support is heavily skewed towards Research and Development Tax Incentive (RDTI), which accounts for around four-fifths of all government support for business R&D – compared to 57 per cent in the OECD average.[6] In 2021–22, small businesses made up 38 per cent of RDTI claimants but received only around 20 per cent of the $11.2 billion in incentives.

Through our consultations, we learned that many SMEs choose to bypass the RDTI altogether, citing the RDTI's compliance burden, limited benefits and delayed returns as barriers.[7]

Finding the balance

An R&D system more fit-for-purpose for SMEs – and businesses more broadly – requires a sharper balance between discovery and commercialisation. Policy must clearly distinguish between research and development, and between discovery and commercialisation activity. Engineers are central to the development phase of R&D, yet government policy often treats the two as interchangeable, with limited attention given to commercialisation.

The task, then, is not to diminish the value of discovery, but to strike a more balanced approach. Aligning funding with the structural needs of our economy – and our recognised gaps in commercialisation – could help ensure Australia's research strengths translate into real-world innovation and economic returns.

Bridging the gap

Beyond structural and market barriers, a deeper question arises: does Australia have the skills base to meet its R&D challenges? As mentioned, the process of commercialisation – turning discovery into products and processes – relies heavily on engineering thought and practice.

As Biomedical College Chair Dr Kelly Coverdale CPEng put it during consultations for the SERD: "In research and development, the 'development' is the process of fundamental engineering design and testing. Engineers are the key ingredient in development. Policymakers often treat research and development as the same, but the processes differ.

"Research is primarily scientific in process, while product development is inherently an engineering practice."

This perspective highlights a crucial point: boosting R&D investment is not enough without the absorptive capacity to translate funding into outcomes. That means sustained investment in the engineering workforce across both research and development.

Global and local trends point to growing skills pressures. Australia's skills challenge is ever-present. The Australian Industry Group notes 37.5 per cent of businesses using science and mathematics skills can't find qualified staff – the second-highest reported shortage in the country.[8]

> "Boosting R&D investment is not enough without the absorptive capacity to translate funding into outcomes. That means sustained investment in the engineering workforce."

ABOVE:
Daniel Salas,
Engineers Australia.

Discover cutting-edge research and innovation, and the latest breakthroughs in applied mechanics at the 12th Australasian Congress on Applied Mechanics.

Engineers Australia's submissions to the SERD similarly underscored the need to grow skilled human capital if the process is to deliver meaningful reform, and called for more attention to be provided to the development and refinement of "commercialisation" skillsets among our graduates. Our submission in response to the SERD issues papers recommended increased government support for work-integrated learning to help engineering students build these broader capabilities.

As global competition for engineering talent intensifies and international R&D investment accelerates, Australia faces a pressing question: how can we attract and retain top-level engineers when our own R&D performance is in decline?

The global trends, in addition to those in Australia, raise hard questions for the viability of our engineering skills pipeline under current settings. Are we building our sovereign capability and producing enough skilled graduates to insulate ourselves from fluctuations in the global talent market and to turn our ideas and innovations into national prosperity and growth? □

Daniel Salas is a Policy & Projects Officer at Engineers Australia.

References

[1] *Department of Industry, Science and Resources. Australia's National Science Statement: A Future Made in Australia. 12 August 2024. https://www.industry.gov.au/publications/national-science-statement-2024*

[2] *World Intellectual Property Organization. Global Innovation Index 2024. World Intellectual Property Organization, 2024. https://www.wipo.int/en/web/global-innovation-index*

[3] *https://www.industry.gov.au/publications/barriers-collaboration-and-commercialisation, https://go8.edu.au/go8-response-to-the-university-research-commercialisation-consultation-paper, https://www.youtube.com/watch?v=ZILe-8IPF7U*

[4] *SERD discussion papers figure 17 & 18 – Comparator nations are Canada, Germany, Japan, South Korea, Sweden and the United States*

[5] *Australian Industry Group, Understanding Australia's declining R&D performance, 2023, https://www.aigroup.com.au/resourcecentre/research-economics/economics-intelligence/2023/understanding-australias-declining-rd-performance/*

[6] *Industry Innovation and Science Australia. Barriers to Collaboration and Commercialisation. Department of Industry, Science and Resources, 27 November 2023. https://www.industry.gov.au/publications/barriers-collaboration-and-commercialisation*

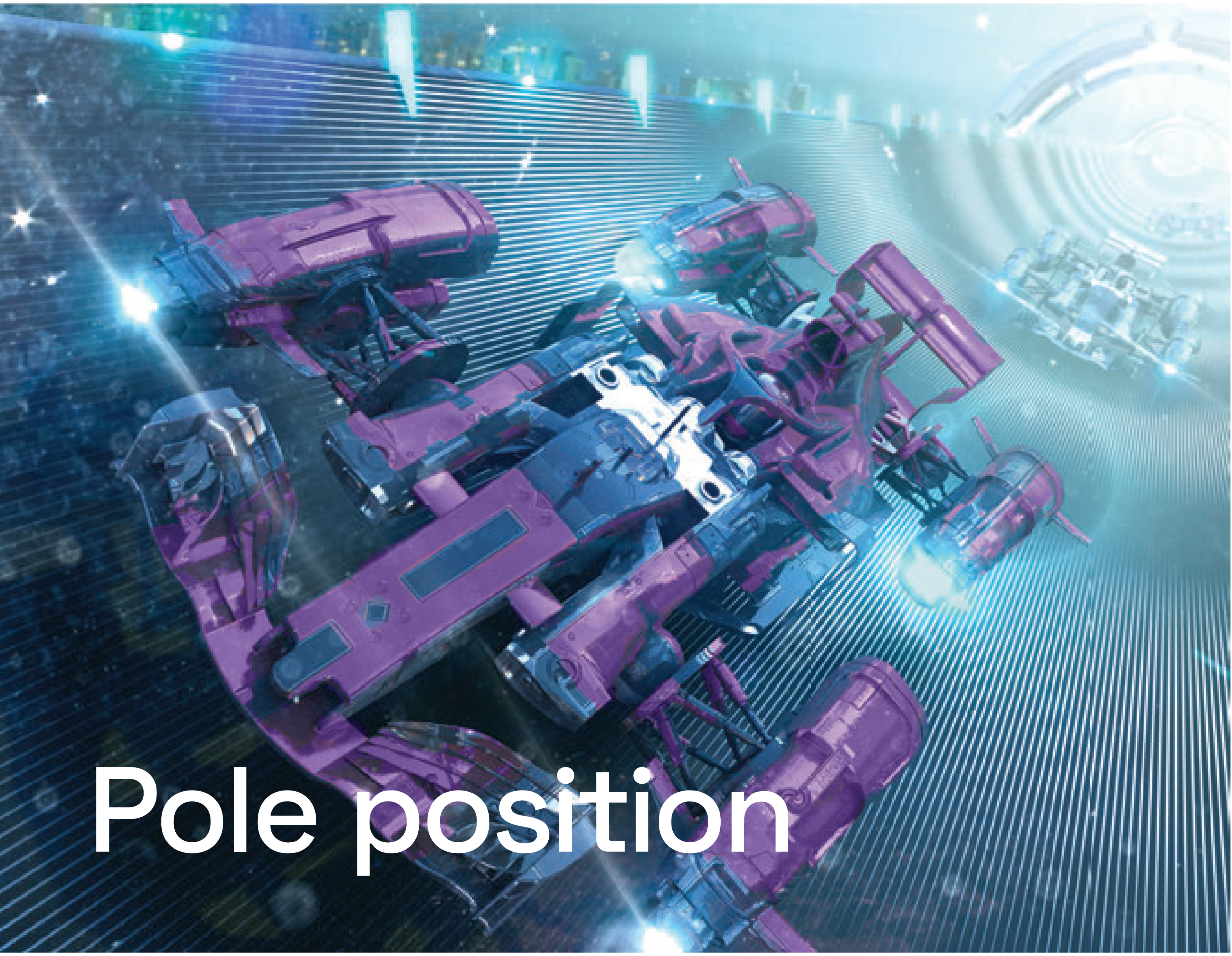
[7] *https://www.oecd.org/en/topics/sub-issues/rd-tax-incentives.html 2023 numbers*

[8] *AI Group*

[9] *Australian Industry Group. Understanding Australia's Declining R&D Performance. Research Note, 2023. https://www.aigroup.com.au/resourcecentre/research-economics/economics-intelligence/2023/understanding-australias-declining-rd-performance/*

[10] *https://www.abs.gov.au/statistics/industry/technology-and-innovation/research-and-experimental-development-businesses-australia/latest-release#methodology*

[Ideas]



Pole position

Formula 1 racing strips engineering down to its essence: speed, precision and teamwork under pressure. This elite performance drives innovation far beyond the track.

Words by Joe Ennis

ABOVE: Katherine Richards AM CSC HonFIEAust CPEng EngExec, Engineers Australia.

Formula 1 is often framed as a spectacle. Look closer and it becomes something far more instructive: engineering at its most exposed, unforgiving and influential. For Katherine Richards AM CSC HonFIEAust CPEng EngExec, Chief Engineer of Engineers Australia, that is precisely why the Grand Prix provides such a powerful platform for the profession.

"Without engineering, there is no Formula 1," she told *create*. "No cars, no track, no fuel, no communications, no safety systems. Everything that happens on race weekend is engineering in motion."

Formula 1 operates as a crucible for innovation. Engineers work at the limits of performance, safety and time, where decisions are tested instantly and failure is highly visible. Excellence is not optional. That pressure reveals what engineering really is: creativity applied with rigour, teamwork under stress and continuous learning.

Team sport

Crucially, the Grand Prix makes the people behind the technology visible. Richards is keen to challenge the outdated stereotype that engineers simply wear high-vis and work on construction sites.

"Engineering is about people animating technology to solve problems," she said.

Behind every driver sits a multidisciplinary engineering team. Civil engineers design pavements and grandstands. Mechanical engineers refine power and aerodynamics. Electrical engineers manage data and communications. Chemical engineers develop fuels. Biomedical engineers design safety systems. None work in isolation. Success depends on collaboration, trust and communication under extreme pressure.

Resilience in action

Formula 1 also demonstrates resilience, a defining professional trait of all engineers. Only one team wins each race. Everyone else must analyse what went wrong, adapt and return stronger.

"You learn, reflect and apply those lessons to the next race," Richards said. "That's engineering."

What happens at the edge of performance rarely stays there. When engineering is pushed to extremes, discoveries flow outward. Advances in materials, safety, energy systems and data analytics developed for motorsport routinely migrate into everyday vehicles and infrastructure.

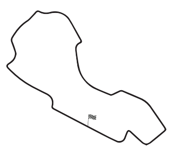
Innovation with purpose

Formula 1 is also evolving. While motorsport is energy-intensive, it is actively pursuing hybridisation, sustainable fuels and new energy storage technologies. Richards said some sectors are difficult to decarbonise, but progress begins with recognising the need to change: a mindset engineers apply across transport, energy and infrastructure.

In 2026, about 50 per cent of a car's power 350kW (470hp) will come via the Motor-Generator Unit (MGU-K), while the remainder will still be delivered via a V6 internal combustion engine, it will run on a new sustainable fuel derived from carbon capture, municipal waste and non-food biomass.

Building on this, Formula 1 has set an ambitious target to become a net zero carbon sport by 2030, demonstrating how engineering innovation can drive meaningful change even in high-performance, hard-to-abate environments.

"Formula 1 shines a spotlight on engineers." Richards said. "It shows STEM skills applied in real time – Newton's laws playing out at speed – and reveals engineering as a profession is defined not by what it builds, but by how it thinks." □



Engineers Australia is a Local Event Supporter of the FORMULA 1 QATAR AIRWAYS AUSTRALIAN GRAND PRIX 2026.

Formula 1 technologies powering everyday engineering

1 HYBRID POWER AND REGENERATIVE BRAKING

In Formula 1, hybrid power units were developed to recover waste energy from braking and exhaust heat, and redeploy it for performance, pushing up efficiency. That same principle now underpins regenerative braking in hybrid and electric vehicles, where energy that would otherwise be lost is captured and reused.

Formula 1 demonstrates that efficiency and high performance are complementary goals – a critical insight for decarbonising transport at scale.

2 AERODYNAMICS FOR EFFICIENCY AND SAFETY

Formula 1 teams obsessively refine vehicle shapes to minimise drag while maintaining stability at extreme speeds, using wind tunnels and simulation to extract marginal gains. Those lessons have flowed into the design of passenger vehicles, trucks and buses, which are now quieter, more stable and significantly more fuel-efficient.

3 ADVANCED BRAKING SYSTEMS

To cope with repeated high-speed braking, Formula 1 pioneered carbon composite brakes, advanced cooling techniques and brake-by-wire systems capable of operating under extreme heat and stress.

Adapted versions of these technologies are now common in everyday vehicles. Innovations developed to protect drivers at 300 kph now help keep road users safe.

4 REAL-TIME DATA AND PREDICTIVE ANALYTICS

Formula 1 relies on thousands of sensors streaming live telemetry from cars to engineers, enabling rapid decision-making and real-time problem solving.

This data-driven approach has since been adopted across transport, manufacturing and infrastructure, supporting predictive maintenance, vehicle diagnostics and smarter asset management.

5 SIMULATION, DIGITAL TWINS AND RAPID PROTOTYPING

Under intense time pressure, Formula 1 teams learned to test designs virtually, using simulation and digital twins, before committing to physical builds.

Today, those same tools are standard across automotive and industrial engineering, allowing faster development cycles, reduced material waste and lower costs.

"Without engineering, there is no Formula 1."

Greater than the sum of their **parts**

WORDS BY JONATHAN BRADLEY

To answer the universe's greatest questions, engineers are pushing themselves to develop intricate and interconnected machines that operate on a scale not found in everyday life.

IMAGE: SKA.

Inside an ancient zinc and lead mine beneath a mountain on the Japanese island of Honshu, Dr Mark Vagins spends his days waiting for a distant star to die. The particular star that the Deputy Director of the Kavli Institute for the Physics and Mathematics of the Universe has his eye on is Betelgeuse, the red supergiant that forms the right shoulder of the constellation Orion.

And thanks to the vast, flooded, sensor-lined laboratory Vagins operates from a cavern deep underground, if Betelgeuse does immolate itself in a supernova explosion – the inevitable outcome for a star of its size – he will be one of the first people on the planet to know.

That's because Vagins is a neutrino hunter, and his finely tuned set-up, named Super-Kamiokande, is so sensitive, it can regularly detect one of the elusive subatomic particles every hour.

"That star is getting ready to die," he told *create*. "When it explodes, instead of a neutrino an hour, Super-K will collect 10 million neutrinos in one second."

ABOVE: Dr Mark Vagins, Kavli Institute for the Physics and Mathematics of the Universe.

LEFT: Square Kilometre Array in Western Australia.

Gathering data about the elementary secrets of the universe is no straightforward task. Vagins is an experimental physicist, but his work relies on a vast complex machine underpinned by an orchestra of subsystems – mechanical, electronic, computational and human – each playing precisely in time.

This pattern of drawing harmony from complexity plays out for other researchers seeking a scientific understanding of the universe's tiniest particles, vastest distances and earliest days.

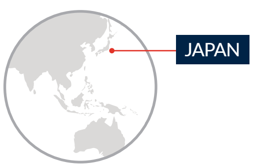
For example, at CERN, the Switzerland-based particle physics laboratory that hosts the Large Hadron Collider (LHC), works a team that Director for Accelerators and Technology Dr Mike Lamont described as having developed "multi-level mastery", with a deep understanding of the forces their machines generate, how reactions take place, and how to ensure extremely high quality.

"A lot of disciplines come together here," Lamont said. "We structure our organisation to deal with that: mastering the individual disciplines, but then bringing it all together >

into a functioning accelerator complex with the LHC as the flagship machine."

Like NASA's James Webb Space Telescope (JWST) and the global network of radio receivers that come together to form the Square Kilometre Array (SKA) Observatory, Super-Kamiokande and CERN are each in their own way grand engineering projects. Every one of these endeavours represents a pinnacle of multidisciplinary integration: mechanical, electrical, systems, data and environmental engineering operating in unison at massive scale.

In this feature, *create* asks the experts involved to share the design principles that bring their diverse technological systems together to help humanity understand the universe's most fundamental mysteries.

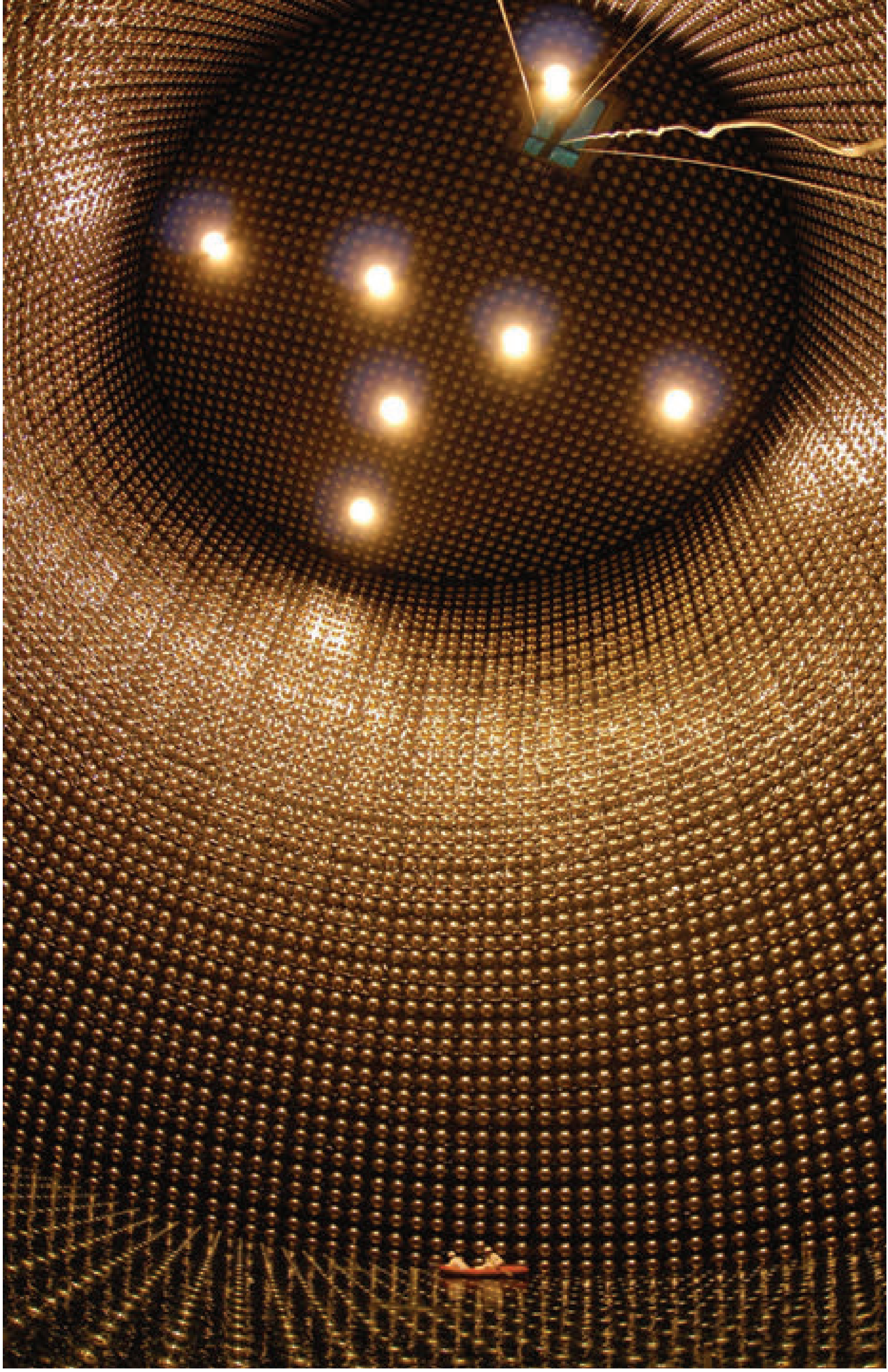


SUPER-KAMIOKANDE

When Vagins began studying for his scientific career, his father offered some words of caution.

"You physicists think you know everything," his father, a mechanical engineer, told him. "But let me tell you something. Your pretty little machines would work once – just one time – if it wasn't for us engineers."

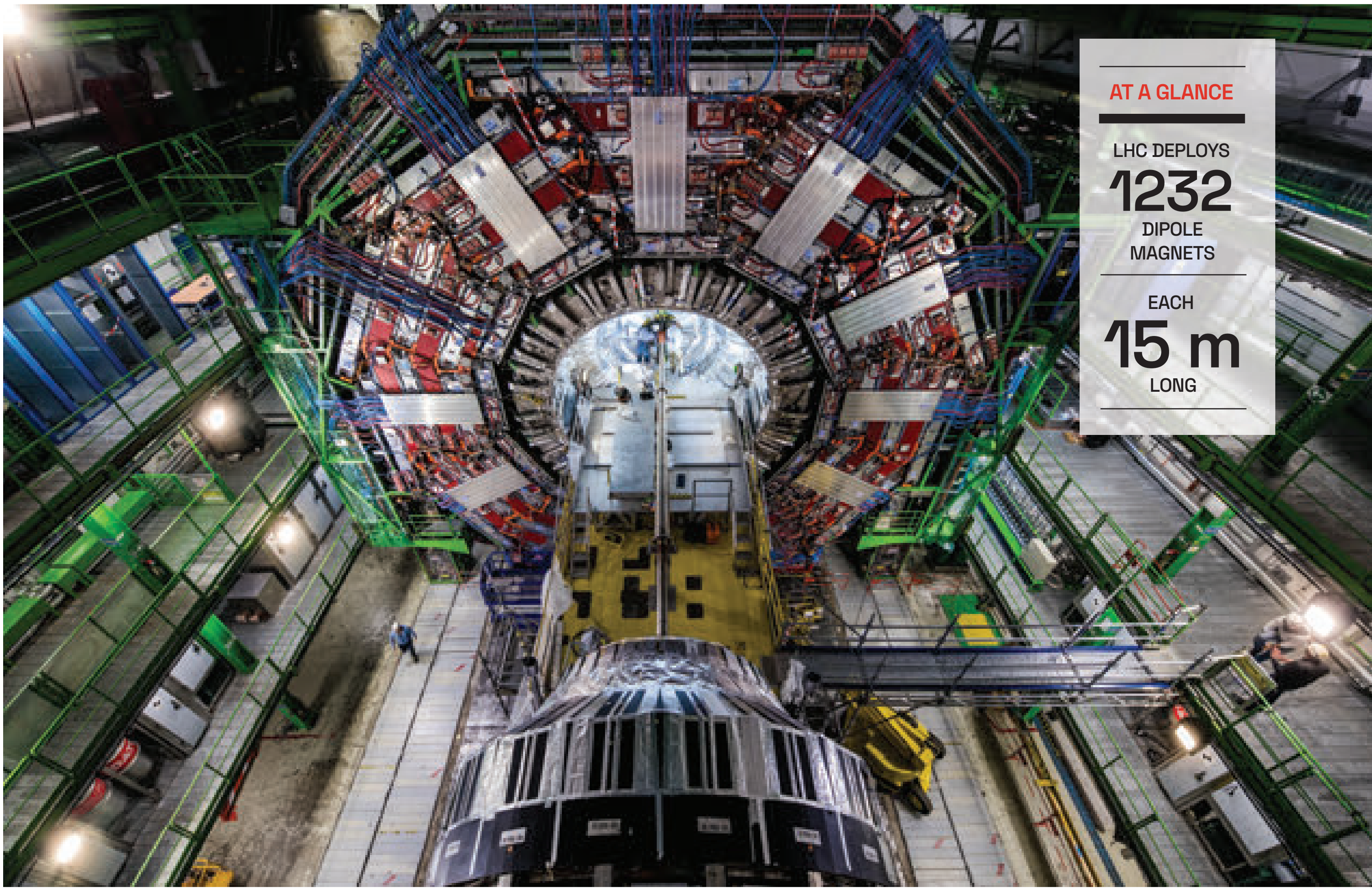
Forty years on, Vagins continues to value engineering as being vital to a project as ambitious as Super-Kamiokande. Working inside a cavern large enough to contain the Statue of Liberty, for instance, needed



ABOVE: The immersive Super-Kamiokande.

"If you were to put one of those giant photo tubes on the moon and you were to light a match and hold it up to the night sky, one of those tubes could tell you when your match went out."

IMAGE: Super-Kamiokande.



AT A GLANCE

LHC DEPLOYS
1232
DIPOLE MAGNETS

EACH
15 m
LONG

geological engineers who could advise on how to safely excavate such a space. Mechanical engineers and electronics engineers are crucial to keep the equipment operating.

"Another thing we have to deal with which is maybe not immediately obvious is that we have all this stuff that is submersed in fluid – usually water, but sometimes cryogenic fluid," Vagins said. "So we have to build electronics that can survive in that kind of an environment. Waterproof connectors we can couple and decouple. All of that is a whole other side of engineering, like deep sea engineering."

There is then the challenge of calibrating equipment that must be able to operate over such a vast range of inputs.

"Super-Kamiokande can see two or three mega electron-volts all the way up to tera electron-volts in the same detector," he said. "It is a multipurpose detector, so it is sensitive over about eight orders of magnitude in energy, which is pretty amazing."

The detectors are bespoke equipment that require an extreme amount of specialist expertise to build. Costing more than $4500 apiece, 11,000 of these golden photo-multiplier tubes, each 500 mm in diameter, line the Super-Kamiokande tank. When a neutrino collides with a water atom inside the apparatus, a flash of light is emitted and absorbed by these sensors.

"These tubes are too big and too rarely purchased to be automated. They're made by hand; the glass envelopes are hand-blown," Vagins said. "If you were to put one of those giant photo tubes on the moon and you were to light a match and hold it up to the night sky, one of those tubes could tell you when your match went out."

ABOVE: The Large Hadron Collider.

IMAGE: CERN.

AT A GLANCE

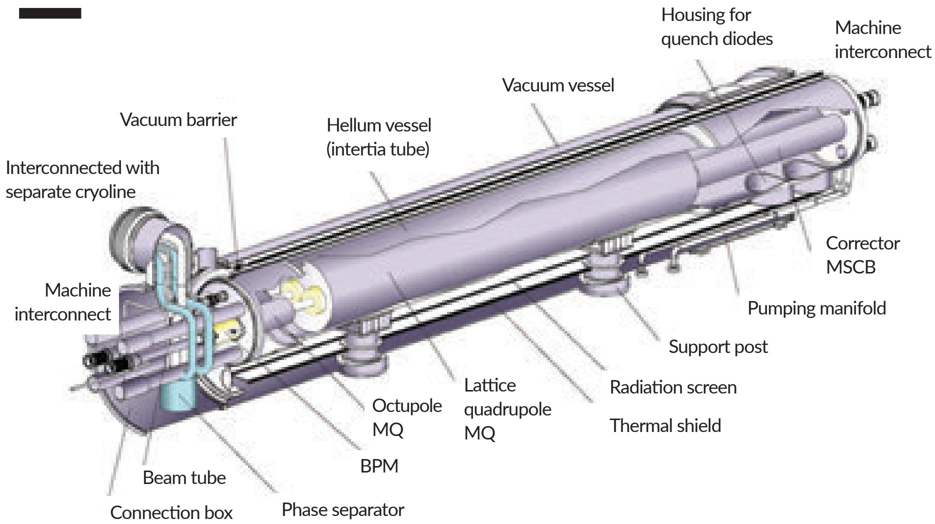
11,000
GOLDEN PHOTO MULTIPLIER TUBES

EACH
500 mm
IN DIAMETER

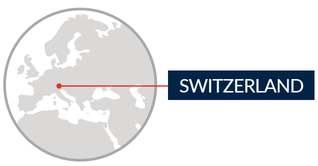
It's these tubes that will capture the burst of light that results from an onrush of supernova neutrinos. But across the entirety of human history, Vagins said, just 24 supernova neutrinos have been found – and they all occurred on the same February day in 1987, before Super-Kamiokande had begun operation. In hopes of a repeat of that excitement, Vagins will keep waiting for Betelgeuse to expire.

"On average, a supernova explodes in our galaxy between one and three times a century. We've been running for 30 years, and we haven't seen one yet." >

Inside the LHC



"The challenge is … exploiting the commonalities between the groups so they don't go off and invent their own control systems."



LARGE HADRON COLLIDER

Of the nine accelerators and two decelerators located at the vast CERN complex on the border between France and Switzerland, the largest is the LHC, a 27 km circuit through which trillions of particles rocket 11,245 times each second.

To bend the particles along this path, the LHC deploys 1232 dipole magnets, each 15 m long, weighing 35 t and drawing a current of 11,080 amperes. The resulting electromagnetic field is 100,000 times stronger than the earth's own, and a superconducting coil ensures no energy from the high currents is lost to electrical resistance.

With all of this power, scientists from CERN are able to smash the charged subatomic particles into one another and use the resulting data to learn about the universe as it exists at its smallest scale.

"CERN's been building accelerators for 70 years now, and over the years it's built up an incredible level of expertise in basic engineering – the real hardcore manufacturing design – in collaboration with European industry for production runs," Dr Mike Lamont told *create*.

"The magnets of the LHC were designed in-house; they were prototyped in-house, but then built in European industry in Italy, Germany and France."

These 14.3 m long superconducting dipoles were produced from niobium titanium and developed by leveraging decades of magnet experience among CERN's engineers, then developing capabilities in superconductivity.

According to Lamont, CERN brings together two communities constituting thousands of workers and researchers: the CERN staff, who operate the accelerators, and the experimental cohort, which builds and operates the detectors. Even so, the biggest experiments using the LHC are international collaborations.

CERN's Accelerator and Technology sector itself, which Lamont oversees, encompasses four departments of 80-100 people each: technology, accelerator systems, beams and engineering. The expertise contained within each of these departments is world-leading.

"The challenge is bringing all that together," Lamont said. "Exploiting the commonalities between the groups so they don't go off and invent their own control systems and making sure that it all works together. There's good communication, they get the resources they need and they do what needs to be done."

Dr Eloise Matheson is one of those engineers – an Australian working in CERN's Mechatronics, Robotics and Operations section. Her role encompasses design, installation, operation and maintenance of the mechatronics systems for the beam intercepting devices, along with offering robotic support for inspections, maintenance and repair.

She said CERN's distinct environment imposes distinct demands on its engineering processes, from the pervasive radiation in many areas to the deep tunnels in which the experiments are undertaken and the immense distances over which the equipment sprawls.

"We have tunnels built in the 1950s that are still being used for more recent tasks, some of which are mapped, some of which are not," she said. "We also

ABOVE: The LHC's electromagnetic field is 100,000 times stronger than the earth's own field.

ABOVE: Dr Mike Lamont and Dr Eloise Matheson, CERN.

DIAGRAM: CERN.

AT A GLANCE

PRIMARY MIRROR
6.5 m

SUNSHIELD
21 m x 14 m

ABOVE: Years of testing were done on the James Webb Telescope.

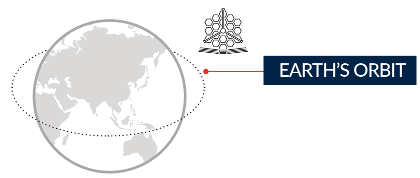
IMAGE: NASA.

have superconducting magnets, very high-energy supplies in certain places, cryogenic setups where we use helium to cool our magnets to superconducting temperatures: 3 or 4°K."

Sending a robot to intervene in such an environment requires planning around the engineering constraints: power supply, actuation, types of sensors, how many arms and the payload it will need to lift.

Operating the facility also brings together an immensely complex set of considerations to achieve precise results. These include constraints around the magnet supplies and magnetic fields, the cryogenic equations and the electricity supply.

"You need a certain rigour, a certain discipline, a certain respect," Lamont said. "It's about building a community where you've got good communications and everybody's got buy-in. You give responsibility and recognition."



JAMES WEBB SPACE TELESCOPE

Launching JWST into orbit, with its 6.5 m primary mirror and 21 m by 14 m sun shield, required condensing the entire observatory into a payload of just 6.2 t.

"That's the most mass you can get out to a million and a half kilometres away, so it has to be very lightweight, having broad, flexible capabilities," explained Dr Marshall D. Perrin, Associate Astronomer with the Space Telescope Science Institute, the operator of JWST.

"One of the things we run into in this kind of scale versus ground-based telescopes is that it's much harder to change things. We will never touch the hardware again, but even as you're building the telescope, the design had to be locked down fairly early on."

To reach that state, Perrin's team needed to conduct years of verification and validation.

"We ended up really relying on multiple disciplines," he said. "Some of it is done with actual piece part testing, where you build a mechanism and put it under strain, or you assess the low-level components: Does this piece of transmissive optics pass enough light through it? Does your detector have the quantum efficiency that it needs to have?

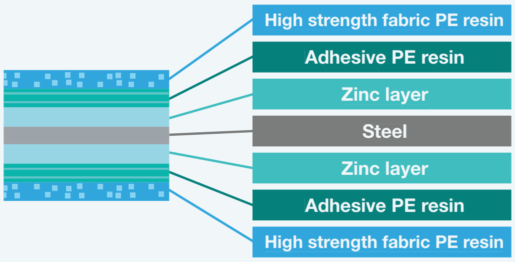
"Some of it you do by integrated modelling, by building a big finite-element model of the system and saying, this is how we think this will work. And sometimes you combine those approaches, and you build a finite-element model and anchor it in lab test data."

That test-as-you-fly approach can be more complex than it sounds. Evaluating the JWST involved constructing a 40 m >

roundel

CIVIL PRODUCTS PTY LTD

Setting new standards for corrugated steel culverts



Roundel's HPL PE-coated steel culverts offer significantly improved durability performance compared to traditional Z600 galvanised steel.

HPL is fully compliant with AS / NZS 2041.4, ASTM A742, and has been extensively tested locally to demonstrate a **100-year life**, with exceptional abrasion performance. It is available for internal and / or external surfaces depending on your requirements.

The coating's superior performance has been recognised by the Department of Transport and Main Roads (TMR) and was approved for culvert relines on the Toowoomba Second Range Crossing.

Over 4,500 tonnes of HPL PE-coated culverts are also being manufactured on-site by Roundel for Rio Tinto's Koodaideri Rail project in the Pilbara, WA.

Roundel welcomes your inquiries for HPL-coated culverts, traditional Z600 galvanised culverts and our wide range of B200 and B381 bolted, corrugated steel structures.

INQUIRIES: WA **08 9404 5391** QLD **07 4789 6700** General **1800 194 746** **roundel.com.au**

vacuum chamber at Johnson Space Flight Center, then cooling it to 40°K using a gymnasium-sized building full of vacuum pumps, cryogenic coolers and tankers of liquid nitrogen.

A distinct challenge was having the device assemble itself after reaching orbit, necessitating a deployment-led design. Perrin compared it to a baby stroller that can be packed into a car boot.

"One of my favorite facts about JWST is that it's much larger than the Hubble Space Telescope – six times larger in terms of the collecting area – but when it's folded up, it's three-quarters of the size," he said. "The assembly that happened in space was the unfolding and unfurling of the umbrella, the sunshield and the solar panels, and the unfolding of the mirror and the secondary mirror coming out on an eight-metre boom to position it in front of the mirror.

"Typically, the initial unfolding is a mechanical tolerance in the order of millimetres, but we needed the mirrors in the right place down to nanometres."

As such, the team undertook an iterative process of sensing the components' position, then adjusting that using mechanical actuators to create a closed loop that could achieve the necessary system performance.

And while the most difficult part of the project was the design and development stage, the team still faces maintenance challenges, which require detailed technical knowledge and history to solve.

Perrin recalls a particularly impressive moment of troubleshooting from JWST's first year of operation, which was enabled by the rigorous approach that had been followed throughout the project's life.

"The mid-infrared instrument has wheels and a spectrograph that interchange different gratings for different spectral resolutions," he said. "The mechanism was starting to show increased friction when you changed positions; there was increased torque in the bearings.

"By using the design records of the assembly, keeping detailed information and talking with experts in cryogenic ball bearings, engineers were able to diagnose what was going on with the ball bearings in these cryogenic arrays more than a million kilometres away."

AT A GLANCE

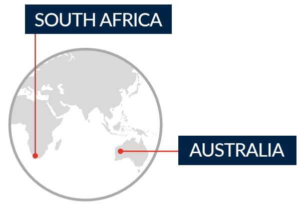
SKA-LOW
131,072
LOG-PERIODIC ANTENNAE

SPREAD BETWEEN
512
STATIONS

TOTAL COLLECTION AREA
419,000 m²

BELOW: James Webb Telescope construction.

IMAGE: NASA.



SQUARE KILOMETRE ARRAY

While the JWST traverses space in its hunt for the universe's most distant galaxies, SKA is an earth-based observatory sprawled across multiple continents, which has been constructed to gather the universe's earliest electromagnetic emissions.

SKA is a global effort more than 30 years in the making that operates sites in Western Australia and South Africa, then compiles the data in the UK. The largest telescope array in the world, the Australian location alone, dubbed SKA-Low, involves 131,072 log-periodic antennae working as one interferometer, which requires nanosecond-level phase synchronisation.

Spread between 512 stations with a total collecting area of 419,000 m², SKA-Low consists of an array of cone-shaped antennae that look like metal Christmas trees. This design is more effective at capturing the low-frequencies that characterise signals from the early universe than the traditional dish antennae used at SKA-Mid, the South African site.

Collecting these signals could not happen simply anywhere, however. It requires a location distant from the radio and television signals that intrude upon the bandwidth.

"We had to find a place on earth that is very quiet on these frequencies, because being very crowded by human interaction, the interference generated by everyday equipment impinges on >

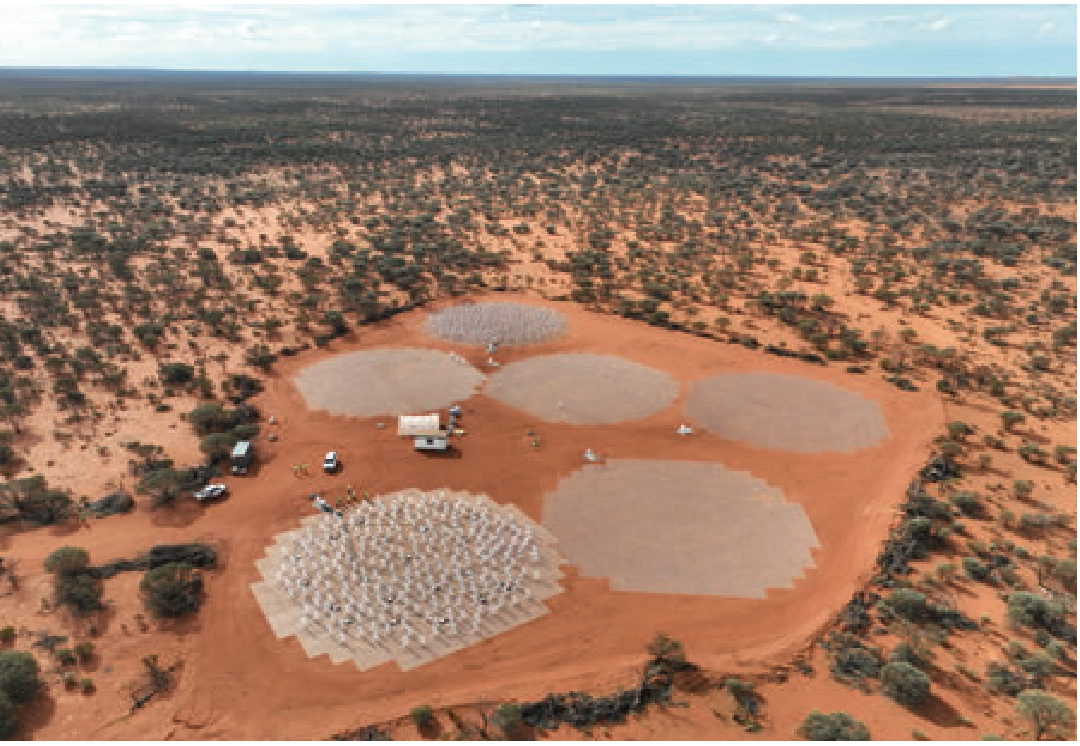
our ability to receive very faint signals," Dr Lucio Tirone ESEP OCMSP, Assembly, Integration and Verification Lead Engineer at SKA-Low, told *create*.

But operating in this remote region imposes logistical challenges that compound the overlapping engineering ones: skills, resources and equipment must be brought hundreds of kilometres from Perth.

Operation of the telescope is not straightforward either, with data processing enabling the engineers to fine-tune the signals each antenna sends to focus on different areas of the sky.

"A traditional dish can point a beam at the sky; in the same direction, our station can point up to 48 beams at the same time."

BELOW: The remote environment of SKA-Low proved challenging.



"We are able to modify the delay by which we receive the signals from individual antennas and point them in the direction that we want through a software approach," Tirone said. "This has a number of benefits. First, there are no moving parts. We don't have hydraulics; we don't have big weights to move and to maintain under wind and other harsh conditions; our antennae are perfectly still on the ground.

"But also, since the processing is digital, we can do it very intelligently. We are able to sum and delay the contributions from each antenna many times over. A traditional dish can point a beam at the sky; in the same direction, our station can point up to 48 beams at the same time."

Getting this right has involved the production of numerous prototypes. Tirone emphasises the years of testing and assessment ensuring the telescope's assembly of disparate components works properly and transmits signals of the right quality.

As an engineering challenge, Tirone said, the "whole is always bigger than the sum of the parts".

"Every two components that interface will sooner or later generate something unexpected," he said. "Then we troubleshoot those defects, we fix them, and then we go on. These are some of the complexities of bringing together such a complex system.

"We need to make sure that the infrastructure is working properly: the antennas, the computers, the networks, the software. There is a very large number of entire disciplines of engineering that converge to make the telescope network."

Out of many, one

The engineers and scientists who come together to create these complex and ambitious projects could not achieve such heights alone. When it comes to understanding the universe's greatest mysteries, subatomic particles and deep space, only the combined and complementary expertise of a broad array of disciplines can deliver answers.

Super-Kamiokande, CERN, JWST and SKA are rooted in big ideas and enormous questions, but the minds behind these machines operate from a deeply practical impulse.

"I love building things that work," Vagins said. "It's definitely a partnership in different ways between the different types of scientists and engineers, and many other disciplines."

It's a challenging task involving novel technologies that have never been tested before at this scale anywhere else in the world.

"What we expect is a lot of work, a lot of challenges, but great achievements that we pursue with a passion," Tirone said. "We believe in the goal of delivering to our scientists this amazing instrument that will allow us to peek into the dawn of our universe and to answer some of the greatest questions." □

IMAGE: SKA.

:(

Connection failures

Engineers are increasingly being asked not just to solve discrete problems, but to manage and design for hyper-complex, interconnected systems.

WORDS BY ELLE HARDY

In November 2023, a routine software upgrade brought Australia's second-largest telecommunications network to its knees. Ten months later in July 2024, a faulty security update crashed 8.5 million Windows computers worldwide. And in April 2025, the entire Iberian Peninsula went dark in just 90 seconds. Three different continents, three different sectors, one common thread: single points of failure that cascaded through integrated networks, bringing critical infrastructure to a standstill.

For Australian engineers designing and managing complex systems, these incidents offer vital lessons about a paradox at the heart of modern infrastructure. On the one hand, we are reaping the benefits of networks becoming more technologically, socially and economically interconnected. Yet this same interconnection can transform localised errors into catastrophic failures that can bring entire countries to their knees. A test of engineering resilience, the challenge isn't to eliminate integration, but ensure our hyper-complex systems are designed to contain failures and prevent contagion.

Optus outage

The Optus outage exemplifies how protective systems mixed with human error can worsen outcomes. A software upgrade at a Singapore exchange triggered an avalanche of network routing changes, including more than 940,000 Border Gateway Protocol announcements in an hour, compared to a normal rate of fewer than 3000. The resulting flood of updates shut down 90 edge routers nationwide.

ABOVE:
Mark A. Gregory FIEAust, RMIT.

The routers did exactly what they were designed to do: disconnect themselves to avoid overload. But this 'fail-safe' response created a worse outcome – total network failure. With the IP Core network down, restoration required physical reconnection or manual rebooting of routers at sites across the country. The outage lasted more than 12 hours and affected more than 10 million customers. Hospitals lost communications, banks couldn't process transactions, Melbourne's

entire train network came to a halt, and even emergency services calls were affected.

When protective systems all responded identically to the same trigger, there was no fallback. According to Mark A. Gregory FIEAust, from RMIT's School of Engineering, "an entire telecommunications network going offline is unusual. The network should be designed in such a way that redundancy (backups) and resiliency are built in from the outset." In his submission to the Senate inquiry on the incident, Gregory added that there should be "'more transparency and improved reporting to the regulator … on network design, management practices, redundancy and resiliency". The inquiry agreed, recommending that telecommunications companies be bound by stricter security requirements, as with other critical infrastructure providers.

As for engineering lessons, mapping and segmenting, with diversity of technology and locations to avoid a single point of failure, are critical. Equally, having the right tools in place to detect catastrophic events and better investment in engineering are key components of avoiding a future event of this magnitude.

CrowdStrike incident

The July 2024 CrowdStrike incident exposed the significant vulnerabilities that arise when software operates outside established boundaries and deep within system architecture. >

ABOVE: The CrowdStrike incident caused extensive travel delays at Dusseldorf Airport in Germany.

BY THE NUMBERS

THE OPTUS OUTAGE LASTED MORE THAN

12 hrs

AND AFFECTED MORE THAN

10 million

CUSTOMERS

A faulty update to CrowdStrike's Falcon Sensor security software – embedded at the Windows kernel level, below user-mode processes – triggered a catastrophic failure. The sensor functions by presenting itself as a device driver, and while its execution is subject to Microsoft's WHQL certification, this process is lengthy. To avoid recertification for every release, CrowdStrike evolved its update model to adjust configuration parameters rather than modify code, enabling rapid, "agile" updates, but shifting greater risk onto the operational environment.

When an untested configuration-parameter update was distributed, it triggered immediate system crashes worldwide. The malformed kernel-level parametric update forced affected systems into continuous reboot-crash cycles, preventing the operating system from loading into user mode. Although CrowdStrike withdrew the update within 78 minutes, the scale of impact was unprecedented: an estimated 8.5 million computers became unusable, each presenting the well-known "blue screen of death". Restoring functionality required manual deletion of corrupted configuration files on individual machines. The cascading consequences were profound – grounded aircraft, postponed hospital procedures, degraded emergency services and widespread operational disruption across multiple sectors

Jawahar Bhalla FIEAust, immediate past-president of the Systems Engineering Society of Australia (SESA), noted that while incidents such as Optus's outage were more an emergent protective behaviour in a complex system of systems, the CrowdStrike failure was more fundamental, compromising the foundational reference architecture of the operating system. "CrowdStrike will stand out as a turning point because it touches on three fundamental pillars of systems engineering: architectural frameworks, transformative engineering methodologies and governance," he said.

> "CrowdStrike will stand out as a turning point because it touches on three fundamental pillars of systems engineering."

ABOVE: Jawahar Bhalla FIEAust, SESA.
TOP: Affected passengers at Newark Liberty International Airport in the US.

BY THE NUMBERS

A FAULTY UPDATE TO CROWDSTRIKE'S FALCON SENSOR SECURITY SOFTWARE AFFECTED

8.5 million

COMPUTERS

According to Bhalla, granting kernel-level access introduced a system-level hazard because it effectively "broke the architecture". The incident illustrated that as digital infrastructure becomes more interconnected and dynamic, reference architectures must evolve, and engineering boundaries must extend beyond the system of interest to encompass its enabling systems. He argues that CrowdStrike may ultimately be viewed as a watershed moment in our understanding of complex systems – but only if its lessons are taken seriously.

To that end, Bhalla identifies four pillars essential for resilient systems engineering: monitoring environmental changes that affect our configuration items; maintaining evolutionary integrity between conceptual design and fielded systems; establishing digital twin environments that faithfully mirror reality to enable synthetic testing and progressive deployment; and ensuring the availability of enabling resources.

ABOVE: Kathryn Guarini, Yale University; Phil Kreveld.

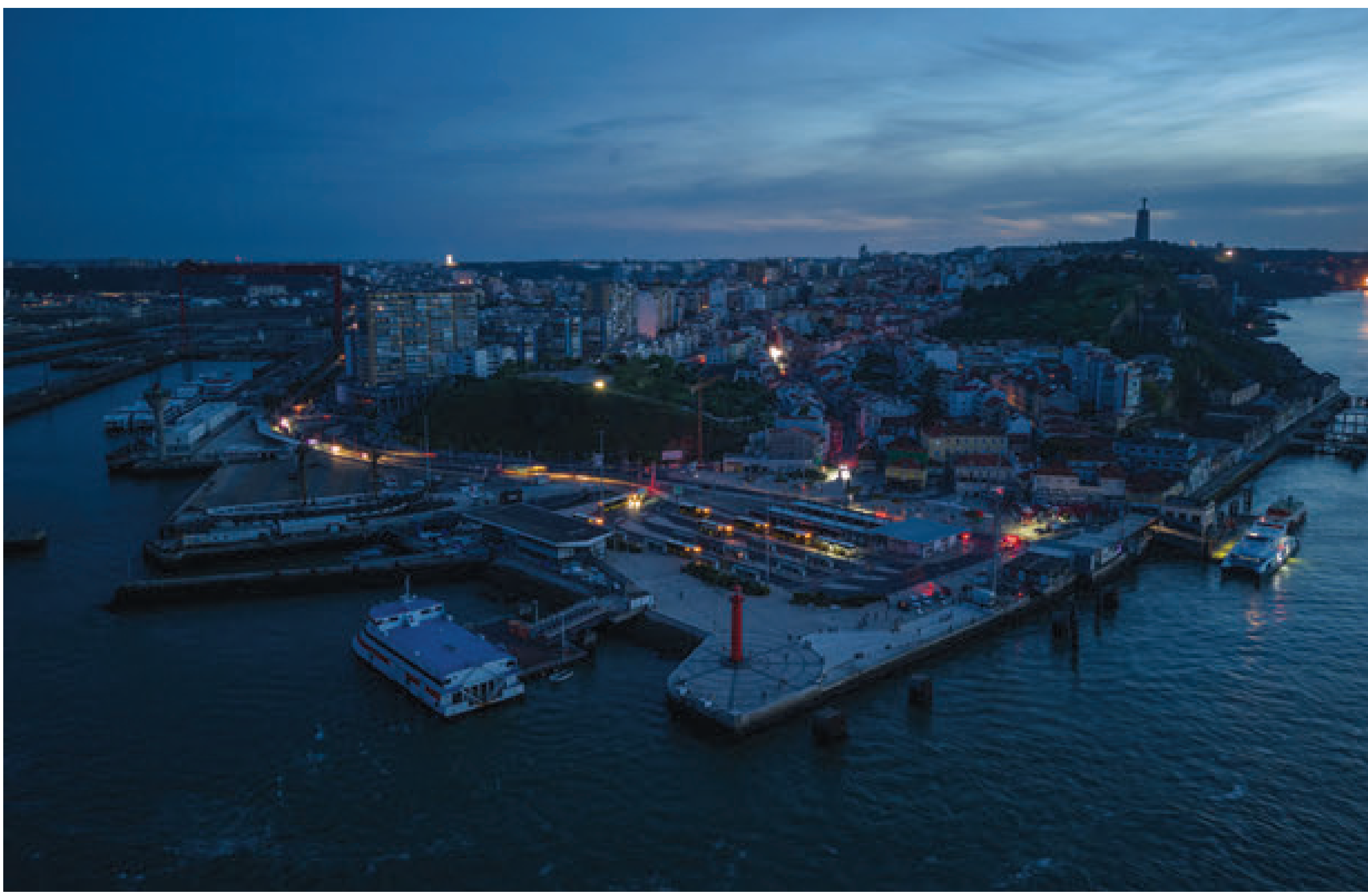
BELOW: Lights out in Almada, Portgual.

"The CrowdStrike failure violated most of these principles – the use of the application as an 'architectural extension' within Windows and itself, the lack of holistic testing, the deployment of a breaking change directly to production, and the absence of enabling capabilities to roll back the change once released."

Kathryn Guarini, a Senior Fellow of Electrical and Computer Engineering at Yale, said the Crowdstrike failure also highlighted the need to improve design robustness through chaos engineering, "where engineers create intentional failures in order to understand their impact, solve problems proactively and avoid large-scale service disruptions". In a crisis, "leadership matters," she added. "Leading through a crisis is a true test of a leader's mettle – just as risk mitigation and crisis avoidance create a lasting legacy."

Iberian Peninsula blackout

The Iberian Peninsula blackout of April 2025 reveals unique challenges in power grid engineering. According to electrical engineer Phil Kreveld, "the salient feature of the breakdown appears to be a simultaneous occurrence of transmission voltage oscillation and lightly loaded transmission lines, and the operator actions taken as a consequence". In an attempt to stabilise the system, >

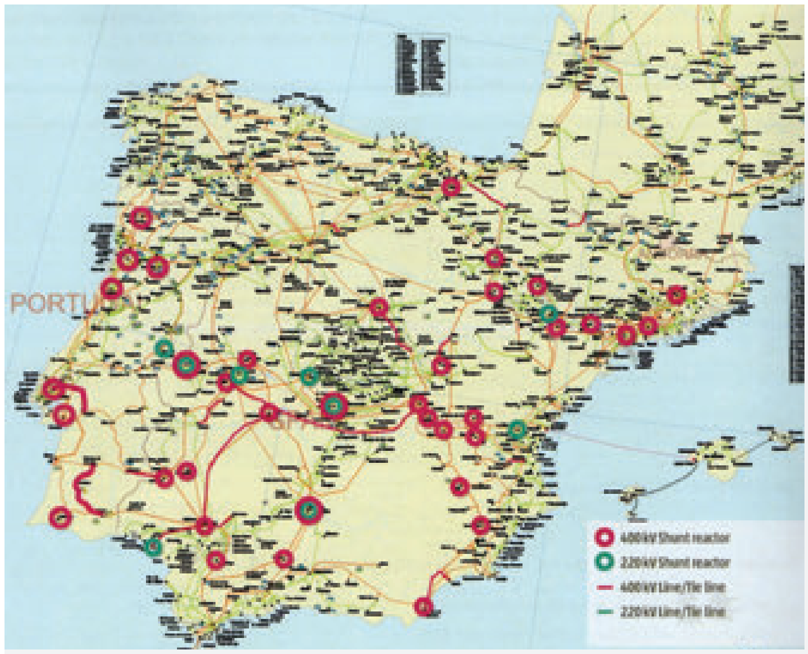


operators paired transmission lines – lowering impedance to damp the oscillations. However, this action also increased the reactive load requiring absorption. "What appeared to be the correct operational procedure in damping oscillation, exacerbated voltage rise in transmission lines – ultimately resulting in over-voltage tripping of generators and a cascading blackout," Kreveld explained. The operators' actions, though technically sound in isolation, created worse conditions in an already stressed system.

The problem was compounded by operational decisions made earlier that day. "To provide voltage support, some synchronous generators were absorbing reactive power from lightly loaded transmission lines," Kreveld said. "This is generally not an advisable procedure as under-excitement can cause instability because of reduced synchronising torque." As generators were selectively withdrawn from service to manage the light load conditions, transmission line voltages rose, causing further automatic shutdowns – a vicious cycle that operators couldn't break.

The Iberian failure offers urgent lessons for Australia's rapidly evolving grid. Firstly, single points of failure can potentially be mitigated via meshed grids, which Spain has, but Australia's are radial and subject to N-1 failure. "In the south eastern Australian grid, lightly loaded transmission lines >

"What appeared to be the correct operational procedure ... [resulted] in over-voltage tripping of generators and a cascading blackout."



RIGHT: The Iberian power network.

As it happened

Around midday on 28 April, 2025, mainland Spain and Portugal experienced a catastrophic grid failure that disconnected 31 GW of load in just 90 seconds. The subsequent blackout affected approximately 50 million people across the Iberian Peninsula, with eight people suspected to have died as a result of the disruption, making it one of Europe's most significant power failures. The first known blackout caused by overvoltage, it plunged the region into a day of chaos with transport, communications and emergency systems all severely affected.

In the hours before the blackout, the grid had been plagued by frequency oscillations, a warning sign that grid operators struggled to address. A photovoltaic solar plant in Badajoz was forcing a persistent 0.6 Hz frequency oscillation while feeding 250 MW into the network. These oscillations indicated underlying instability in the system's ability to maintain the frequency required for stable operation.

The failure of a substation in Granada triggered a domino effect: grid infrastructure in Badajoz and Sevilla rapidly disconnected as protection systems responded to the frequency deviation. Critically, the 2.8 GW interconnector to France – the peninsula's primary link to the European grid – automatically decoupled to protect the continental network from the disturbance. Within seconds, the Iberian Peninsula was an electrical island cut off from support.

The blackout exposed fundamental questions about grid control philosophy and the interactions with automated systems. Traditional grid operation has relied on human judgment supported by the natural time buffers that inertia provides, providing time to make adjustments in a crisis. But as renewable penetration increases and inertia decreases, those precious seconds evaporate.

The Iberian operators followed established procedures when pairing transmission lines to damp oscillations. But in a low-inertia, high-renewable grid, those procedures proved catastrophic. Reports into the disaster have already tasked engineers with rethinking energy grids for an environment where conditions change in milliseconds rather than seconds.

"The regulators appear to foresee voltage control problems through lack of reactive power by specifying volt-var control, and ultimately volt-watt control."

occur during high distributed energy resources energy production in distribution grids during the middle of the day," Kreveld said. The Australian Energy Market Operator (AEMO) is already grappling with similar reactive power challenges.

The technology solutions being deployed differ between regions. "In Australia, AEMO and transmission line operators are recommending and specifying synchronous condensers," Kreveld said. "Mainland Spain uses VAR compensators which can respond very quickly." While both technologies address reactive power management, synchronous condensers provide the additional benefit of system inertia – a critical advantage as renewable penetration increases.

ABOVE: Jared Lillywhite FIEAust CPEng EngExec, Aurecon.
TOP: The Anna Meares Velodrome will be a key track venue at the 2032 Olympics and Paralympics.

"The regulators appear to foresee voltage control problems through lack of reactive power by specifying volt-var control, and ultimately volt-watt control," he added. "Notwithstanding this, synchronous condensers will be required unless grid forming inverters can provide voltage stability. There are trials underway, but transmission line operators prefer synchronous condensers."

As Australian engineers manage our own energy transition, the Iberian blackout highlights the unknown knowns of hyper-complex infrastructure systems. The incident serves as a reminder that the energy transition isn't simply about adding green sources – it's about ensuring resilience and stability, and that renewable integration and grid reliability advance along this path together.

2032 Brisbane Olympics

How we can take the lessons of these events and secure systems against the possibility of failure is a challenge for all engineers – not least those tasked with planning the Brisbane 2032 Olympic and Paralympic Games.

For Jared Lillywhite FIEAust CPEng EngExec, a Principal at Aurecon with 25 years' experience designing major infrastructure projects, the challenge is both exciting and daunting. "What makes it unique >

is that the bulk of people who are experiencing the event are doing so remotely," he said.

The digital technology broadcasting of the games is an added layer of critical infrastructure for a harmonious event. Furthermore, unlike a typical piece of infrastructure that serves a consistent purpose, Brisbane 2032's infrastructure must scale from zero to maximum capacity and then to its legacy purpose – all while the world is watching. A single point of failure, whether in power systems, transport networks or cyber security, could become a global embarrassment.

Studying what's gone wrong at previous Olympics and major events – power infrastructure, for instance – is vital. Cascading delays can be caused by transport bottlenecks, Lillywhite said, where "failure in that logistical infrastructure can have significant ramifications".

After determining risk assessments based on likelihood and consequence, Aurecon uses digital twins, supporting design-phase modelling and operational monitoring, which it conducts upfront to simulate scenarios.

Yet for an event of Olympic scale, all the desktop modeling and simulation in the world can't replace the real thing. "One of the keys is to validate that desktop work through physical testing," Lillywhite said – running failure scenarios in real life, such as simulating a major-venue power outage and running through the process to validate redundancy plans.

Learning lessons

Australia's size and geographic isolation create unique challenges. Our infrastructure often lacks international redundancy options, making domestic resilience even more critical. Therefore, the goal isn't just bouncing back from failures, but engineering systems that learn and improve from disruptions.

As our infrastructure becomes more complex and interconnected, the question isn't whether failures will occur, but whether we've designed systems that fail safely.

The examples of Optus, CrowdStrike and the Iberian Peninsula demonstrate what happens when we don't. □

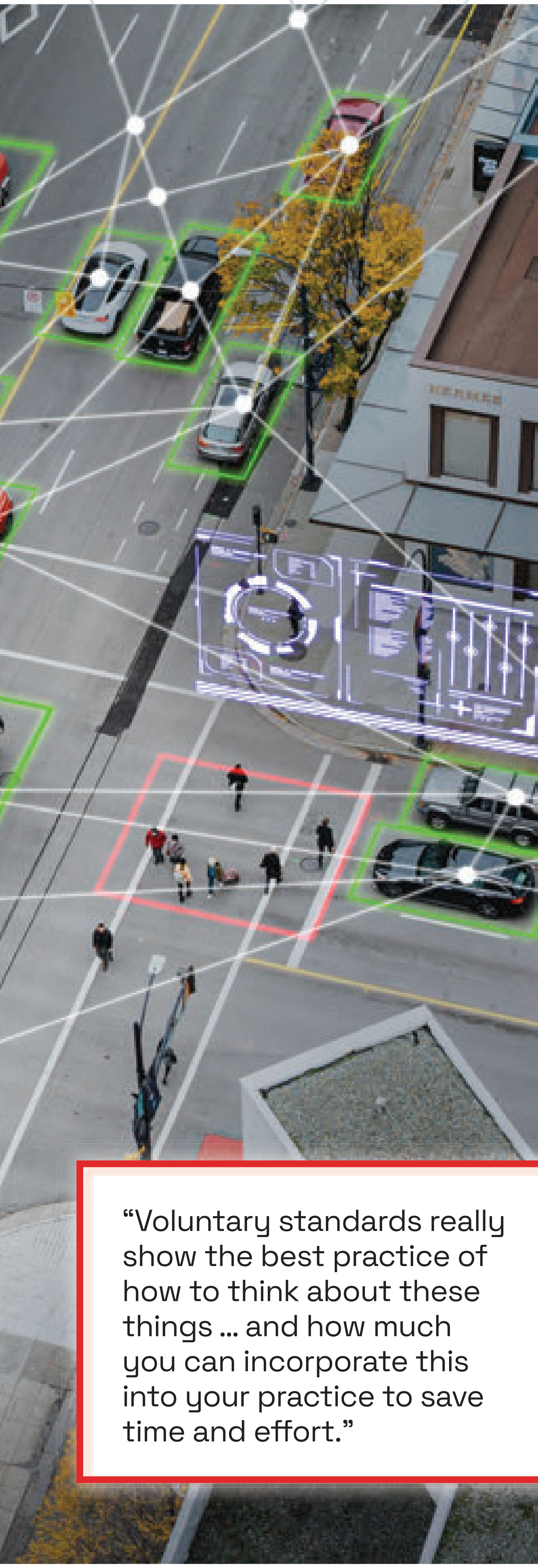
ABOVE: Bowens Hill Interchange, with the Brisbane CBD in the background.

"What makes [the Brisbane Olympics] unique is that the bulk of people who are experiencing the event are doing so remotely."

Proof of thought

WORDS BY SIAN POWELL

Engineers are increasingly expected to show evidence that AI, digital and infrastructure systems are safe, fair and socially responsible. A growing ecosystem of ethics standards is helping them do it.



"Voluntary standards really show the best practice of how to think about these things ... and how much you can incorporate this into your practice to save time and effort."

As AI upends industry norms and recasts the nature of employment, engineers have to design for hyper-complex, interconnected systems in an increasingly technologically driven world.

These tectonic shifts require new ways of thinking and problem-solving. The coming years will test how well engineers can embed values into systems as technologies become more autonomous, data-driven and socially embedded.

From AI-enabled systems and smart infrastructure to social media and environmental management, design decisions are now expected to include bedrock ethical considerations. A set of standards formulated by the Institute of Electrical and Electronics Engineers (IEEE) guides the way.

A global organisation of about 500,000 professionals, the IEEE in 2021 issued the flagship IEEE7000 standard: Model Process for Addressing Ethical Concerns during System Design. Described as a "set of processes by which organisations can include consideration of ethical values throughout the stages of concept exploration and development", the standard has been adopted around the world.

It includes steps that organisations of any type or size can take to ensure ethical values are considered in the creation of new systems or technology – from the earliest plans through to final development, and it shows how those values can be tracked as they are built into the system's goals, design and technical requirements.

Engineer Ruth Lewis MIEAust is Vice President (Standards) of the IEEE Society on Social Implications of Technology (SSIT) and Chair of its standards committee. She worked on the development of the 7000-2021 standard, describing it as consensus-driven and fundamental in showing organisations how to embed ethical principles into the engineering design process from concept onwards.

"Voluntary standards really show the best practice of how to think about these things, particularly in the engineering field or in the IT field, and how much you can incorporate this into your practice to save time and effort," Lewis told *create*.

"It's how you can imbue those sorts of ethical parameters or ethical thinking into that, and apply them to the engineering design process." Apart from increasing global competitiveness, she added, these standards "make the market move properly".

Aligning approaches

Now adopted by the International Organization for Standardization (ISO), the 7000-2021 standard gives engineers and technologists an implementable process that shows how to align innovation management processes, system design approaches and software engineering methods, so organisations can address ethical concerns or risks during the design process.

The standard emphasises stakeholder involvement and includes processes to identify the system's stakeholders throughout the its life cycle, >

> "There's a lot of pressure from the developers ... many AI developers fear over-regulation will stifle innovation."

and ways to choose stakeholder representatives. The standard requires analysis of the ways the system will be controlled and the collation of relevant data on its social, legal and environmental feasibility.

Reaching agreement on the standard's process was not always straightforward. "There's a lot of pressure from the developers," Lewis said. "Many AI developers fear over-regulation will stifle innovation."

Overall, the series of IEEE 7000 standards can provide a blueprint for engineering professionals navigating the often uncharted waters of AI. These standards, Lewis added, can assist in determining how best to embed ethical principles in technological projects. These principles include fairness, transparency, inclusivity, privacy and sustainability – built on the understanding that ethical design decisions should have a positive effect for individuals, society and the environment.

Appropriate use

The IEEE began its journey towards the 7000 series standards encompassing ethics, AI and engineering in 2015, with an initiative called Ethically Aligned Design. This initiative is a set of guidelines and principles concerning the creation of autonomous and intelligent systems. Human wellbeing and transparency are prioritised.

The IEEE Principles of Ethically Aligned Design were adopted around the world, including by the OECD and UNESCO.

"It was really the first framing, and it remains also Australia's AI ethics principles," Lewis said, noting Ethically Aligned Design is also acknowledged on the Department of Industry website.

The 7000 series of standards includes IEEE 7010-2020, which incorporates an engineering process to assess the impact of AI on human wellbeing, to be used before, during and after design and deployment of any AI system; and IEEE 7007-2021 which defines an ontology for defining ethics in AI and

ABOVE: Ruth Lewis MIEAust, IEEE Society for Social Implications of Technology.

robotics. This standard has been used internationally to define fail-safe mechanisms in lethal autonomous weapons.

Dr Katina Michael, Program Director of the MBA (Technology and Digital Strategy) at the University of Sydney Business School, said standards are vital because they help organisations benchmark against best practice.

"The whole point is to be able to demonstrate that you've not only adopted AI or any other technology, but that you're using it appropriately – and that requires evidence. Policies, stakeholder descriptions, design and development life cycles, user testing results, audit logs, meeting records and any other documentation that could shed light on actual practice."

Standards emerge when professional bodies identify gaps in the existing landscape, Michael said. They then determine the most appropriate way to address those gaps, whether through a global standard, a national standard or a sector-specific standard.

An increasing number of ethically aligned design standards now cover the growing range of AI and AI-enabled systems in order to identify and mitigate risks.

"There are standards still in their infancy that begin at the industry level, and then gradually rise to national adoption. Those national standards, in turn, feed into the development of international standards," she said, adding that the field of AI is broad and rapidly expanding, and standards have been developed to keep pace.

"As new developments emerge, different groups need to focus on different elements. We recently saw the release of the AI >

Ethical frameworks and how they are used

FRAMEWORK	ORIGIN / SCOPE	HOW IT'S USED BY ENGINEERS
Engineers Australia Code of Ethics (2024 revision)	Engineers Australia national framework for professional conduct	Use as baseline values – integrate ethical questions in design reviews and risk registers
IEEE 7000 Series – Ethical System Design	Global standards for AI and autonomous systems	Process model mirroring systems engineering: define stakeholder values, trace ethical requirements, verify compliance
IEEE 2089 Series – Age-Appropriate Digital Services	5Rights principles for children. Age Appropriate Risk Register for Digital Services	Process framework to support the design of "age-appropriate" software and digital services for the wellbeing and flourishing of children online
ISO 26000 – Social Responsibility	Global standard for organisational ethics and corporate social responsibility	Use for supply chain and ESG decision audits
AS/NZS 5377 – Responsible E-Waste Management	Regional environmental standard	Apply ethical life cycle principles to product end-of-life design
EA–IEEE MOU (2025)	Collaboration agreement for shared standards	Enables Australian engineers to adopt IEEE ethical frameworks as practice guidelines
UNESCO AI Ethics Recommendation (2021)	UN global policy framework	Inform AI governance within infrastructure and public data projects
INCOSE Systemic Risk & Ethics Model (2023)	Systems engineering community guideline	Integrate ethical failure modes into risk analysis and systems resilience planning

and procurement standard, and there are many other standards that specialise in distinct domains."

Social media concerns

In 2025, Australia's eSafety Commissioner cited the IEEE 2089-2021 and IEEE 2089.1 standards in connection with the new social media age-verification regulations, encouraging providers to consider the engineering ethics frameworks.

Since 10 December 2025, a number of social media platforms, including Facebook, Instagram, Kick, Reddit, Snapchat, Threads, TikTok, X and YouTube, have been required to take "reasonable steps" to prevent Australian children under the age of 16 from creating or keeping a social media account.

Michael, the working-party chair for the IEEE 2089-2021 standard which embeds the 5Rights Framework for children, said the standard requires providers to follow best practice in identifying risks and mitigating them through interventions.

"Our hope is that, through the 5Rights principles embedded in the standard, there's harm minimisation towards eradication," she said. "It's placing the onus on the developers who are creating software and systems and services."

The 5Rights for children are the "right to remove", so children can edit or delete content they have created; "the right to know", so children understand who holds or profits from their data and how that data is used; "the right to safety and support", protecting children from illegal practices; the "right to informed and conscious use", so children can engage creatively online and have the capacity and support to disconnect; and the "right to digital literacy", so children are taught how to use, create and critique digital technologies.

The age-appropriate digital risk register in the standard identifies risks early in the development and design phase, so risks can be addressed before implementation, Michael said. These risks include digital services that take the biometrics of a child and study their emotions, in-game purchasing without parental consent, location tracking, and even data privacy breaches.

"Auto-scrolling as a default feature locks young people into additional screen time, behaviourally reinforcing that there is no end-point to a digital service."

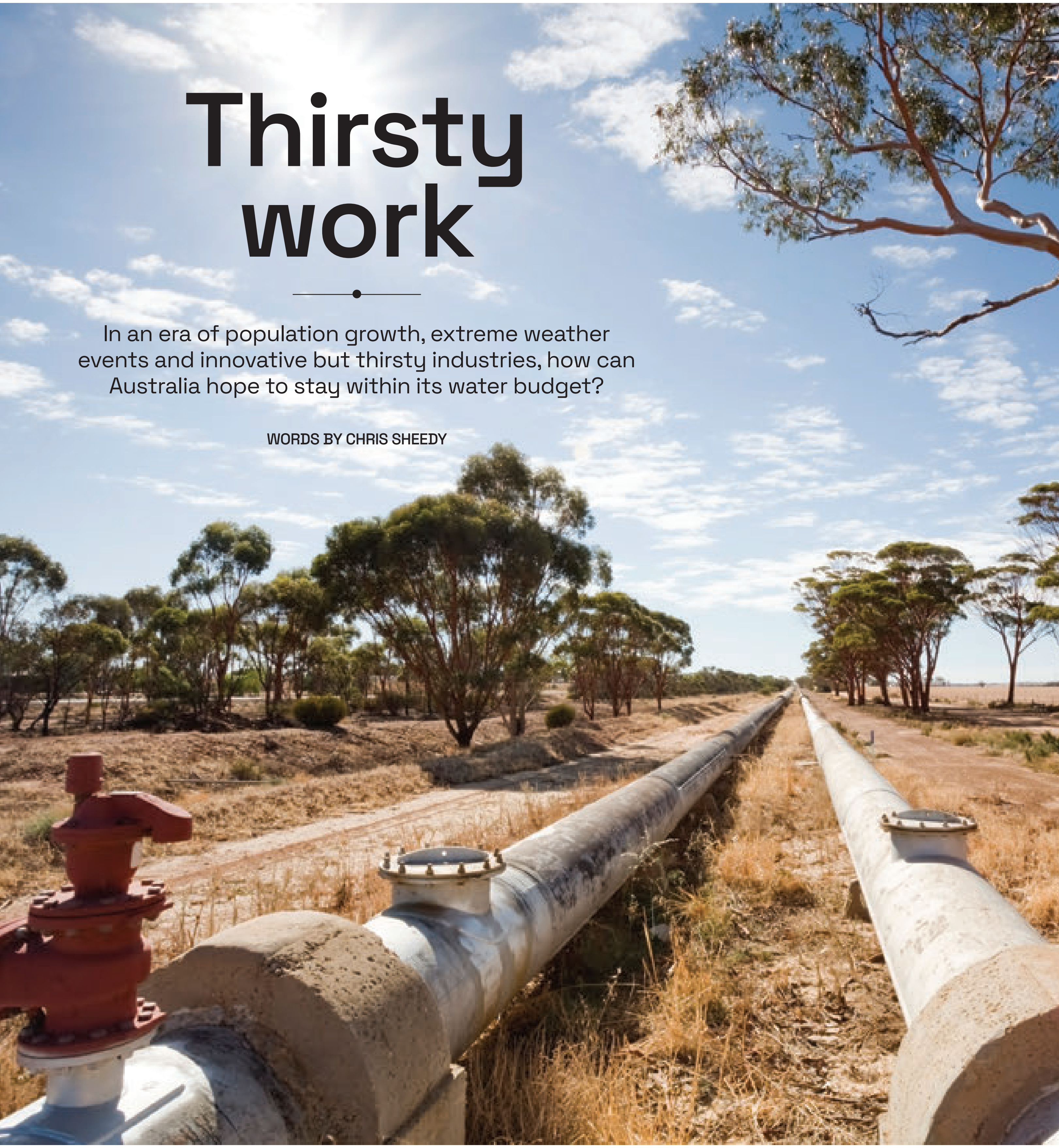
Major international platforms, she added, have already been hit with penalties of hundreds of millions of dollars for breaches in regulation, particularly in the European Union, for breaching children's privacy.

An eSafety Commissioner spokesperson said the Commissioner encourages the relevant social media platforms to consider current and emerging international standards in terms of deploying age assurance technology, including ISO/IEC FDIS 27566-1 and IEEE 2089.1. Yet alignment or accreditation against a particular standard, the spokesperson said, is not mandatory to comply with the new Social Media Minimum Age legislation.

"Our guidance encourages providers of age-restricted social media to consider relevant international standards and accreditation schemes on a range of matters to inform the taking of reasonable steps," the spokesperson said. "Alignment with international standards and independent accreditation can help demonstrate that a provider has applied eSafety's guiding principles in implementing age assurance technology." □

> "The whole point is to be able to demonstrate that you've not only adopted AI or any other technology, but that you're using it appropriately – and that requires evidence."

ABOVE: Dr Katina Michael, University of Sydney.



Thirsty work

In an era of population growth, extreme weather events and innovative but thirsty industries, how can Australia hope to stay within its water budget?

WORDS BY CHRIS SHEEDY

At first glance, the rampant growth of data centres, particularly in and around Sydney and Melbourne, appears to have little to do with the supply and demand of water. But dive a little deeper and the connection becomes clear.

Australia has more than 260 data centres, according to an ABC report. Around a third of these are in Sydney. And more are being developed "at a rapid rate", said Professor Katherine Daniell MIEAust, Director of ANU's School of Cybernetics and Deputy Chair of Engineers Australia's National Committee on Water Engineering.

In fact, the use of AI and cloud computing will necessitate an extra 175 new facilities by 2030, the *Australian Financial Review* has reported.

"We did research around one of the more efficient data centres in Western Sydney," Daniell said. "Our approximate calculation showed that on a day over 32°C, that data centre would use the equivalent of 1000-2000 households worth of water."

ABOVE: Professor Katherine Daniell MIEAust, ANU.

Clearly, there is an increasingly complex interrelation between water and other sectors, including:

Technology: the more we rely on it, the more water it consumes, particularly for cooling

Energy: the largest extractor of water from the environment

Agriculture: the largest consumer of water

Economics: businesses rely on water for their survival

Society: people rely on water for life, dignity and wellbeing

That interconnectedness means that, on the world's driest inhabited continent, a careful balance must be engineered as we move forward, particularly as weather events become more powerful and longer lasting.

"In extreme circumstances we effectively turn agricultural water off, except for certain perennial crops," Daniell said. "We introduce restrictions so people can't fill their pools or wash their cars. Golf courses and parks don't get water. But can you turn a data centre off?

"In extreme moments we're going to see this system cracking, and we have to figure out how many locked-in systems can't be turned off. We may face a choice between water for firefighting, for drinking and for keeping our data centres on. What do we sacrifice if we haven't already designed these solutions into the system?" >

"Our approximate calculation showed that on a day over 32°C, that data centre would use the equivalent of 1000-2000 households worth of water."

Competing demands

The production of green hydrogen requires somewhere between 15-110 L of water per kilogram of green hydrogen, depending on various factors, said Dr Kate Holland, a CSIRO Principal Research Scientist and Groundwater Management Group Leader.

Holland led a study into green hydrogen production that found it wasn't the cost of the water that made certain plants unfeasible. It was the inability to supply the enormous amount of water.

"We had a look at small-scale developments," Holland said. "They could potentially use existing surface water subject to water planning, or groundwater with some treatment.

"But once you got up to the larger scale hydrogen hubs, you were just looking at desal for supply. The current technology is a really big water user."

The modelling results depend on such factors as the quality of the water and the cooling technology. Data centres are a similar story.

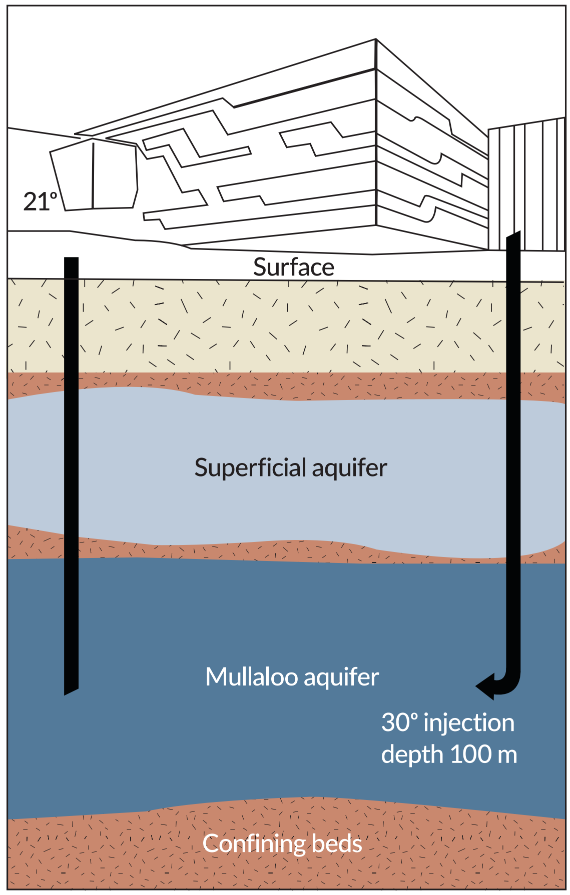
"In data centres, cooling technology really matters. They're not in remote regions, so water supply is typically more reliable. What is a problem is the stress they put on water systems."

That's where engineering comes in, Holland said. There are choices that can be made around the development of data centres in different geographical locations that can share the load if others must be switched off, for example. And in cooling technologies, greater innovation is required.

For example, the CSIRO-developed groundwater cooling system for the Pawsey Supercomputing Centre in Western Australia involves pumping cool water from a shallow aquifer beneath Kensington in Perth. That water runs through an above-ground heat exchanger to cool the supercomputer, before it is reinjected underground. The geothermal process is estimated to have saved 14 million L of water in its first two years of operation alone.

One other emerging competitor for water, Holland said, is critical minerals.

"Critical minerals will involve an integrated extraction and processing method," she said.



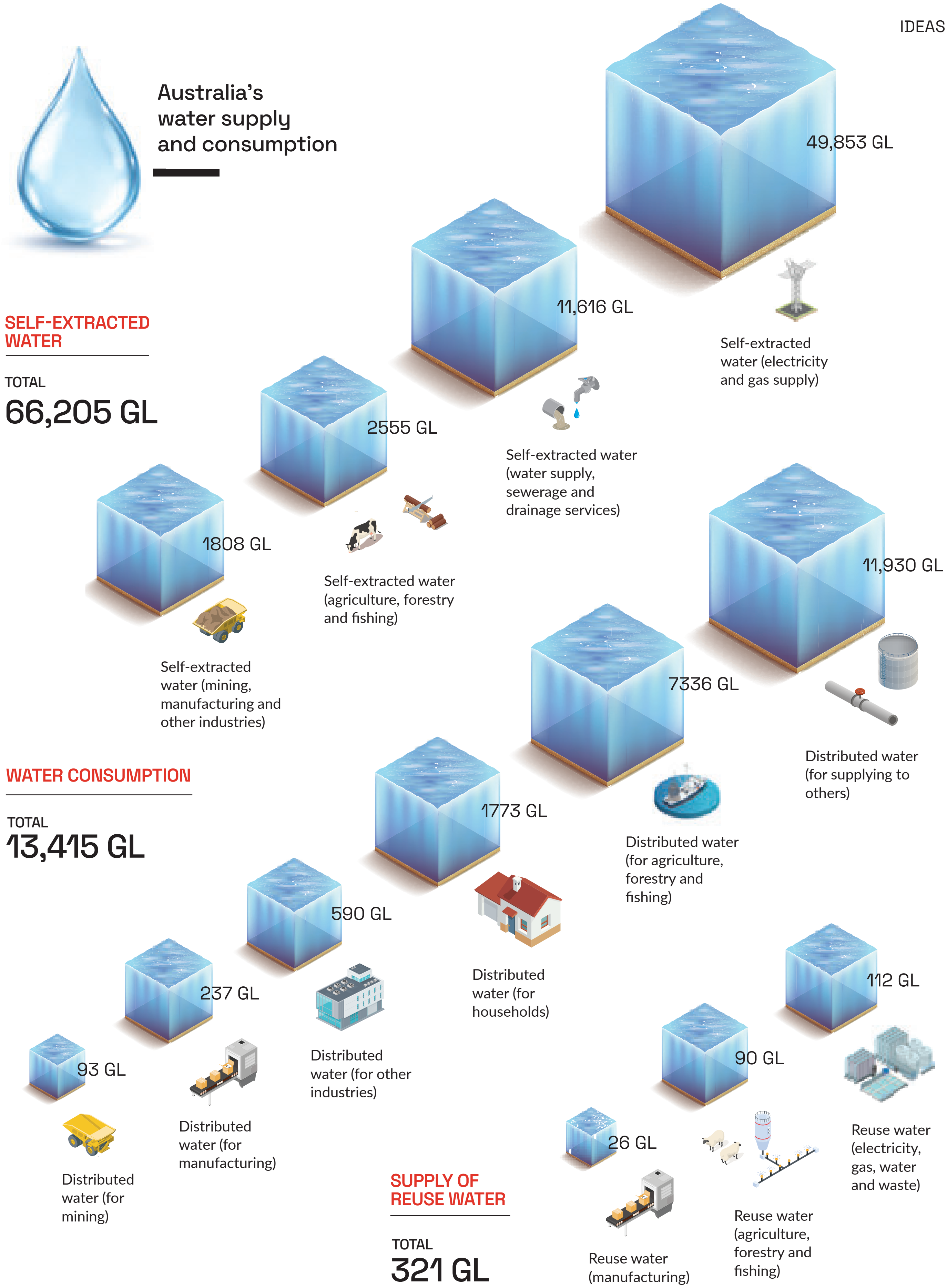
"That potentially requires a lot of water for processing. Each region has its own set of aquifers and its own climate. It really matters where water comes from at a regional scale."

ABOVE: Dr Kate Holland, CSIRO. **TOP:** Groundwater cooling beneath the Pawsey Supercomputing Centre. **LEFT:** The data centre exterior.

Intervention strategy

Across Australia's landmass are countless local weather regions. The simplest way to slice the country is north/wet and south/dry, Daniell said. From there, water researchers can narrow their data down by state, region, city, suburb, coastal, inland, riverine, arid and more. >

"In data centres, cooling technology really matters. They're not in remote regions, so water supply is typically more reliable. What is a problem is the stress they put on water systems."



Source: ABS Water Account. All figures based on 2021-22 data.

There is no one-size-fits-all approach to water knowledge, meaning nothing is more powerful than local knowledge.

Data from the Australian Bureau of Statistics (ABS) tells us that Australia extracts around 70,000 GL annually from the environment, much of which is returned. Of this, around 13,000 to 15,000 GL is consumed and not returned.

At a national scale, that understanding is useful. But the most impactful knowledge comes from understanding at a localised resource level how water is being used, and whether regions are at risk of exceeding their budgets.

There are various ways to do that. The Murray Darling Basin has a series of accounting methods, sustainable diversion limits, and other targets and objectives. It has a market mechanism to allocate resources to the most impactful places, overlaid with policy and regulations.

Just as important as policy and regulation is engineering. Water is a space in which engineering innovation and intervention can have a significant and positive effect as weather patterns continue to change.

Here are some top engineering interventions that will shape Australia's water future:

Desalination innovation

Desalination generates one unavoidable byproduct: brine. But engineers such as Jerome Douziech, Vice President of Operations and Performance at SUEZ, see this not as waste but as opportunity.

ABOVE: Jerome Douziech, SUEZ. **TOP:** Murray River.

"There is a research trend gathering momentum around recovering minerals from the brine," he said. "For instance, could we recover the minerals that we need to rebalance the water, or minerals that have a value on the market, like magnesium?

"If we could do that, we would not only reduce our carbon footprint, but also reduce our dependencies on other parties."

Managed aquifer recharge and water banking

Just as the energy sector has made advances in storage with big batteries, water has also made moves into storage by recharging aquifers, which eliminates evaporation.

"Water banking can increase water security for regional communities and industries during drought," Holland said. "However, a key challenge is navigating the rules for how we manage this water stored in each aquifer in each state and territory across Australia."

Reuse of industrial water

Whether for production of green hydrogen, data centre cooling, water

use around gardens and parks of new suburbs or even recycled drinking water, industrial and other wastewater could be applied more effectively to help solve challenges, Holland said.

"Our reuse, looking through the ABS numbers, is only around 2 per cent – higher in South Australia and WA, probably because they're the driest. We can do much better."

Circular wastewater treatment and resource recovery

Sewage treatment plants are beginning to evolve into resource recovery centres, said Adam Lovell, Executive Director of the Water Services Association of Australia. The further engineers can take this idea, the better.

"Wastewater is not waste. It's a resource," Lovell said. "That mindset shift underpins the infrastructure we're building now."

Integrated systems

The overwhelming message from experts is that everything is connected to water, and water is connected to everything.

"My advice to engineers is to broaden their perspective, because no engineering today is isolated," Douziech said. "You need to have a larger skill set, be curious and open in your perspective, and keep learning."

We're at the point where engineers can't just think about "pipes and pumps", Lovell said. They've got to consider cities, geographies, data, customers, carbon and resilience – because everything connects. Engineering in water has become systems work.

"It's not enough to optimise a single asset or a single system anymore," Daniell said. "You need to understand how >

ABOVE: Adam Lovell, Water Services Association of Australia. **TOP:** Victorian Desalination Plant.

> "Could we recover the minerals that we need to rebalance the water, or minerals that have a value on the market, like magnesium?"

"It's not enough to optimise a single asset or a single system anymore. You need to understand how the whole system interacts, including the social, ecological and technological."

the whole system interacts, including the social, ecological and technological. The future of engineering is not just about materials or hydraulics. It's about governance, behaviour and adaptation."

Changing the flow

An interconnected view is beginning to be mirrored in government frameworks, where decisions increasingly link water security to energy transition, housing growth and climate adaptation.

The National Water Initiative (NWI), currently under review by the Federal Government, is seeking to address some of those systematic integration needs in a modern way.

What we know of the NWI so far makes it clear that water policy can no longer sit in isolation, Lovell said. It connects to housing, energy, climate, digital and more.

"How do we weave AI into a water utility's data?" Lovell said. "How do we use urban stormwater or recycled water to keep the urban areas green and healthy? How do we break down bureaucracy and manage challenges from an engineering and technical perspective?

"We believe the upcoming national policy reform is a major step forward. It enables everybody to get on the same page and, in the face of climate change, start acting quickly on water supply security, on flood risk management and on a range of weather extremes, which the current NWI is really not designed to do." □

ABOVE: Geehi Dam in the Snowy Mountains.

Supply and demand

How much water do we have in Australia? How much water do we use annually, and how? And is it possible to blow the budget?

For water usage data, most experts refer to the *Water Account Australia*, published by the Australian Bureau of Statistics (ABS).

The latest report, from 2021-22, said the total volume of self-extracted water – water extracted directly from the environment, including rivers, lakes, groundwater and desalinated seawater – was **66,205 GL**, an increase of 3 per cent on the year before.

However, it's important to note that "self-extracted" does not mean consumed. Much of the self-extracted water, for hydroelectric plants, for example, is returned to the same place it was taken from.

Households consumed **1773 GL,** the rest extracted by industry. The lion's share **(49,853 GL)** goes to electricity and gas supply, with water supply, sewerage and drainage services the next most thirsty sector, at **11,899 GL.**

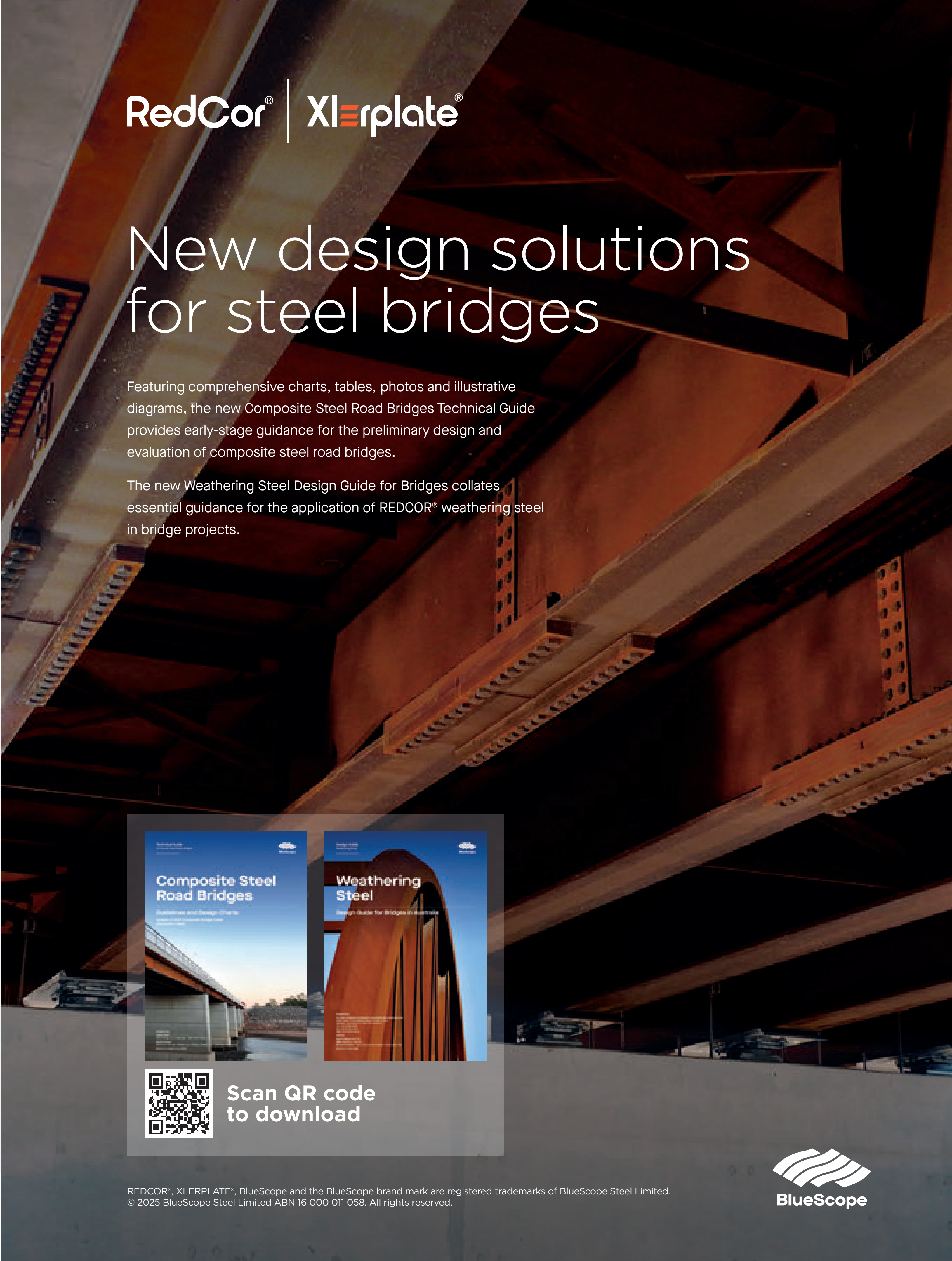
Agriculture, forestry and fishing use just **2555 GL**, but these sectors represent the largest consumers.

How does this compare to the total available?

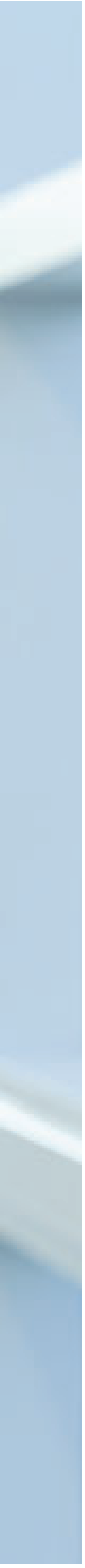
It depends on the weather in various regions, but during the 2021-22 period, the ABS said, we extracted **93 per cent** of our total surface water supply, **4 per cent** of groundwater and **2 per cent** of potential seawater for desalination.

Could we over-spend on our water budget?

That's absolutely possible in local areas, particularly in drought years and without fallback plans and local management strategies. Those in the Adelaide Hills are no stranger to such challenges, as water carters had to be brought in during early 2025, with some households reporting a wait of several weeks.


RedCor® | Xlerplate®
New design solutions for steel bridges
Featuring comprehensive charts, tables, photos and illustrative diagrams, the new Composite Steel Road Bridges Technical Guide provides early-stage guidance for the preliminary design and evaluation of composite steel road bridges.
The new Weathering Steel Design Guide for Bridges collates essential guidance for the application of REDCOR® weathering steel in bridge projects.
Composite Steel Road Bridges
Weathering Steel
Scan QR code to download
REDCOR®, XLERPLATE®, BlueScope and the BlueScope brand mark are registered trademarks of BlueScope Steel Limited.
© 2025 BlueScope Steel Limited ABN 16 000 011 058. All rights reserved.
BlueScope

“The aggregation of marginal gains which we got through people, market, assets and finance ended up turning into what Boral’s performance is today.”



All in the mind

WORDS BY KAREN JAMAL

Understanding complexity, delivering solutions. In a nation built on engineering, Australia needs more engineers in its boardrooms.

Australia is an engineering nation. More than half of the country's industry value-add comes from just six engineering-intensive sectors, according to Engineers Australia's Engineering Tomorrow report.

Our prosperity, resilience and living standards are shaped by engineering decisions in our energy systems, transport corridors, digital infrastructure and advanced manufacturing. Yet the people who design and deliver these systems are largely absent from the rooms where national decisions are made.

Just 9 per cent of federal politicians hold a science or engineering qualification. In the boardroom, engineering, manufacturing and construction experience account for just 7 per cent of board appointments, according to the 2025 Board Diversity Index. While accounting, law and finance dominate boardroom discussions, the disciplines that manage risk, scale systems and translate complexity into practical solutions are underrepresented.

"Not having an engineer in the boardroom of engineering-intensive sectors creates a potential blind spot," said Dr Raj Aseervatham FIEAust CPEng EngExec, immediate past-President of Engineers Australia. Our national decisions increasingly involve systems that are technically dense and economically consequential, he said. Without engineering judgement in the room, boards risk making decisions that look efficient on paper, but fail under real-world conditions.

The engineering mindset – pattern-based, evidence-driven, commercially literate and focused on human need – is critical to good governance. Engineering brings risk literacy, often forged through billion-dollar projects. Engineering bridges technical feasibility and economic value. As our economy becomes more complex, these strengths are strategic assets.

Boards and governments don't just need engineers because of their technical knowledge. They need engineers because engineers change the quality of decisions: they ask different questions, spot different patterns and see the downstream consequences that others miss. >

LEFT: Vik Bansal FIEAust FAICD, Boral.

DATA IN THE DETAIL

When Vik Bansal FIEAust FAICD joined Boral as CEO and Managing Director in 2022, the business was grappling with what he describes as "all the significant fundamental problems across people, customers, assets and finance you can think of".

Boral had endured COVID construction shutdowns, La Niña rainfall events on the Australian east coast and substantial energy cost inflation. Performance had slipped. Capital had been misallocated. Morale was low. Market share was eroding.

Bansal's instinct – influenced by his training as an electrical and computer systems engineer – was to pull the issues apart.

"We needed to understand each issue and start solving them one by one."

The approach was systematic, and classically engineering: start by reducing complexity to its smallest observable units, then rebuild the system only once the interactions between those units are understood.

It is a mindset that serves boards and business leaders very well.

Twelve months after Bansal's appointment, Boral's share market value had climbed by more than $2 billion. In 2025, the recovery was recognised with the Large Company Turnaround Award at the Turnaround Management Association Australia Awards.

"The aggregation of marginal gains which we got through people, market, assets and finance ended up turning into what Boral's performance is today," he said. "Anchoring in facts and data was fundamental."

Three fundamentals

The word "engineer" hints at the mindset behind the discipline. The Old French *engin* gives us the practical application – a builder of devices and an operator of complex machines. The Latin *ingeniator* and *ingenium* evoke innate talent, invention and clever creation. Combined, they describe a profession born of both machinery and imagination: the person who understands how things work, and the person who devises something new when they don't work.

Engineers have always used science, mathematics and invention to meet human challenges. The tools shift with each era – from stone to steel to software – but the underlying instinct to solve remains. For Aseervatham, three foundational habits of thought – an "engineering mindset" – shapes how engineers solve problems and how they lead.

CHARACTERISTIC #1 Seeing the real human problem

Engineers characteristically say they are problem-solvers. But Aseervatham takes it a step further: "Why is that a problem? Why does it exist? And often it begins with a societal or human need, preceding a technical scope."

Aseervatham is emphatic. Technical brilliance can be "a seductive but dangerous thing". When engineers become "immersed in the technical wonder", they risk forgetting why the work exists at all. The strongest engineering solutions, he argues, are rarely the most elaborate, but are anchored in a human or societal problem.

And this is precisely why engineering leadership strengthens governance: engineers return decisions to the real-world need.

ABOVE: Dr Raj Aseervatham FIEAust CPEng EngExec.

OPPOSITE: Tanya de Hoog, MIEAust FIStructE CEng, Aurecon.

CHARACTERISTIC #2 Using evidence and analysis

The instinct to apply precision and pattern recognition is often innate. "As an engineer, you're seeing how processes or operations work in patterns, and then looking for curious variations," Aseervatham said. "You see how something works a thousand times and then doesn't work for the one thousand and first. You look for those patterns and ask why. And then you apply that skill to complex systems."

It's a world view based on what is observable and repeatable – drawing a line outwards to see what it means at real-world scale. This ability to mentally scale a system gives engineers a different kind of judgement in leadership settings. They're not swayed by isolated incidents. They note signal over noise. They're wired to spot outliers, diagnose failure modes and ask analytical questions to inform everything from infrastructure planning to big capital decisions to risk mitigation across long time horizons.

CHARACTERISTIC #3 Seeing value beyond cost

The third discipline tends to emerge later in an engineer's career, Aseervatham said, as they move from designing components to shaping systems. "In engineering, scale is associated with a dollar sign with a tail of zeros behind it." At that point, purely technical judgement is not enough. Decisions require economic reasoning, although not in the accountant's sense.

"Understanding cost is >

THE HUMAN STORY

Structural engineer Tanya de Hoog MIEAust FIStructE CEng was five years into her career when she began work on one of Europe's largest structural challenges, the Estádio da Luz, Benfica's home stadium. The vast, shimmering Stadium of Light is beloved by the city of Lisbon.

But what stayed with de Hoog, now Aurecon's Chief Engineering, Eminence and Innovation Officer, wasn't the engineering scale. It was the way people responded to it.

"People were so passionate about their team and that stadium. Many people wanted to be part of building it, often volunteering, because it was part of the fabric of their community. It helped me understand early in my career the impact and importance of engineering beyond the structure."

The experience set the tone for her career, which would cross continents, disciplines and leadership roles, culminating in her appointment as President of the Institution of Structural Engineers in 2024. It also became the lens through which she could see the wider arc of her profession – its impact on communities, cities, environments and even history – and how those insights offer a leadership perspective unique to engineers.

"Engineers can hold many variables in their heads at once." This means they can see how a single decision cascades across cost, risk, climate, community impact and long-term performance – often before anyone else in the room has clocked the connection.

"It helped me understand early in my career the impact and importance of engineering beyond the structure."

IMAGE: Ross Coffey.

"We embarked on some of Australia's most sophisticated automation in distribution and fulfilment centres. These were billion-dollar investments."

necessary, but not sufficient." The harder question is: "Why is that cost worth bearing for the impact that it creates?" This is the shift from calculating cost to understanding value.

Aurora of benefits

The engineering mindset is whole when all three principles meet, centring solutions on the human problem, using data, analysis and technical rigour to solve it, and weighing the variables so the solution is viable in the real world.

Not all engineers have this mindset. Some remain "scope takers" throughout their careers, Aseervatham said. They are handed a brief and they deliver – precisely, often brilliantly, but within boundaries drawn by someone else.

Leadership emerges when engineers become "scope makers". Scope makers step beyond the technical edges to consider the broader system – the community impacts, the budgetary consequences, the unintended effects, the hidden opportunities.

This creates an "aurora of wider benefits", a halo effect beyond the technical that lifts engineers to the status of leaders. They bring a way of thinking shaped by systems, grounded in real conditions and oriented to long-term value.

Australia's prosperity has always relied on engineering minds in the field. Its future depends on having more of them in the boardroom. □

RIGHT: James Graham AM FIEAust EngExec.

IMAGES: Ross Coffey.

Engineers Australia is delivering two AICD Company Directors Courses™ exclusively for members. Secure your place using the QR code.

CHEMISTRY OF GOOD JUDGEMENT

When James Graham AM FIEAust EngExec stepped down from the Coles board in April 2025, he carried with him a curious coincidence. For several years, three of the most senior people steering one of Australia's largest retail businesses had all trained as chemical engineers.

"I studied chemical engineering at the University of Sydney," he said. "Steven Cain, our inaugural Coles CEO, was a chemical engineer from Imperial College London. And our former chief financial officer, now CEO, Leah Weckert, is a chemical engineer from the University of Adelaide."

At first glance, these engineering foundations look far removed from retail. But in practice, they shaped Graham's approach to business. A long-serving Wesfarmers director from 1998, Graham was appointed Chair of Coles in 2018 from the date of its demerger. He helped guide the company through COVID lockdowns, the sale of Coles Express, the purchase of two food manufacturing businesses, and substantial investments in automation, new technology and store development.

"Coles is an extremely diverse business. We embarked on some of Australia's most sophisticated automation in distribution and fulfilment centres. These were billion-dollar investments. We needed to understand the technology, the market, the financial risk and commercial dynamics – and understanding multidisciplinary frameworks is what engineers are trained in."

THINKING IN SYSTEMS

When Davina Rooney was appointed CEO of the Green Building Council of Australia (GBCA) in 2019, the association had certified more than 2250 Green Star projects. But the sustainability landscape was shifting fast. Climate science, disclosure frameworks, nature targets, and health and wellbeing expectations were expanding the GBCA's remit. This complexity proved fertile ground for Rooney, who trained as a civil engineer.

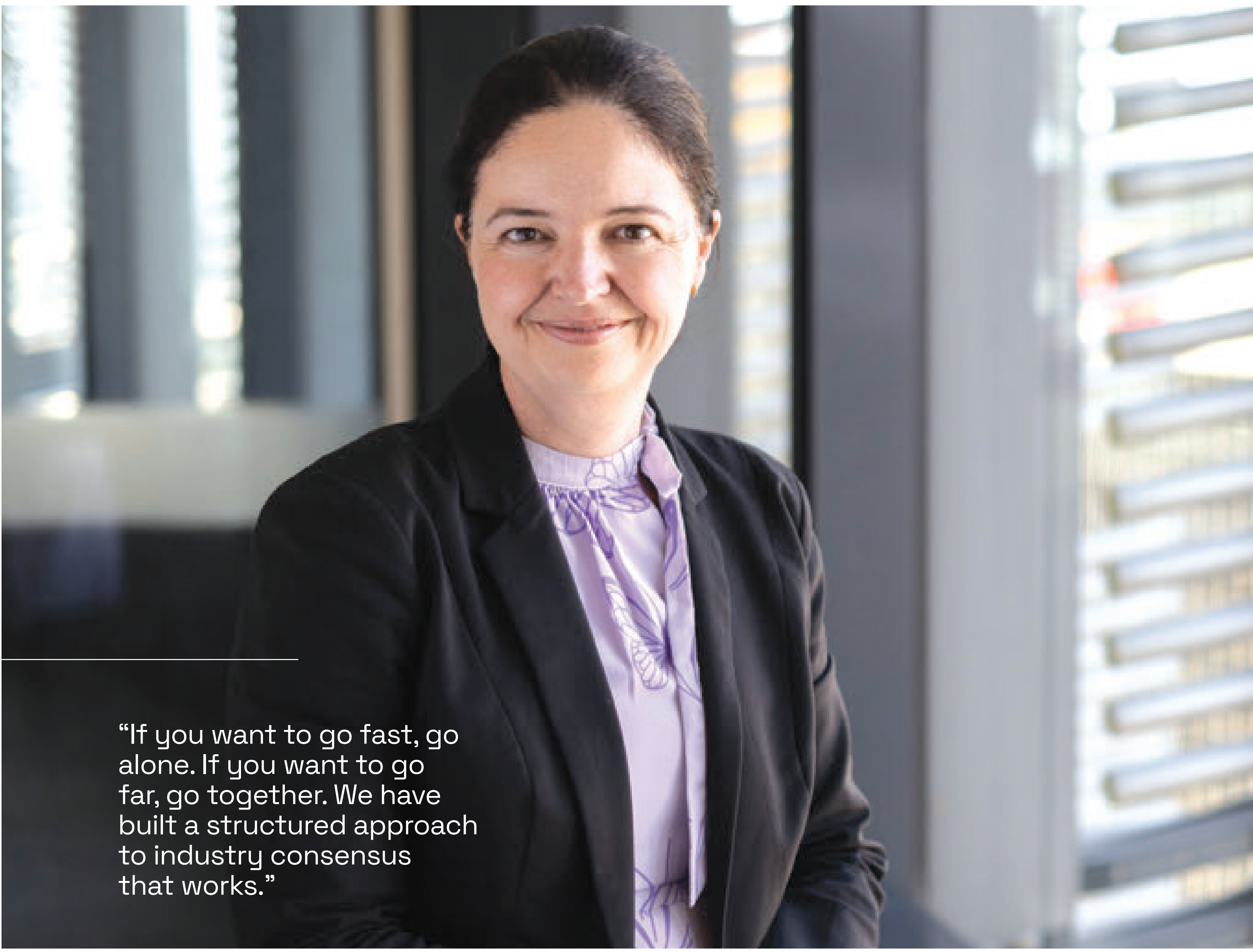
"Engineers are trained to see the system – the plan, the pathways and the implementation steps – in a very structured way. We think in terms of both design and delivery. We know how to fly the kite and how to land the kite."

This systems perspective shapes how the GBCA scans global signals, breaks down emerging issues and interprets them for Australian conditions. "If we know how to do something, we put it into a rating tool. If it's still an emerging issue, we frame it in a discussion paper and work through a consensus process."

The value is in framing the problem clearly, not in rushing to a solution. "If you want to go fast, go alone. If you want to go far, go together. We have built a structured approach to industry consensus that works."

What distinguishes this approach is not just technical fluency, but an ability to translate complexity into collective action – a skill boards need as they navigate dense regulatory, climate and market shifts.

BELOW: Davina Rooney, Green Building Council of Australia.



"If you want to go fast, go alone. If you want to go far, go together. We have built a structured approach to industry consensus that works."

Projects

River race

WORDS BY CHRIS SHEEDY

After cyclonic flooding destroyed Kuranda Weir, engineers had less than a year to design and construct two dams, stabilise the rail corridor, keep workers safe and reinstate power – all before the next big wet.

Tropical Cyclone Jasper dumped record rainfall across Far North Queensland in December 2023 and the Barron River rose to levels never previously recorded.

It was one of the highest rainfall events on record in parts of Cairns, according to GHD Dams Service Line Leader APAC Nick Thomas-Kinsella CPEng. The water levels reached the top of the embankment, which was not designed for overtopping. In fact, the river had never before overflowed the clay-core, rock-fill structure, which was constructed in 1962-63.

When that did finally occur in late 2023, the embankment failed. "Once it overtopped, it resulted in head-cutting erosion on the crest and eventual back erosion and breach of that embankment," Thomas-Kinsella said.

The consequences were immediate and severe. "The power station could no longer supply water because there was not enough head to run through the penstocks and power the turbines."

Barron Gorge Hydroelectric Power Station, capable of providing renewable energy to 50,000 homes every year, was suddenly unavailable. Water bypassed Kuranda Weir, which acted as a regulating pool to provide water to the power station. The reservoir was also vital for whitewater rafting tourism operators downstream, who lost the controlled releases they rely on.

ABOVE: Nick Thomas-Kinsella CPEng, GHD. **TOP:** The project was named an Outstanding Nomination in the Engineers Australia QLD's Project of the Year Award.

TROPICAL CYCLONE JASPER

PROPERTIES AFFECTED

900

COST TO REGIONAL ECONOMY

$390 MILLION

BARRON GORGE POWER STATION

POTENTIAL CLEAN ENERGY GENERATED ANNUALLY

66MW

SUPPLIES ENERGY TO (EQUIVALENT)

50,000 HOMES

ABOVE: Geoff Woodgate MIEAust CPEng, CleanCo. **BELOW:** The weir was "one of the most constrained sites conceivable".

The clock began ticking. The next wet season was around the corner. To reinstate the weir's function and restore generation, engineers from GHD and energy developer, generator and retailer CleanCo Queensland had to achieve in less than 12 months what might usually take three or four years.

"This wasn't a linear project," said CleanCo Asset Engineering Manager Geoff Woodgate MIEAust CPEng. "A civil works project like this would typically have an active horizon of about four years, with up to 10 years of feasibility and financial investment work."

Rail, rain, risk

The project lay within one of the most constrained sites conceivable. It was wedged between the Barron River, a live Queensland Rail (QR) tourist line, unstable geology and damaged access roads, all within a protected World Heritage rainforest.

"The first challenge was the brownfield nature of the site," Thomas-Kinsella said. "We didn't have the time and opportunity to plan, and we were nestled between Wet Tropics national park vegetation, the Kuranda rail and the power station."

QR's iconic Kuranda Scenic Railway had suffered landslide damage during the same storm.

"We had to work with their engineering team," Woodgate said. "They had constraints on their issues as well. And we had heavy equipment crossing the railway every day, multiple times. We had to work within their rail schedule."

Access was problematic. Every truck, excavator, crane and concrete load had to pass through sensitive residential streets.

"It was an active and very public site," Thomas-Kinsella said. "Once it was back in operation, the train would go by two to four times a day and everyone would wave."

"Building a cofferdam across a flowing river is a major hazard. It was absolutely necessary, but it was a massive task."

Compounding these constraints was the river itself, flowing fast toward Barron Falls just 500 m downstream. "Building a cofferdam across a flowing river is a major hazard," Woodgate said. "It was absolutely necessary, but it was a massive task."

PHASE A

Rock-fill cofferdam

To create a safe, dry work zone and restore generation, the team first had to design and place a temporary rock-fill cofferdam.

"We used conventional earth moving equipment … progressively loaded and placed in the river, working from the right bank towards the left," Thomas-Kinsella said. "We initially placed a platform of very coarse rock, around 500 mm in diameter, or boulder-sized." >

Finer materials were then worked into the matrix to slow the water flow. This was followed by a bitumen geomembrane liner. "The liner wasn't completely essential, but it was an improvement, allowing us to operate more confidently."

CleanCo's risk management focus also called for a 24/7 system of sensors – tilt meters, water level detectors, etc – to provide automated, real-time warnings in case of any movement.

James Archer MIEAust CPEng, CleanCo's Site Manager Barron Gorge, said risk was a deep focus.

"For me, the biggest key element to this was how we understood risk and managed risk," he said. "At any point in time, if people said 'What's the risk?', we were able to tell them.

"We used a risk management tool called CGR. A lot of the risk surrounding this project went into CGR, and we used that as a basis for risk assessments and managing controls."

The risk analysis, monitoring system, emergency action plan, inspection regime and training program were developed over weeks rather than years. Still, the deadline was merciless. Phase A was successfully completed within six months, allowing the power station to return to operation by July 2024.

PHASE B

Iced concrete and workers in cages

With the river partially diverted and power restored, the next step was a more robust structure, a mass-concrete gravity wall to be built as the initial weir reinstatement. But pouring mass concrete in warm and wet Cairns required innovation.

"We needed placement temperatures under 25°C," Thomas-Kinsella said. As ambient temperatures rose throughout each day, target temperatures became difficult, and sometimes impossible, to achieve.

At first, chilled water was used in the mix, but that didn't do enough to cool the concrete. The contractor then moved to adding bagged ice at a late stage of mixing, which also proved to be too little, too late. Finally, ice was added earlier in the process, which kept temperatures below the target range.

The team also deployed a highly specialised conveyor system. "We used a telebelt to deliver the concrete," Woodgate said. "Because of our tight site

ABOVE: James Archer MIEAust CPEng, CleanCo.

BELOW: Construction on Kuranda Weir took place within a year.

BESPOKE CONCRETE MIX

LOW CEMENTITIOUS CONTENT
290 KG/M³
(MAXIMUM)

LARGE AGGREGATE SIZE
40 MM
(NOMINAL)

CONTROLLED WATER CONTENT
150 KG/M³

MEDIUM WORKABILITY
80 MM
SLUMP

60%
LESS CARBON DIOXIDE EMISSIONS THAN CONVENTIONAL CONCRETE

> **"Now, we have more people in the industry who have built both a dam and a weir. That has been a real highlight."**

and because speed was an issue, it helped a lot."

Concrete pours were sheltered from rain where possible.

The eight-metre-high gravity wall was cast in blocks with an optimised mix including high fly-ash content, reduced cement and oversized 40 mm aggregate. The low-carbon mix, adapted from GHD's recent Rookwood Weir experience, delivered both sustainability benefits and performance under thermal constraints. Embodied carbon emissions were reduced by 60 per cent.

A further challenge was to get workers onto the intake structure in the centre of the weir. After various designs, analyses and discussions about temporary suspension and cantilever bridges, including with specialist scaffolders in Germany, it was decided that a 200 t crane and a workbox was the only solution for the first month, until a more stable connection was made between the riverbank and the structure.

Phase B reached completion in December 2024, days before the river rose again. "It got to within about 50 mm of overtopping the Phase B works," Thomas-Kinsella said. "The cofferdam was completely under water by then."

ABOVE: Pouring mass concrete required innovation.

PROJECT STATS

VALUE TO LOCAL ECONOMY

$22 MILLION

(EXPECTED TO RISE TO $42 MILLION)

EMPLOYMENT

>500

WORKERS

LOCAL SPEND

>80%

Collaboration key

An impressive outcome of the project, Thomas-Kinsella said, was the transfer of skills and knowledge.

"We had a senior technical director in Brisbane who was a great mentor and support. That meant I could lead, and there was also skills transfer to two more junior engineers. Now, we have more people in the industry who have built both a dam and a weir. That has been a real highlight."

None of it would have been possible without deep collaboration between CleanCo, GHD, QR and the local Cairns contractor.

"The risks were quite high, and the consequence of any failure potentially catastrophic," Archer said. "But the engineering went very well, community sentiment has remained really positive throughout after a lot of communication, and the holistic, collaborative approach to this project made it a success." □

Rise of the robots

WORDS BY CHLOE HAVA

A world-first Australian trial evaluates whether robotic solar panel installation can keep pace with rising panel sizes and tight construction timelines.

When Bouygues Construction Australia took on the development of the 500,000-panel 250 MW Goorambat Solar Farm in Victoria, it was keen to test whether robotic installation could support or accelerate large-scale solar delivery. As solar farms continue to scale to meet national energy targets, current manual installation methods are proving too slow and labour-intensive to keep pace.

And the industry's increasing shift to larger, heavier modules, designed to boost generation, is making manual installation even less sustainable. Meanwhile, much of the installation workforce is made up of backpackers, with difficulty securing enough people for remote sites who can stick out a six-month contract.

ABOVE: Luminous robots at work at Goorambat Solar Farm in Victoria.

Along with Bouygues, the Goorambat project attracted interest from European firm Equans, which had just finished building the Coleambally Solar Farm and was interested in understanding whether robotic technology could boost installation speed, improve safety outcomes and operate effectively.

The project required a robot that could integrate into existing workflows, adjust to site

conditions, collaborate with crews and learn onsite.

As one of only three robotics companies worldwide automating processes on solar farms, Luminous Robotics Australia was contracted to deliver a 5000-panel one-block pilot, a self-contained section that could be directly compared with traditional manual installation.

Perfect fit

Luminous Robotics, a US-based company founded just two years ago by entrepreneur and robotics engineer Jay M Wong, was built on a philosophy that diverges from other robotics startups, said Tenzin Crouch, General Manager Australia.

"Unlike many robotics engineers, Jay's thought process was 'I want to actually go and find a problem to solve,'" Crouch said.

Wong's search for a real-world problem led him to volunteer on a solar farm. "He found the biggest challenge was the mechanical installation, particularly the manual labour of putting the panels in place by hand."

This led to the development of Luminous Robotics and the fourth-generation, fully electric LUMI Series 4. Luminous Robotics Australia then launched in 2025 with support from Australian Renewable Energy Agency funding, and has now built, tested and deployed five robots across three different sites in six months.

Unlike some systems that require farms to be redesigned around the technology, Luminous aims for full compatibility: automating the most valuable tasks first, then redesigning systems for further automation.

"We specifically designed LUMI robots to fit into the exact workflow that all the construction companies use already."

The LUMI robot automates the "pick and place" task, removing the most laborious and injury-prone aspect of solar construction while leaving fine-fastening tasks to human workers.

"A human will unbox the modules, then the robot will use computer vision to detect the position of that module," Crouch said. "It will use its arm to come down, pick up that module, lift it up, detect where on the rail to place it, move the arm out and place it down, and repeat that process over and over."

Manual installation typically requires a six-person crew. But with LUMI, only two people are needed, one to fasten and one to torque the bolts.

"A team of six is expected to install between 600 and 700 modules per shift. While the robot might only install 450 modules per shift, the number of people used on the job is less than half."

The key metric the team was tracking was modules per person per hour.

"Towards the end of the deployment we reached around a 3.3-times efficiency improvement," Crouch said. "The robot consistently installed 75 modules per hour with a crew of just two."

Computer vision

With robotic installation, delays typically occur in small, incremental ways – for example, if unboxing takes longer than expected or when the robot needs to reattempt a placement. And the robot's computer vision occasionally misdetects modules and rails, requiring retries and adding to the overall placement time.

"But we expect that over time, as the technology matures, we'll get it up to nameplate capacity of 130 modules per hour."

Solar farms are often built in challenging environments. With >

"We expect that over time, as the technology matures, we'll get it up to nameplate capacity of 130 modules per hour."

ABOVE: Tenzin Crouch, Luminous.

rolling terrains, changes in lighting and dust that can interfere with sensors. These environmental variables can't be simulated perfectly in a lab.

"I can get a software release from my team in the US, put it on my robot, take it out to the farm – and something doesn't work. Why? Because they tested indoors, or they didn't have sloped terrain when they tested it," Crouch said.

"We had some data from our initial projects in the US and used that to built out our initial algorithms for the different components of the robotic installation process: detecting the module and rail, and how to make the movement between the two."

Critical insights

A critical element of the Goorambat deployment was gaining insights to improve efficiencies, including simple but high-impact learnings such as module staging.

"We decided that to lay out all the modules in the arrangement we theoretically planned was the best approach. But when we got onsite, we found it actually wasn't the most optimal."

The crew had to rearrange all the staged pallets of panels, adding a two-day delay to a month-long project. That experience informed planning for Luminous's next deployment, where smaller test layouts will precede full staging. "We've fed that learning into the next one," Crouch said.

During the Goorambat deployment, the US engineering team issued 27 software upgrades in just one month, each addressing real-world edge cases discovered onsite.

"The idea is that you don't need an engineering degree to operate them. We need to build the technology in a way that anyone can operate it."

"We had this continual improvement cycle on a day-to-day basis. We collect the data from the site and push that back into improvements in the software itself."

Safety measures

At present, Luminous Robotics operates on a rental model, supplying a robot and a technician to each project. These technicians – typically mechatronics engineers or mechatronics-trained technicians – undergo internal certification before deployment.

For onsite workers, a Safe Work Method Statement was needed.

"For example, if there are two rows of trackers, the robot would be in the middle, picking and placing with the human on the other side of the tracker," Crouch said. "So even if something did go wrong, there's no way they're going to get hit by the robot."

ABOVE: The fully electric LUMI Series 4.

BY THE NUMBERS

PRODUCTIVITY GAINS FROM A ROBOTIC INSTALLATION WORKFORCE

MANUAL CREW: 6 INSTALLERS vs ROBOT-ASSISTED CREW: 2 INSTALLERS

MANUAL OUTPUT: UP TO 65 PANELS PER HOUR vs ROBOT OUTPUT: UP TO 75 PANELS PER HOUR

ROBOT NAMEPLATE CAPACITY: 130 PANELS PER HOUR

EFFICIENCY GAIN: 3.3x MORE MODULES PER PERSON PER HOUR

A short familiarisation period was built into the schedule, with about two days allocated for the team to get up to speed.

"The familiarisation was focused on how to work with the robot safely. It's not a brand-new task for them; it's more about working with the robot's movement instead of the crew that would be lifting the module."

Given Luminous is still working with the first 10 units of its initial production model, there are likely further technical upgrades that will be made to the robots.

"But as we scale the company and as the technology matures, the goal is to train people to be operators, either onsite or fully remote," Crouch said. "The idea is that you don't need an engineering degree to operate them. We need to build the technology in a way that anyone can operate it, and it's intuitive and easy to understand."

Part of this work includes building a dedicated training program, which is expected to be developed within the next 12-18 months. But the process is already in the works.

"We have already hired one of the people we were working with onsite at Goorambat. While we'll upskill him in some technical areas, he brings valuable skills across production."

Full integration

While initial per-watt costs of robotic installation are on par with manual labour, the long-term vision extends far beyond a single robot performing a single task.

"We can see a very clear pathway to achieving our mission: a 10-times expansion of solar globally," Crouch said.

Key to that outlook is automated module movement. Currently, skid steers deliver pallets to site, but Luminous plans to automate those logistics so robots can coordinate with each other.

"We are now on another site deploying 10,000 solar panels and we have five robots here in Australia that we are already operating."

Another frontier is fastener redesign. The current clips, bolts and torque requirements aren't built for robotic dexterity. So Luminous is collaborating with module and racking manufacturers to redesign fastening systems with automation in mind.

"Is there a push-pin approach?" Crouch said. "Is there a completely different system, even riveting instead of nuts and bolts? I estimate it will be a couple of years before that's more widespread, but it's something a lot of people are looking at." □

BELOW: With LUMI's help, only two people are needed to install a solar panel.

WORDS BY LARISSA FOSTER

Refilling the basin

Repurposed gas infrastructure, dense-phase carbon dioxide transport and a purpose-built compression facility have turned Moomba into a global-scale hub for carbon capture and storage.

When Santos's Moomba carbon capture and storage (CCS) project began its first injections of carbon dioxide into depleted gas reservoirs in South Australia's Cooper Basin in September 2024, it signalled an important shift in Australia's engineering landscape.

What had been one of the country's longest-running gas processing centres became one of its most significant pieces of decarbonisation infrastructure.

For commissioning engineer April Travis, who helped bring the facility in the state's north-east online, the transformation marks a significant development in the pursuit of net zero.

"The startup went really well," she told *create*. "We went straight to full rates, or at least until we ran out of carbon dioxide from the actual plant, which was amazing."

The early results are remarkable not only for the engineering achievement, but for the regulatory milestone. Early in November 2025, Santos received 614,133 Australian Carbon Credit Units (ACCUs) for the first six months of Moomba CCS operations, which is the largest single issuance ever made by the Clean Energy Regulator. Each ACCU represents one tonne of carbon dioxide equivalent that would otherwise have entered the atmosphere.

The numbers behind the project illuminate the scale. By mid-2025, Moomba CCS had stored one million tonnes of carbon dioxide equivalent, a climate impact equivalent to removing all electricity-related emissions from every household in Adelaide for a full year.

Clever repurposing

As Australia's first large-scale onshore hub for the capture and geological storage of carbon dioxide, Moomba can store more emissions every four days than 10,000 electric vehicles avoid in an entire year. Its first-year total of 1.3 million t (achieved despite historic flooding of the Cooper Basin that temporarily disrupted operations) is comparable to taking approximately 530,000 petrol-fuelled cars off South Australian roads.

For engineers, the core of Moomba's achievement lies in its clever use of existing infrastructure and well-established process technologies. Travis explained that the site has been separating carbon dioxide from natural gas for decades through the Benfield process.

"One of the really cool things about CCS is that it doesn't use a lot of brand-new technology," she said. "It's using what we already use in processing facilities, but with a different fluid in the pipes."

What's new is the purpose-built compression and dehydration facility that receives this separated carbon dioxide and prepares it for geologic storage. The system's design leans on fundamentals while pushing them towards new performance boundaries. The carbon dioxide is passed through multi-stage compression, with precise temperature management due to the sharp thermal swings gas undergoes during pressure changes.

"Carbon dioxide gets really hot and really cold when you change pressure. A lot of the process is managing that."

ABOVE: April Travis, Santos.

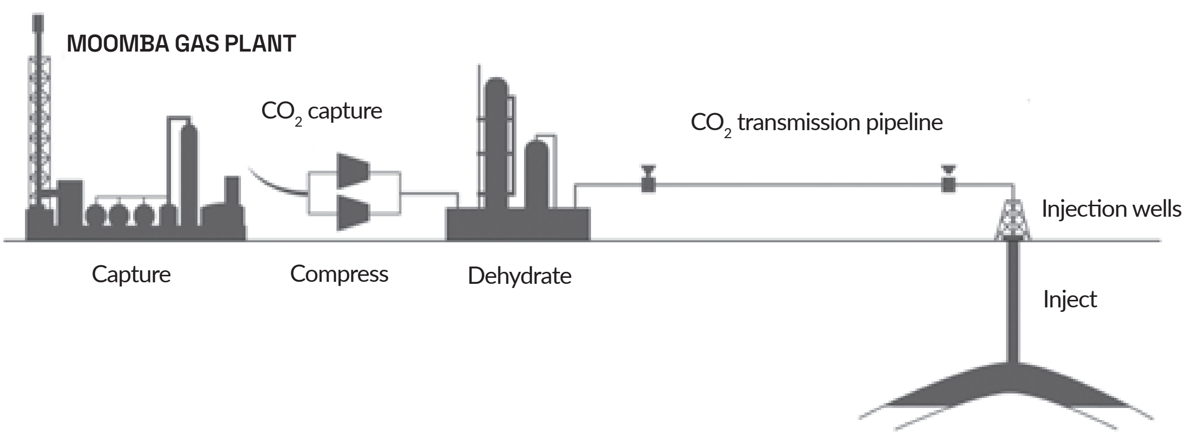
After compression, the gas is dehydrated to avoid carbonic acid corrosion in pipelines. From there, it is transported in dense phase, allowing high mass transfer efficiency and stable behaviour under pressure fluctuations. "Dense phase behaves like a gas, but is dense like a liquid."

The dehydrated carbon dioxide then travels along a dedicated 50 km pipeline, mostly underground, to former hydrocarbon reservoirs in the Cooper Basin. These reservoirs, which held natural gas securely for millions of years, are now being repurposed as long-term storage formations.

"We know our reservoirs really well," Travis said. "We've been operating in the basin for decades. We have monitoring wells outside our injection wells so we can see where the carbon dioxide is going and make sure it's not leaking." >

"One of the really cool things about CCS is that it doesn't use a lot of brand-new technology. It's using what we already use in processing facilities, but with a different fluid in the pipes."

Moomba's carbon capture and storage process



ABOVE: The site of Santos's CCS facility.

LEFT: Santos has been operating in the Cooper Basin for decades.

For engineers, this subsurface aspect is often the most technically complex. “Selecting the right reservoir and proving it's suitable for long-term storage takes real technical expertise.”

The facility uses a 30 MW compressor, and the emissions associated with its operation are included when calculating the net carbon dioxide stored. The compressor is also part of a broader innovation: its gas turbine exhaust heat is recovered to generate high-pressure steam, which is then reintegrated into the existing Moomba gas plant for use in heating and power generation.

“Having the CCS facility so close to the gas plant means we can generate steam from waste heat and give it straight back to Moomba. It makes the whole site more efficient.”

“Having the CCS facility so close to the gas plant means we can generate steam from waste heat and give it straight back to Moomba. It makes the whole site more efficient.”

This interplay between old and new infrastructure is a defining feature of the project. Repurposing decades-old separation systems, leveraging existing basin knowledge and adding new compression and storage capacity has reduced both Moomba's and Santos's overall emissions intensity. "It's a significant drop," Travis said.

Moomba CCS will also help Santos meet its obligations under the Safeguard Mechanism. Projects such as Moomba are expected to supply surplus ACCUs that the company can use to offset high-emitting operations elsewhere as it transitions its portfolio.

Capability uplift

Looking ahead, the scale potential is enormous. Moomba CCS and its potential future phases have a future storage capacity estimated at around 20 million t of carbon dioxide per year. This figure puts it among the world's most substantial CCS hubs.

Since 2024, operational CCS facilities worldwide have increased from 50 to 77 and the total number of facilities in the development pipeline has increased from 628 to 734, according to the 2025 report of the Global CCS Institute.

Santos is now evaluating additional project stages and the possibility of accepting carbon dioxide from third parties in Australia and Asia. The transport mode, whether via pipeline, shipping or by truck, will depend on the location of future hubs.

"It will be different for different areas," Travis said. "It depends where the hub is and where the carbon dioxide is coming from."

This evolution turns CCS from a waste-management strategy into a business strategy. "CCS becomes another strand of the company. It becomes a commercial opportunity."

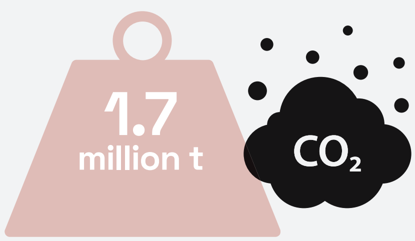
The Western Australia CCS hub, meanwhile, is in early-stage front-end engineering design, in parallel with ongoing customer negotiations for carbon management services.

For Travis, one of the project's biggest successes is the capability uplift across Santos's engineering teams. "We used a lot of our people in-house. We gained a lot of experience in how to operate and troubleshoot a CCS facility. And we've learned a lot about the potential and what doors this opens in carbon markets, too."

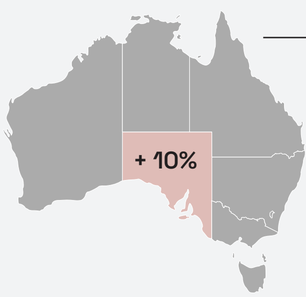
As Australia works towards a net-zero future, Moomba CCS stands out as an example of what's possible, demonstrating how engineering innovation is often less about invention and more about intelligent integration, bringing together proven technologies, trusted infrastructure and deep domain knowledge to craft something new.

"Carbon capture is definitely viable. A lot of the pathways to net zero need CCS. There are technologies where we just can't use renewables. CCS lets us manage the energy transition responsibly." □

By the numbers



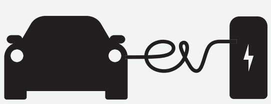
Moomba CCS phase 1 has the capacity to store **1.7 million t of carbon dioxide a year**



That's more than **10% of South Australia's total emissions**

x 700,000

And the equivalent of taking **700,000 petrol cars off the road a year**



x 10,000

Moomba CCS is **avoiding more emissions in four days than 10,000 electric cars in one year**

Experience

DISASTER

Under pressure

The accidental decompression of diving chambers on a Norwegian oil rig in 1983 caused the sudden deaths of five people and forever altered diving operations.

Words by Lachlan Haycock

The *Byford Dolphin* was a semi-submersible oil rig located in the Frigg gas field in the North Sea, approximately 200 km off the coast of Norway.

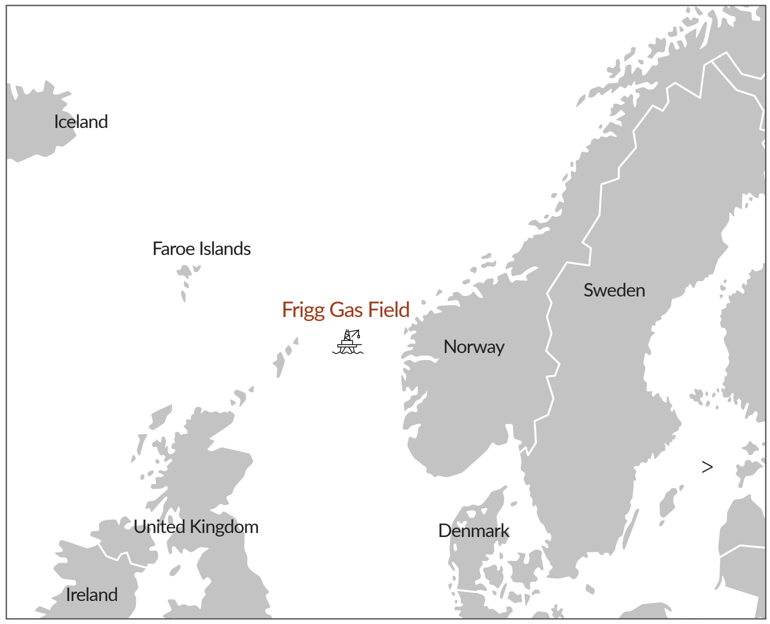
By 4am on 5 November 1983, two workers, Edwin Arthur Coward and Roy P. Lucas, had returned from a dive and entered a system of decompression chambers on the rig's deck. These chambers served as living quarters during saturation diving operations, where workers would live and sleep in heavily pressurised environments between shifts.

Another pair of divers, Bjørn Giæver Bergersen and Truls Hellevik, rested in one of the chambers at a pressure of 9 atmosphere (atm). The chambers were connected to the diving bell by a short passage known as the trunk. Two dive tenders, William Crammond and Martin Saunders, sealed the connection from outside with a clamp (Figure 1).

The usual procedure for decompression, as outlined by a medical investigation into

LEFT: The *Byford Dolphin* in 2008.

RIGHT: Location of the 1983 incident.



the accident published in *The American Journal of Forensic Medicine and Pathology*, would be to:

1. Close the diving bell door
2. Slightly increase the bell pressure to seal the door
3. Close the door between the trunk and chamber 1
4. Depressurise the trunk to 1 atm
5. Open the clamp to separate the bell from the chamber system

The first two steps had been completed when the clamp sealing the tunnel off from the diving bell was released, causing the highly pressurised chamber system to drop from 9 atm to 1 atm instantaneously.

Coward, Lucas and Bergersen died instantly during a rapid decompression. The autopsy identified the effects on their bodies.

"The most conspicuous finding was large amounts of fat in the large arteries and veins and in the cardiac chambers, as well as intravascular fat in the organs, especially the liver," the autopsy report said. "The blood must have begun to boil

Figure 1: Diver locations at the time of the disaster

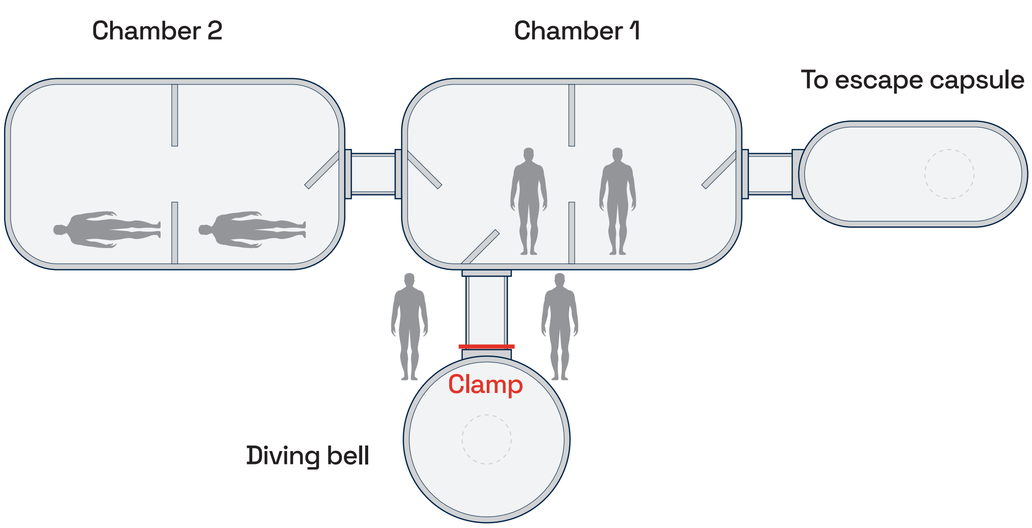
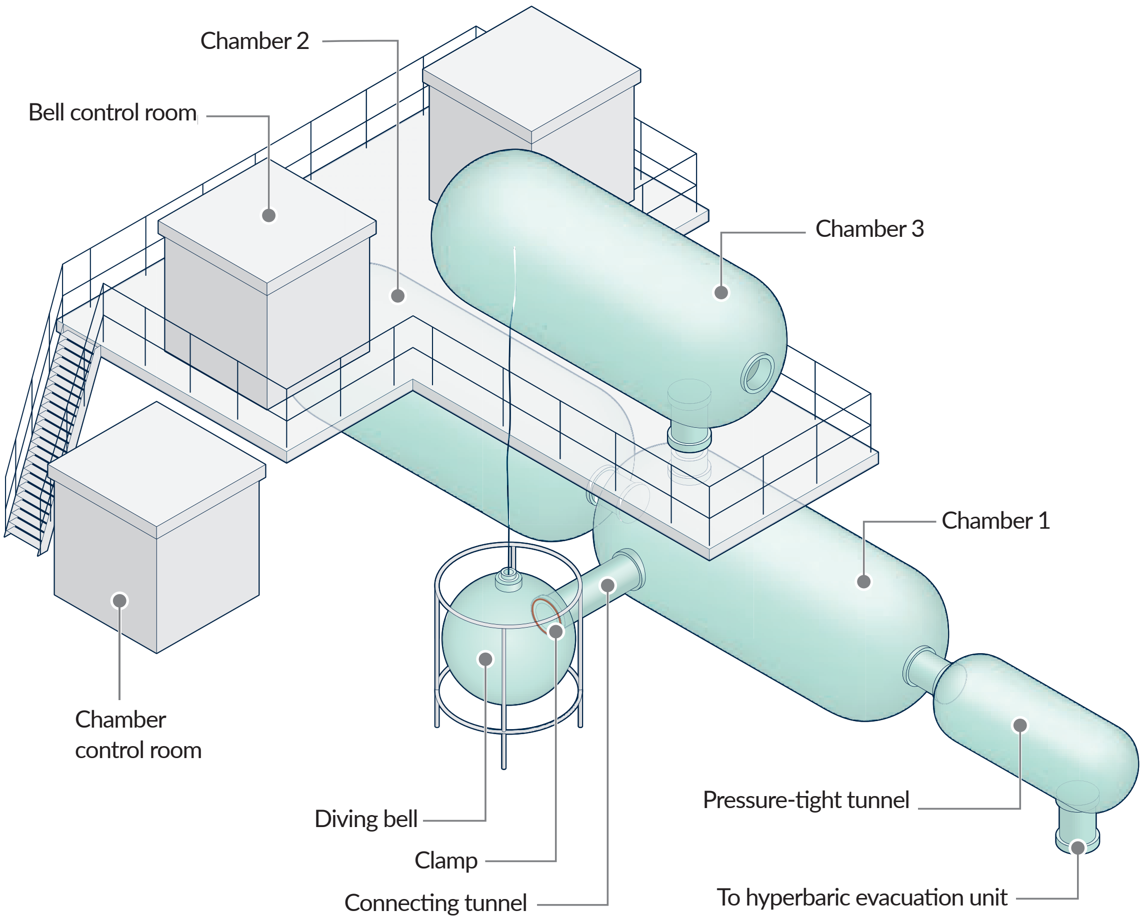


Figure 2: Isometric view of the decompression chambers



instantaneously, leading to an instantaneous and complete stop of the circulation ... It is suggested that the boiling of the blood denatured the lipoprotein complexes, rendering the lipids insoluble."

Hellevik, who was standing by the door to the chamber, faced the most serious consequences. As he was exposed to the highest pressure, his body was pushed through the partly opened door, which was 60 cm in diameter, resulting in the bisection of his thoracoabdominal cavity. The door was jammed so tightly it was later opened with an acetylene burner.

Outside the chambers, the diving bell swung wildly, fatally colliding with Crammond and severely injuring Saunders.

Out of date

Modern safety interlocks are designed to prevent disasters such as this, but outdated equipment on the *Byford Dolphin* precluded this possibility.

The direct cause of the explosive decompression was the coupling lock connecting the diving bell to the chamber system being opened prematurely, while the system was still pressurised and with all internal doors open.

The *Byford Dolphin* diving system was based on rules outlined in 1975, which did not outline any specific arrangements for the locking arrangement. This had since been superseded by updates made in 1982. Among other things, these new requirements mandated that the coupling mechanisms between bell and chamber should be constructed so that they can't be opened while the connection tunnel is under pressure. Critically, such a modification had not yet been implemented on the *Byford Dolphin*'s system.

Further, a Norwegian Official Report into the incident

DIAGRAM: Adapted from Norwegian Official Report.

BY THE NUMBERS:
BYFORD DOLPHIN

BUILT
1974

DESIGN
Aker H3

MAXIMUM DRILLING DEPTH
6096 m

TRANSIT SPEED
~4.5 kn

VARIABLE DECK LOAD
3021 MT

CRANAGE
2 X

49 MT
CAPACITY

identified an operational error involving premature unlocking. Specifically, the coupling lock was unscrewed and opened before pressure in the connecting tunnel was released and before the chamber door was closed.

The detailed procedural steps for transferring divers, which were not correctly followed during this critical phase, emphasise the high risks inherent to such operations, according to the report. It attributes the direct cause to human error relating to the dive leader's and lock operators' failure to maintain proper sequence and safety checks. However, the report concludes that, due to the deaths of key personnel involved in the locking phase, the exact sequence is difficult to reconstruct completely.

New controls

The *Byford Dolphin* incident transformed how diving safety is approached, particularly in the context of saturation diving.

The Norwegian Official Report outlined measures designed to prevent similar accidents from occurring. These emphasised the need for improved technical safety features and procedural controls in diving systems, especially saturation diving setups. The recommendations included:

- The installation of fail-safe interlocking mechanisms on connections such as the diving bell and chambers so they can't be opened when the system is under pressure
- Upgrading equipment to include outboard pressure gauges for continuous, visible pressure monitoring
- Improvements in communication systems to provide clear and reliable contact between divers, supervisors and surface control
- Developing and enforcing strict operational procedures and training to minimise human error during critical operations like transfer under pressure
- Rebuilding diving systems to meet the latest safety regulations, even if older systems are not initially subject to retrospective orders
- Mandatory inspections and certifications by relevant authorities to ensure compliance with updated safety standards
- Specific attention to the control of "transfer under pressure" operations, including mandatory closing of all internal doors during transfers or installation of automatic door-closing devices in the event of pressure loss

The Norwegian Government paid undisclosed compensation to the families of the six divers involved in the incident in 2009. The *Byford Dolphin* rig continued to be in service until 2016. ◻

RISKY BUSINESS

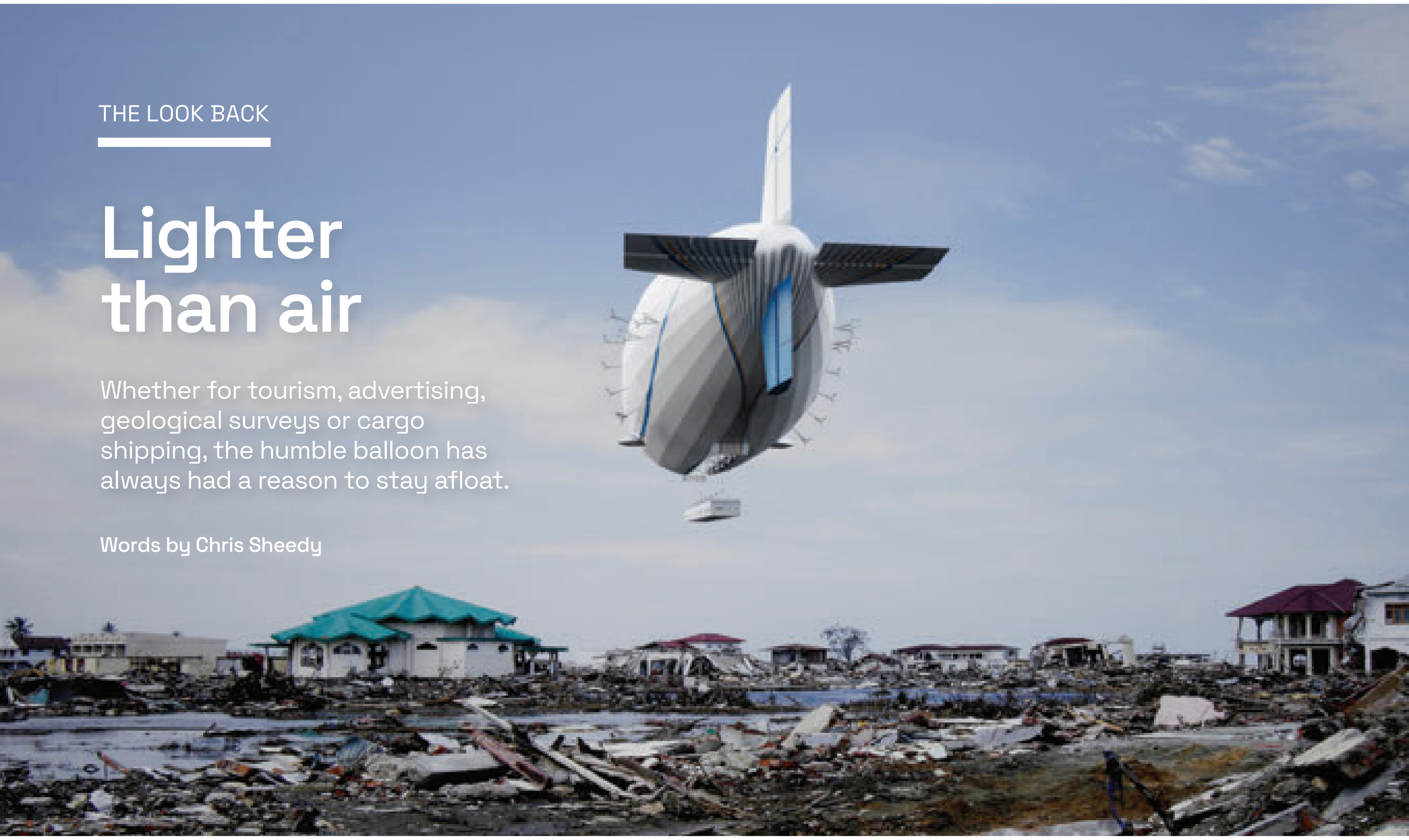
The *Byford Dolphin* disaster was not the first time death had greeted North Sea divers, who often worked in extremely high-risk environments. It was also not the last.

British diver Bradley Westell died in 1995 when his lifeline was caught in the propellers of the *Stena Orelia*, a diving support vessel operating off the Norfolk coast.

The incident led to the imprisonment of the diving supervisor for perverting the course of justice during the investigation, a first for the offshore oil industry in the North Sea.

Sources

Giertsen et al., "An Explosive Decompression Accident", *The American Journal of Forensic Medicine and Pathology*, 1988;
The Byford Dolphin Diving Accident, *Norwegian Official Report*, 1984



THE LOOK BACK

Lighter than air

Whether for tourism, advertising, geological surveys or cargo shipping, the humble balloon has always had a reason to stay afloat.

Words by Chris Sheedy

Airships, hot air balloons, zeppelins, dirigibles, aerostats, thermal airships. Call them what you will, they've managed to survive seemingly against the odds.

Various experiences from throughout history – including the 1897 North Pole expedition resulting in the deaths of three Swedish adventurers, the 1937 Hindenburg disaster and the 2011 Goodyear blimp crash in Germany that took the life of its Australian pilot – might have seen them relegated.

Instead, the aerospace sector is experiencing a resurgence in lighter-than-air (LTA) technology, considered more sustainable in terms of fuel use, noise pollution and ground infrastructure requirements.

According to U-LTA, a European body initiated to upscale LTA technology, it is being considered for:

- Long-haul cargo
- Telecommunication in remote or disaster-affected areas
- Infrastructure inspection, including powerlines and pipelines
- Surveillance
- Emergency aid
- Passenger transport

Old and new

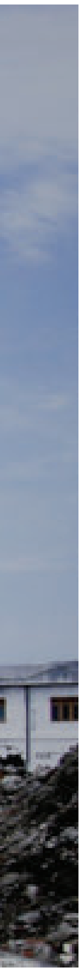
Empyreal Galaxy, a Mumbai-based airship manufacturer, is combining age-old engineering with new materials and technologies.

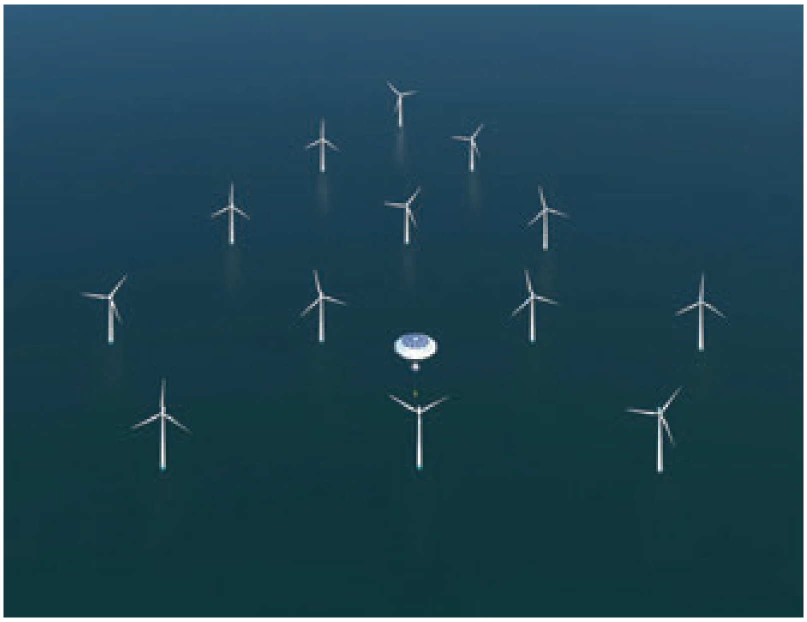
The lightweight envelope of its planned airship utilises a combination of aluminium and carbon fibre, with each airship claiming a working life of 40 years. Its first generation, with a payload capacity of 15-20 t, will be powered by standard aero engines. Later models are planned to have power supplied by solar photovoltaic units and batteries.

LTA Research is combining titanium, Kevlar and carbon fibre reinforced polymers in its hulls,

ABOVE: Flying Whales's vision for disaster aid. **BELOW:** The infamous Hindenburg airship disaster.

IMAGES: Flying Whales; Wikimedia Commons; SkyLifter.





LEFT, CLOCKWISE FROM TOP: SkyLifter is developing "flying cranes" to service remote destinations such as offshore wind farms; close-ups of the SkyLifter and Flying Whales designs.

with 12 electric motors lining the sides and tail, each of which can rotate 180 degrees. This will offer excellent low-speed and high-wind manoeuvrability. LiDAR sensors will continuously calculate the volume of helium in the gas cells.

Flying Whales, a French airship producer, is developing a vehicle known as the LAC60T that utilises 180,000 cubic metres of helium to lift 60 t payloads into remote areas. The hull, 200 m long and 50 m in diameter, will boast a 96 m long, eight-metre high and seven-metre wide cargo hold. The LAC60T is expected to have a maximum speed of 100 kph and a flight ceiling of 3000 m.

Flying Whales is currently working with the Ivory Coast's Ministry of Transport to decarbonise freight transport with a fleet of 160 airships connecting 22 countries.

Another model, pioneered by organisations such as AT2 Aerospace with technology developed at Lockheed Martin, combines aerostatic lift with aerodynamic lift from the hull, meaning both vertical and running take-off are possible.

AT2's Z1 hybrid airship claims a payload of 21 t and an ability to carry 19 passengers, with a range of 1400 nautical miles. It should have the ability to land on fields, water, snow or sand, with an air-cushioned landing system borrowing from hovercraft technology.

Load exchange

When a technical problem arose in the Goodyear blimp he was piloting in Germany in 2011, Australian pilot Michael Nerandzic took the airship to two metres from the ground and told the three passengers to jump for their lives. The change in weight caused the airship to rise suddenly. A fire then quickly consumed the airship and Nerandzic died in the crash.

It was a tragic demonstration of one of the greatest technical risks of airship operation – the load-exchange challenge. How can designers get around this?

In the case of the LCA60T, as the airship begins lifting cargo, the plan is to simultaneously pump water up into the baffled (to prevent sloshing) ballast tanks. When cargo is delivered, the tanks are emptied. Hybrid airships, on the other hand, rely more on their heavy on-ground nature. When the payload is dropped, the airship will typically be settled.

Australia's involvement

In the Australian outback, billions must be spent on roads and railways to transport resources. These vast distances could instead be served by cargo airships, reducing carbon footprints of mining operations.

It's not surprising, then, that some projects are considering the Australian outback for their development. One is Skylifter, a mega-lifting drone also being touted as a flying crane.

The Skylifter concept is a saucer-shaped gas balloon system with a top covered in solar panels, a biodiesel propulsion system, a flight deck suspended below the hull, and lifting infrastructure below that, planned to be capable of lifting 150 t. Range is estimated at 2000 km and air speed 83 kph.

Not yet discussed is how local authorities will cope with the massive influx of UFO sightings. □

Events

MARCH to OCTOBER 2026

MARCH

12-25
MAR 2026
Elevation 2026 Careers Expo

Location: *Various locations*
Website: *engineersaustralia.org.au/elevation*
Are you a final-year student or recent graduate? Secure your ticket to explore real opportunities and make career-shaping connections with leading employers.
Register now

APRIL

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

Location: *Sydney*
Website: *clems.eventsair.com/sete26/*
Join SETE 2026 to explore how AI and data engineering are reshaping systems engineering. Four days of insights, collaboration and networking opportunities.
Register now

JUNE

16-18
JUN 2026
Australasian Congress on Applied Mechanics (ACAM)

Location: *Melbourne*
Website: *engineersaustralia.org.au/acam*
Whether you're driving innovation in industry or exploring new frontiers in postgraduate studies, ACAM 2026 is your gateway to the future of applied mechanics.
Early-bird registration closes 16 March

AUGUST

17-19
AUG 2026
Conference on Railway Excellence (CORE)

Location: *Adelaide*
Website: *rtsa.com.au*
This is where the future of railway policy, operations and engineering takes shape. Join dynamic discussions, technical tours and networking opportunities.
Early-bird registration closes 14 June

SEPTEMBER

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

Location: *Sydney*
Website: *icas2026.com*
This premier forum highlights the latest research, emerging technologies and next-generation aviation. Help shape the future of aerospace by submitting an abstract.
Early-bird registration closes 8 June

OCTOBER

28-29
OCT 2026
Australasian Structural Engineering Conference (ASEC)

Location: *Melbourne*
Website: *engineersaustralia.org.au/asec*
Abstracts are invited for this year's theme: smart sustainable structures, focusing on the innovations and challenges redefining the engineering profession.
Abstracts close 2 March

4 Mar 2026
World Engineering Day

Location: *Virtual*
Website: *engineersaustralia.org.au/wed*
Join us for a free webinar exploring smart systems engineering, sustainable networks and the vital role of engineering in shaping a sustainable future.
Register now

5-8 Mar 2026
FORMULA 1 QATAR AIRWAYS AUSTRALIAN GRAND PRIX 2026

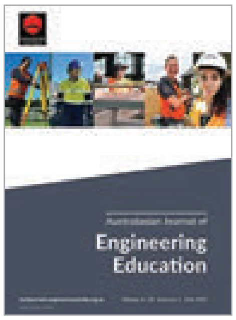
Location: *Melbourne*
Website: *engineersaustralia.org.au/grandprix*
As a proud Local Event Supporter, Engineers Australia will celebrate the crucial role engineers play in inspiring the next generation and shaping the future of motorsport on and off the track.
Stop by the Innovation Hub presented by Engineers Australia

9-10 Jun 2026
Transport Conference

Location: *Cairns*
Website: *engineersaustralia.org.au/transport*
Hop on board Transport 2026. Discover how to build inclusive, equitable and resilient transport systems with expert sessions, bold ideas and a gala dinner in Cairns this winter.
Early-bird registration closes 2 March

Resources

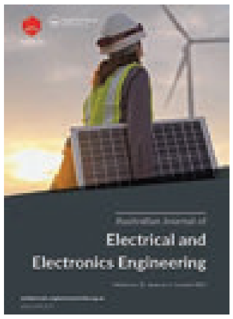
JOURNALS



EDUCATION

Comparing peer-reviewed competence frameworks for engineers: A systematic review and critical discussion of backgrounds, development and content

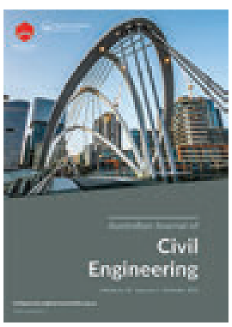
This study proposes core attributes for an ideal framework to guide educational efforts to integrate non-technical competencies into engineering education.
bit.ly/3XZ2Rwt



ELECTRICAL

This paper presents an optimal framework for power dispatch of islanded microgrid considering the extra reserve requirements of renewable distributed generations

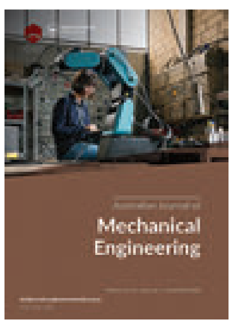
This study aims to compare cup-headed bolts and hex-headed bolts in terms of their practical applications and structural capacity in timber post-to-beam connections through a combination of industry surveys and experimental testing.
bit.ly/3Y5msuV



CIVIL

Lower energy consumption-based approach to utilising spent coffee grounds and biochar in cement mortar and concrete

This paper investigates a lower-energy approach of using spent coffee grounds and biochar derived by acid hydrolysis methods.
bit.ly/3MuI7Ku



MECHANICAL

Multi-objective optimisation for wire EDM cutting: A comprehensive study for machining AL6061 aluminium alloy

This paper investigates the optimal setup for machining aluminium alloy AL6061 materials by using wire electrical-discharge machining.
bit.ly/4ox76dD

RESOURCE RECOMMENDATIONS

Switched on

The Energy is an award-winning publication dedicated to covering the business of energy, focusing on the people, capital, projects and emerging technology involved.
theenergy.co/

Support hub

The Overseas Qualified Engineers Career Support Hub is your go-to for credible, industry-specific guidance, supporting you to take the next step in your Australian engineering career.
bit.ly/3LBtfJU

Data-rrific

Pull up *Our World in Data* and be prepared to stay for a while as you browse interactive data visualisations on topics ranging from energy and environment to technological change.
ourworldindata.org/publication-library

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

THE LESSON LEARNED

Michelle Tan MIEAust CPEng

A recurring fastener failure on multiple trains sent mechanical engineer Michelle Tan into a year-long root-cause investigation. This taught her a lot about commercial realities, stakeholder pressures and the courage to take a pragmatic path.

As told to Joe Ennis

While working for a railway operator, I inherited a problem no-one wanted to own. We were commissioning new trains, and across the entire fleet we saw recurring failures in several fasteners – components that shouldn't have been failing at all.

For three years the failures had been increasing. As the trains were still under warranty, we lodged a defect claim. The manufacturer pushed back, arguing the failures were caused by our track. We believed the evidence pointed to the trains. Initial attempts to fix the problem – changing fastener types, strengths and assembly procedures – did not make a great deal of difference.

So we agreed to conduct a joint root-cause investigation with the manufacturer. In theory, it was the logical engineering approach: understand precisely why something is failing so you can fix it properly. In practice, it became something else.

Each party hired its own consultants to lead the review. It got commercial instead of collaborative, with each set of consultants representing the interests of their employer and neither leaning towards accepting liability.

A year of testing later, while a lot of good work had been done, we still had not determined a definitive root cause both sides could accept. Meanwhile, every failure meant taking trains out of service. This caused a drain on maintenance resources and reduced train availability for operations. Ultimately, we came up with several mitigations collectively to resolve the problem. However, only later did I fully appreciate the turning point we missed. Before all the investigations, the supplier had offered to explore a redesign of the bolted joint which would have removed the need for the problematic fasteners entirely. In hindsight, we probably should have accepted that offer. We might not have found the root cause, but the problem would likely have been resolved faster.

It reinforced a fundamental practical principle: sometimes the most technically satisfying path is not the wisest one. □

KEY LESSONS

01
Know when a problem is intractable and when a pragmatic fix is the better choice.

02
Engineering decisions have commercial contexts and consequences. Understand them early.

03
Early collaboration beats adversarial investigation. Align stakeholders before positions harden.

Michelle Tan MIEAust CPEng is the National Deputy Chair of the Engineers Australia College of Leadership and Management, and National Deputy Chair of the Railway Technical Society of Australasia.


THE UNIVERSITY OF QUEENSLAND AUSTRALIA
UNIVERSITY OF OXFORD
Saïd Business School
Transform project outcomes with our world-first program
Register your interest to join our 2026 cohort.
The pressure to execute large-scale infrastructure projects that deliver on time, budget and value has never been higher.
The 6-month UQ-Oxford Transformative Project Leadership Program is designed to enhance your ability to lead complex projects with clarity and purpose.
Developed and delivered by The University of Queensland's Business School and Saïd Business School, The University of Oxford, you'll learn alongside Australian leaders in Brisbane and Oxford.
Turn ambitious visions into legacy, backed by the expertise of two globally renowned universities.
Discover more
study.uq.edu.au/tplp
CRICOS Provider 00025B • TEQSA PRV12080