VOL. 9 | NO. 6 | JULY 2023

create

ENGINEERING IDEAS INTO REALITY

ENGINEERS AUSTRALIA

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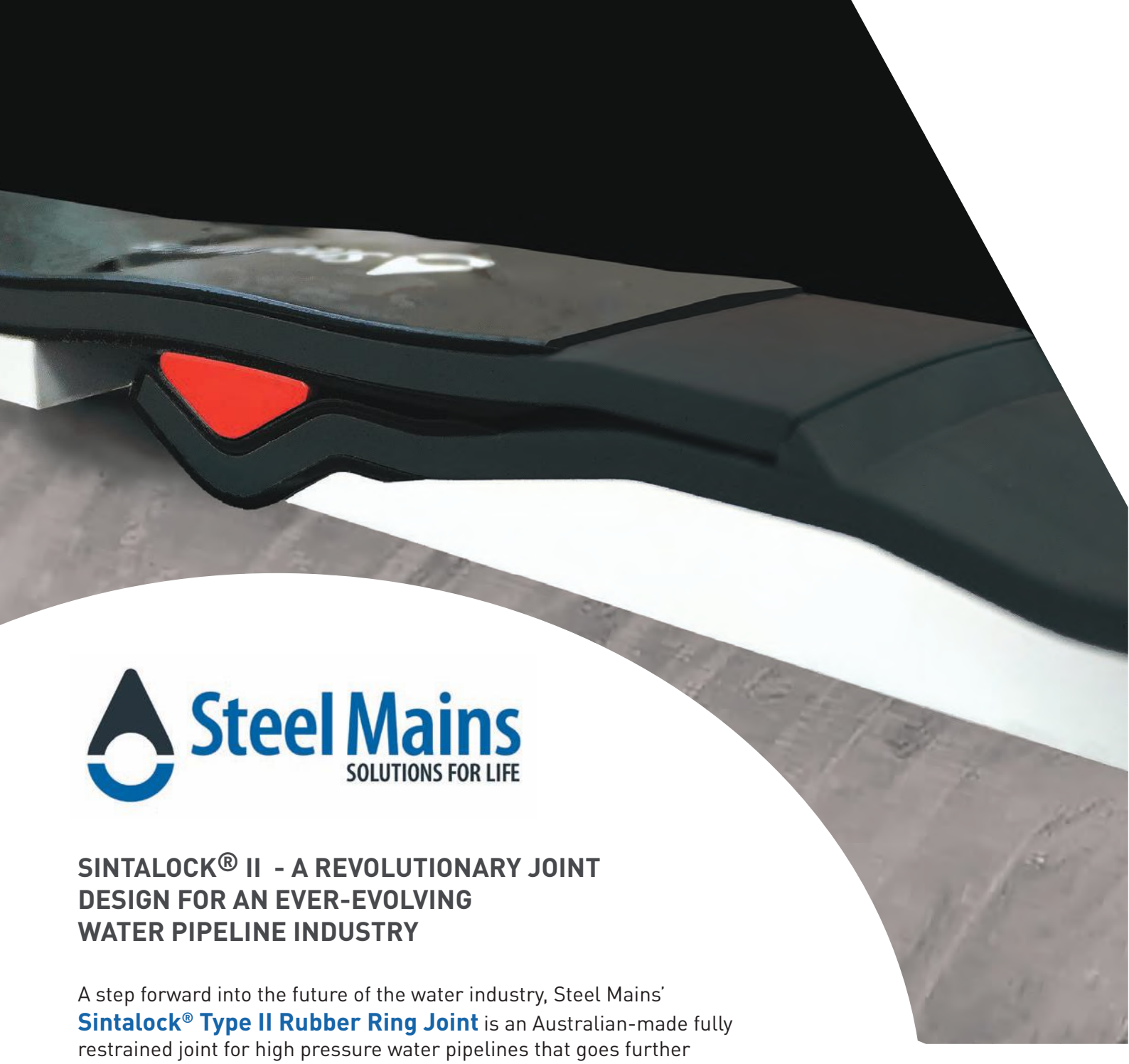

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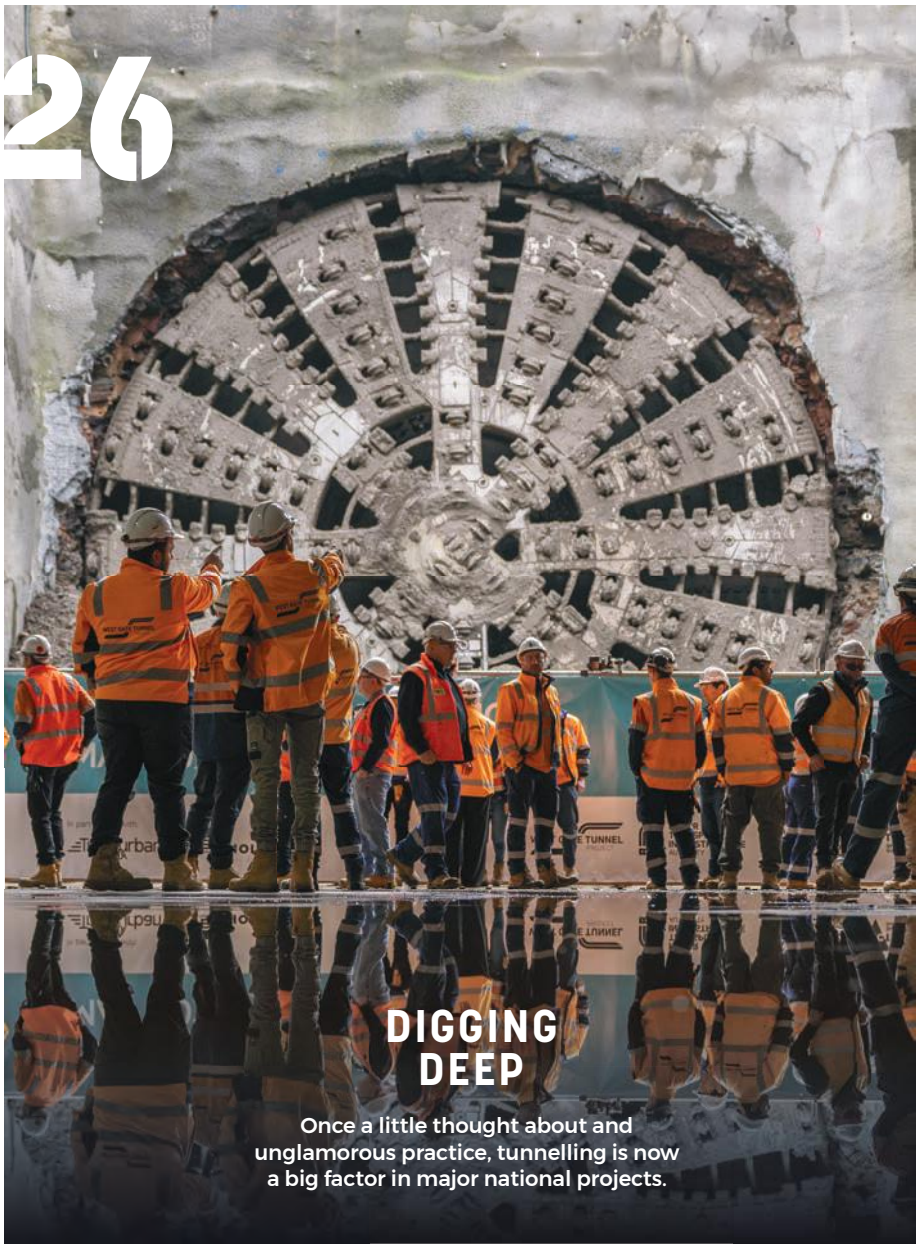

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DIGGING DEEP

Once a little thought about and unglamorous practice, tunnelling is now a big factor in major national projects.

IMAGE: NED MELDRUM

ENGINEERS AUSTRALIA

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Check out the *create* website — your best resource for the latest engineering news and information from Australia and the world.

The boring issue

AUSTRALIA'S TUNNELLING RENAISSANCE IS ONE OF THE MANY FORWARD-THINKING IDEAS CURRENTLY CAPTURING THE IMAGINATION OF ENGINEERS.

Welcome to the July issue of *create*. The calendar year is racing on and the new financial year is off to a great start at Engineers Australia.

This edition's cover feature is boring.

It's a little-known fact that Australia leads the world in tunnelling engineering expertise, mostly thanks to the evolution of safety and innovation driven by the mining and infrastructure sector.

These have direct applications for the extensive infrastructure projects underway in our capital cities that promise to deliver faster travel routes across town by road and rail.

Tunnelling is enjoying a renaissance for its ability to maximise available space in high-density urban environments by taking transport corridors underground.

Geotechnical engineers are vital to this highly specialised sector, and it is up to the profession, along with its allies in industry and academia, to foster a new generation of talent into the field.

Research shows that mentoring and role modelling are among the strongest influences in helping students choose a career in engineering, so share your stories and help shape the future.

Carbon capture technologies are increasingly being recognised as a necessary tool in the arsenal to address climate change. In this issue, we explore how technological advances in direct air capture (DAC) could drive down emissions and put us closer to staying below the two-degree increase the Intergovernmental Panel on Climate Change calls "catastrophic".

While some of the technology is still a work in progress, there are calls to activate DAC programs at scale and pace to capture carbon and help put the brakes on global warming.

Australia has lagged in the conversation around addressing legacy carbon in the atmosphere, which has left us with catching up to do.

Some of the world's largest companies have put their names to initiatives that will underpin an effective carbon market and CSIRO has given the green light to take some local carbon capture projects to proof-of-concept stage. It's an exciting frontier that could shift the balance in the fight against climate change.

Drone technology is used for everything from firefighting to seed spreading — but will it ever bring you a cheeseburger?

While drone delivery systems play a crucial role in transporting medical supplies and aid in remote areas, *create* takes a look at why commercial applications for deliveries in urban environments have proven more complex. Whether for documents or coffee, early forays into drone delivery services have been hit and miss.

But the field continues to make advances that may yet overcome the challenges urban applications present.

Read on to see how Sydney lays claim to the world's best building.

Quay Quarter Tower, the upcycled AMP Centre on Circular Quay, was named the 2022 World Building of the Year at the World Architecture Forum for its innovation in reuse and redesign, delivering a structure that is as efficient as it is striking.

It is clever developments like this one by Arup and its project partners that bring us inspired spaces to live and work in and the kind of forward thinking that puts sustainability at the heart of construction.

Enjoy.

"Tunnelling is enjoying a renaissance for its ability to maximise available space in high-density urban environments by taking transport corridors underground."

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DEBATE AND DISCUSSION BY *CREATE* READERS

Taking the lead on safety

It was alarming to read of the increasing volume of batteries being transported, stored and ultimately disposed of, in the absence of any standard industry practice or legislation covering these activities ("Charged with Safety", *create* June 2023).

It is particularly concerning that the battery type most commonly used, the nickel-manganese-cobalt battery, has a higher risk of thermal runaway than the alternatives.

In his recent book, Professor Alan Finkel warns us of the massive scale of renewable proliferation ahead of us if we are to get anywhere near the targets that are being politically set.

However, like much of the renewables story, wherein the load has been developed before the generation on which it will rely, we are building a mountain of high-density energy storage devices capable of combusting, without any accompanying standards of legislation governing their safe storage and use.

By contrast, the petroleum and chemicals industries have for decades been well regulated through the application of AS1940 (Storage and handling of flammable and combustible liquids) via state and federal government legislation. Licensing of storage facilities typically requires a HAZOP study wherein risk levels are rigorously assessed, including the location of the proposed facility.

Perhaps this is an opportune time for our profession to lead on a matter of public safety.

TERRENCE J MCNAMARA CPENG

"We are building a mountain of high-density energy storage devices, without any accompanying standards of legislation governing their safe storage and use."

Back to the future

The AI that designed the cover for the June issue must surely have evolved in 1950s America, with its depiction of almost empty motorways everywhere, all with hardly any cars on them, no traffic jams, no freight, no public transport and not one person walking anywhere.

If this is what AI is going to bring us, I assume that it will soon be inventing McDonald's, colour television and Barbie dolls and working out how to go to the moon.

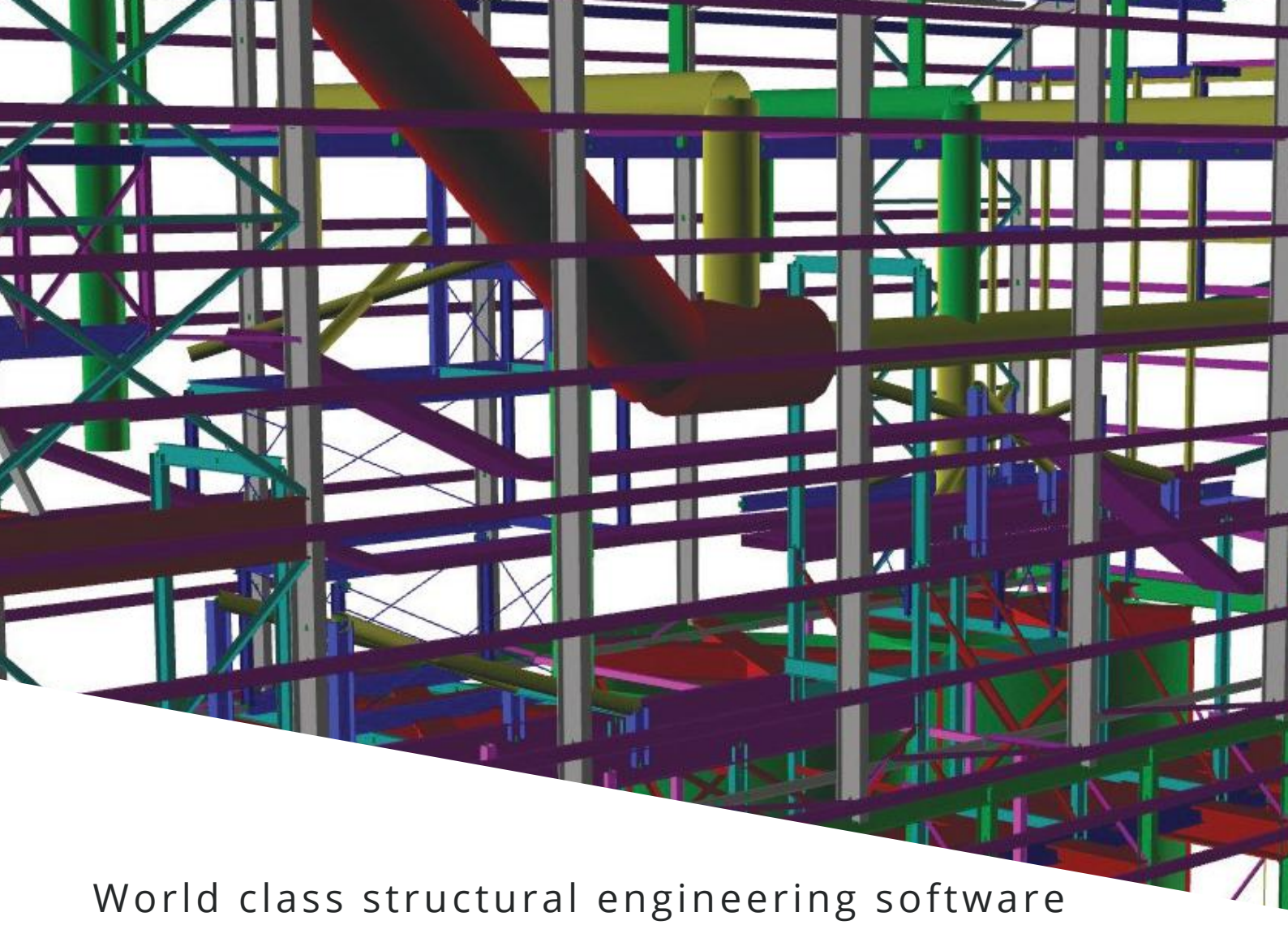
BASIL HANCOCK CPENG (RET)

create

welcomes feedback from the community

Do you know of an exciting project we should write about? Is there an outstanding engineer in your midst? Are you working on an innovative technology that you'd like to share with your fellow members? Are there engineers out there doing their bit to help the community? Do you want to comment on an article you've read in *create*?

Email *letters@engineersaustralia.org.au* and we'll be pleased to consider your suggestions.



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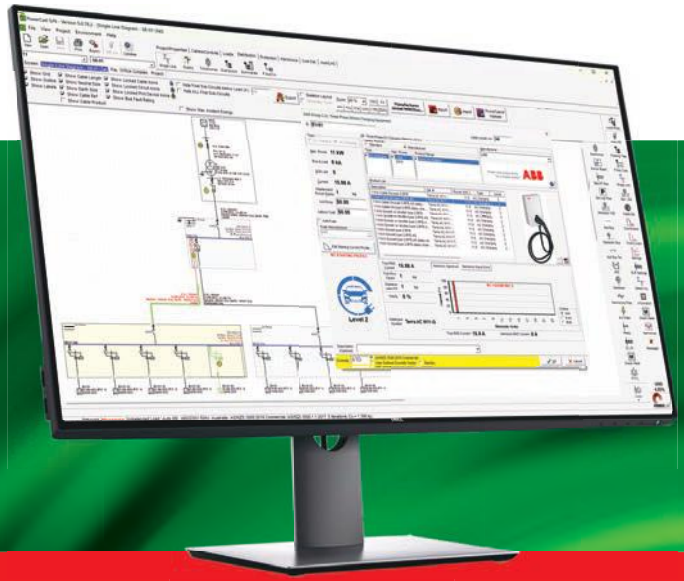

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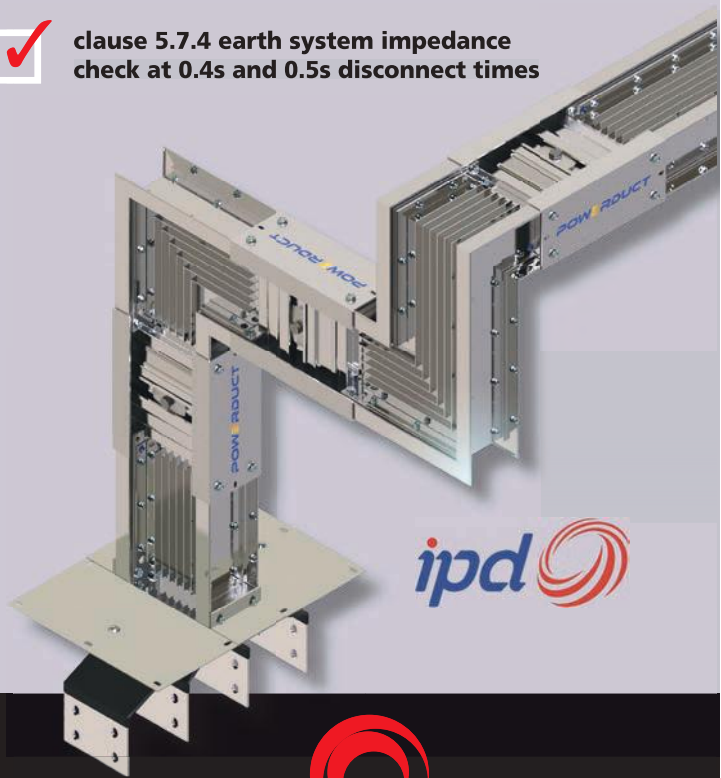
- ✓ **clause 5.3.3.1.1 protective earth conductor thermal stress check**
- ✓ **clause 5.7.4 earth system impedance check at 0.4s and 0.5s disconnect times**



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Service to the profession

ENGINEERS AUSTRALIA CONGRATULATES THE ENGINEERS RECOGNISED IN THE KING'S BIRTHDAY HONOURS.

SHOWING THE breadth of influence of engineering, the 2023 King's Birthday Honours recipients included engineers working in road safety, education, technology, social services and the military.

Engineers Australia National President Dr Nick Fleming said he is proud to see the work of our members acknowledged.

"I congratulate each of our members listed in the 2023 King's Birthday Honours list. Their dedication to improving their local communities and the profession is something all engineers can respect," Fleming said. "We know that great engineering has a positive and lasting impact on society. Australia will continue to benefit from the service of the engineers recognised today for many years to come."

Engineers Australia CEO Romilly Madew AO said the honours shine a light on those who've worked hard to make impactful and positive contributions to society.

"Engineers have a critical role to play in helping the nation and the world take leaps forward to address the challenges we face," she said.

"Whether they are developing technology to help tackle global issues like climate change, mentoring their younger peers or volunteering at their local sporting club, engineers give their time and expertise in meaningful ways.

"Their contributions make a difference and Engineers Australia is pleased to see them receive this recognition that is so justly deserved." ●

Engineers Australia members honoured

MEMBER OF THE ORDER OF AUSTRALIA (AM)

Emeritus Professor Raphael Hilary Grzebieta FIEAust CPEng for significant service to the transport industry through road safety research and promotion.

Dr Peter Rogers for significant service to engineering, education and the community.

Christopher Charles Vonwiller HonFIEAust for significant service to science and technology development.

MEDAL OF THE ORDER OF AUSTRALIA (OAM)

Dr David Smyth FIEAust for service to the community through social welfare organisations.

Lieutenant Commander Anthony Ian McCann CPEng for meritorious service in the field of Navy Aviation Engineering.

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Captain Lachlan William Attard for outstanding achievement in the performance of duty as the Project Engineer and Site Lead for the Cook and Tiroas Barracks infrastructure project in Vanuatu from August 2021 to May 2022.

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Sending a message

MARLENE KANGA HAS AN URGENT MESSAGE FOR THE GLOBAL COMMUNITY: ENGINEERS ARE ABSOLUTELY CRUCIAL FOR ADDRESSING CLIMATE CHANGE AND FOR SUSTAINABLE DEVELOPMENT.

WHEN DR Marlene Kanga travelled to New York to attend the United Nations Science Technology and Innovation Forum in May, her hope was that the world would hear how important engineering is to achieving the UN sustainable development goals (SDGs).

That message matters because the world has committed to achieving the 17 SDGs by 2030 and, right now, the world is not on track to fulfil that commitment.

"We are halfway through the UN's vision of sustainable development for all, and more than half [the goals] have not been progressed. I think 30 per cent have declined," Kanga told *create*.

"We really need to do something different to shift the needle, and I think recognising the role of engineers in developing practical solutions is very important."

The UN agreed to the SDGs in 2015 to provide an integrated approach that eradicates extreme poverty and takes on climate change while improving health and education, reducing inequality and spurring economic growth.

ABOVE: Dr Marlene Kanga attended the United Nations supported by Engineers Australia's Climate Smart Engineering Initiative.

Kanga, who has been President of the World Federation of Engineering Organizations and is a former Engineers Australia National President, participated in four events during the four-day forum, during which she highlighted that the UN's 2023 *Global Sustainable Development Report* contained just one mention of engineering across its hundreds of pages.

"It's ironic in that it appears in the context of the role of engineers in addressing the hole in the ozone layer," Kanga said.

"The hole is shrinking, and is set to disappear by 2066. Ironically, they put that [reference] in a box in a case study on the work of engineers. Yet the whole [report] is about science, not about engineering."

In the late 1980s, countries agreed to ban the use of chlorofluorocarbons, an inert ▸

"WE ARE HALFWAY THROUGH THE UN'S VISION OF SUSTAINABLE DEVELOPMENT FOR ALL, AND MORE THAN HALF THE GOALS HAVE NOT BEEN PROGRESSED."

ingredient used in aerosols and refrigerators.

"It was engineers who then developed alternative refrigerants. These were implemented in buildings and ventilation and air conditioning systems across the world," Kanga said.

The importance of engineering as a tool for achieving sustainable development came through during day one of the forum, Science, Technology and Innovation in Africa Day.

For this, Kanga chaired a session exploring how frontier technologies can advance the agriculture sector on the continent, particularly in rural areas.

There is a huge demand for engineers in Africa, Kanga said, noting that while nations in the developed world have about 100 engineers per 10,000 people, some African nations have just two.

ABOVE: Kanga speaking at the 2019 World Engineers Convention in Melbourne.

"WE NEED OUR POLITICIANS, OUR COMMUNITY, TO UNDERSTAND THE ROLE OF ENGINEERS, HOW VITAL THEY ARE FOR OUR FUTURE, AND TO ADDRESS CLIMATE CHANGE IN ALL ITS ASPECTS."

"The goal from Africa Day, in particular, was to come together with initiatives that can be delivered on the ground," she said. "[Determine] who's doing what, collate what projects are actually in play at the moment and have been delivered on a smaller scale, bring them all together, get some funding from some foundations, and progress that on a larger scale across the continent.

"This is a positive and practical step forward. It wasn't just a talkfest."

Among the challenges the panel considered were sealing roads – just 27 per cent of roads in Africa are paved – coordinating natural disaster risk management, and expanding access to engineering training through an online portal such as the WFEO Academy, which is led by Kanga.

The panel also hosted two engineers from the continent, including one from Mali who had developed an artificial intelligence app, but was unable to travel to the US.

"He sent a video, which was rather poor quality, and they weren't going to use it. I said, 'No, I want to use it'," Kanga explained.

"It shows young people with so many difficulties and a lack of resources still want to compete there on the world stage and show their intelligence and creativity in developing this app to help farmers.

"And it also shows the dire need for good infrastructure – electronic infrastructure, electricity – and so on. It actually conveyed two messages, and it was really powerful."

Kanga's presence at the UN forum was supported by Engineers Australia's Climate Smart Engineering Initiative (CSEI), and she said activities such as CSEI provided the vision and strategy required to help engineers address the challenges involved.

"The Climate Smart Engineering Initiative – and I did talk about this at the UN – provides that kind of structure. We've got an [Engineers Australia] strategy and vision, which comes from the top, from the president and CEO," she said. "The benefit of the [CSEI] structured strategic approach, is the focus that it gives on the role of engineers. I think we need to communicate this not just on a global scale but nationally.

"We need our politicians, our community, to understand the role of engineers, how vital they are for our future, and to address climate change in all its aspects." ●

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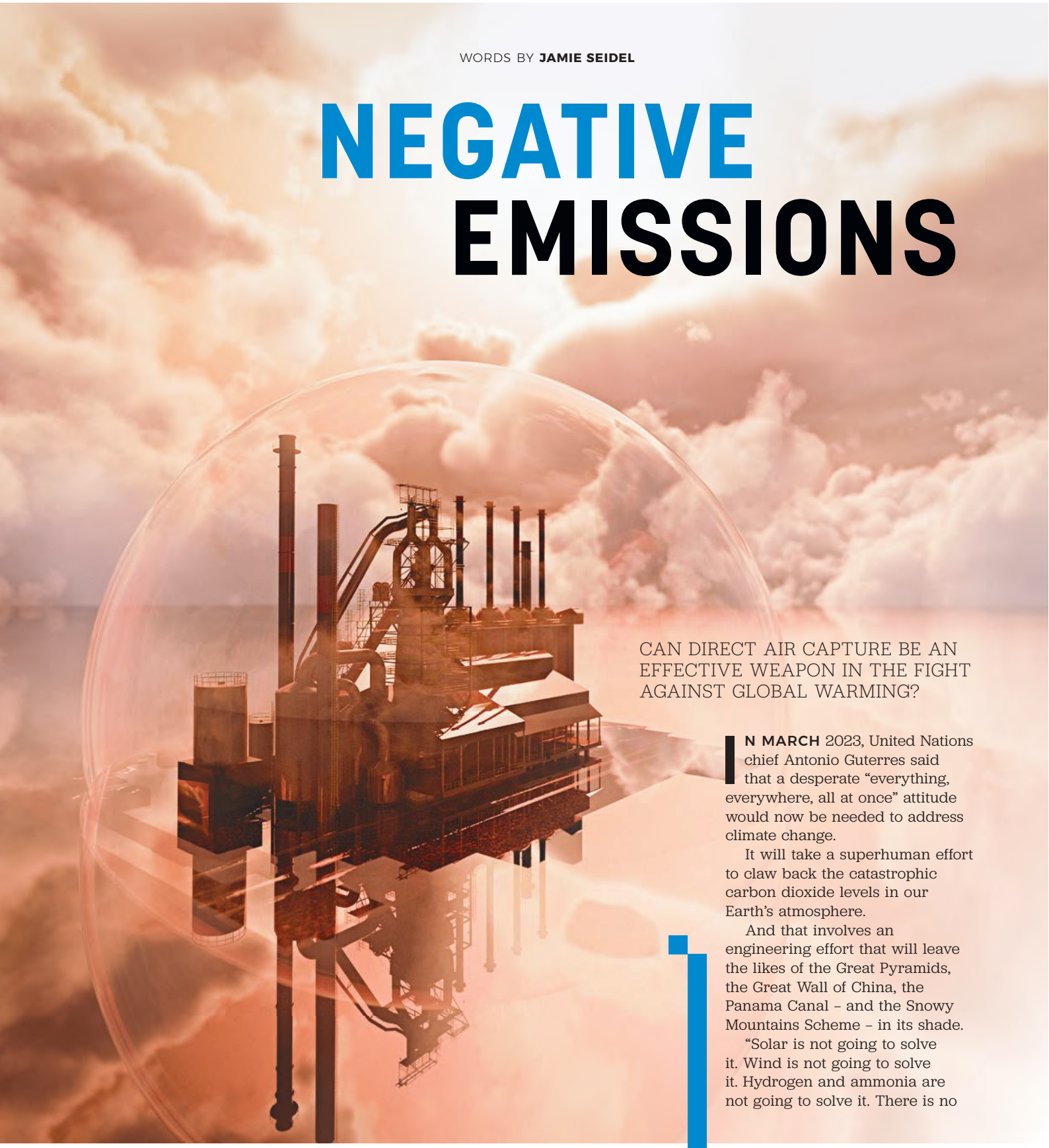
NEGATIVE EMISSIONS



CAN DIRECT AIR CAPTURE BE AN EFFECTIVE WEAPON IN THE FIGHT AGAINST GLOBAL WARMING?

IN MARCH 2023, United Nations chief Antonio Guterres said that a desperate "everything, everywhere, all at once" attitude would now be needed to address climate change.

It will take a superhuman effort to claw back the catastrophic carbon dioxide levels in our Earth's atmosphere.

And that involves an engineering effort that will leave the likes of the Great Pyramids, the Great Wall of China, the Panama Canal – and the Snowy Mountains Scheme – in its shade.

"Solar is not going to solve it. Wind is not going to solve it. Hydrogen and ammonia are not going to solve it. There is no

silver bullet," said the University of Sydney's Director of the Net Zero Initiative, Professor Deanna D'Alessandro. "We need to be pragmatic and practical about needing a portfolio of options."

The Intergovernmental Panel on Climate Change (IPCC) said in its sixth and most recent report that, despite decades of warnings, the world remains on track to exceed the catastrophic 2°C warming threshold.

Renewable energy, reversed deforestation, careful carbon accounting: the need for these remains critical. But they're no longer going to be enough.

"All of these technologies have pros and cons," D'Alessandro said.

"Just look at the amount of steel you need for wind turbines and the lifecycle of solar panels. Then you'll get some semblance of the issues we face."

Humanity invented fire. It devised concrete and steel. It also created the internet. These and just about everything in between contribute to global warming and, at this point, we've got just one trick left to reverse it.

"Direct air capture [DAC] is the only technology that can give us negative emissions," said CSIRO Research Group Leader Amir Aryana.

But there are problems with DAC technology too.

It's costly and it's inefficient. But it must be deployed on a mind-boggling scale. And fast.

"Given the cost challenges we have, I focused on the logistics all the way through the value chain," Aryana said.

"It's an enormous ask – even if we design our systems based on what is available off the shelf, integrate it with other existing technologies, and turn the CO_2 into a value-added product. But it's doable."

"SOLAR IS NOT GOING TO SOLVE IT. WIND IS NOT GOING TO SOLVE IT. HYDROGEN AND AMMONIA ARE NOT GOING TO SOLVE IT. THERE IS NO SILVER BULLET."

A CALL TO ARMS

The International Energy Agency believes a billion tonnes of carbon dioxide will have to be pulled from the atmosphere each year by 2050 to meet global net-zero goals.

By 2100, four billion tonnes will have to be drawn down each year to limit the already inevitable heat surge to acceptable levels.

"We can't wait," said Aryana.

"We have to start now, do our best with what we have, and get better at it fast."

The World Economic Forum and the US Department of State have created the First Movers Coalition. Its 82 members include names like Apple and Microsoft committing to paying a premium for carbon credits linked to reduction projects.

Look closer at the list, and you will also see BHP, Fortescue Metals and Rio Tinto. Their initial goal is modest: just 50,000 tons of carbon dioxide removed by 2030.

There are nature-based options. Trees and plants soak up carbon dioxide. As does ocean life.

But the scale and urgency of the problem means nature no longer has the capacity to self-correct.

RIGHT (from top): A University of Sydney carbon capture prototype; the CarbonAssist unit.

"We hear a lot about nature-based offsets, which, at the minute, is really the only widespread mechanism we have for dealing with carbon removal," said D'Alessandro. "But the reality is that we're relying too heavily on nature. We know we need short, mid and long-term options."

It would take an estimated 862,000 km^2 of new, healthy forest to recapture one billion tons of carbon dioxide – almost the entirety of South Australia.

Current DAC technologies need between 1500 km^2 – two Canberras of new geothermal ▸

power facilities – and 66,000 km^2 – an area the size of Tasmania covered with wind turbines – per billion tonnes of capacity.

But that's just part of the challenge.

Existing liquid-solvent DAC systems use between one and seven tonnes of water to capture a tonne of carbon dioxide. That's comparable to the consumption rate of steel and concrete.

Some solid absorbent systems need up to 1.6 t of water. Others must contend with unwanted water being drawn from the air and clogging up the process.

"We have technologies based on centuries-old, well-known chemistries," said D'Alessandro.

"These are the ones closest to market. And that's great because those companies are the early movers that recognised the urgency of the problem. But then you've got other, more innovative developing technologies that could soon leapfrog these existing technologies in terms of their cost-benefit analysis."

ABOVE: Capturing carbon dioxide via a molecular gas-liquid contactor.

"THE REALITY IS THAT WE'RE RELYING TOO HEAVILY ON NATURE. WE KNOW WE NEED SHORT, MID AND LONG-TERM OPTIONS."

ADVANCE AUSTRALIA

"We are further behind the rest of the world here in Australia," said D'Alessandro.

"Those of us who recognised a big part of the net-zero conversation was missing had to self-assemble ourselves across Australia. And that conversation was about dealing with legacy emissions in the atmosphere."

But the CSIRO is now putting its weight behind several local carbon capture projects to produce large-scale demonstration and proof-of-concept plants.

One of these, the CarbonAssist unit, uses existing, off-the-shelf ingredients in new ways to ➤

DIRECT AIR CAPTURE: THE SCIENCE

The challenges are shared, but the solutions are many and varied. Capturing carbon dioxide needs efficient sorbent materials that can be manufactured at enormous scales.

They must be capable of expelling that gas and returning to a state ready for another capture cycle.

And the whole process must be as energy-efficient, cost-effective and resilient as possible.

"When it comes to carbon dioxide capture technologies, we basically have liquids and solids," said CarbonAssist's Amir Aryana.

"There are liquids like amines. Then there are solids like membranes, metallic-organic frameworks [MOFs], and so on. We focused on a hybrid of the two."

Amine droplets, he explained, offer a limited surface area, reducing their carbon-capture efficiency. The race to turn solids into a viable large-scale option is still on.

"We've created, in essence, a very high CO_2 affinity sponge by combining solid and liquid elements," Aryana said. "We drew inspiration from the evolutionary leap that escalated life on Earth: the photosynthesis process."

Most importantly, he said, the ingredients – though the exact composition is secret – are common.

"[The ingredients] are being produced at the million-tonne scale already for different industries, so I know we can get costs down with quantity of volume," he said.

And the resulting powder is safe to handle.

"It can be disposed of safely, and we have got another use for it," he said.

"That's why I'm happy to get this material back and eliminate that waste concern for whoever uses our DAC technology."

The metal-organic frameworks used by Southern Green Gas are a new class of materials that could be the key to carbon-capture success.

"One teaspoon of these [MOF] powdered materials has the surface area of a football field or the Sydney Cricket Ground," D'Alessandro said.

"So that underpins the fact that they can be used to process very, very large volumes of gas. And as materials chemists, we can design these materials to be highly selective – such as for specific gases."

But everything about MOFs is in the very early stages of development.

"We had full knowledge of this challenge when we started," D'Alessandro added.

"That's why we have worked so hard to interface these amazing materials with a flexible engineered system."

Chemists and engineers work shoulder-to-shoulder to ensure each discovery's full implication is reflected in a "designed for manufacture" process.

"We've gone through a number of materials developments," said D'Alessandro. "We now have a selection of champion MOFs composed of Earth-abundant metals. And we can use green chemistry approaches to make their components."

But that still needs an entirely new industry to be established.

"There is no current mass application for MOFs in the world," explained Southern Green Gas's Brett Cooper.

"At the moment, we can make MOFs in small quantities for use in laboratories. But we have to go beyond that and develop ways of mass manufacture."

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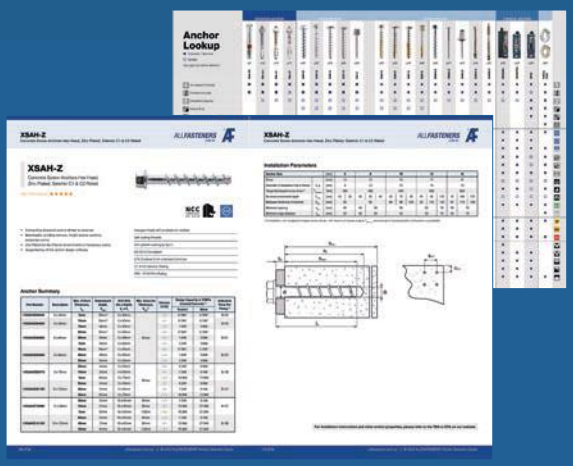

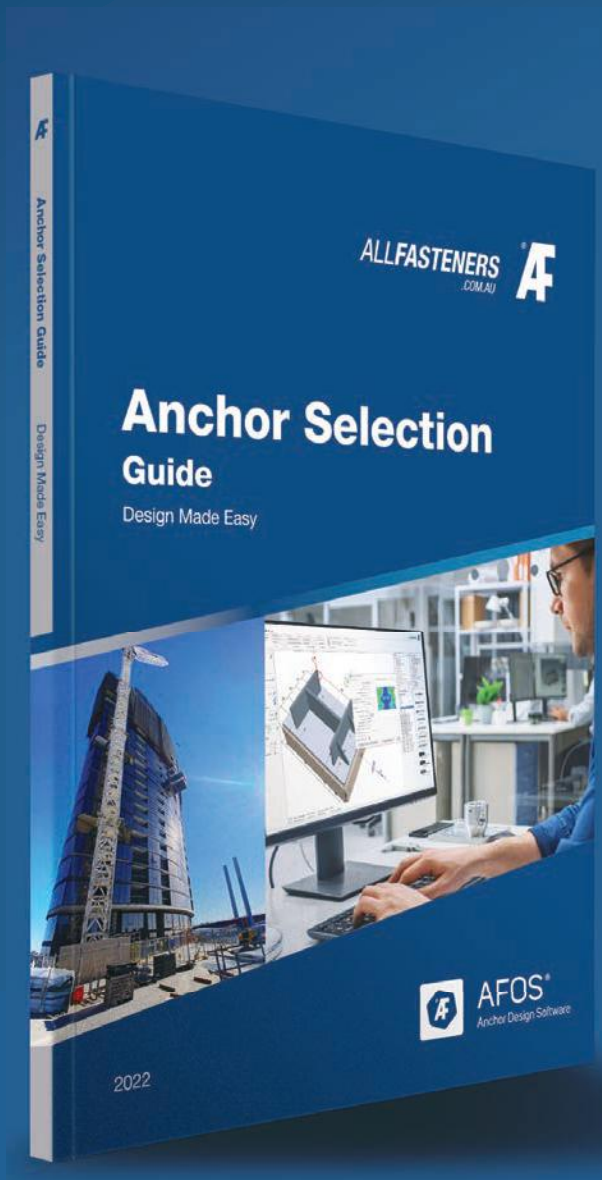

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LEFT: Southern Green Gas's David Hedger adjusts a module.

generate new materials for maximum efficiency. The resulting reaction agent can, therefore, quickly be scaled up to mass production and distribution.

Southern Green Gas, meanwhile, is built on advanced new materials science for water-free technology. But this requires a new reagent production industry to be fast-tracked.

"You have to start somewhere," said Brett Cooper, Co-Founder and Business Development Manager of Southern Green Gas.

"But this is a massive, positive opportunity for the engineering industry, the mining industry in Australia."

Because of the country's vast scale, it is possible to build capture fields almost on top of geo-sequestration sites.

"We've got the below-ground mining industry expertise to secure that, and the renewable energy sources can sit nearby," he said.

The technology, the resources and the space all exist. All that's needed now, Cooper said, is the will.

"There are groups across Australia that have their technology ready to go, but we don't have a clear transition plan," he said.

"THE ENERGY REQUIREMENT IS MUCH LOWER IF WASTE HEAT AND RENEWABLE SOURCES ARE USED. ABOUT 70 PER CENT GOES INTO HEAT, AND 30 PER CENT IS FOR THE OTHER STUFF."

"We're being held back by a lack of legislation."

But according to D'Alessandro, momentum is beginning to shift.

"I think the responsibility that lies with us, as scientists and engineers and those who understand these technologies, is to ensure that this transition will set Australia up for a safe, responsible future," she said. "That means setting up responsible policy and legislation. It means working with the communities on the ground who will be affected by these technologies. And it means developing a whole new ecosystem needed to support it."

ABOVE: Southern Green Gas's direct air capture modules.

CLIMATE ENGINEERING

The common thread between Australia's DAC technologies is the need for cheap, mass-produced infrastructure. But they also must operate with the minimum possible energy input and maintenance.

"It needs to be picked up, shipped internationally, slotted in, switched on and ready to go," said Aryana. "DAC must be as simple and flexible as possible to catch on."

Cooper said there's an overwhelming need to ground projects in economic reality.

That's why investor and adviser Dr Alan Finkel introduced his team to former General Motors Holden production engineer Andrew Hynson.

"He's able to say, 'Well if we use this particular thing, I know the automotive industry produces that on a massive scale. So instead of engineering one that costs five dollars, you can get it for fifty cents'," Cooper said. "But that may mean we must adjust the science a little to get the balance right." ▸

That balance is the name of every aspect of the game.

Aryana said CarbonAssist's technology is comparable to an average commercial cooling tower. It does not need a powerful fan. Its vacuum pump is of the same scale as common commercial fish tank varieties.

"So the longevity of the chemicals right now is between three to five years," he said.

"And normal cooling towers last about 15 to 20 years."

The technology operates with carbon-capture powder laid out in stacked trays. Air is blown across them, with the heat needed to release the CO_2 into a vacuum provided by hot-water heat exchangers.

"The design allows for the heat exchanger to utilise waste heat or renewable energy. It provides the flexibility needed to go across multiple sectors," Aryana said.

The unit currently consumes one-megawatt hour to secure one tonne of carbon.

"The energy requirement is much lower if waste heat and renewable sources are used," Aryana said. "About 70 per cent of it goes into heat, and 30 per cent is for the other stuff: the fan, the actuator, the vacuum pump."

And the vacuum isn't only about removing concentrated CO_2 from the unit.

"Think of gas-liquid-solid phase envelopes, such as with water," Aryana said. "You can change these states through temperature. But you can also do that with pressure. The vacuum allows me to play down that curve and release the CO_2 at 75°C."

Aryana said a working prototype is up and running.

"We're already extracting about 0.25 t per day," he said. "And in March next year, we will have a one-tonne per day unit deployed to [South Australia's] Moomba [gasfield] ."

Mass-volume production is the next step, and commercialisation is currently under way.

PURSUING EFFICIENCY

Cooper described the core technology behind Southern Green Gas as "like a printer cartridge, where we can pull it out and replace it because it's either worn or because Deanna has come up with a more efficient system".

"Over time, our chemistry will improve. Our sourcing of materials will change," D'Alessandro said. "And COVID has already meant we had to turn our attention to metal-organic framework [MOF] resources that are plentiful here in Australia and take advantage of the advanced manufacturing of Australia's raw resources."

"WE'VE GOT MANY GROUPS ACROSS AUSTRALIA THAT HAVE TECHNOLOGIES READY. BUT THEY NEED TO KNOW HOW WE WILL TRANSLATE AND INTEGRATE THAT INTO A CARBON ECONOMY."

The form of the cartridge is yet to be finalised, but it could involve 3D printing the MOFs to maximise airflow exposure and eliminate the need for supporting substrates. And the candidate MOFS must be heated to about 90°C to release the captured CO_2.

"Southern Green Gas is [at time of writing] building and testing prototypes of this technology at the Advanced Robotic Manufacturing (ARM) Hub in Brisbane," said Cooper.

One prototype is about the size and shape of a two-person tent. Another is the size of a shipping container. Both incorporate the solar panels needed to power them. The first prototypes are expected to be delivered within months.

"We should be able to capture – including the allowance for the energy – somewhere in the range of 500 to 800 t of CO_2 per annum, per hectare," he said.

A NEW HOPE

The challenge isn't so much the engineering, Cooper said.

"It's in the price signals that we need to bring this industry on, and bring it on fast."

While the federal government cut investment for carbon capture in last October's budget, it did announce a new $141 million negative emission fund.

The real money comes from international investors.

"The cost for us doing carbon removal at the moment would probably be up around $1000 a tonne because we're hand-building the prototype modules," said Cooper.

"But it's just going to follow the price-drop pattern of the photo-voltaic industry."

Australian carbon credits, meanwhile, are trading for about $40 a tonne.

"We're going to have to accept that we need a transition plan," said D'Alessandro.

"We've got many groups across Australia that have technologies ready. But they need to know how we will translate and integrate that into a carbon economy." ●

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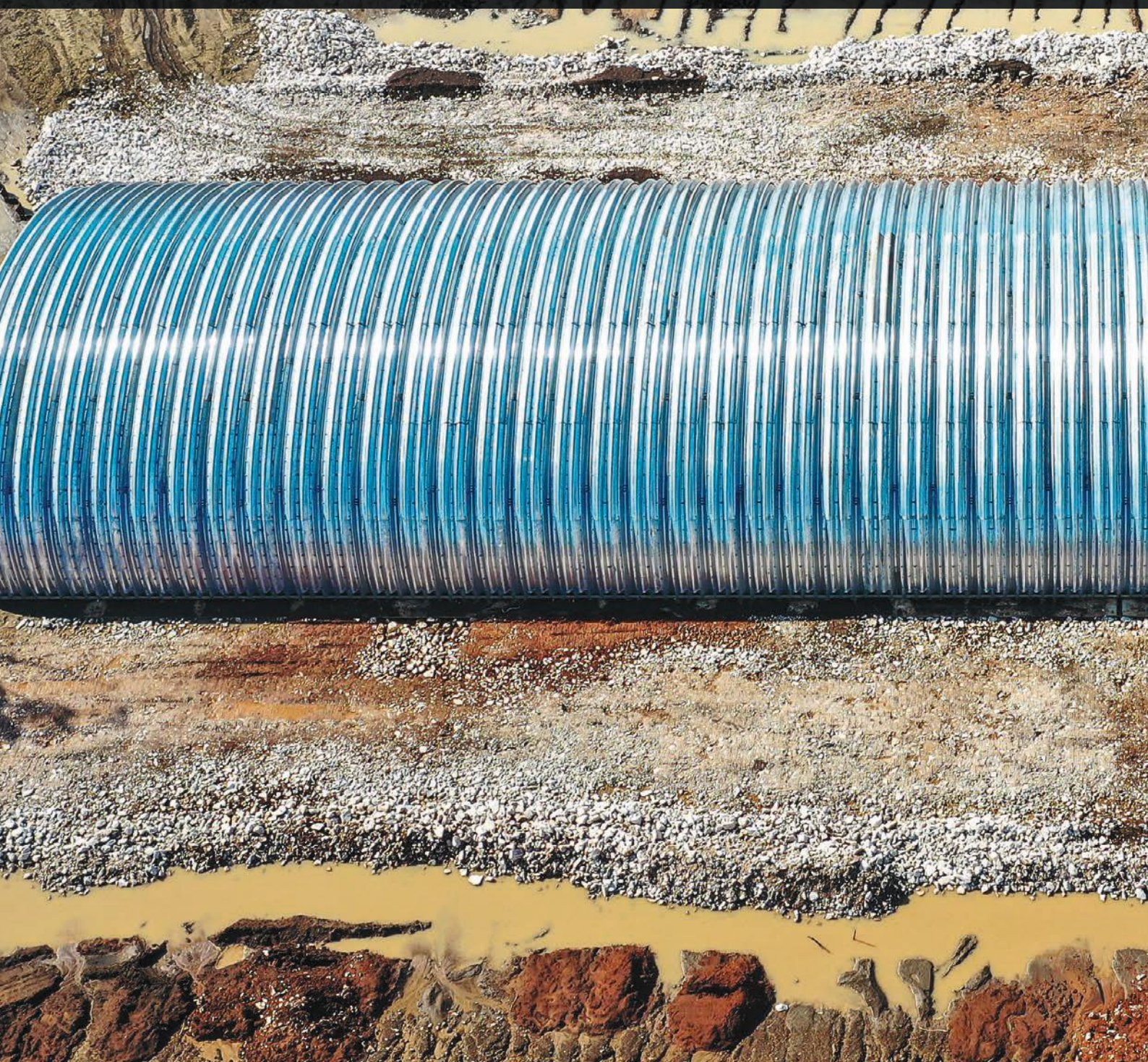

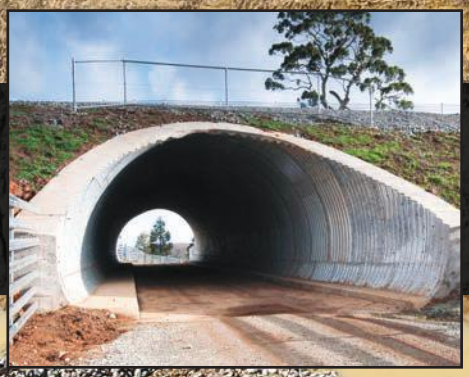

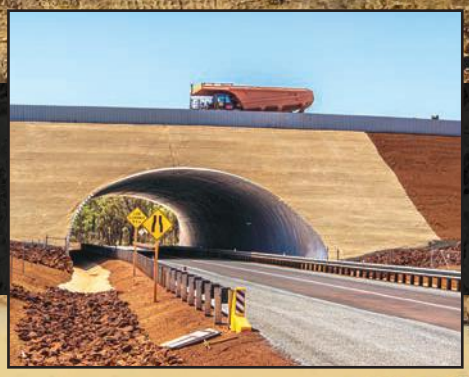

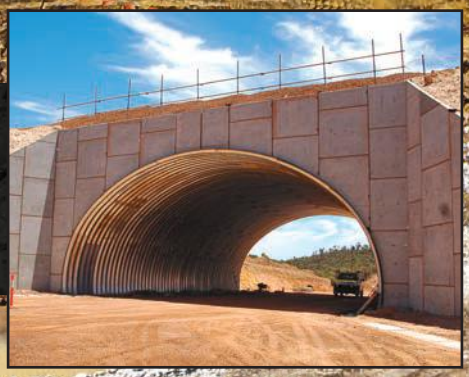

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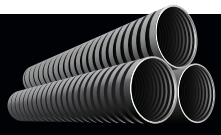

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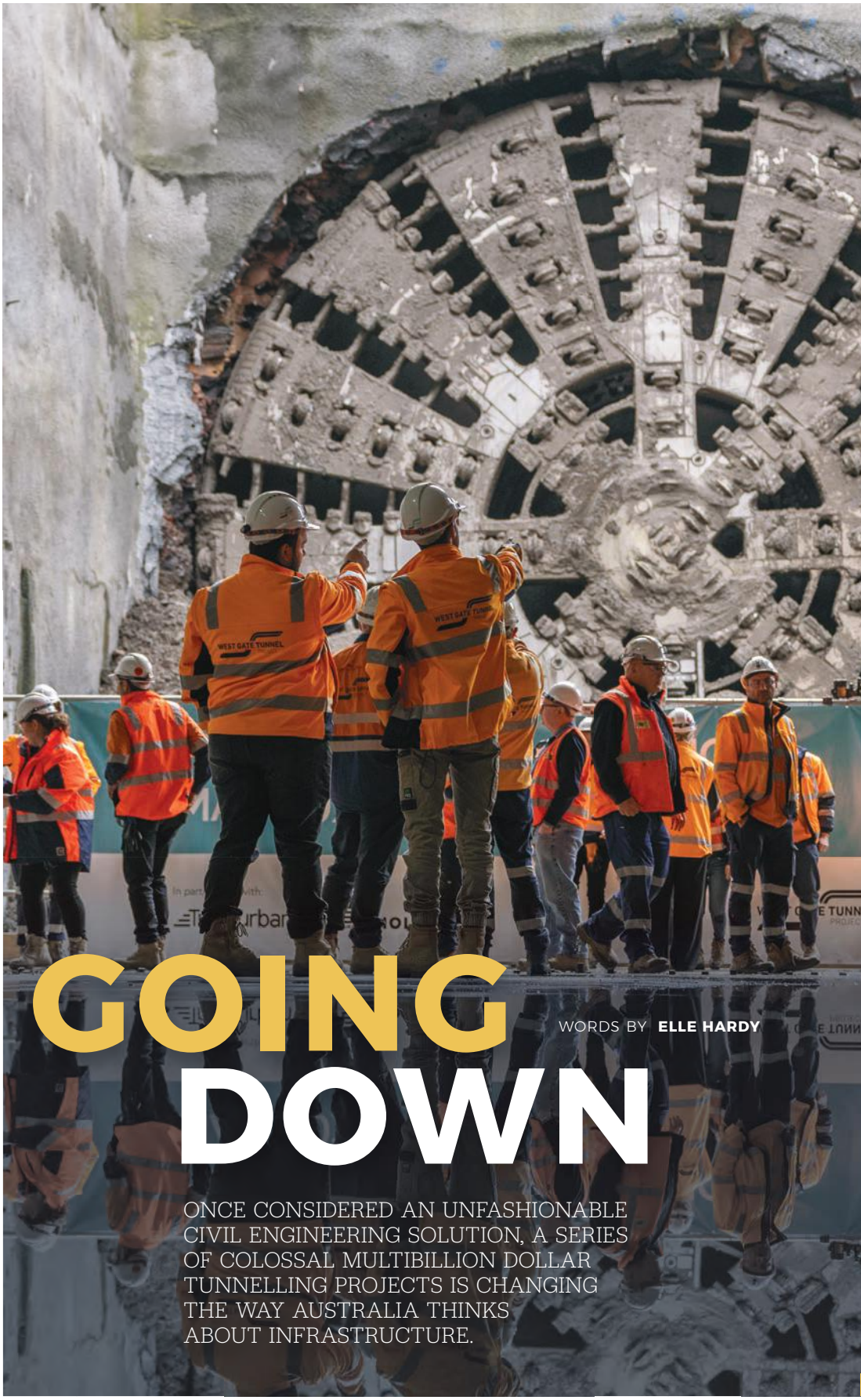


GOING DOWN

WORDS BY **ELLE HARDY**

ONCE CONSIDERED AN UNFASHIONABLE CIVIL ENGINEERING SOLUTION, A SERIES OF COLOSSAL MULTIBILLION DOLLAR TUNNELLING PROJECTS IS CHANGING THE WAY AUSTRALIA THINKS ABOUT INFRASTRUCTURE.

TUNNELLING HAS long been associated with European know-how, with vast rail projects carved through mountainous terrain, or high-tech societies such as Singapore, where complex underground systems have enabled urban high density.

Yet Australia's tunnel engineering expertise is now being recognised globally, along with pioneering innovations that have arisen from the sophisticated local mining industry and unique conditions.

As the populations of the country's major cities continue to grow, so too does the demand for efficient transportation systems, water management and utilities.

By some estimates, Australia is in the midst of an infrastructure boom the likes of which has not been seen since the 1980s.

Tunnelling has come a long way since then and meets community expectations in terms of sending traffic and resources underground, minimising disruption to existing infrastructure and preserving valuable above-ground real estate.

Consequently, major tunnelling projects have boomed in recent years, with a surge in investment and technological advancements leading to bigger and more complex operations.

In terms of scale alone, in the 1980s, there were only about 90 projects worldwide with an excavation width span between 15 m and 20 m, whereas today, tunnels regularly go up to 30 m.

Better safety standards and the development of new materials and construction methods have also allowed engineers to build tunnels in a wider range of environments, including underwater and in geologically challenging terrain.

Significant Australian projects currently underway include the Melbourne Metro and West Gate Tunnel in Victoria; WestConnex, Sydney Metro and Snowy 2.0 in New South Wales; and Cross River Rail in Queensland.

Major new tunnels are also being planned, such as the North-South Corridor in

IMAGE: NED MELDRUM, SNOWY HYDRO

LEFT: A tunnel boring machine breaks through Melbourne's West Gate Tunnel. BELOW: Harry Asche, Aurecon. RIGHT: The Snowy Hydro project was an early Australian tunnelling triumph.

Adelaide, the Greater Western Highway in the Blue Mountains and the Inland Rail Tunnels in South-East Queensland.

With this appetite for state-of-the-art infrastructure not expected to slow down any time soon, tunnelling is set to play an increasingly important role in shaping Australia's future.

To appreciate how far we've come – and to learn about the opportunities and challenges in this exciting field – *create* sat down with a number of leading Australian tunnelling engineers.

A PROUD HISTORY

"Australia has a long and proud history of tunnelling, even before the Snowy Mountains Scheme," said Aurecon engineer Dr Harry Asche, the head of the Australian Tunnelling Society.

"There was, however, a time in the '70s and '80s, which was the freeway age, when population density hadn't grown to the extent it has now. By the end of the 1980s, a resistance developed to putting freeways through suburbs, and tunnels became more popular again in Australian cities."

"THE FIRST WORKING ROCK TUNNEL BORING MACHINE IN THE WORLD WAS ACTUALLY IN TASMANIA. IT SET RECORDS THAT JUST BLEW EVERYONE'S MIND."

In recent years, Asche said, the resurgence in tunnelling for new railway lines, roads and sewers has been seen particularly in Sydney, Melbourne and Brisbane.

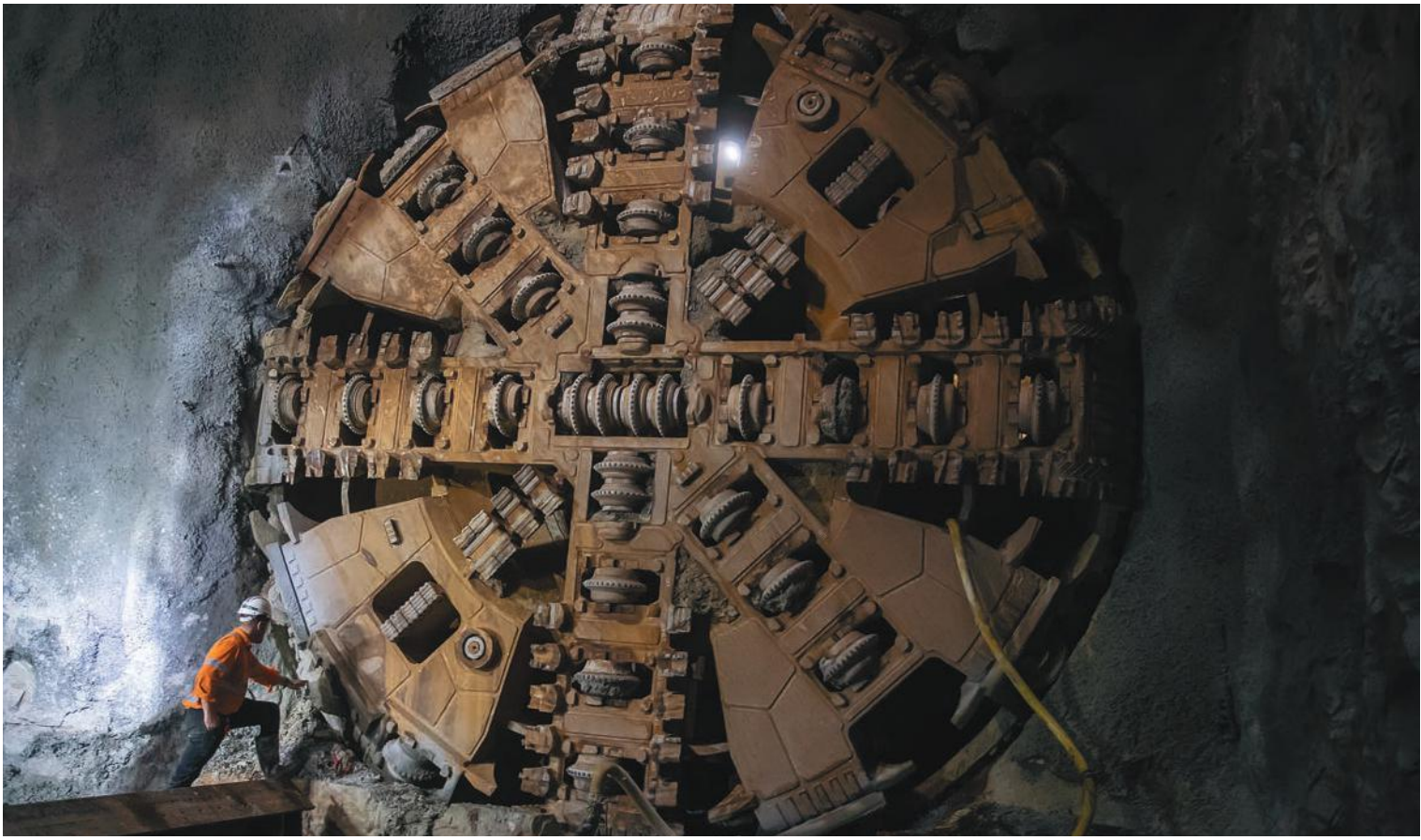
He is currently working on Sydney's Western Harbour Tunnel, which is using the largest tunnel boring machine in Australia to connect the city's Inner West with its northern suburbs.

"Around 40 years ago I commenced my career on a project with essentially the same alignment called the second Sydney Harbour crossing, which ultimately failed for political reasons," he said.

"That tunnel was 10 km across, which at the time was considered way too long; now we have WestConnex, which, when joined up, is over 20 km long.

"The other issue was that the ability to build a tunnel in mixed ground with soft material and water under the harbour was not really feasible back then with the tunnel boring machines we had."

Asche explained that Australians played a significant role in the revolution that is tunnel boring machines, with local engineer David Sugden helping to perfect the disc-cutting technology ▸



that is used in all of today's big rock machines.

"The first working rock tunnel boring machine in the world was actually in Tasmania," Asche said.

"It set records that just blew everyone's mind, doing more than 200 m in a week – well beyond what anyone else had ever done."

Asche believes that one thing in Australia's favour is that there is no "Australian method" of tunnelling. Instead, the country's engineers have sourced the best innovations from around the world.

"All of the vehicles are less polluting than they used to be, and the ventilation and fire requirements are better understood," he said.

"Road safety technology is much better than it used to be in a 10 km long tunnel and, of course, the tunnel excavation and safety of doing that is much more versatile than it used to be."

Asche maintains that tunnel projects make cities more resilient, sustainable and capable of decarbonising – and new methods of automation are something that will only make the process better.

But he added that there is little worry about ChatGPT being asked to start drawing up plans for major infrastructure programs and putting engineers out of work, with automation used largely as a safety feature.

"I recently visited the West Gate Tunnel project in Melbourne that I worked on the design of, and it was really interesting to see how many precast, prefabricated items are being used in the tunnel construction," Asche said. "A lot of manual labour is being taken out, which makes it safer and cheaper, without taking away from the skill of people who are working on it."

ABOVE: The West Gate Tunnel has reduced the amount of manual labour required with precast and prefabricated items used in construction. LEFT: Rob Bertuzzi, Pells Sullivan Meynink.

SAFETY INNOVATIONS

Australian experts highlight that the improvements in tunnelling safety play a key role alongside technological advances.

Pells Sullivan Meynink (PSM)'s principal geotechnical engineer Robert Bertuzzi CPEng labels the industry's view on health and safety of staff and workers – and the community in general – the biggest change he's witnessed over 30 years in the tunnelling industry.

IMAGE: SYDNEY METRO

"No one works under unsupported ground, and that's an innovation that came from Australia's mining industry – and it's fairly unusual compared to most other countries," he told *create*.

While the modern era of tunnelling is widely regarded as having begun in the 1970s, it was the Australian innovation of the permit-to-tunnel (PTT) system, which commenced about 15 years ago, that has been a game changer.

"The PTT said that every 24 hours, or every time we excavate the face, we get in the geotechnical engineer, the tunnelling engineer and the construction team together to review the conditions and the ground behaviour and confirm that there is a design to cater for those conditions and that it's safe to proceed," said Bertuzzi.

"It's a big improvement."

Australia continues to pioneer the PTT system globally and has tried to introduce it into other jurisdictions.

However, Bertuzzi has reservations about the increasing amounts of paperwork involved in Australian tunnelling and is concerned that the benefits of the PTT could be lost if this paperwork continues to become attached to the system.

"We could do better in terms of bureaucracy, where projects have become more contractually onerous," he said.

"There is a place for them, but we've got management plans that cover design, dust control, air quality, water quality, noise, spoil management – and the list goes on.

"These documents can be 50 or 60 pages each, which is a phenomenal burden. Foreign construction companies come in and get caught out, because they're not aware of just how much paperwork is required to operate in Australia."

Bertuzzi doesn't want Australia's culture of tunnelling innovation to suffer, especially given that much of it has been driven by the desire to remove people from unsafe areas.

"A LOT OF MANUAL LABOUR IS BEING TAKEN OUT, WHICH MAKES IT SAFER AND CHEAPER, WITHOUT TAKING AWAY FROM THE SKILL OF PEOPLE WHO ARE WORKING ON IT."

"The industry recognised that the design is under construction, and we don't have complete knowledge of what the ground will look like until you excavate it," said Bertuzzi.

"Even the best geotechnical model, taking into account a reasonable range of conditions, can turn up surprises when you get to excavating."

He said that the level of engineering done in Australia is to an exceptional standard.

"The comments I receive from international engineers is that we exceed in the detail and other considerations when it comes to the actual engineering of the problem."

On this front, he notes that many companies now use laser or optical scanning to get the excavated profile, which is useful for surveying and quantifying the amount of materials that have been used, as well as for geological mapping.

"We have developed equipment to be able to remotely install rock bolts and shotcrete and, I'm sure in the next few years, tunnellers will adopt the mining approach of more remotely operated equipment, such as roadheaders and tunnel boring machines," he said.

"One innovation that PSM has designed is handlebar plates, which are a structural connection ▸

BREAKING GROUND

WestConnex *Sydney, New South Wales*

Description: Australia's largest road infrastructure project will establish 33 km of traffic-light–free motorway network, connecting Sydney's west to the CBD and airport.
Estimated cost: $21 billion

North East Link *Melbourne, Victoria*

Description: This new freeway link will connect Melbourne's eastern and northern suburbs, including construction of a 6.5 km twin-bored tunnel, taking an estimated 15,000 trucks off local roads each day.
Estimated cost: $16 billion

Metro Tunnel *Melbourne, Victoria*

Description A new rail tunnel from South Kensington to South Yarra, passing through five underground stations, including 9 km of twin tunnels.
Estimated cost $12.58 billion

West Gate Tunnel *Melbourne, Victoria*

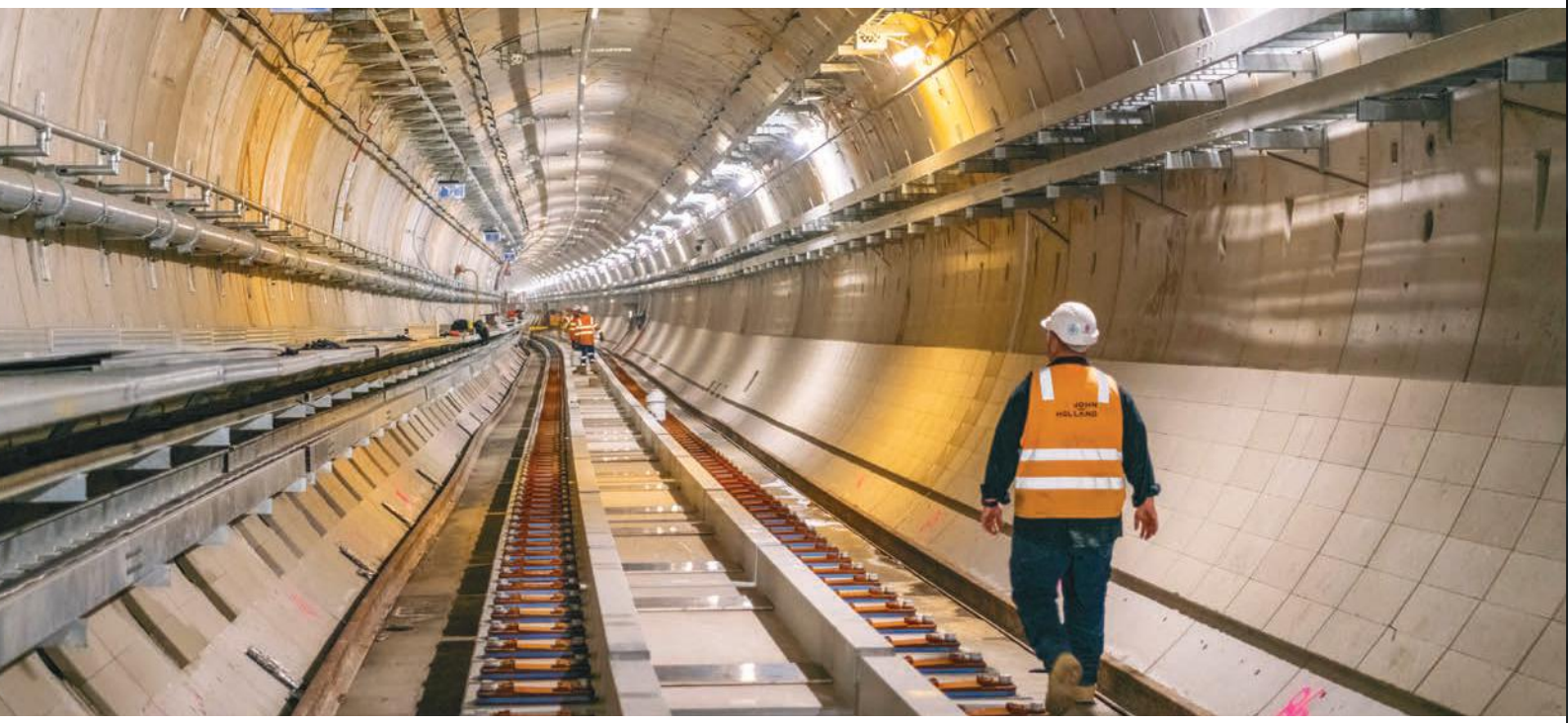
Description: The project is an alternative route to the West Gate Bridge and includes the construction of a new tunnel along with an elevated road above Footscray Road.
Estimated cost: $10 billion

Cross River Rail *Brisbane, Queensland*

Description: Running through the city's central business district, this new rail line features 5.9 km of twin tunnels under the Brisbane River.
Estimated cost: $6.3 billion

Snowy 2.0 *Southern New South Wales*

Description: Expansion of the existing Snowy Mountains hydroelectric scheme involves the construction of a new underground power station and the excavation of large tunnels to transport water between dams.
Estimated cost: $6–10 billion



between the shotcrete lining and the rock bolts. It's particular to our tunnelling environment where our permanent lining is often installed at the face."

The moderately strong rock that typically underlies the major cities of Australia's east coast means that there is high stress for their relatively shallow tunnels.

"Because we are designing for civil applications, we cannot accept any kind of cracking or signs of failure," he said.

"We've come up with ways to counteract that through stress relieving slots, void formers in our lining to accommodate subsequent displacements [and] we monitor the displacement through endoscope cameras in the boreholes, which are all innovations particular to Australia."

SHORING UP TALENT

Elena Gavazzi, an associate principal at Arup, began her career in the United Kingdom before moving to Australia three years ago to work on the Melbourne Metro – a massive engineering project that involves navigating design and construction, space constraints, building in a busy environment, and having to deal with multiple stakeholders, subcontractors and supply chains.

"AUSTRALIA'S SIGNIFICANT MINING HISTORY MEANS THERE IS EXPERTISE THAT CAN BE TRANSLATED INTO ALL MAJOR INFRASTRUCTURE PROJECTS."

"Once it's open, Melbourne Metro will showcase Australia's expertise in terms of building tunnels," she told *create*.

"It's a highly innovative project, creating a cathedral-sized tunnel underneath Melbourne. The only time this has been done before is in Moscow, Russia.

"The design and construction advancement that has gone into building means that, apart from the acoustic sheds, you wouldn't know something is going on underneath."

Gavazzi notes that Europe has seen something of a downturn in its major works projects, but the growth and evolution of Australia's major cities has meant a lot of tunnelling projects are currently under way – and that it's an exciting time to be working in engineering here.

"Australia's significant mining history means there is expertise that can be translated into all major infrastructure projects," she said. "From an engineering perspective, one of the biggest challenges is actually servicing the amount of work with the skills that are out there, and that skills shortage includes construction and other specialists.

"Fire engineers are particularly difficult to find on the market to service these major projects."

Fire safety is a key consideration for both construction and operation of a tunnel, with emergency evacuation and egress schemes required to be in place from start to finish.

"Covid had a big impact on a migration workforce coming to Australia to fill the skills shortage," Gavazzi said.

"We also need to be looking at our young graduates and universities to see how we can better help with upskilling and get them interested in the tunnelling industry." ▸

ABOVE (from top): Tunnelling for the Melbourne Metro; Elena Gavazzi, Arup.

IMAGE: COURTESY OF METRO TUNNEL PROJECT

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BLAST: The 800m long steel deck had a total of 60,000 square meters to repaint. The underside of the steel deck was abrasive blast cleaned.

PRIME & FIRST COAT: Zincanode® 402 was applied with a Cold Cure Hardener. The two-pack epoxy zinc rich primer is ideal for use over abrasive blast cleaned steel.

SECOND COAT: The second coat of surface tolerant epoxy Durebild® STE was then applied.

THIRD COAT: Durebild® STE MIO added a layer of surface tolerant micaceous iron oxide, working as a barrier coat for protection against water ingress.

FINISH: A final topcoat of Weathermax® HBR MIO ensured a high build finish.

Gavazzi is part of the Australian Tunnelling Society committee, which is engaging with universities by looking at their programs and seeing how to get students involved with initiatives such as the Victorian Tunnelling Centre, a specialist state government-funded training school for workers involved in the construction and operation of a variety of tunnels.

"Everybody needs to be on board when it comes to upskilling graduates, from universities to industry to contractors and consultants – it cannot be just one party," she added.

"When someone takes a course, they need to be supported in understanding the opportunities and how their career can progress in the field."

The industry is also working on a number of initiatives with universities, including organising site visits and talks with different companies involved in design, building and constructing Australia's biggest infrastructure projects.

"Attracting talent from different backgrounds is also important – you don't see a career if [you] don't see somebody else that looks like you out there," Gavazzi said, acknowledging that she wants to help tunnelling become less of a "blokey" industry.

"Forefronting examples of engineers from diverse backgrounds will help more young people see a future in our field."

ABOVE: Brisbane's Cross River Rail project. BELOW RIGHT: Dr Jurij Karlovsek, University of Queensland.

SUSTAINABLE TUNNELLING

University of Queensland geotechnical engineer Dr Jurij Karlovsek is similarly passionate ▸

"A KEY QUESTION WE ARE ASKING IS HOW TUNNELLING CAN SUPPORT URBANISATION WHILE SIMULTANEOUSLY REDUCING THE ENVIRONMENTAL IMPACT IN A HEAVY CONSTRUCTION INDUSTRY."

about educating and preparing a new generation of engineers to lead major projects.

One way to help attract young workers to the field is to highlight a renewed push on the sustainability of tunnelling, which has not always been considered "green".

"The tunnel industry is increasingly shifting its focus towards sustainability and environmental responsibility," Karlovsek said. "A key question we are asking is how tunnelling can support urbanisation while simultaneously reducing the environmental impact in a heavy construction industry."

Karlovsek said that the creation of underground assets in urban environments has been made possible with tunnelling. A significant amount of material – specifically concrete – is invested in creating these spaces, tunnelling remains an essential tool for urbanisation.

"As a representative of Australia at the International Tunnelling Association, I am proud to announce our initiative to develop sustainability indexing in the tunnelling industry," he said.

"DESPITE ITS RELATIVELY SMALL POPULATION, AUSTRALIA IS RENOWNED FOR LEADING INNOVATION, WITH EXPERTISE IN SUPPORTING SIGNIFICANT PROJECTS WORLDWIDE."

"This indexing aims to highlight the value that tunnelling provides towards sustainable urbanisation.

"We are focusing on achieving a more sustainable vision for our planet and working with the United Nations to promote these indexing efforts globally."

While digital technology has enabled the philosophy of sustainable indexing in tunnelling, Karlovsek added that the industry now has access to information modelling and data analytics tools that allow it to measure and monitor projects and assets more effectively, helping to focus on the value of tunnel development in urban areas.

ABOVE: Sydney's WestConnex, at more than 20 km, is far longer than once imagined for tunnel projects.

"Despite its relatively small population, Australia is renowned for leading innovation, with expertise in supporting significant projects worldwide," he said.

"The tunnelling industry is a global market, with companies competing and tendering for the same global projects."

Several Australian universities, including the University of Wollongong, the University of Technology Sydney, the University of Newcastle and the University of Queensland have established research centres and courses for underground development and technologies.

"However, industry support is crucial for these activities to be effective," Karlovsek said. "With increasing difficulties in bringing in overseas talent for large projects, more industry support is necessary for universities to work effectively in this space."

He believes that the Australian Tunnelling Society's young members group is already increasing diversity in the society.

With its international counterpart at the International Tunnelling Association, which now has representatives from over 30 member nations, opening up conversations across borders. ●

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4. Reduced costs for labour, transport and consumables

Compared with a conventional propping system, Coates estimates that Quadshore 150 will reduce transport costs due to its lighter weight and higher capacity, which means less equipment, machinery and labour are required on site. The boltless design will also result in significant cost savings on consumables throughout the entire lifecycle of the product.

5. Lower carbon footprint due to less transport

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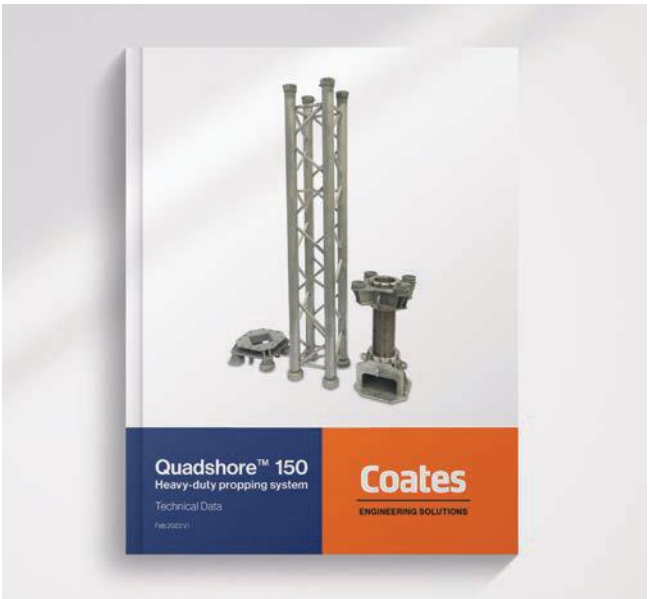

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NEW HEIGHTS

WORDS BY **JONATHAN BRADLEY**

A NEW SKYSCRAPER ON SYDNEY'S CIRCULAR QUAY HAS A LONGER HISTORY THAN ITS GLEAMING NEW FAÇADE AND UP-TO-THE-MINUTE DESIGN MIGHT SUGGEST.

WHEN THE AMP Centre, an oblong monolith of glass and concrete overlooking Circular Quay at 50 Bridge Street, was completed in 1976, it was the tallest building in Sydney.

Martin Place's new MLC Centre would snatch the title the following year, and time and a growing Sydney skyline have overtaken the once imposing skyscraper in other ways.

As the AMP Centre approached its half-century anniversary, it was also approaching the end of its life. That meant, said Arup Principal Robert Saidman, the owners AMP Capital had some pretty serious thinking to do.

"They had quite a challenge with the existing building," he said.

"When we first looked at it around 2010 or 2011, it had an original façade, which was prone to a lot of leakage. It had pretty poor performance generally; with all the glazing technology that has evolved, it had started to fall well behind its peers. Its mechanical systems were ageing and inefficient; it had very poor air distribution; and its water and energy performance weren't great."

But rather than quietly retiring a structure that was approaching obsolescence, AMP Capital sought to "upcycle" the building, working with Arup, structural engineers BG&E and architects 3XN and BVN to preserve much of the original structure while creating something entirely new.

"The basis of the scheme, in simple terms, involved removing the northern portion of the existing building up to the edge of the existing core, and then extending new floor plates to the north," Saidman said.

The result preserved 65 per cent of the existing floor plates and 98 per cent of the core, while approximately doubling the net lettable area of the tower and creating a distinctive spiralling look to the skyscraper, as if five separate blocks were twisting around its axis.

The outcome: a saving of 12,000 t of embodied carbon, which BG&E says is the equivalent of 70,000 flights between Sydney and Melbourne. The tower has been accredited with a 6 Star Green Star Office Design v3 by the Green Building Council of Australia and is designed to be capable of achieving a 5.5 Star

RIGHT: Quay Quarter Tower replaced the AMP Centre on Sydney Harbour.

IMAGES: © 3XN; PHOTOGRAPHER ADAM MORK

QQT BY THE NUMBERS

Height 200 m
Floors 50
Retail podium 4000 m²
Usable area 102,000 m²
Embodied carbon savings 12,000 t
Existing structure 65% retained
Cost savings 20%

NABERS Office Base Building Energy Rating,

But it is not just its green credentials that have captured attention. Quay Quarter Tower was named World Building of the Year at the 2022 World Architecture Forum and was a national finalist in the 2022 Engineers Australia Excellence Awards, as well as being recognised by such industry groups as Urban Taskforce and the NSW Master Builders Association.

"THE BASIS OF THE SCHEME INVOLVED REMOVING THE NORTHERN PORTION OF THE EXISTING BUILDING UP TO THE EDGE OF THE EXISTING CORE, AND THEN EXTENDING NEW FLOOR PLATES TO THE NORTH."

CHANNELLING THE PAST

Bringing 21st century construction methods to a 1970s skyscraper is not a straightforward process.

To work with the structural elements they wanted to maintain, the engineers first had to dive into the past.

"We needed to understand the existing building," Reza Hassani, BG&E Seniors Associate, Structures, told *create*.

"We had a set of existing drawings, but they were design drawings – they weren't as-built drawings. First … we needed to verify the as-built condition of the structure and compare it to the existing drawings that we had."

That required gaining a full understanding of the building's geometry using 360-degree cameras to create a full-point cloud survey: the sizes of the columns, the thicknesses of the walls and slabs, whether certain features had been built as the plans showed or whether they were offset by even 100 mm.

"In terms of the materials, we needed to understand the strength of materials and also their durability," Hassani said, adding that the team took 1600 core samples of concrete from the building. "The other test you need to do is the durability test. Durability tests show how much concrete has degraded through time; usually it degrades because of a chloride diffusion.

"The chloride exists in the seawater, and because this structure is close to the harbour and seawater, the chloride degrades the quality of concrete. We tested that and we made sure that the structure will still be safe in another 50 years."

The team also tested for carbonation, Hassani said.

Adding to the challenge, the team needed to begin construction before the testing was complete. The engineers conducted their first tests at the concept stage 10 years ago and continued them until the project's completion. ▸

"You don't have the luxury of doing a full scheme test on the structure because the structure was under service when we started doing the concept design. The concept design of this structure started 10 years ago and the building was used by AMP – by lawyers and banks," he said. "Most of the testing was conducted after the building was evacuated in 2017. We had designed the structure; we needed to go and confirm. We tested some areas where the strength was better than our assumption, and some areas the strength was lower than our assumption. We had to redesign and recheck."

Saidman said much of Arup's work involved understanding the decisions various engineers made throughout the life of the building.

"For us, it was from a building services perspective and a façade perspective – so lots of time digging through drawings, crawling around site, and then understanding why did they arrange the composition of the building as they did," he said.

ABOVE (from top): Reza Hassani, BG&E; Robert Saidman, Arup.

IMAGE: © 3XN; PHOTOGRAHER ADAM MORK

"WE NEEDED TO VERIFY THE AS-BUILT CONDITION OF THE STRUCTURE AND COMPARE IT TO THE EXISTING DRAWINGS THAT WE HAD."

Arup Associate Principal Ryan Crabbe agreed.

"You do get into the head of the previous designers a bit," he said. "You unpick it and you can see why they made certain decisions and you can see how they augmented the design over time."

TURNING AROUND

The distinctive design of the building also offered challenges, from the use of inclined columns, which required the core to support additional horizontal forces, to the way that the tower's rotating form meant there was no such thing as a "typical" floor.

"It means that it's a lot of effort for the engineer and the design and construction team," Hassani said. "You can't replicate your design, for example, from level 21 to level 22, so that means a lot of effort. But what we've done with this building, we've modelled every piece of the structure and we've designed and analysed [them] as individual or independent elements ... We had to design every floor and every column and every wall as a different package."

BG&E also had to oversee the tower's cantilevered floors, which were designed to maximise floor space but also had to be built so as to not overshadow the nearby Royal Botanic Gardens.

"We had to build inclined columns and hanging columns to satisfy the architectural intention of the northwest corner of the building cantilevering out," Hassani said. "We built a temporary cantilevered platform, which was sitting on rails and on the level below, and there were construction workers pushing it out. It was a temporary construction platform so the construction team could stand on that platform and build the top floor."

The ingenuity extended to the tower's interior, too.

"We proposed a double deck lifting system with two lifts locked together, and that allowed passengers on consecutive floors to use the elevators simultaneously," Saidman said. "To achieve this required a split-lobby design approach with an upper and lower deck to allow simultaneous loading of two cars. What that achieved was that enabled the design team to save nine lift shafts compared to a traditional system, representing about 120 m^2 of space per floor."

That, Saidman said, was the world's first ever instance of a double-deck lifting system being retrofitted into a commercial building, and it permitted the team to reduce the size of the tower's core, adding to the embodied carbon savings.

CONCRETE SAVINGS

Although Quay Quarter Tower's embodied carbon savings – totalling 12,000 t – are impressive, they were not originally a priority for the engineers. At the time, they were thinking about the overall project feasibility that could be realised by reusing part of the structure.

"This was conceived back in 2011, and back then embodied carbon was not considered nearly as much as a design input as it is today," Saidman said. "The outcomes were fantastic, but as a design target, it wasn't established that we want to achieve specific kilograms of CO_2 per square metre for the building.

"But we are doing that now, so it would be interesting to see, would we have done some things differently and pushed the outcome even harder?"

When it comes to minimising carbon emissions, Hassani said, rule one is to retain as much of the structure as possible. But Quay Quarter Tower had additional sustainability approaches.

"We used the greenest possible concrete – the minimum embodied carbon," he said.

"We worked with concrete suppliers to come up, as much as possible, with a green structure. Also in the new structure, we used a lot of steel members – steel columns and steel beams – and steel is a much greener material compared to concrete, because steel is recyclable."

Efficiency in the building's services also added to its sustainability, as did the façade, which uses high-performance glazing and sunshades to deliver a 30 per cent reduction in solar radiation while still maintaining the building's stunning views of Sydney Harbour.

"The façade was a great success, generally, from an amenity and operational carbon perspective," Crabbe said. "A lot of work went into that shading and the horizontal and vertical form."

And the engineers took a "right-sizing" approach, which disavowed unnecessarily oversizing equipment.

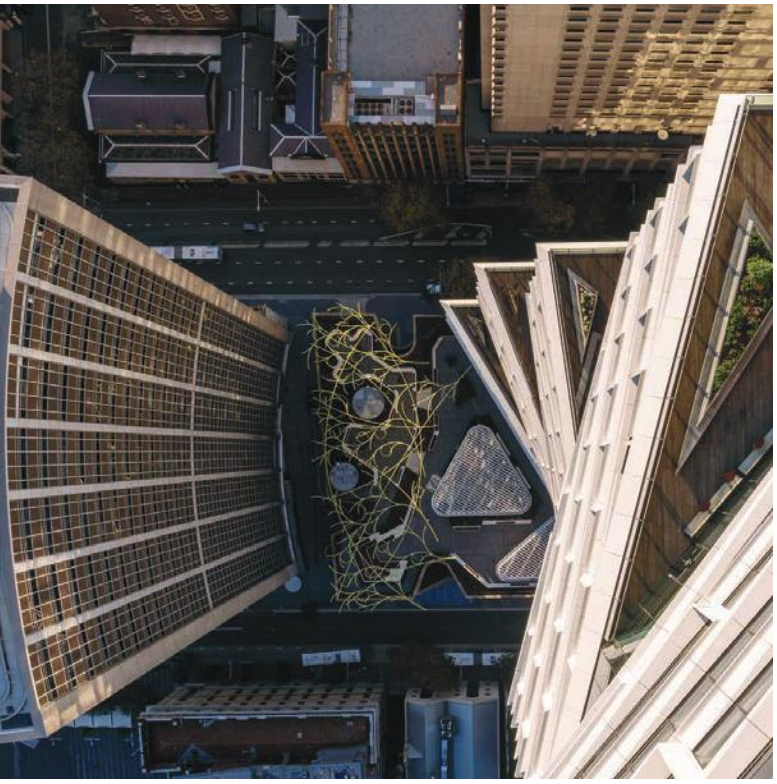
"Designing the façade loads down as much as we can to get better façade performance; the mechanical chilled beams that we've got around the perimeter are all smaller; the pipework going to them is smaller; the chillers and the equipment are all smaller," Saidman explained. "That's an embodied carbon benefit at the end of the day: just by designing efficiently you need less equipment to meet the capacity of the building."

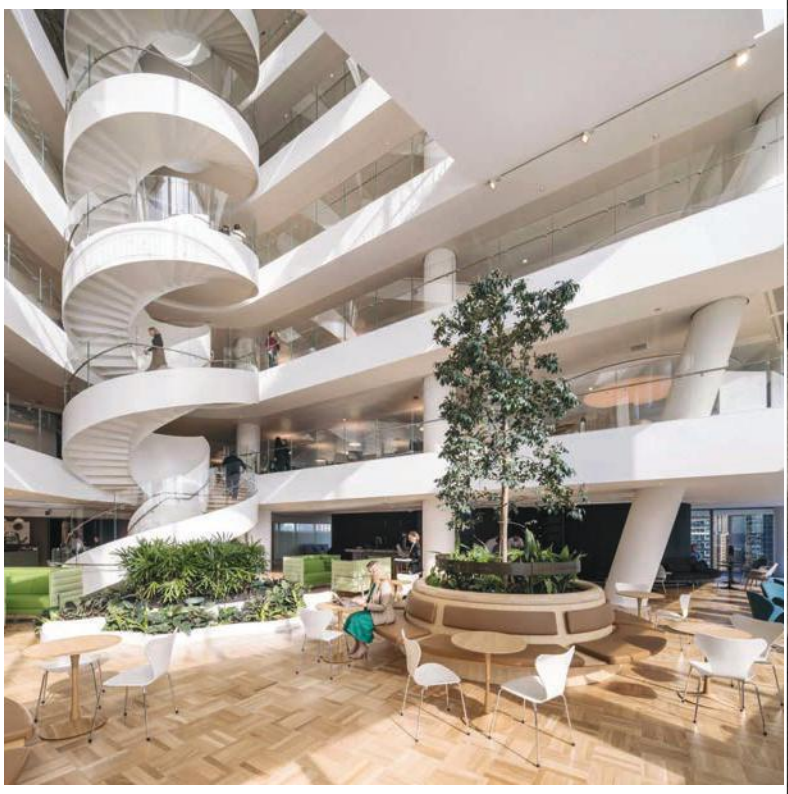
BELOW: Turning the old AMP Centre into the new Quay Quarter Tower.

BACK AND FORTH

Part of the success of the project, Hassani said, came from the highly detailed instrumentation dispersed throughout the building during its construction.

"BECAUSE THIS STRUCTURE IS CLOSE TO THE HARBOUR AND SEAWATER, THE CHLORIDE DEGRADES THE QUALITY OF CONCRETE. WE MADE SURE THAT THE STRUCTURE WILL STILL BE SAFE IN ANOTHER 50 YEARS."





"This was the first time engineers were designing such a thing," he said. "There hasn't been any tower upcycled with this extension at this height. We have the engineering principles, but this building is unique."

To ensure the real-life structure of concrete and steel matched the complicated models with which the engineers were working, BG&E sought data on everything it could.

"We were measuring the building inclination, building frequency, and we were calibrating our structural models on a weekly basis, making sure that our structural model was a good representative of site condition," Hassani said.

"Instrumentation is common for bridges and dams: they use it a lot because they are public assets and there are lots of factors you need to consider. With buildings, we don't do that much. We just do a few surveying measurements.

"But with this building, we had tilt sensors, accelerometers – for the safety of the structure and also for calibrating our structural analysis and making sure that our digital twin in our software was a good representative of the construction site."

"WE HAD TO DESIGN EVERY FLOOR AND EVERY COLUMN AND EVERY WALL AS A DIFFERENT PACKAGE."

This led to one particularly satisfying moment for Hassani.

Because Quay Quarter Tower was being demolished and rebuilt simultaneously, its centre of mass shifted over time – and the team estimated how significant this shift would be.

"When we demolished the building, the building moved to the south because the centre of mass was changing, and when we rebuilt it, the building started moving to the north," Hassani said. "After four years of construction and building – demolishing, building, demolishing, building – we measured … it was right on spot. It was plus or minus 20 mm." ●

TOP: Removing vertical columns permitted open space in the lobby. ABOVE: Frank Johnson, Engineering Heritage Sydney.

BETTER DESIGNS

Frank Johnson, Chair of Engineering Heritage Sydney, told *create* he admires the work on Quay Quarter Tower not because the original structure was a work of engineering heritage, but because the new skyscraper demonstrates what can be done with all older buildings.

"This is really where the ingenuity of the engineers comes through," he said.

"The design and construction were so well integrated. It's not like the designers handed over the plans, and then the constructors took over and went on their way. The designers obviously had a lot of involvement right through it."

It shows, he said, how engineers can approach other projects.

"There's pressure on from developers to create some new structure but can engineers provide alternatives?" he asked.

And how should engineers apply this approach to their own work?

"I think giving reuse high priority, rather than just rushing into demolish and rebuild — to think through the alternatives," Johnson said.

IMAGES: © 3XN; PHOTOGRAPHER ADAM MORK

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WORDS BY **MICHELLE WHEELER**

DRONE DELIVERY HAS BEEN CREDITED WITH SAVING HUNDREDS OF LIVES IN RURAL AFRICA. BUT WHETHER IT CAN OPERATE AS A LAST-MILE SOLUTION IN CITIES IS UP IN THE AIR.

READY TO DELIVER?

IN RWANDA, the little red boxes parachuting from drones carry life-saving blood to children with malaria. In Ghana, they signal the arrival of COVID-19 vaccines. In Japan, it's prescriptions for residents of the hard-to-reach Goto Islands.

For people in far-flung places, the buzz of a delivery drone can be the difference between life and death. But despite years of fanfare, drones are yet to take off for more mundane cargo in cities.

Will the technology used to fly medicine to remote hospitals in Africa ever make sense for everyday deliveries in Sydney?

For Rwandan women, having a baby is dangerous. Every birth in the African nation comes with a one in 400 chance of dying, making it six times riskier than base jumping.

One of the most common complications is severe bleeding after childbirth, or postpartum haemorrhage. It's a medical emergency that can be treated with blood transfusions – assuming you have the correct blood type on hand.

But with 82 per cent of the population living in rural areas and notoriously hilly terrain, new mothers die before the blood that could save them makes it to remote hospitals.

It's a picture drone delivery company Zipline hoped to improve when it started flying blood in Rwanda. The San Francisco startup currently delivers 75 per cent of the country's blood supply outside of the capital Kigali.

Doctors in rural hospitals can order blood by text or phone call, and the products they need are loaded into an autonomous drone. The drone flies the blood up to 100 km before parachuting it down to a landing zone about the size of two parking spaces.

Research published last year found Zipline's drones resulted in an 88 per cent reduction in deaths from postpartum haemorrhage in Rwanda. The study's "back of the envelope calculations" suggest they saved the lives of between 43 and 157 mothers each year.

A separate study in medical journal *The Lancet* found Zipline deliveries cut delivery times and reduced blood wastage in Rwanda by 67 per cent.

PICTURED: A Zipline drone makes a delivery.

DELIVERY DROIDS

What's less clear is whether drones have a place in cities, where the logistics can be infinitely more difficult and the package more mundane.

In March, Zipline unveiled a second-generation platform designed for home delivery in a dense city, suburban town or rural area. Instead of the parachutes used in Zipline's first-generation aircraft, the system features a "delivery droid" that lowers to the ground on a winch while the aircraft hovers above.

Both the drone and the droid are autonomous. The droid's side-to-side motion is controlled by small, integrated fans, meaning it can position itself precisely even in high winds.

The system can deposit packages in an area as small as a table.

Zipline said sending a meal with the platform uses 97 per cent fewer emissions than a petrol car, thanks to the drones being small, fully electric and able to fly directly to their destination.

And it said each drone is designed to fly further in its lifetime than an average car drives – more than 400,000 km.

The platform comes with a dock that typically attaches to the outside of a restaurant, healthcare centre, warehouse or other building.

The drone lands at the dock, and the droid lowers into a loading portal inside the building. Humans place a package inside the droid, which then returns to the drone for take-off.

Zipline's promotional material makes the process appear seamless. The company already sends a package every 90 seconds and, in February, hit half a million deliveries.

Still, it's unclear whether drone delivery is finally coming of age. Years of predictions that drones would take over the skies have failed to eventuate.

Amazon founder Jeff Bezos first unveiled plans to fly packages to customers almost a decade ago, and Prime Air completed its first delivery in 2016. But the company's long-awaited drone delivery service is reportedly expected to cost a whopping $63 per package in 2025.

Domino's made history with the world's first drone pizza delivery in 2016, but it then appeared to pause its drone delivery ambitions until last year.

CITY LIMITS

Professor Jonathan Roberts is the co-founder of the UAV Challenge, an international flying robot competition that sees teams use drones to search for a lost bushwalker in the outback.

He's wary of claims that drones will take over deliveries in our city centres.

"I actually don't think they'll be delivering in inner city areas," he said. "It just doesn't make any sense."

Roberts, an aerospace engineer and Professor of Robotics at Queensland University of Technology, said the challenges are more about practicality than the technology in the drone itself.

He believes that for drone transport to work in cities, it would need to be designed into the built environment. That might look like apartment blocks with a secure rooftop area for deliveries.

"It's very hard to retrofit this idea of flying things delivering stuff into existing buildings in the inner city," Roberts said.

Retrofitting buildings also hasn't happened for current deliveries by humans.

Roberts points to a recent trip to New York when he was regularly woken by Amazon delivery drivers. Many buzzed every apartment in his building until someone opened the shared front door.

"With humans on the street delivering, it's already completely ridiculous," Roberts said.

"So I can't understand how you could have drone delivery. That's even more ridiculous."

Where Roberts does see real application is in remote medicine. That's where the big advantage of ▸

RIGHT: Professor Jonathan Roberts, Queensland University of Technology.

EACH DRONE IS DESIGNED TO FLY FURTHER IN ITS LIFETIME THAN AN AVERAGE CAR DRIVES: MORE THAN 400,000 KM.

RIGHT: Competitors in the UAV Challenge.

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drone delivery – speed – comes into its own.

"It's quite clear that you could potentially get stuff much quicker than you would otherwise," Roberts said. "Which is why I've always thought it was a good idea for certain things. Very interestingly, you will see demonstrations of people getting food, coffee, and you start to question whether that's worth it."

Roberts envisages drones delivering life-saving treatments or collecting pathology samples from remote places such as islands.

"It seems pretty compelling," Roberts said. "I think the business case [for medicine] makes a lot of sense, because the outcomes are so important."

In Australia, only two companies have CASA approval for commercial drone deliveries: Wing Australia and Swoop Aero.

Google-backed Wing has polished promotional videos, matched by a slick app that customers can use to order smoothies, sushi and fried chicken.

When they arrive at their destination, Wing's drones convert from aeroplane to helicopter mode, hovering while they lower packages to the ground using a tether and hook system. It makes the drones more suitable for fragile cargo like coffee or eggs than the parachutes of early drone delivery systems.

Wing is also building a library of aircraft tailored for the delivery of different products.

The company has completed more than 300,000 deliveries worldwide.

Melbourne-based Swoop Aero, like Zipline, has focused instead on faster medical transport. The company has delivered vaccines, pathology samples and other medical supplies in Vanuatu, the Democratic Republic of Congo, Mozambique and Malawi.

Last year, Swoop Aero announced it would start shuttling samples from Queensland's Moreton Bay islands to pathology labs.

ABOVE: Wing Australia makes a delivery.

"THE BUSINESS CASE FOR MEDICINE MAKES A LOT OF SENSE, BECAUSE THE OUTCOMES ARE SO IMPORTANT."

The company said it will slash six hours off the time it takes vital blood tests and COVID-19 swabs to reach the lab for analysis.

Wing's drone delivery service has approval to operate in North Canberra and in Logan, between Brisbane and the Gold Coast.

Roberts said there's a reason why drone companies opt for trials on the urban fringes. He thinks it's the only place where everyday deliveries are realistic.

"There's actually a reasonable reason to use it, because you might live a long way from the shops," he said.

"And you've got space around you so that it makes the drone coming in and dropping stuff off easy."

Roberts said current drone delivery trials are just about demonstrating that the concept can work.

"Whether these things in a commercial sense actually stack up … I'm sceptical," he said.

DO LOOK DOWN

University of Technology Sydney computer scientist Professor Michael Blumenstein has spent years teaching AI algorithms to "see" the world from a drone.

He's one of the creators of SharkSpotter, a technology that can detect sharks and other marine life swimming off Australian beaches.

The platform uses the real-time feed from a high-resolution camera attached to a drone. The software ▸

processes the video stream and analyses it, looking for sharks in the ocean.

SharkSpotter is trained to recognise several objects, including 16 different types of marine life and humans, using deep learning. Blumenstein said the technology is given "supervised training", where researchers provide labelled samples to learn from.

But Blumenstein said identifying objects in a city is not like spotting them in the ocean.

"In an urban environment, delivery has got a lot of problems that you have to overcome that you don't have on an open beach," he said. "[The beach is an] open environment with lots of visibility in all directions – it's different."

In 2018, a Little Ripper drone used by the SharkSpotter team performed what is believed to be the world's first drone rescue.

The aircraft dropped an inflatable rescue pod beside two teenagers struggling in heavy surf.

But Blumenstein said adding a package for delivery is very tricky.

"The payload on any drone causes a different dynamic around its speed, navigation, its resistance to being affected by environmental conditions, wind and so forth," he said.

Still, Blumenstein said sending a rescue pod to swimmers was easy compared to the challenges of urban areas.

"When you're dropping it, you're dropping it in the ocean," he said. "It's not like you have to worry about how it's going to be delivered in a conventional sense."

Blumenstein said perishable food would need to be protected to prevent contamination. The payload would also need to be secured in a way that can't possibly detach.

"There needs to be a mechanism in place that assures people that what's going over their heads is going to stay there until the delivery point," he said.

The mosquito-like buzz of drones is also a big issue in urban areas. While Blumenstein said he's never had a complaint about the SharkSpotter drones, early Wing food delivery trials were derailed by noise complaints. (Zipline said its latest drones are "almost inaudible".)

LEFT: Michael Blumenstein, SharkSpotter (top); a Little Ripper drone of the type used in a SharkSpotter rescue effort.

FLIGHT LOG

ZIPLINE: PLATFORM 1
Speed: 97 km/h
Range (roundtrip): 200 km
Altitude: Cruising altitude of about 90 m, briefly lowering to 20-30 m as a package is released
Payload: 1.8 kg

ZIPLINE: PLATFORM 2
Speed: 112 km/h
Range (roundtrip): 38 km
Altitude: Cruising altitude of about 90 m, staying high while a delivery droid transports the package to the ground
Payload: 3.6 kg

WING AUSTRALIA
Speed: 104 km/h
Range (roundtrip): 20 km
Altitude: Cruising altitude of about 45 m, descending to 7 m for delivery
Payload: 1.2 kg

"IT'S VERY HARD TO RETROFIT THIS IDEA OF FLYING THINGS DELIVERING IN THE INNER CITY."

Blumenstein said progressing beyond the trial stage will bring even more challenges.

He believes we lack the infrastructure to support mass drone deliveries, and traffic management plans would be needed for drones the way they are for aircraft.

"That is a challenge, when you start getting busy skies and busy traffic," Blumenstein said.

"You've got to worry about collisions, you've got to worry about scheduling, you've got to worry about the safety of individuals. There's a lot more to it."

Roberts maintains that drone delivery will be great, but it won't work for everything.

"People get excited by all this stuff, but it's just going to be a niche thing, I think," he said. ●

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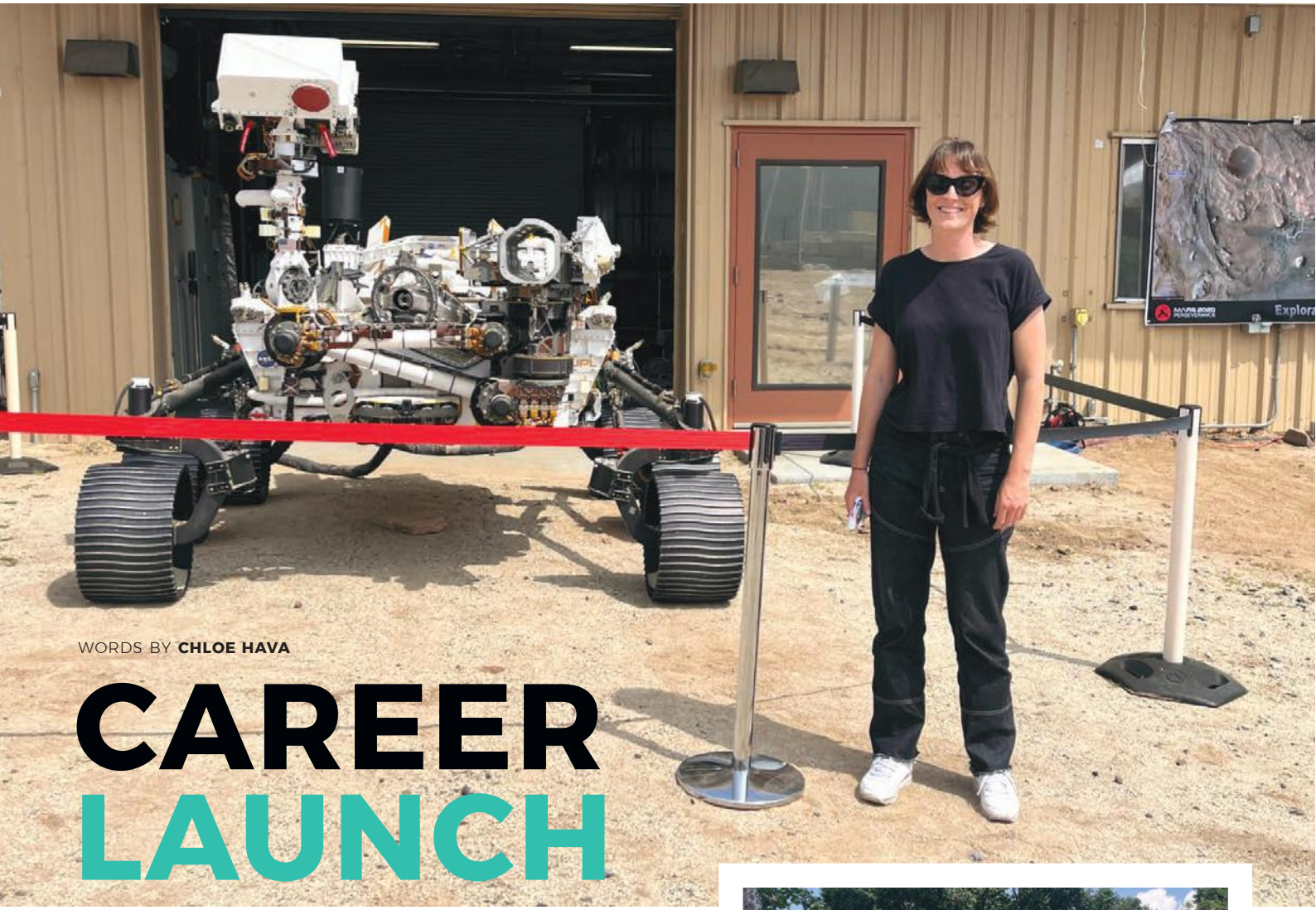

WORDS BY **CHLOE HAVA**

CAREER LAUNCH

AN AUSTRALIAN PHD STUDENT SPECIALISING IN SATELLITES IS LIVING EVERY YOUNG AEROSPACE ENGINEER'S DREAM.

IN EARLY March, University of Sydney student Anne Bettens arrived at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California to begin a prestigious 10-week internship, sponsored by Australian space research centre SmartSat CRC.

One of only two Australian PhD students chosen to partake in the program, Bettens's research focuses on vision-based navigation for space exploration – leveraging trained machine learning algorithms for a more accurate estimation of space situational awareness.

"One of the main things I do is look at satellites that are in close proximity to one another to estimate the position and orientation," she said.

"That's quite useful for space debris removal or if the satellites come together to do repairs on each other."

But the work she's doing at NASA tackles a different terrain.

"This work involves vision-based navigation, but for a lunar rover that will hopefully be on the moon's surface someday," she said. "I'm [also] looking forward to becoming more familiar with the artificial intelligence and machine learning technologies being developed by JPL for planetary exploration."

ABOVE: The University of Sydney's Anne Bettens at NASA's California Jet Propulsion Laboratory.

FOCUS SHIFT

A lunar rover is a new type of robotic spacecraft to which Bettens, a satellite specialist, has had to adjust.

"They behave a little bit differently and you have to account for different things," she said. "For example, lunar rovers have to navigate around craters, whereas satellites approach each other and can move in any direction without a flat surface to move on."

As part of JPL's robotic perception group, Bettens's research experience led her to a subset of the team that looks at vision localisation on the moon.

"My team looks at the moon in darkness," she said.

"For example, when [the rover] navigates at night or on the dark side of the moon, that presents a whole other set of challenges."

NASA's focus on sustainable space exploration is also of particular interest to Bettens, who is a keen environmentalist.

"There's a lot of policy and procedure around making sure what we send into space is sustainable," she said.

"For example, a rover landing on the moon needs to be clean and sterile, without contributing to the space debris problem."

The benefits are twofold, with JPL's Earth-observation technology capable of providing data on weather monitoring, allowing development of more sustainable solutions on Earth.

"Being ethical as an engineer is very important to me," Bettens added.

While the program is technically a mentorship, Bettens has freer reign as a PhD student who "understands how to conduct research".

"JPL is halfway between industry and academia," she said.

"As a PhD student, my work is predominantly done on my own, so it's good to be able to work in a team, learn from them and pick up on things I normally wouldn't get the opportunity to, while validating my own research."

BROWSING NASA

As a curious aerospace engineer, Bettens has her eye on some other cutting-edge robotics projects, including the engineering twin of the Mars 2020 Perseverance Rover, which is currently exploring the planet looking for signs of past microbial life.

"The cool thing about the Perseverance mission is that it has the Mars helicopter, Ingenuity, on board which is pretty impressive from an engineering perspective," she said.

"I also recently got to see a demo for the EELS project – an autonomous snake-like robot – which is pretty sci-fi."

The self-propelled Exobiology Extant Life Surveyor, designed to slink around hard-to-reach terrain such as the ocean beneath the surface of Saturn's icy moon, Enceladus, has been tested at JPL's Mars Yard and the snowy Southern California mountains.

But no placement at NASA would be complete without watching a rocket launch or two.

"Being a little nerd, one really cool thing for me was seeing JPL's Mission Control Operations Center, which is where all the satellites and missions exploring planets are all controlled from in one room," Bettens said.

"LUNAR ROVERS HAVE TO NAVIGATE AROUND CRATERS, WHEREAS SATELLITES APPROACH EACH OTHER AND CAN MOVE IN ANY DIRECTION WITHOUT A FLAT SURFACE TO MOVE ON."

ABOVE: California landscape photograph by Anne Bettens.

Picture of success

University of Sydney PhD student Anne Bettens is also an avid photographer.

Aside from navigating lunar landscapes with NASA's Jet Propulsion Laboratory, she has also taken the opportunity to explore California's unique landscape.

"Because there's been so much rain, we had a superbloom this year, so I got to go out and take some photographs of wildflowers," she said.

A stargazing trip to Joshua Tree in the Mojave Desert is next on the cards for this space enthusiast.

"It will be nice to get out of the pollution in LA and see the stars," she added.

FUTURE OUTLOOK

Post-internship, Bettens plans to stay on at JPL until the end of September to soak up as much invaluable information as possible, while developing her own fledgling space mobility start-up, Deneb Space.

"We're aiming to develop an autopilot in space to increase the agility of satellites so we can observe Earth more accurately and get better, higher resolution images," she said.

"Some of the technology we're developing will also hopefully extend the life of robots, which will lead to less debris up there." ●

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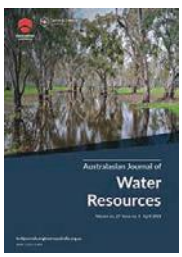


CHARACTERISING WATER SENSITIVE CITIES THROUGH INQUIRY-BASED LEARNING SYSTEMS

Journal: *Australasian Journal of Water Resources*
Authors: M.R. Shelton, J.J. Bos, K.B. Collins, R.L. Ison & B.L. Iaquinto

—

Transitioning to water-sensitive cities in Australia is necessary for creating urban areas that are resilient to natural disasters, water shortages and climate change. This paper reports research to enable systemic-transformations praxis, enhancing institutional innovation and investment and offers insights into future research and planning for enabling systemic-transformations praxis in multiple sectors and contexts.

EFFECT OF ASPECT RATIO ON THE RECIRCULATION REGION OF 35° AHMED BODY

Journal: *Australian Journal of Mechanical Engineering*
Authors: N.A. Siddiqui & M. Agelin-Chaab

—

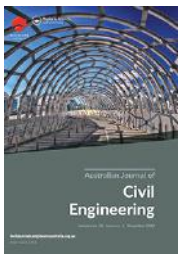
This paper reports a numerical investigation of the effect of aspect ratio on the flow structure around the 35° Ahmed body, a simplified vehicle model. The analysis reveals that early flow separation in the AR1 causes a reattachment at the rear slant end, which leads to an increase in drag.

EXAMPLES OF PERFORMANCE REQUIREMENT DERIVATION THROUGH MODELLING AND SIMULATION IN COMPLEX PROJECTS

Journal: *Australian Journal of Multi-Disciplinary Engineering*
Authors: G. De Visser & S. Knight

—

As complexity increases in modern systems development, performance requirement derivation in defence materiel acquisition projects continues to present challenges. This work describes two such examples of operational analysis modelling and simulation used in a recent project for the derivation of system performance requirements and the facilitation of trade studies and design negotiations.



Effect of elevated temperature on the calcined clay-limestone and marble stone blended cement concrete

Journal: *Australian Journal of Civil Engineering*
Authors: S.M. Gunjal & B. Kondraivendhan

The impact of high temperatures on calcined clay-limestone cement concrete (LC^3) and calcined clay-marble stone cement concrete (MC^3) is studied in this paper. M25 and M35 grades of concrete were prepared using LC^3 and MC^3 cement and ordinary Portland cement (OPC), which were then subjected to 100˚C, 200˚C, 400˚C, 600˚C and 800˚C temperatures. The result shows that when the temperature exceeds 400˚C, the mass loss in OPC was more than LC^3 and MC^3 concrete.

BELOW RIGHT: Cracks occurred in M25 OPC, LC^3 and MC^3 concrete specimens.

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11-13 JUL 2023
INTERNATIONAL CONFERENCE ON BULK MATERIALS STORAGE, HANDLING AND TRANSPORTATION

Location: in-person *Wollongong*
Website: *icbmh2023.com.au*
This conference will provide an excellent forum for practitioners, researchers and designers to come together to review and exchange ideas and experiences in established, new and emerging technologies for bulk materials.
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15-18 AUG 2023
AUSTRALASIAN COASTS AND PORTS

Location: in-person *Sunshine Coast*
Website: *coastsandports2023.com.au*
The theme, "Working together: 50 years of coasts and ports", will bring together professionals to focus on the technological, scientific, policy, planning and design issues related to our diverse and developing coasts.
Register now

07-08 SEP 2023
RISK ENGINEERING CONFERENCE 2023 (RISK 2023)

Location: in-person *Brisbane*
Website: *engineersaustralia.org.au/risk2023*
RISK 2023 will feature an exciting line-up of expert speakers exploring "Risk engineering for a resilient 2030". Join your colleagues from a wide range of engineering professions and disciplines practising engineering-related risk management, risk analysis and risk-based decision-making.
Early-bird registrations close 10 July 2023.

11-13 OCT 2023
SEVENTH WORLD ENGINEERS CONVENTION

Location: in-person *Prague, Czech Republic*
Website: *wec2023.com*
The global engineering community will reunite to explore the breakthrough technologies and capacity development focused on the United Nations Sustainable Development Goals.
Early-bird registrations close 15 July 2023

12-15 NOV 2023
HYDROLOGY AND WATER RESOURCES SYMPOSIUM 2023

Location: in-person *Sydney*
Website: *engineersaustralia.org.au/hwrs2023*
Innovation, collaboration and engineering excellence come together for HWRS 2023, with this year's theme "Living with extremes". Topics cover the spectrum of engineering hydrology and the progress made in understanding the uncertainties facing water resources managers now and in coming decades.
Early-bird registrations close 31 August 2023

07-09 FEB 2024
11TH AUSTRALASIAN CONGRESS ON APPLIED MECHANICS (ACAM 2024)

Location: in-person *Brisbane*
Website: *engineersaustralia.org.au/acam2024*
ACAM 2024 aims to bring together engineers, academics, postgraduate scholars and industry managers to share research and development in all aspects of applied mechanics for a resilient and sustainable future.
Abstracts close 11 August 2023

29-30 NOV 2023

Climate Smart Engineering Conference 2023

Location: in-person *Melbourne*
Website: *engineersaustralia.org.au/cse*

This November, the profession reunites to accelerate Australia's transition to net-zero emissions. Join us at the must-attend sustainability conference of 2023. CSE23 will feature an exciting line-up of plenary and technical speakers. Book early to secure your seat and save with early bird and group registration.
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LOCAL WINNERS ANNOUNCEMENT

4–8 September 2023

Location: various locations
Website: *engineersaustralia.org.au*
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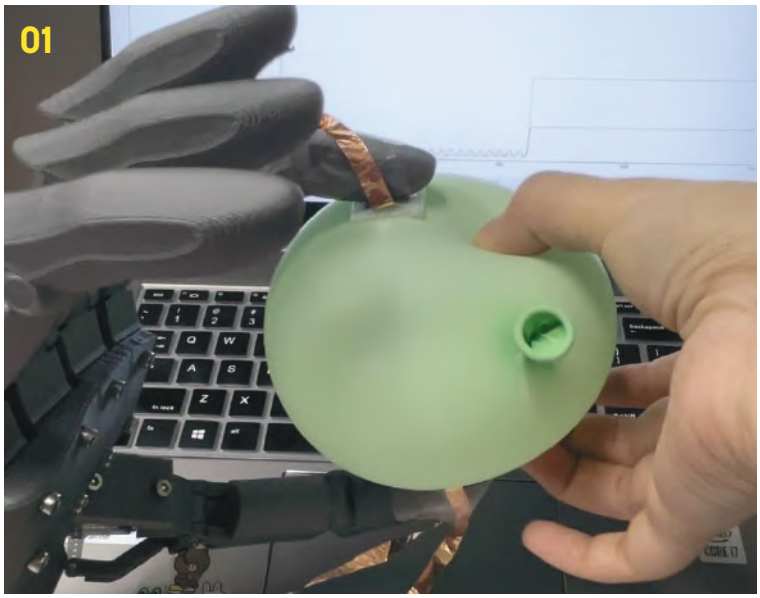
THE LATEST DEVELOPMENTS FROM AROUND THE WORLD.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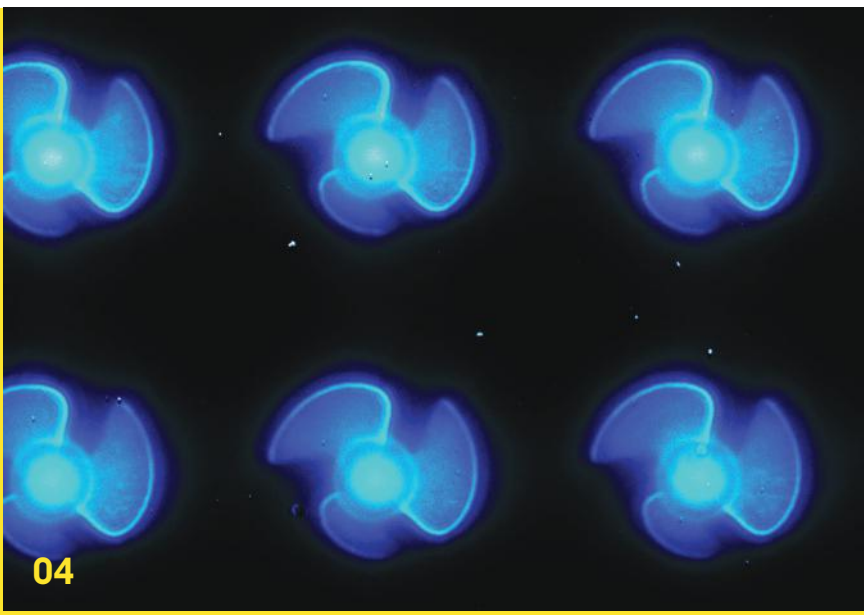
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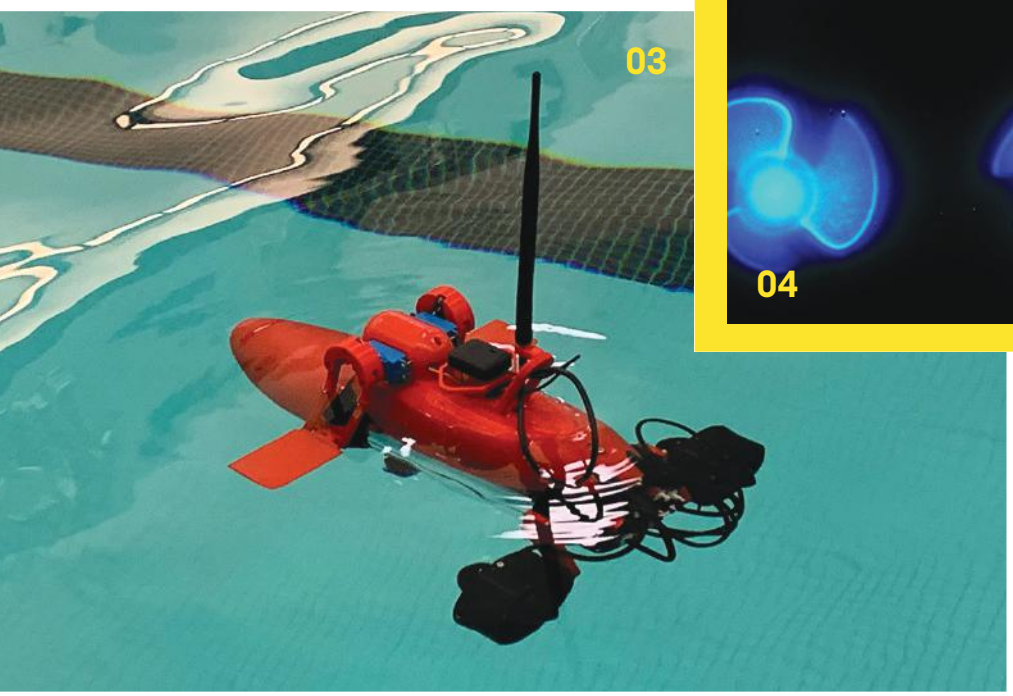
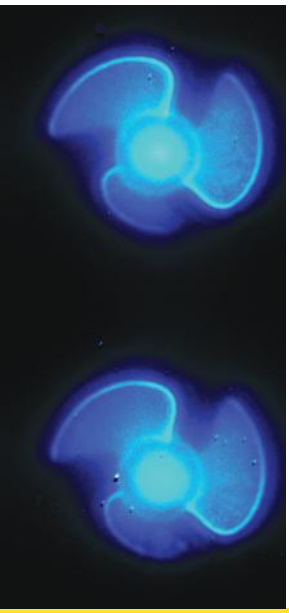

03

01

Inhuman touch

A robot hand tests this ultrasensitive sensor against a balloon.
Image: Cheng Group

Researchers at Penn State University in the US and Hebei University of Technology in China have developed a sensor that is highly sensitive to changes in pressure, responding in a manner similar to human touch. This makes it suitable for such purposes as operating robotic limbs or detecting subtle pulses, as well as determining subtle changes in weight. The sensor uses microstructure patterns that increase its linear range, making it flexible enough so that its sensitivity does not decrease when the pressure it measures increases. The sensor itself is formed from micro-pyramidal structures with an ultrathin ionic layer. "The sensor can detect a tiny pressure when large pressure is already applied," said Penn State Professor of Engineering Science Huanyu "Larry" Cheng. "An analogy I like to use is it's like detecting a fly on top of an elephant. It can measure the slightest change in pressure, just like our skin does with touch."



02

Augmented reality

This 3D-printed AR screen is flexible and transparent.
Image: Cesar Nicholas

A University of Melbourne team has led the creation of a flexible, transparent augmented reality display screen. A world first, the screen is created using low-cost materials and 3D printing and can be bent and curved to fit uneven surfaces and unusual shapes, offering flexibility in how it can be integrated into potential products. Because the screen is transparent, it allows digital content to be overlayed on a natural and unrestricted view of the world. "In the gaming industry, flexible and transparent AR displays could be integrated into gaming accessories such as goggles or visors, providing a more immersive and realistic gaming experience," said Associate Professor Ranjith Unnithan. "In education, AR displays could be incorporated into educational tools and simulations, allowing for interactive and engaging learning experiences. In healthcare, AR displays could be used in medical training, assisting surgeons with real-time information during operations, but there are many other potential applications, from transport to tourism."

03

Semi-submersible craft

The WSU craft demonstrates the most efficient way for a watercraft to travel.
Image: Washington State University

Engineers from the US's Washington State University (WSU) have created a semi-submersible craft to demonstrate the most effective way to travel through water. Sailing at the water line, the unmanned craft does not need to withstand the high pressures a submarine experiences and is able to transmit data via a small platform exposed to the atmosphere. "A semi-submersible vehicle is relatively inexpensive to build, difficult to detect, and it can go across oceans," said Professor Konstantin Matveev. "It's not so susceptible to waves in comparison to surface ships since most of the body is underwater, so there are some economic advantages as well." The WSU craft is built from 3D-printed and off-the-shelf parts, is 450 mm long and can travel at 1.5 metres per second, but could be scaled up for more sophisticated uses. At lower speeds, it barely breaks the surface, but since it experiences less drag in the water, it can operate more economically.

04

Medical microrobot

Air bubbles in these tiny robots could be used to propel them through the human body.
Image: Shields Lab

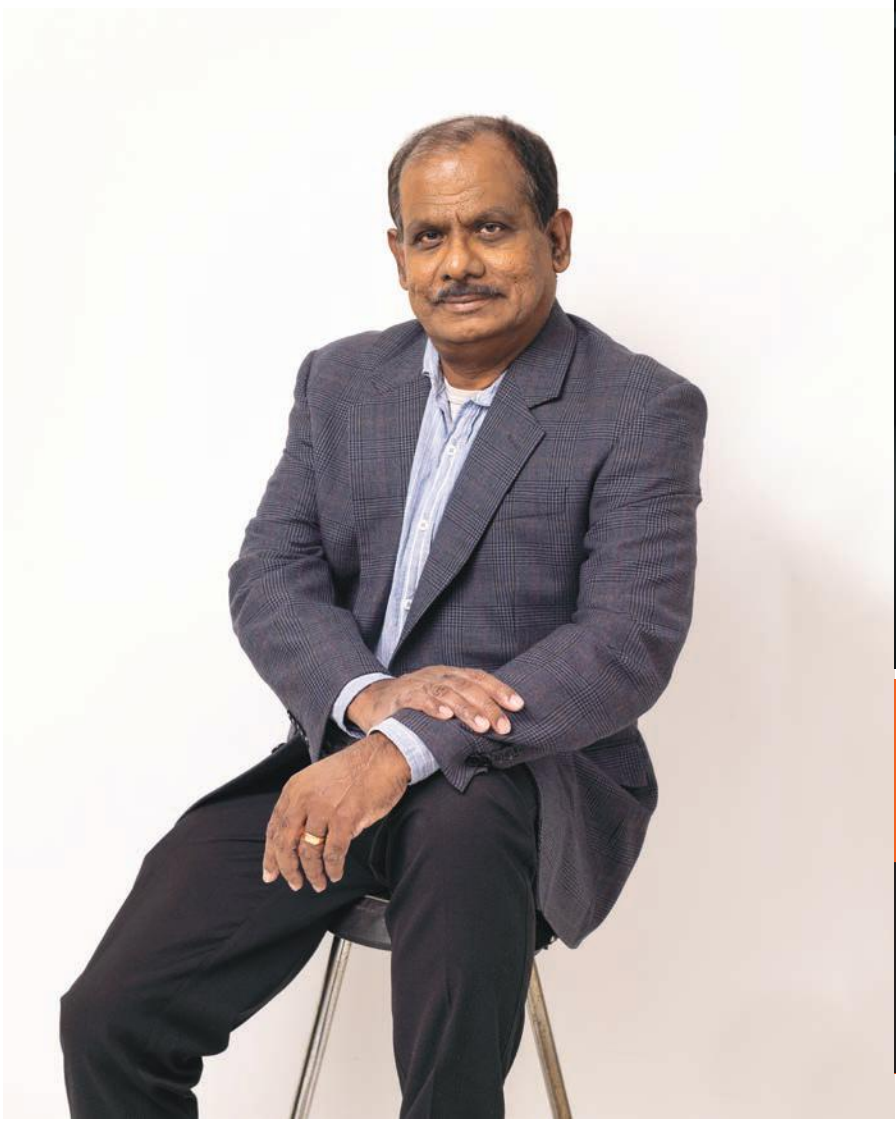
Engineers at the US's University of Colorado Boulder have created a tiny, self-propelled robot that could be one day used to deliver medication to locations in the human body. Travelling at about three millimetres per second and, at 20 µm, smaller than the width of a human hair, the robots were tested by having them deliver a steroid named dexamethasone to the bladders of lab mice. "Imagine if microrobots could perform certain tasks in the body, such as non-invasive surgeries," said Dr Jin Lee. "Instead of cutting into the patient, we can simply introduce the robots to the body through a pill or an injection, and they would perform the procedure themselves." Made from biocompatible polymer materials and designed with fins, the robots are propelled with the help of a trapped air bubble inside them; when exposed to an acoustic field, the air in the bubbles begins to vibrate.

ENGINEERS AT THE PINNACLE OF THE PROFESSION

Jude Nirmalaraja

CPEng, Senior Stormwater Engineer
City of Onkaparinga

FOR JUDE NIRMALARAJA, ENGINEERING IS ABOUT MORE THAN FIGURES AND CALCULATIONS. HE USES HIS TALENTS TO BETTER THE WORLD AROUND HIM.



GROWING UP, Jude Nirmalaraja had a talent for science and mathematics.

That's not why he became an engineer, though.

It was his desire to contribute to his community and to help the people around him that truly inspired his career.

Today he is a senior stormwater engineer with South Australia's Onkaparinga Council.

"As a civil engineer, I worked in different sectors, but then I found that water is an essential component of the community," he tells *create*.

"Engineering practitioners use our knowledge and skill for the benefit of the community and to create engineering solutions for a sustainable future.

"On a regular basis we meet with community stakeholders and engage in problem-solving of the issues they have … these are things I am passionate about."

The role also involves applying his expertise in water-sensitive urban design and integrated water management to deliver solutions for managing urban water.

Among his accomplishments at the council were helping to formalise and communicate guidelines for stormwater and water resources.

He is also proud of steering local stormwater harvesting and reuse processes.

"[This ensured] water quality by constructing a bio-filtration system and permeable pavers for a stormwater harvesting and reuse scheme," he explained.

He subsequently brought this expertise to Stormwater South Australia, on which he is a committee member.

"I am really passionate about water resources as part of my job; it's really challenging and it's something you deliver to the community."

Nirmalaraja's enthusiasm for and contribution to the community in which he lives has now been recognised by the South Australian Institute of Public Works Engineering Australasia, which this past December presented him with its Public Works Engineering Professional of the Year award.

It was also his desire to support the needs of the local community through his work in local government that inspired Nirmalaraja to become a Chartered engineer.

"It gives an assurance of practising competency," he said. "When you are dealing with the community in the engineering sector, you have that [Chartered] brand — that knowledge, that experience, that leadership … that gives you more opportunity to get involved in major projects or major initiatives." ●

04 TIPS FOR SUCCESS

1 Have a solid understanding of your plans for the future.

2 Focus on continuing professional development that complements your interests.

3 Work with groups like Engineers Australia to improve your opportunity to develop leadership abilities in your sector.

4 Share your skills and knowledge with young graduate engineers

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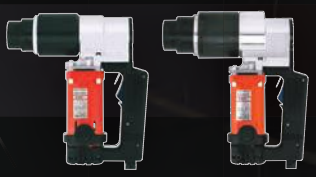

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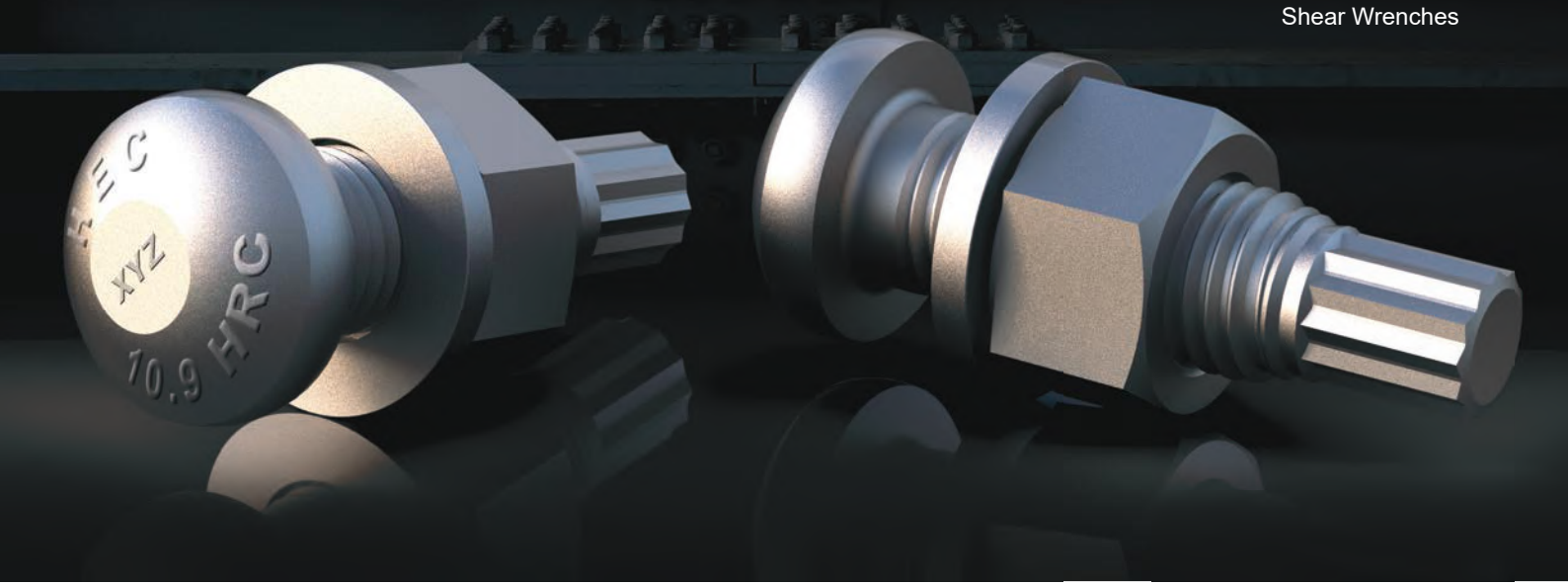

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