

› **Who built** the Sydney Harbour Bridge?

› **How did** they pipe water from Perth to the goldfields?

› **Was the** world's first 'computer' really an Australian invention?

› **When, and how,** did our skies become so much safer?

Behind every engineering achievement first lay a vision, if not a dream, to improve the society in which we live. Many of those ideas were created by engineers; almost without exception they were planned and executed by one. This book celebrates the men and women who blended that innovation, expertise and toil to shape a nation.

Some are unknown, such as the earliest indigenous pioneers who built fish traps and constructed weapons using the land before them. Others are household names, giants of their profession like J J C Bradfield, Sir William Hudson, or Sir John Monash.

There are pioneering engineers of contemporary times, be it Colin Austin's software, John O'Sullivan's WIFI, or Marita Cheng's life-changing robotics, who developed world renown through their ingenuity.

And there are industry leaders, figures such as Sir Rod Eddington or Kathryn Fagg, who used the foundation of engineering to build highly respected careers in business.

To celebrate its centenary year in 2019, Engineers Australia has chosen 100 significant engineers who typify the impact and influence of their vocation.

These are their stories.

ENGINEERS AUSTRALIA

CELEBRATING OUR CENTENARY

100

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Anything is possible



ENGINEERS AUSTRALIA

CELEBRATING OUR CENTENARY

Australian engineering leaders

Anything is possible

100 | Australian engineering leaders

ENGINEERS AUSTRALIA

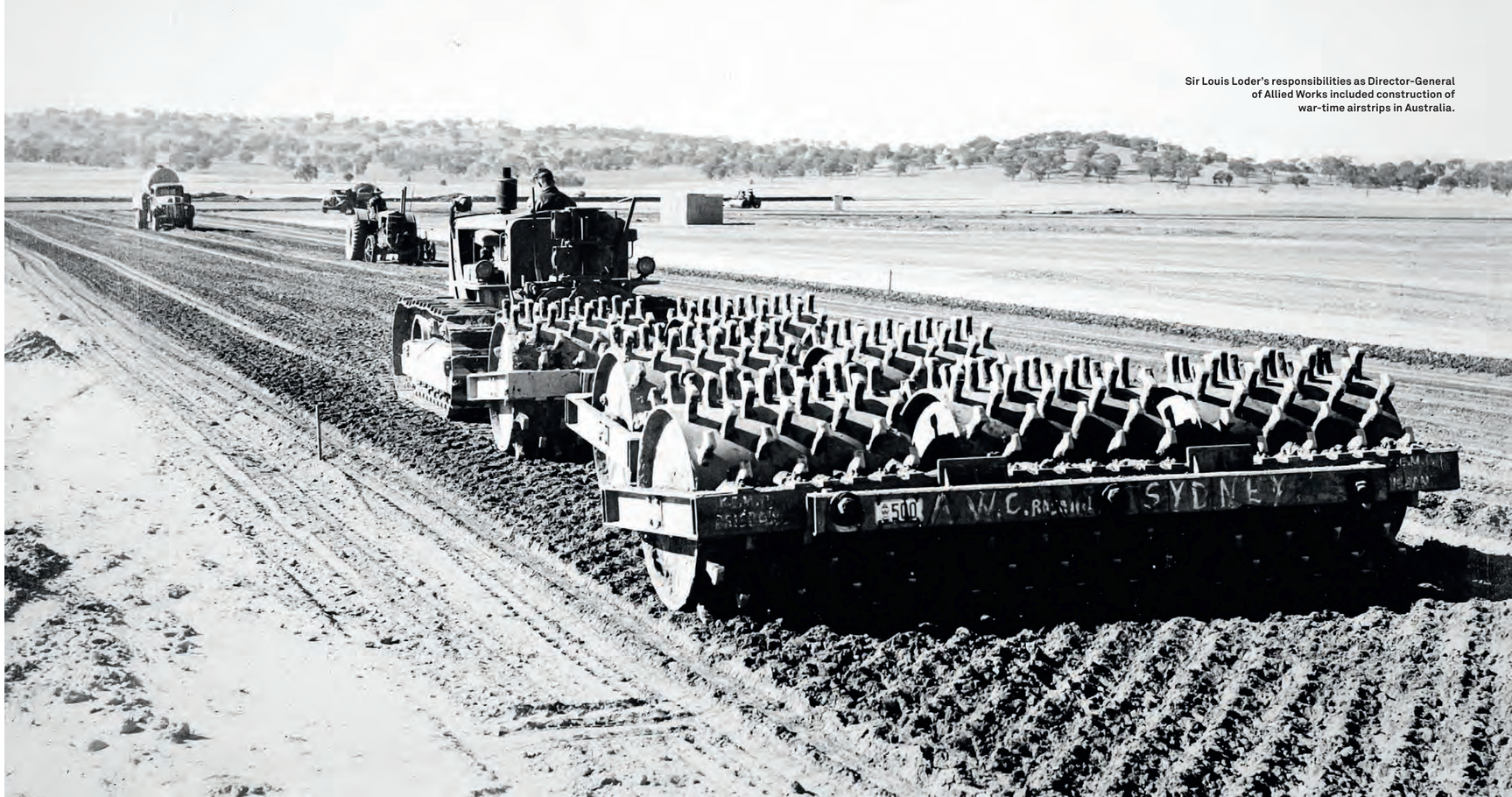
100 CELEBRATING OUR CENTENARY

The Institution of Engineers Australia t/as Engineers Australia
Engineering House
11 National Circuit, Barton, ACT 2600
www.engineersaustralia.org.au

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Sir Louis Loder's responsibilities as Director-General of Allied Works included construction of war-time airstrips in Australia.

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EVERY ENGINEER 126

A look at the motivation, inspiration and characteristics of the engineers who grace the pages of this book.



In February 1922, Keith Fraser was appointed as one of two Resident Engineers on the massive Sydney City Railway project. Four years later, as pictured, St James Station was one of the first two stations opened.



The Lennox Bridge in Glenbrook, NSW, stands as testament to the engineering excellence of David Lennox. A stone arch bridge standing nine metres above water level, Lennox completed the structure in 1833.

FOREWORD

In considering Australia today – where we have come from and where we might be in a generation – it is impossible to overstate the impact engineers have made and continue to make.

The very things that make Australia unique – including (but not limited to) the vast distances our continent spans, our harsh climate and the deposits of natural resources located in remote areas – have created both challenges and opportunities.

How we have overcome the challenges and capitalised on those opportunities is, in many ways, a tale of engineering.

And it is a tale of the engineers who have, quite literally, built our nation and shaped our society.

The ability of engineers to see challenges as problems to be solved rather than insurmountable barriers has turned ideas into real solutions for the Australian people.

For individuals, this problem-solving ability has unlocked interesting and rewarding careers. On projects, it has been the difference between faltering at the first hurdle and ultimate success. And, as a nation, it has connected us socially and economically, powered our homes and streets and positioned us to take on the world.

This book tells the story of some of those engineers.

As we look to the future and consider challenges not yet known and opportunities not yet dreamed of, this past success should give us enormous hope and optimism. The next generation truly stands on the shoulders of giants that have come before them.



General David Hurley AC DSC FTSE
Governor-General of Australia

PREFACE

This book has been prepared for the centenary of Engineers Australia, as companion to ***Wonders Never Cease***. The first book celebrates amazing Australian engineering projects and achievements, while this companion volume celebrates individual engineers making a difference in Australia. It does not attempt the impossible task of selecting the best or most influential engineers over more than 200 years, but provides a wide range of noteworthy engineers who have lived or are living in Australia and shown leadership during times of challenging technological and social change. In some cases a representative had to be chosen as there were engineers who performed similar roles in different states.

The engineers have included the original Australians before European settlement, the early colonial engineers bringing British skills and techniques, to be supplemented over time by immigrants from elsewhere, and the development of engineering concepts and expertise within Australia.

The early requirements of settlement for water and transport in an isolated continent led to the development of manufacturing and utilization of the natural resources and the broadening of infrastructure for an expanding population.

Technological change led to the strengthened education of engineers and the expansion of disciplines from civil and mechanical engineering to the demand for mining, metallurgical and electrical engineers.

The intervention of war brought out the technical and managerial skills inherent in engineering training that were utilised by Australia and the empire overseas. War also focused industrial production on material supply and on secure and expanded infrastructure on the home front.

Peace brought a substantial expansion in national development with more diverse immigration of both skilled engineers and refugees who were prepared to work and learn in a new country. It also heralded a shift from emphasis on government doing things to a breadth of consulting engineers and engineering contractors who could lend their skills to government and private enterprise development projects.

The recognition of engineering leadership occurred spontaneously through promotion to senior management within mining and manufacturing organisations and some government instrumentalities, but engineers also reached the highest levels of management and leadership in less expected places.

From the late 20th century, technological change was accompanied by profound social change as engineering and science became more enmeshed in communications, information technology, biomedical technology and robotics. Social aspects included a growing awareness of the environment and climate change and the role and influence of women in society. The engineering profession which previously was almost exclusively male has embraced these changes in both the growth of membership and in its leadership.

As trade and communications have become generally more international, the profession has kept pace through the export of engineering skills, products and education, as well as the internationalisation of consulting and contracting services and associated international recognition.

In all of this there are increasing opportunities for anyone with an aptitude for STEM subjects at school to gain the qualifications to become a member of the engineering team in the traditional areas of engineering or in the ever expanding and diverse fields in which engineers in Australia are engaged and exercising leadership.

FROM THE PRESIDENT
ENGINEERS AUSTRALIA

Engineers touch almost every aspect of modern life, making the seemingly impossible become a reality.

Each of Engineers Australia's 100,000 members can be proud of our profession and the value we bring to our communities. However, we tend to be quiet achievers, content in the legacy of our work and quick to acknowledge the role of the team over the individual.

To celebrate Engineers Australia's Centenary, this book showcases 100 individual engineers, past and present, who have made a difference. Some, like Sir John Monash, are celebrated names but most are little known.

Deciding which 100 engineers to feature must have been a challenging task, and I thank the volunteers from our group Engineering Heritage Australia for settling on a terrific series of people who contributed in a range of ways.

Humanitarian contributions include that of Louis Challis, who invented audible-tactile pedestrian crossing signals to help people with sight impairment but refused to patent them so they could be generally available at the lowest possible cost.

Graeme Jameson AO's 'Jameson Cell' froth floatation mineral separation device has netted Australia billions in mineral export revenue, and contributed to the environment via reduced energy use in mineral extraction, removal of blue-green algae from waterways and clean-up of industrial wastewater.

Many of those featured contributed across a range of areas. Take Marita Cheng, for example: she is behind a mobile phone App to help blind people recognise objects in real time that has been downloaded over 500,000 times in 23 languages. Her Teleport robots enable people to interact remotely, so children with cancer can 'attend' school from hospital and socialise with friends, the ill and immobile can 'join' family members at events, and security guards can remotely scout potential incidents without physical risk. She also founded Robogals Global, which has taught robotics to over 100,000 girls around the world.

Reading about the engineers and their achievements makes me proud to be an engineer, and proud to lead Engineers Australia.

I hope that this book serves as a tribute to the engineers featured, and to the profession generally, and as an inspiration to the engineers of today and tomorrow to achieve even greater heights.



The Hon. Trish White
National President and Board Chair,
Engineers Australia



One of the pride of Robert Clifford's InCat fleet, the 100 m Saint John Paul II, ventures between Malta and Sicily, a superb example of the evolution of Clifford's global business.

ACKNOWLEDGEMENTS

From the start this book was to be a companion to Wonders Never Cease, which was recognised as magnificent record of the achievements of Australia's engineers. It also helped identify that something was missing – the stories of the engineers who were responsible for so many significant Australian achievements.

In November 2018, Peter McIntyre, the CEO Engineers Australia, authorised the publication of a companion book to be available in November 2019 at the culmination of Engineers Australia's centenary year; 12 months from start to finish! Engineering Heritage Australia accepted the challenge and set to work.

Thankfully, we were able to draw on the experienced team from Wonders Never Cease and a number of new contributors who were able to provide special skills and fresh enthusiasm.

A new committee was formed with Owen Peake, Bruce Cole, Grant Watt and Neil Hogg, from the Wonders Never Cease team, joined by Keith Baker, himself an experienced author. The team immediately started work by calling for nominations from the nationwide Engineering Heritage Australia cohort and across the entire Engineers Australia membership.

More than 200 nominations (accompanied by supporting documentation) were received and all were evaluated by the committee according to defined criteria to arrive at the final 100.

In order to source an independent assessment of our decisions, the services of four engineers – each eminent in their own right – were engaged to provide an independent review of the stories selected for inclusion in the book. I would like to thank James Hood, Doug Hargreaves, John McIntosh and David Cruikshanks-Boyd for undertaking this role so diligently and enthusiastically, conducting their own research and making a number of valuable recommendations.

We were fortunate to be able to call again upon James Weston and Paul Marcolin, and later Steve Randles, from Spike Creative to present the biographies in a striking and accessible form.

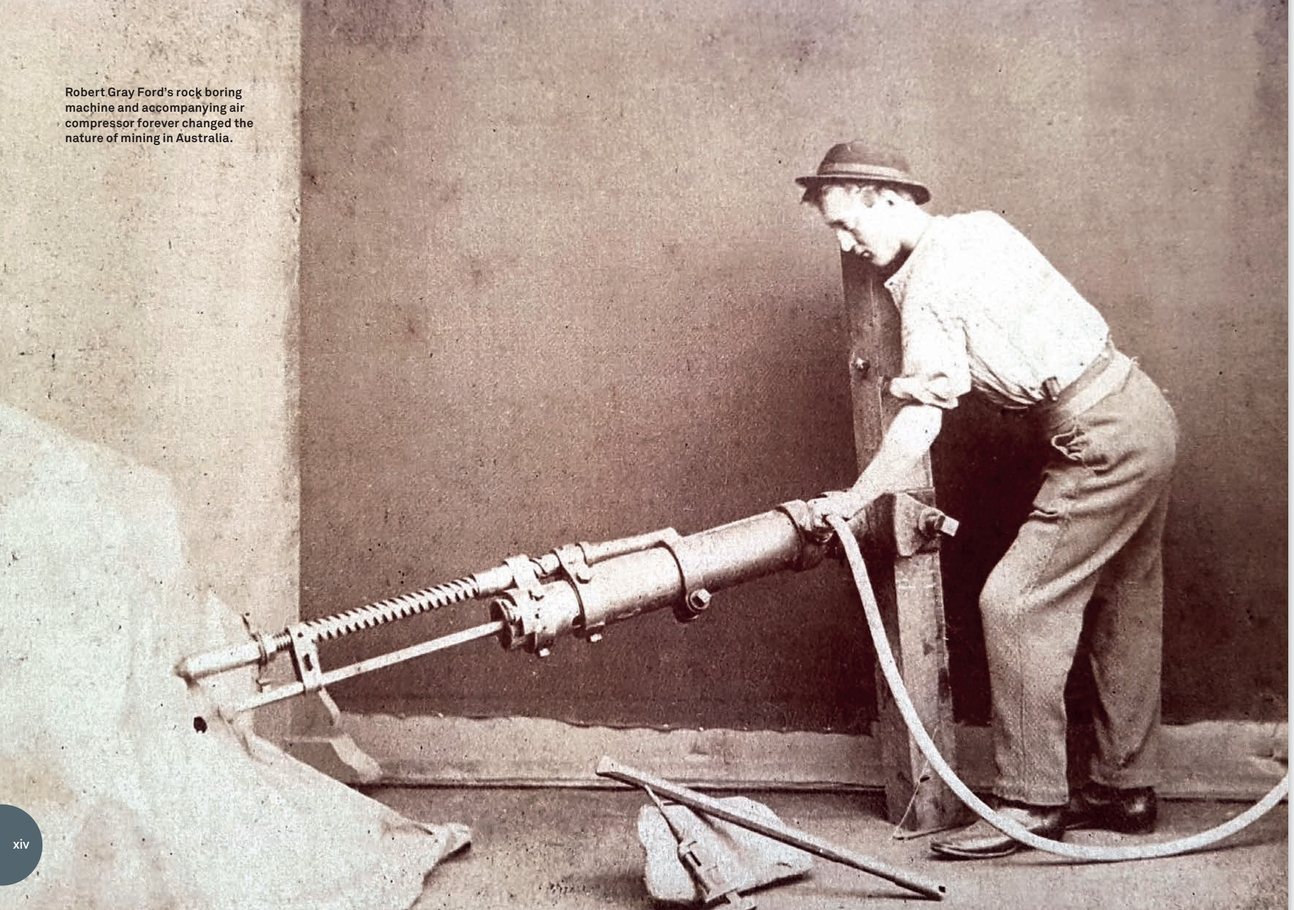
I would particularly like to thank the book committee members who have contributed thousands of hours to produce this book. It has been especially pleasing to observe how they have complemented each other and worked with the other contributors. Although all members performed all tasks when required, Owen Peake and Bruce Cole proved very adept at researching and distilling long and eventful careers into relevant and concise accounts and of seeking out and obtaining images from the most obscure sources.

Keith Baker has been able to assemble the stories of 100 diverse individuals in a way that demonstrates their individual contributions and also the development of Australia and the engineering profession throughout our history. Neil Hogg and Grant Watt have co-ordinated the multitude of people and tasks that have been required to complete the book.

In addition, the incredible dedication and knowledge-bank represented by the Engineering Heritage Australia cohort has been invaluable as has been the support of Sheryl Harrington and her EA Learned Society team.

To you all, thank you for a job well done.

Neil Hogg
Chair, Centenary Book Committee (Number 2).



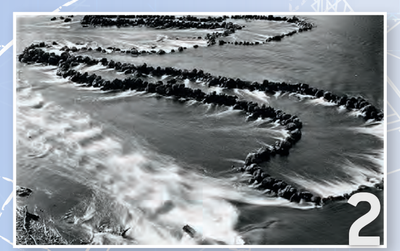
Robert Gray Ford's rock boring machine and accompanying air compressor forever changed the nature of mining in Australia.



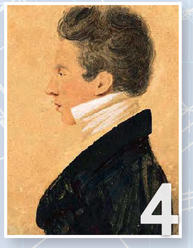
As elaborate as it was effective, Headlie Taylor's reaper-thresher introduced unprecedented efficiency in grain farming.

1 FIRST ENGINEERS

When we think of Australia's first engineers, most minds turn to the Royal Engineers and British colonial engineers that accompanied or followed the First Fleet. While they laid some essential foundations, there had been a history of thousands of years of the first inhabitants living with the landscape and creating structures and tools to suit their lifestyle and manage the accompanying resources. This knowledge and history of creative adaptation was largely ignored and repressed by the new settlers, but is now being recognised for its ingenuity.



BREAKING OLD GROUND



WILLIAM DAWES



DAVID LENNOX



JOHN WHITTON

OUR FIRST ENGINEERS

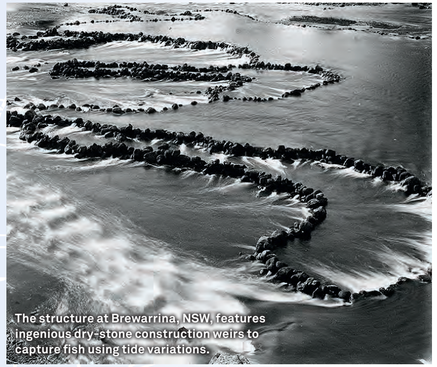
BREAKING OLD GROUND

Elements of the oldest known engineering on earth remain in place today

If there is a characteristic common to the engineers spanning all disciplines in this book, it is ingenuity, which by definition is the quality of being 'clever, original and inventive'. For our earliest engineers, the indigenous people of Australia and surrounding lands, those words ring profoundly true.

In place of formal training, our earliest settlers used their instinctive, generational understanding of land and water to build a civilisation, then feed, clothe and shelter it.

Many were nomadic hunter gatherers, but equally there were more stable settlements in areas where the climate better lent itself to a sustained existence. In both environments, unique forms of astronomy and navigation tracking, refined land management, agriculture, and engineering marked life well before Europeans set foot on this vast land, and continue to this day.



The structure at Brewarrina, NSW, features ingenious dry-stone construction weirs to capture fish using tide variations.

Examples of this resourceful approach range from weapons, to aquaculture, to construction. Take, for instance, the boomerang, a symbol of the enduring strength of Aboriginal culture and a weapon underappreciated for its genius. In the 1970s, a mathematical model evolved to explain its attributes: a convex top surface, distinctive curve, thin body and wide surface area are essential to its aerodynamic properties. Yet boomerangs existed 10,000 years ago, to which the oldest models are dated, or indeed 20,000 years to Kimberley rock paintings which feature them.

Engineering is also evident in elaborate stone fish traps, large-scale fishing facilities and associated aquaculture ponds. The best known fish traps are at Brewarrina, NSW, a number of dry-stone construction weirs and holding ponds in the Barwon River which allow fish to be herded and caught during both high and low river flows.

At Budj Bim, near Lake Condah in western Victoria, basalt structures were designed to trap, hold and grow eels which came up from the sea. These ruins were used, maintained and extended by the local Aborigines over thousands of years; relatively complex in construction, some of the channels were more than 450 m long and around half a metre deep and wide, some with clay embankments.

There are countless other examples of this ingenuity, such as 'firestick farming', in which they would aim the fires in a specific direction to flush out animals for food. New grasses grew in the burned off areas, creating ideal conditions for animals such as wallabies to return time and again, while encouraging low-growing food plants to prosper – a self-renewing source of meat and plant food.

The woomera was just as impressive. A hardwood handle whose leverage tripled the distance a spear could be hurled, it could also be used for carrying water-soaked vegetable matter as well as small food items.

Then there is thermoplastic resin, made from porcupine grass and grass trees. Beaten out of the grass, the resin was cleaned and heated over fire to create a sticky black substance. As it cooled, it was strong enough to bind rock to wood, allowing the creation of tools such as spears, woomeras and axes.

If there were no manuals for the indigenous to consult, there were certainly teachers. The oral tradition of learning through the generations ensured constant improvement in the sourcing of food and shelter, this country's first engineering 'graduates' playing a critical role in sustaining their people and culture.



An indigenous canoe and fishing spears, here on display in the Australian National Museum, typified the ingenuity of Aboriginal hunters using material at hand, and often brilliant engineering instincts.

A TRUE PIONEER

WILLIAM DAWES



William Dawes set about developing his new home from the moment he stepped off the First Fleet

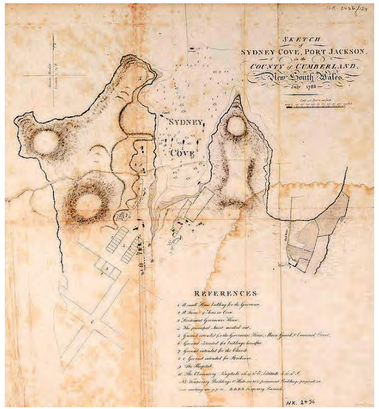
Of the gallant, intrepid individuals who set out on the First Fleet, few would mark their new home more significantly than William Dawes, an officer of marines, scientist and administrator, who hailed from Portsmouth, England.

A volunteer for service to New South Wales, Dawes was known as a competent astronomer and on the recommendation of the astronomer royal, Rev. Dr Nevil Maskelyne, the Board of Longitude supplied instruments and books for an observatory and asked Dawes to watch especially for a comet expected in 1788.

He sailed upon the Sirius, and from March 1788 he was employed ashore as an engineer and surveyor. Dawes built an observatory on what is now Dawes Point – though the comet never did appear.

As engineer and surveyor he constructed batteries on the points at the entrance to Sydney Cove, laid out the government farm and the first streets and allotments in Sydney and Parramatta. In December 1789, he led a party into the mountains across the Nepean River, penetrating only 24 km in three days because of the difficulty in traversing precipitous ravines.

Dawes explored the upper Nepean, opened the way to the Cowpastures and joined many other expeditions on which his training and skill were invaluable in computing distances and in map making.



A gifted astronomer, surveyor, and civil engineer, Dawes drew one of the earliest known maps of Sydney Cove.

Notably, he was interested in scientific studies and in the Aborigines, on whose language he became an authority, and he hoped to support himself in part by farming. A man of principle, he fell into conflict with Governor Arthur Phillip over two matters in which he sided with first a convict and later an Aborigine – in both instances Dawes was led by his conscience, and he later refused to apologise on either matter.

While his formal approval as an engineer was received in 1791, and he was clearly a man of value in this pioneering land, Phillip could not forgive the ongoing tension. The result was that Dawes sailed for England in December of that year.

Before reaching England, he wrote to Maskelyne that he still hoped to return to New South Wales "whenever a Chief Man may be appointed who is sincerely a lover and protector of scientific pursuits". In 1794, he told William Wilberforce that he would like to settle in the colony and was recommended for appointment as superintendent of schools, but nothing came of this suggestion or of John Hunter's request for him as an engineer in 1798.

Dawes lived his out his days in other colonies of the empire, first Sierra Leone then Antigua, where he died in 1836.

As the first engineer to practise in modern Australia he set a fine example of competence and moral responsibility, even at heavy cost to his career.

BREAKING NEW GROUND

DAVID LENNOX

A product of, Ayr, Scotland, David Lennox was trained as a stonemason early in the 19th century, growing his reputation as a skilled bridge builder across England and Wales. Following the tragic death of his wife, he emigrated to Australia in 1832, seeking a new start in life.

The young colony of New South Wales had no skilled stonemasons, let alone a craftsman of Lennox's capabilities. By now a Master Stonemason, he would soon become Superintendent of Bridges and be responsible for a number of landmark structures which stand today.

Within his first 12 months, Lennox was commissioned to oversee bridge construction for the new road over the Blue Mountains, including over Brookside Creek at Lapstone Hill, to be built by 20 convicts who had little, if any, masonry skills. The graceful, single arch 20 ft (6 m) span sits 30 ft (9 m) above water level and was named Lennox Bridge, the keystones of which still bear his name.

Notably, he was a kindly taskmaster who sought mitigation of the sentences of convicts who gave good service, and Lennox seldom had trouble with any of the hundreds of prisoners employed on his projects.

Lennox Bridge is the oldest surviving complete bridge on the Australian mainland (it is predated by Richmond Bridge in Tasmania, completed in 1825). The gifted Scot was also responsible for the 34 m Lansdowne Bridge over Prospect Creek, stone being quarried some seven miles (11 km) away on the right bank of Georges River. Lansdowne Bridge still carries traffic on the Hume Highway.

During his tenure in NSW, other notable bridges were built to cross the Parramatta River at Parramatta; the Wingecarribee River at Berrima; Duck Creek Bridge on the Parramatta Road, 21 km from Sydney; and a design for Bentley's Bridge at Rushcutters Bay. He also oversaw the construction of the Liverpool Dam, one of the first engineered weirs built in NSW, which both supplied water to the town of Liverpool and served as a causeway across the Georges River.

Lennox moved to Melbourne in 1844 to take up a position responsible for bridges in the Port Phillip District. He built 53 bridges in the nine years he was in Victoria, including the second Prince's Bridge over the Yarra River in central Melbourne, which was opened in 1851. This bridge was replaced by the existing bridge in 1888 as it was of insufficient length and created a choke in the river which exacerbated flooding.

Lennox retired in November 1853, and returned to NSW two years later where he lived in Parramatta. He died on 12 November 1873, and was buried in old St John's Cemetery, Parramatta.



David Lennox brought his unique stonemasonry to a new land and his handiwork spanned countless rivers



Parramatta's sandstone Lennox Bridge remains in place today, a monument to the man behind its construction.

BETWEEN THE LINES

JOHN WHITTON



Building a career on integrity and knowledge, John Whitten became the father of NSW railways

Having worked extensively preparing plans and tenders for railway construction and waterworks in his native England, Yorkshire-born John Whitton was in 1856 appointed engineer-in-chief to lay out and superintend the construction of railways in New South Wales.

On his arrival, Whitton found a modest arrangement at best. It featured just 37 km of 4 ft 8½ ins (144 cm) gauge railway, four locomotives, 12 passenger carriages and 40 trucks. The gauge, of course, would prove the most contentious – early the following year he vainly advocated conversion to the 5 ft 3 ins (160 cm) gauge adopted in Victoria and South Australia, not completely grasping the proprietary nature of the colonies towards their own burgeoning infrastructure.

Yet his perseverance would endure over decades. By the time of his retirement in 1890, he had supervised the laying of 3,494 km of track on which no accident had occurred attributable to defective design or construction.

As much as applying the disciplines learnt in his mother country, Whitton also identified inefficiencies in the Department itself. He reorganised accounting and costing and took charge of the rolling stock, line maintenance and workshop departments. This was a time of corruption, and Whitton had charges levelled against him several times, but investigation not only cleared him but reinforced his reputation.



Crossing the Zig Zag No 1 Viaduct in the Blue Mountains, NSW.

Indeed, long-standing NSW premier Sir Henry Parkes' regarded him as "a man of such rigid and unswerving integrity, a man of such vast grasp, that however his faults may occasionally project themselves into prominence, it would be difficult to replace him by a man of equal qualifications".

Whitton also fought a constant battle to secure Government funds, balancing the need for high standards with the demand for rapid expansion at the lowest cost. Yet he persisted, building the Blue Mountains line which included two great 'zig zags' and opened in 1876. From 1880-85, the unprecedented growth in railways saw 1600 kms of new track carry nine million more passengers.

In 1886 and 1887 Whitton submitted drawings for a proposed suspension bridge across Sydney Harbour from Dawes Battery to Milson's Point. It failed, but his Hawkesbury River project motivation did not. This was the final link in the railway system from Brisbane through Sydney to Melbourne and Adelaide, though Whitton had to fight for adequate finance throughout the process.

A member of the Hunter River floods commission, the Sewage and Health Board, and the Board for Opening Tenders for Public Works, Whitton was a NSW commissioner for the Melbourne International Exhibition in 1880.

The bust at Sydney Central Station proclaims John Whitton the Father of NSW railways.



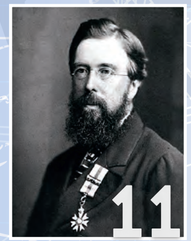
Sydney Harbour's Fort Denison, completed by former Royal Engineer and then-Governor Sir William Denison, features a distinctive Martello Tower, the only of its type in Australia.

2 BREAKING NEW GROUND IN THE COLONIES

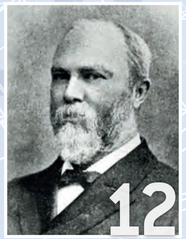
As population grew in settled centres and beyond, there was an increasing demand for water over a wider area within the large dry continent. It also created demand for better infrastructure in transport, communications and sanitation. Governance was managed by the separate colonies as they progressively developed autonomous state structures under British control. There were parallel developments through shared ideas between colonies, but also fierce competition and independence at times resulting in a lack of sensible standardisation.



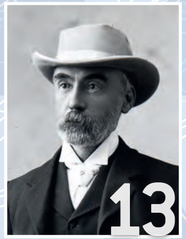
JOSEPH BRADY



SIR CHARLES TODD



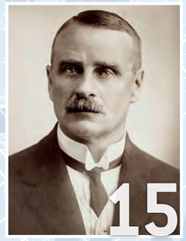
GEORGE CHAFFEY



CHARLES (C.Y.) O'CONNOR



WILLIAM THWAITES



ERNEST MACARTNEY DE BURGH

2

ON THE WATERFRONT

JOSEPH BRADY



Joseph Brady shaped Melbourne's ports and water supply to the Victorian goldfields in the 19th century

Joseph Brady was born in 1828 in Ireland, yet it was his impact this civil engineer had on the other side of the world, in far-flung Australia, that would make his life so noteworthy.

Having studied and developed his professional capabilities in England, Brady migrated to Sydney in 1850, taking work on the city's Sydney Railway Company before soon heading south to Victoria, proving his worth splitting time between rail and water networks design and construction in regional Victoria.

From 1858-63 he was engineer for the Sandhurst (Bendigo) waterworks, where he designed and constructed the original town reservoir and reticulation, before committing himself to the Melbourne to Sandhurst railway. Brady won the Victorian Government's premium of £500 for the best scheme for a water supply (to the Bendigo and Mount Alexander goldfields), and he was appointed to survey and design the system now known as the Coliban River water supply.

This honour elevated him to prominence, and his reputation soon saw him aligned with some major projects in both water supply and rail, in all eastern States, including a contract to improve navigation on the Brisbane and Bremer Rivers through submarine blasting. His next role was a natural extension of that work, as Brady became immersed in the work of the Melbourne Harbour Trust.



Victoria Harbour, on the Yarra River, Melbourne, was a fine example of Brady making the city's port a more modern, efficient precinct.

Arguably his most telling legacy sits in the waters of the Yarra River. In 1877, Brady was appointed by the Harbour Trust to work alongside Sir John Coode on the Port of Melbourne, and he became recognised specifically for his work on the Coode Canal and Victoria Dock.

Not only did he carry out the basic development of the Port of Melbourne but his force of character, experience and sound judgment enabled him to provide convincing argument against the developmental scheme provided by the Trust's consultants, Sir John Coode & Son. Brady's changes saved much expenditure, reduced the time of construction by several years – critical given the harbour accommodation was inadequate – and, what proved of greatest value, made the port structures more readily adaptable to changing shipping patterns.

Hence, modern ships are accommodated at what are still basically his original structures.

In the 14 years that Brady served the Trust he was responsible for the spending of £3.5M on works of the port, about half of which was on the Coode development. When he resigned in 1891 he engaged in private practice as a consultant and arbitrator until 1894 when he retired from professional pursuits.

CROSSING THE LAND

SIR CHARLES TODD

Charles Todd was a man of many talents, including astronomer, meteorologist and electrical engineer, though he started humbly at the age of 15 as a supernumerary computer at England's Royal Observatory at Greenwich in 1841.

Early in 1854 he was given the job as superintendent of the galvanic apparatus for the transmission of time signals. This involved close co-operation with some of the leading figures of the day in the new field of electric telegraphy. Thus was born a fascination with telecommunications.



Engineering Heritage Australia recognition ceremony at the joining point of the lines from Port Augusta and Darwin.

When the South Australian Government sought a Superintendent of Telegraphs, Todd applied and was appointed. He reached Port Adelaide in November of 1855, armed with ideas of telegraph connections within Australia, followed by a link with England.

It started with modest beginnings with the first government telegraph between Adelaide and its port then he and his Victorian counterpart convinced their states to adopt the Morse system to link Adelaide, Melbourne and New South Wales and eventually Singapore and on to England. The concept of a national communications system, one of the most significant colonial decisions of the century, had started.

In England, proposals for telegraph connection with Australia had been mooted as early as 1854 though, notably, never through the uncharted centre of the continent.

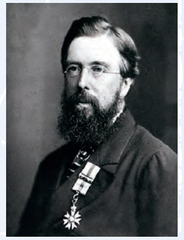
John McDouall Stuart's 1862 south to north crossing of the continent proved the feasibility of a transcontinental telegraph along that route. In 1863, South Australia had gained control of the Northern Territory, providing suitable cable landing places there, but multiple proposals of varying routes continued to cloud the best solution.

In 1870, Todd became SA's Postmaster-General and Superintendent of Telegraphs. With support from Henry Bell Strangways, Premier of South Australia, he decided to build an overland line from Port Augusta to Darwin, some 2900 km away. Handicapped by lack of time and inadequate survey, he relied on Stuart's journals and maps for the greater part.

Determined and confident, Todd divided the work into three sections and personally directed the project. The line was completed on 22 August 1872, an epic construction project providing one of the greatest advances in communications between England and Australia.

He did not leave behind his astronomy and meteorology. By the early 1880s Todd had organised astronomical observations, time services, weather recording stations, a standard point for geodetic surveys, and gradual improvement in the accuracy of climatic statistics. He was recognised by and held leading positions in numerous learned societies and educational and public institutions in the colony and internationally, including as a Fellow of the Royal Society, and was always ready to assist and advise.

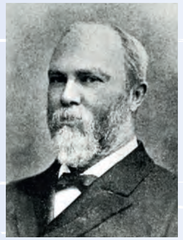
He remained in the State public service until 1907, when he was 81 years of age.



Among his multiple achievements, Sir Charles Todd rightly was best known for the Overland Telegraph

BRINGING LAND TO LIFE

GEORGE CHAFFEY



Led by George, the Chaffey brothers put two country towns on the map

As a child in Ontario, Canada in the 1850s, George Chaffey knew where his interests lay, and it was not the classroom. Rather, he was drawn to the machinery in his father's shipbuilding yard, so it was no surprise when he was apprenticed as a marine engineer on Lake Ontario.

Thus would begin a lifelong fascination with water. George became a partner in the shipyard, achieving a deserved reputation as designer and builder of shallow-draught steamers, but in 1878 his father – George Chaffey Snr – moved to Riverside, near Los Angeles, California, to join other Canadian families in the Santa Ana River irrigation settlement.

The large profits that flowed from the Riverside venture encouraged George Jnr and his younger brother, William, to become partners in irrigation colonies on California's Cucamonga Plain, where the use of concrete pipes in main water channels was highly efficient. Town planning, social institutes and prohibition were features of what were regarded as model settlements.

Across the Pacific, northern Victoria was in severe drought, such that government minister Alfred Deakin, who was also chairman of a royal commission on water supply, in 1885 visited the irrigation areas of California. He met George and William Chaffey, admired their skill and energy, and discussed the possibilities of irrigation in Victoria.

George was taken with Deakin, and Deakin equally enamoured of the Chaffeys' enthusiasm and knowledge, indicating George could secure 250,000 acres (101,172 ha) of Crown Land on favourable terms. George rashly sold his Californian interests, then hurried to Victoria.

Selecting a derelict sheep station at Mildura for his first irrigation settlement, George formally committed to spend at least £300,000 on improvements in the next 20 years. While opposed by locals – he and brother WB were referred to as 'cute Yankee land grabbers' – the Chaffeys also accepted an offer of equal scale from the South Australian Government, choosing Renmark, some 130kms further down the Murray River.



Chaffey's steam driven irrigation pumps still stand at the Psyche Bend Pumping Station, in Mildura.

With 500,000 acres (202,345 ha) of desert to develop, George showed astonishing energy and initiative in the next four years. Despite transport challenges, 3,300 people were at Mildura by December 1890, and 1,100 at Renmark, relying on pumped water from the Murray River to irrigate grape and citrus crops. The towns were well laid out and street trees planted lavishly in the style of Chaffey's American settlements, but water loss through seepage was an ongoing problem they could not overcome.

Put simply, the Chaffeys did not have sufficient capital to sustain the townships, and they slipped into liquidation before George's return to North America, as William remained to see it through. Yet they had put two towns on the map, with the irrigation colonies at Mildura and Renmark growing to prosperity with assistance from the relevant governments.

CREATING A LANDLINE

CHARLES YELVERTON O'CONNOR

In April of 1891, Sir John Forrest, Premier of Western Australia, offered Charles O'Connor the position of Engineer in Chief. In reply to O'Connor's inquiry as to whether his responsibilities would cover railways or harbours or roads, Forrest cabled 'Everything'.

Such was the breadth of the challenge, but also the reputation O'Connor had built during his 25 years in his adopted New Zealand. Irish-born, O'Connor had emigrated to New Zealand in 1865, his work involving the provision of controlled supplies of water for the pumping and sluicing needs of the goldminers, locating tracks and roads, building bridges, and improving harbour facilities.

C Y O'Connor's first task was a harbour at Fremantle; required for the sizeable royal mail contractors which were the largest steamers coming to Australia. With characteristic independence and thoroughness O'Connor examined all the data, and collected more: he had observations and soundings made; and he consulted everyone who handled ships and knew the area's seas, currents and winds.

Forrest was convinced by the clarity of O'Connor's presentation. In November, 1892, the inauguration ceremony of the harbour works took place, and by 1897 Lady Forrest opened the harbour.

It set O'Connor's course as an intelligent, trustworthy planner and engineer. He set to work on building and operating the Government railways. For the first time, they paid their way.

With the rush following the discovery of rich gold at Coolgardie (1892) and Kalgoorlie (1893), the lack of water in the region became serious, such that O'Connor established the goldfields water-supply branch within the Department of Public Works. He began work on a plan to provide an abundant, permanent supply of fresh water for the Coolgardie goldfields.

Enthusiasm met imagination: water would be stored on the wet western slope of the Darling Range near Perth. From there, it would be lifted a thousand feet (304 m) over the escarpment and pumped 528 km across the plateau to a reservoir at Coolgardie. By the end of 1902, as planned, the work was completed within the estimated cost: the great reservoir was ready, the series of steam driven pumps installed, the main laid to Coolgardie and extended another 40 km to Kalgoorlie.

Both Forrest and O'Connor saw this success in a wider context, as part of a related plan to enhance the colony's development: a harbour at Fremantle; railways and communications; water for railways, potential settlements, goldminers; and, later, the western link of an Australian transcontinental railway.

O'Connor had been a man of strong personality and initiative. To contemporaries he seemed a genius. But he was overworked, exhausted, anxious, and exasperated with the press, Parliament and bureaucracy. Just two days after the first testing, in March of 1902, he tragically took his own life.



The Goldfields pipeline (here under construction in 1902) changed the face of the prospering region.



C Y O'Connor's name stands proudly among those of Australia's engineering royalty

CLEANING UP A CITY

WILLIAM THWAITES



By overseeing the construction of Melbourne's sewerage system, William Thwaites helped restore the city's pride

While he began his career as a pupil-draftsman with the Victorian Department of Railways in 1874, William Thwaites was destined to impact most notably on the waterways and sewerage systems of his home town of Melbourne.

An early engineering graduate of Melbourne University, his career began with Thwaites completing engineering surveys for Sir John Coode's reports on Portland Harbour, Lakes Entrance and the Sale navigation, as well as a survey for defence purposes of Swan Island in Port Phillip Bay.

Transferring to the water supply branch, he designed the Toorourrong reservoir, the Essendon and Caulfield service reservoirs, and other facilities. Robust in build and seemingly inexhaustible, he had few interests outside his work and as engineer of roads, bridges and reclamation works he made his mark on Melbourne's landscape. This included the draining of Elwood swamp and the Port Melbourne lagoon, and the Dight's Falls scheme, which directed salt-free water to the lakes in the Botanic Gardens and Albert Park.

His reputation grew quickly. Thwaites was a co-examiner and council member of the University of Melbourne, and he presented to the Royal Commission into Melbourne's sanitary conditions, providing a detailed and comprehensive scheme for underground sewers.



The Spotswood Sewerage Pumping Station sat among Thwaites' finest achievements.

Little wonder he was appointed engineer in charge of the water supply branch, and in 1891 he was appointed engineer-in-chief of the Melbourne and Metropolitan Board of Works (MMBW), which had been established to build the sewerage system urgently recommended by the Royal Commission.

While James Mansergh is regarded as the architect of Melbourne's sewerage system, Thwaites deserves credit both for its design and construction. His work helped reduce the cost by half, to a more affordable £3.5 million, driving home the option to bring all the sewer mains to Spotswood on the western side of the Yarra River; to build a pumping station there; and to pump the sewerage up a rising main to a point where it would flow by gravity to the treatment farm at Werribee.

Thwaites oversaw all aspects of the design and construction of the scheme, a visionary solution which started in 1892 and was designed to cope with a future population of 1.5 million. An innovative administrator, Thwaites managed all aspects of the work, making use of the recently introduced telephone to check on progress until the systems became operational in 1897.

Although he never travelled abroad, Thwaites had one of the best engineering libraries in Victoria and was well informed on overseas engineering practice. His knowledge of the physical and climatic characteristics of the metropolitan area amazed his colleagues. He 'had a genius for statistics' and carried out most of the MMBW's statistical projections, in the engineering area and in relation to finance.

BRIDGING THE GAP

ERNEST MACARTNEY DE BURGH

On 21 March, 1885, Irish civil engineer Ernest de Burgh arrived in Melbourne aboard the Orient, and he soon moved north to join the New South Wales Department of Public Works. It was in NSW that de Burgh made his reputation – and indeed his name adorns the bridge that crosses Lane Cove River in Sydney, and the unique truss design that marked his influence across Australian waterways.

E M de Burgh was initially engaged for two years on survey work for Sydney's southern outfall sewer and in 1887 was sent to construct bridges over the Murrumbidgee and Snowy Rivers. After the turn of the century he became Supervising Engineer for Bridges.

In this latter role he superintended the construction of those over the Darling at Wilcannia and Wentworth; the Murray at Albury, Corowa, Mulwala, Barham and Swan Hill; the Murrumbidgee at Wagga Wagga and Darlington Point; the Hunter at Singleton and Morpeth; the Macleay at Kempsey; and the Tweed at Murwillumbah.

That completed a body of work of which most engineers would be proud, especially his highly reliable truss design – introduced in 1899 – which achieved the record for the longest span of timber truss bridges constructed in the colony.

But de Burgh was just beginning. He continued to rise through the ranks, assuming responsibility for rivers, water-supply and drainage, he was a member of the Sydney Harbour Bridge Advisory Board, and would soon travel to England and France to study dam construction and water-supply.

On his return he was given special responsibility for the construction of Cataract Dam for the Sydney water supply, a role which led to his influence in the River Murray Waters Act.

De Burgh became Chief Engineer for Harbours and Water Supply, and was a member of the committee of management of Cockatoo Island Dockyard. Yet his works on dams continued – from 1913 he was chief engineer for water supply and sewerage, and was responsible for the design and construction of the Cordeaux, Avon and Nepean dams, the Chichester scheme for Newcastle and the Umberumberka scheme for Broken Hill.

Such experience led to his involvement with the original plans for Canberra's water-supply, a role in which his ability to manage and persuade politicians – be it through persistence or simply his characteristic Irish wit – became evident.

For his work on the bridges, dams and water supply services across the country, de Burgh was regarded as one of the most capable civil engineers in Australia. A twice winner of the Telford Premium from the London Institution of Civil Engineers, he retired in 1927.



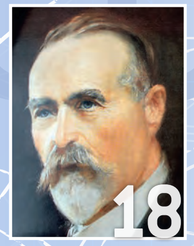
Bridge across Murray River at Barham, NSW, with timber trusses and a steel lift span.



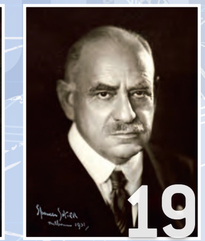
A bridge truss design and engineering versatility carried E M de Burgh to prominence in NSW

3 CONSOLIDATING STATE INFRASTRUCTURE

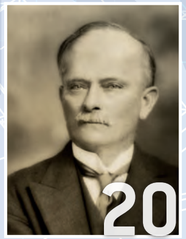
While the states yielded some of their powers to the Commonwealth at the time of Federation, there continued to be major state responsibilities through expanded networks and new technologies such as electricity generation and distribution. This resulted in large, state-based instrumentalities which were owned and run by the states concerned, with direct employment of staff and construction workers.



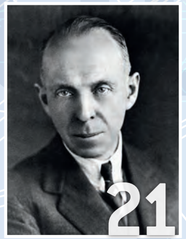
WILLIAM CALDER



SIR JOHN MONASH



JOHN BRADFIELD



SIR HAROLD WINTHROP CLAPP



ALBERT FEWTRELL



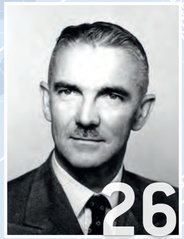
WILLIAM NIMMO



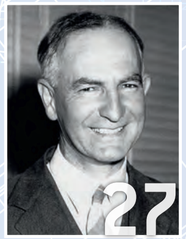
SIR RUSSELL DUMAS



SIR JAMES HOLT



SIR RONALD EAST

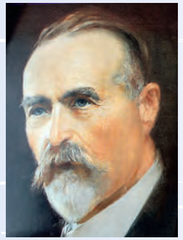


SIR ALLAN KNIGHT

3

ROADS WELL TRAVELLED

WILLIAM CALDER



Innovative and meticulous, William Calder shaped Victoria's country roads

Perhaps it was William Calder's upbringing on a sheep farm near Dunedin, New Zealand, that eventually drew him to the work for which he was best known.

Having worked for the NZ Government's survey department, Calder crossed the Tasman in 1888 and found work in private engineering and surveying firms in Victoria before becoming assistant town surveyor for the City of Footscray, then town engineer.

His transfer to the City of Prahran was concurrent with ongoing night studies, securing certificates as a municipal engineer (1890) and engineer of water-supply (1892), and from 1897-1913 Calder was city engineer and building surveyor for that inner city council.

He was active and innovative, constructing possibly Australia's first asphalted carpet-road surface and the first refuse destructor in Australia, while completing a major drainage project in the area. Yet his major stamp on the community took him back to his country roots.

By 1912, the appalling condition of Victorian rural roads was a major concern to both farmers and motorists, as many areas had invested in rail, not roads. A Country Roads Board (CRB) was established and Calder was appointed chairman.

A meticulous note-taker and enthusiastic photographer, Calder's observations were used as a basic reference for many years.



The iconic Calder Freeway, pictured here north of Melbourne, stands as a lasting memorial to its namesake.

Maps were published showing the roads selected for improvement and, facing a struggling post-War economy, it was Calder who campaigned for more funds, especially for arterial roads.

Meanwhile, his engineering inquisitiveness saw him evaluating the use of cement concrete (the American model) against that of bituminous pavement (the British); he favoured the latter for Australian conditions. Other Calder recommendations included experiments with new materials, a fuel tax to replace the vehicle tax, and the importance of maintenance. A report on the overall state of roads, published in 1924, is widely regarded as a classic of road-construction practice and road-administration.

Many of Calder's ideas were included in the important Victorian Highways and Vehicles Act of 1924, which provided for the declaration of state highways, two-thirds financed by the state Government through the CRB. This network of highways is perhaps his main achievement, and the road from Melbourne to Bendigo and Mildura, Calder Highway, was named after him.

Calder retained a pleasant but definite Scots burr all his life. Small, with a pointed beard and a 'puckish sense of humour', he was a conscientious and methodical worker, of conservative disposition and unchallenged integrity. Calder had hoped to retire to his small property at Red Hill, but he sadly died of cancer, aged 67, in 1928.

AN AUSTRALIAN GIANT

GENERAL SIR JOHN MONASH

It is difficult to encapsulate the achievements of many engineers in this book, noting the fullest of lives in service, community and of engineering itself. Yet special reverence is held for the accomplishments of General Sir John Monash: authoritative engineer, war hero, captain of industry, and a genuine shaper of a community.

From the precocious, 16-year-old dux of mathematics and modern languages at Scotch College, Monash was clearly an intuitive, gifted talent. His engineering experience at the University of Melbourne was short-lived due to financial hardship – he would later complete numerous qualifications while working at the Melbourne Harbour Trust early in the 1890s, before striking out on his own as a consulting engineer and contractor.

Monash soon became one of Australia's foremost experts in reinforced concrete for bridges, railways and other large construction projects, yet it was a precursor to his most influential role, that of military commander. Having joined the newly formed University Company, D Company, 4th Battalion, Victorian Rifles as a 19-year-old, by 1913 he was a soldier with a deep knowledge of military matters. When World War One broke out, Monash was primed to contribute, and contribute he did: he was among the first under fire at Gallipoli.

In June of 1916, Monash and his command were transferred to the Western Front. Despite his high community status and obvious abilities, Monash suffered prejudice regarding his German Jewish heritage, being a colonial commander among British gentlemen officers and being from the 'militia' rather than a professional soldier. Nevertheless, the British High Command was impressed by Monash's planning and management abilities and enthusiasm. In May 1918, he was promoted to Lieutenant General and made commander of the Australian Corps, at the time the largest individual corps on the Western Front.



The Morrell Bridge across the Yarra River was the first bridge in Australia built using reinforced concrete by Monash and Anderson.

In 1918 King George V knighted him on the battlefield for his role in the Battle of Hamel Hill. Many historians consider him to be the foremost Allied military commander of the First World War.

His legacy was arguably secure, but after the war he returned to engineering and became the first Chairman of Victoria's new State Electricity Commission. During his time as Chairman the SECV he undertook the technically difficult development of the brown coal resources of the Latrobe Valley, including the building of Yallourn Power Station.

In his last years, within his community and service activity he supervised construction of Melbourne's Shrine of Remembrance, oversaw the public appeal for funds, and rewrote the inscription planned for the west wall.

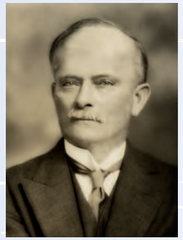
In 1929, the Institution of Engineers, Australia awarded Monash its highest honour, the Peter Nicol Russell Memorial Medal, and two years later the University of Melbourne gave him the Kernot Memorial Medal for distinguished achievement in Australian engineering.



Few men impacted society and generations more so than military and engineering legend Sir John Monash

BRADFIELD'S BRIDGE

JOHN BRADFIELD



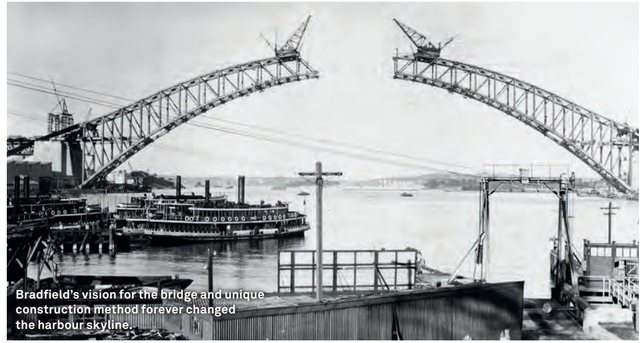
Of all the men involved in the creation of Sydney's iconic Harbour Bridge, only J J C Bradfield could rightly claim it as his own

The year of John Job Crew Bradfield's birth in Queensland to English immigrant parents is a little uncertain, though the day, Boxing Day, is not. It would seem that their need to enrol their precocious boy into a more senior school led to the backdating of his birth to 1866, and later he himself perhaps used the same flexibility when, at age 24, he sought membership of the British Institution of Civil Engineers, a year too young by their rules.

J J C Bradfield enrolled in the newly founded Engineering School at Sydney University, the staff of which consisted of only the charismatic Professor William Warren. After graduation with the University Medal, he worked on iconic projects such as the Cataract Dam for Sydney's water supply, and Burrinjuck Dam for inland irrigation and power.

Yet his career focus soon shifted to the transport needs of Sydney, specifically the building of the great bridge across its harbour and the electric railways beneath its streets. In 1914, he toured the United States, Britain and Europe to gather information and ideas – it can only be imagined how Sydney would be different had he not narrowly avoided internment in Germany as the Great War erupted, or if his attempt to enlist in the AIF in London had not been thwarted by his age.

Bradfield's long journey home allowed for production of his master plan, which commenced in 1916 but due to war time delays was only partially completed by 1932, the year on which the Sydney Harbour Bridge opened. A decade earlier, his loyal Secretary, Kathleen Butler, had been chosen by Bradfield to ceremonially throw the switch to start an air-compressor, the first act of construction of the bridge.



Bradfield's vision for the bridge and unique construction method forever changed the harbour skyline.

At the time of completion, a heated argument erupted between Bradfield and the British engineer engaged by the contractors, Ralph Freeman, as to who had designed the bridge. Such was the emotion of the debate that both men were called to order by the Institution. Whatever the argument, there can be little doubt that Bradfield had driven the project, creating the public demand that it be carried through.

His Sydney work complete, Bradfield returned to his birth state and was appointed consulting engineer on the Story Bridge.

Elsewhere, as the Hawkesbury River Railway Bridge failed in 1939, Bradfield descended deep below the river in a shaft mined into the rotten concrete. Such was the respect in which he was held, his immediate report to the Government resulted, only three days later, in the decision to replace the whole bridge.

Bradfield died in 1943. His planning for 'his' bridge over the Harbour includes a sketch of it being illuminated at times of national celebration, specifically its curved profile replicating the AIF badge. It is fitting that this vision is recognised each New Year's Eve.

A MAN OF VISION

SIR HAROLD CLAPP

Few Australian public servants have been so closely identified with their Departments as Harold Clapp. To many, he was the railways, having in 1920 taken over the position of chairman of the Victorian Railway Commission and in the following two decades transformed them into an efficient, well managed metropolitan and State-wide network.

Clapp was a 'tall, gaunt, loose-limbed figure, with deep-set eyes and a sharp nose'. He bore an American accent, but in truth was born and educated in suburban Melbourne before serving his apprenticeship (1893-95) at the Austral Otis Co.'s engineering works at South Melbourne.

Clapp's exposure to large project management came when he journeyed to America in 1900, assuming roles in the electrification of sections of the Pennsylvania Railroad, plus the suburban railways of Oakland, Alameda and Berkeley in California. This experience would prove invaluable when the attraction of home proved overwhelming.

From his 1920 return to Melbourne, Clapp set about modernising Victorian rail as Chairman of Commissioners. He first completed the electrification of the suburban lines. Clapp also extended, regraded and improved the network, redesigned locomotives, introduced welded rails for smooth running, revised timetables and even refined storekeeping methods.

As the motorcar began to erode what had been a captive rail market, Clapp recognised the importance of service. He established the Department's own butchery, bakery, laundry and poultry farm, a childcare nursery, and ran stalls at city stations. He improved dining car buffet facilities, while the Better Farming Train, a joint venture with the Department of Agriculture, was equipped to demonstrate latest techniques to farmers.

He created the famous 'Man in Grey' at Spencer Street station to answer travellers' queries and added Sunday country trains with parts of multiple campaigns to make the railways as user-friendly as possible.

Yet the Depression bit hard with Department profits slipping into the red at record levels by 1931. Rail was not a competitive freight option, despite Clapp drastically reducing rates, so he set sail for America, Britain and the Continent to investigate developments overseas. His visionary project, the 'Spirit of Progress', made its first Melbourne-Albury run late in 1937.



Clapp's lifetime drive for innovation resulted in the majestic 'Spirit of Progress'.

In 1939, as war escalated, Clapp was seconded to become general manager of the Aircraft Construction Branch of the Commonwealth Department of Supply and Development. He was knighted in 1942. As co-ordinator of Commonwealth and State road and rail transport, he led major policy development and argued for the standardisation of Australia's railway gauges.

The first Victorian Railways diesel-electric locomotive was named the 'Harold W. Clapp'. In 1952, he rode in the driving cabin as the train was launched, just months before his death. Prime Minister Robert Menzies spoke of Clapp's 'superb honesty as an adviser and administrator', others of his 'genius for administration'.



Sir Harold Clapp's imagination created a brilliant Victorian rail system

THE MAJOR GENERAL

ALBERT FEWTRELL



In both war and peace, railway engineer Albert Fewtrell aimed his abilities at marking change around him

As with so many prominent men of their age, Albert Fewtrell was forced to balance the demands of two world wars with those of his profession. Few did it so expertly, and with such impact.

Fewtrell's family came to Australia a year after his birth in 1885, settling in Queensland where the youngster was educated. He joined the Queensland Railways as a cadet engineer on leaving school and in 1908 joined the NSW Railways as a draftsman. It started an association that lasted a lifetime and changed the infrastructure of a rapidly growing State.

A man of undoubted ability, Fewtrell rose quickly to be a resident engineer by 1913. When he enlisted for World War One he was given the rank of Major and command of the 5th Field Company of Engineers. The details of his military achievements are best understood in the wider context of the war, but they included command of the Anzac Light Railways and the award of the Distinguished Service Order (DSO) and promotion to Lieutenant Colonel.

Ill-health led to his repatriation to Australia in 1918, where he assumed the role of Resident Engineer at Newcastle and oversaw major expansion of the Zaara Street Power Station. In 1920, however, he followed his passion back to the 'mainline' railway network, where his career blossomed. In 1932 he was briefly a Railway Commissioner under a short-lived



Fewtrell oversaw the construction of the critical upgrade of the Hawkesbury River Railway Bridge.

re-structure of the transport departments, but soon afterwards became Chief Civil Engineer, a position he held for the rest of his life.

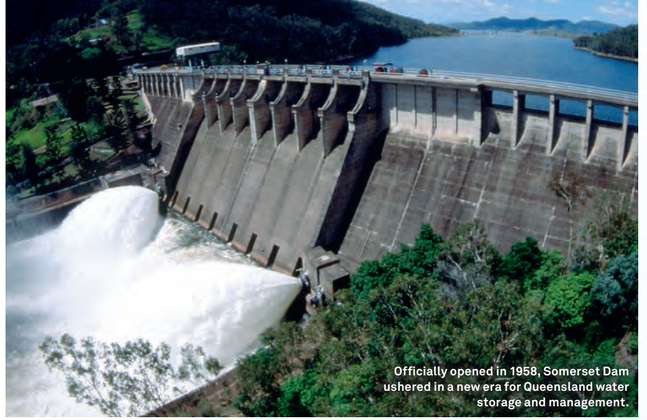
In 1939, and now in his mid-50s, he returned to military duties within Australia as General Officer Commanding NSW Lines of Communication, where he was responsible for the coastal defence planning for Newcastle, Sydney and Wollongong, rising to the rank of Major General.

Still, Fewtrell never relinquished his position as Chief Civil Engineer. Having made the decision in 1939 to replace the failing but strategically important Hawkesbury River Rail bridge, he was now responsible, in both his roles, for keeping the old bridge open and designing and building the new bridge where he made many visits.

On his return from military service in 1943 he took swift personal control of construction of the new bridge. He went on to play a key role in the design of Sydney's eastern suburbs railways, and the development of the Circular Quay railway station and surrounding works.

Interestingly, his military experience informed his views on railways – he was not in favour of dieselisation of the railways, for example, unless oil was found in Australia, believing that no enemy could cut off coal supplies as they could oil.

Fewtrell, known to all as 'the Major General', died in office at the age of 65 in 1950.



Officially opened in 1958, Somerset Dam ushered in a new era for Queensland water storage and management.

AHEAD OF HIS TIME

WILLIAM NIMMO



By using techniques rarely seen in Australia, William Nimmo was a ground-breaking force in water storage and movement

After initial experience as a draftsman and engineering surveyor, William Nimmo joined the Tasmanian Public Works Department in 1913, where he designed the State's first concrete-arch dam and the first reinforced-concrete bridge.

He soon joined the new Hydro-Electric Department, worked out the hydrology of the Great Lake and, as Resident Engineer, constructed the Liawenee diversion canal from the Ouse River to the Lake. He also began a lifelong practice of using investigations at construction sites along with sound theoretical knowledge in the design and construction of major works.

He moved to Brisbane in 1924 as Civil Engineer to the Metropolitan Water and Sewerage Board and then advanced to become Designing Engineer of the burgeoning Main Roads Commission. In 1933-34 he returned to the subject of water, undertaking ground-breaking work investigating the water-supply and flood-mitigation requirements of Brisbane.

Nimmo completed the investigation almost single-handedly. It is believed he was the first in Australia to use unit-hydrographs and flood-probability studies, combined with a flood-plain map of Brisbane, for his economic assessment.

As a result, the Stanley River Works Board was established in 1934 to construct the Somerset Dam (not completed until after World War Two) and Nimmo was first Designing Engineer, then Chief Engineer in this new Board. Innovations in design and construction included measures to prevent hydraulic uplift, and hydraulic model studies of dissipator and sluice gates.

It was unsurprising that in 1942 with Japan in the war, he was appointed as Chairman of the board (reporting to the Deputy Director General of Allied Works), responsible for constructing the top-priority Cairncross Dock on the Brisbane River. When completed in 1944 it was the largest dry dock in the Southern Hemisphere.

In 1949, he became Commissioner for Irrigation and Water Supply and directed the Department at a time of great expansion, including the construction of the Tinaroo Falls Dam and the Mareeba-Dimbulah Irrigation project.

Nimmo was unassuming in manner but definite in what he wanted, and he had both the admiration and affection of his staff. He gave much back to engineering – from his student days he was an active member of professional associations. A foundation member (1919) of the Institution of Engineers, he was especially active in the Brisbane Division, made an Honorary Fellow from 1960, and he led the Australian delegation to the International Committee on Large Dams in Rome in 1961.

Always ready with a useful reference, he was adept at devising investigation and construction techniques. His doctoral thesis contains some 56 published papers, discussions and reports written from 1916-62. He was awarded the Peter Nicol Russell Memorial Medal of the Institution in 1950, the Kernot Memorial Medal of the University of Melbourne in 1956, and the CBE in 1962.

THE BASIS OF CIVILISATION

SIR RUSSELL DUMAS



The long, visionary career of Russell Dumas was dedicated to public works

In 1925, with experience in constructing locks on the Murray River, Russell Dumas and his family moved to Western Australia to join the Metropolitan Water Supply, Sewerage and Drainage Department, where he took on the role of resident engineer for the construction of Churchman Brook Reservoir.

This began a lifetime of service to his adopted State, the World War One veteran becoming one of the most distinguished public servants in West Australian history.

Between 1929 and 1933, while engaged in dam and weir construction in the South-West of Western Australia, Dumas completed a thesis on the design of high masonry dams and was awarded a Master of Engineering by the University of Adelaide.

Following appointment as Chief Engineer of the Public Works Department in 1934, he led the design and construction of the Canning, Samson Brook and Stirling Dams. At 45 metres, Stirling was the then highest earthen dam in Australia. While proud of these engineering achievements, Dumas was critical of the state's lack of forward planning. His famous quote is 'no time or money for preparation, plans barely a nose ahead of construction'.

Appointed Director of Works and Buildings in 1941, Dumas was the engineering head of the Public Works Department. He had great faith in his profession: 'Engineering is the basis of civilisation', he declared. In that context, an adequate water supply was crucial, and the Depression had highlighted the WA wheat-belt's need for a comprehensive and reliable water supply.

The preferred scheme, based on raising Mundaring Weir and Wellington Dam as well as new electric pump stations and pipelines, was to become the State's major post-war public works project, with the 1947 commitment of Commonwealth funds being primarily Dumas's achievement.

He then shifted his focus to the North-West of the State and its potential for increased settlement and productiveness. Irrigation was again the solution, and Dumas identified the Ord River as the most promising site – he promoted the Ord River Scheme, seeing it as a forerunner of many similar settlements.

Dumas went on to be a highly effective engineering visionary, chairing countless committees that adopted his bold initiatives and strong sense of planning. He was instrumental in attracting and delivering major projects, including the Kwinana Oil Refinery, where he co-ordinated all Government works required for development of the Kwinana Industrial Area.

After delayed retirement in 1953, aged 67, Dumas remained a close confidante of then-Premier Sir Charles Court and continued to shape the State's approach to development. In recognition of his services, the State Government ministerial office building, adjacent to King's Park, is named Dumas House. He was awarded the Peter Nicol Russell medal in 1952 and appointed CMG in 1950, KB in 1959 and KBE in 1964.



Overseen by Dumas's robust planning, the BP-operated Kwinana Refinery is the largest oil refinery in Australia.

A PIONEER OF FLOOD MITIGATION

SIR JAMES HOLT

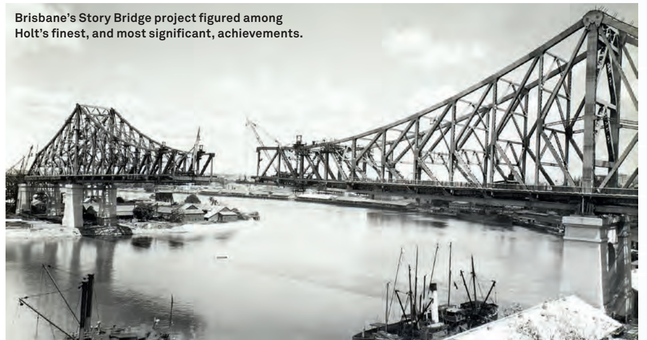
From the Sydney Harbour Bridge, significant war-time administrative and planning roles, to the overseeing of design and construction of multiple dams and bridges in Queensland, Sir James Holt left an indelible mark of expertise and integrity on each of the projects in which he was involved.

Holt graduated from the University of Sydney in 1921 and spent a decade working on the design and supervision of construction of the Sydney Harbour Bridge with the NSW Department of Public Works under the direction of Dr John Bradfield. This included nine months' work in London concerned with the approval of Dorman Long and Company's detailed working drawings. The five years to 1932 were spent as Supervising Engineer on the inspection of fabrication and erection of the steelwork of the main arch and the approach spans.

In 1934, Holt entered the service of the Queensland Government. As Supervising Engineer for the Bureau of Industry Bridge Board, he assumed responsibility for the design and supervision of the contract for the construction of the Story Bridge, being built by a consortium of contractors with Bradfield as design consultant. Holt's experience on the steel Sydney Harbour Bridge made this a logical progression and it became the first of his many bridge projects constructed across the State.

His standing was enhanced during a war-time change of responsibility beyond state based public works to those of national necessity, being in charge of all Bureau of Industry war-time activities under the direction of the Allied Works Council. Works included hangars for the US Army Air Force, ordnance stores and workshops for the Australian Electrical and Mechanical Engineers, stores for the RAAF and a large pre-fabrication depot in Brisbane as well as highways and aerodromes in northern Australia.

Brisbane's Story Bridge project figured among Holt's finest, and most significant, achievements.



A sound administrator, Holt did not seek the limelight and was determinedly apolitical. His recommendations for projects were always decided on technical merit, supported by meticulous attention to detail, specialist knowledge and an overall sense of the benefits accruing to Queensland and the nation.

As Chief Engineer of the Queensland Co-ordinator-General's Department, responsibilities included construction of the new University of Queensland, the completion of Somerset Dam and designing and building the Tully Falls hydro-electric Scheme. Holt then ascended to the role of Co-ordinator-General of Public Works, which he held until his 1968 retirement.

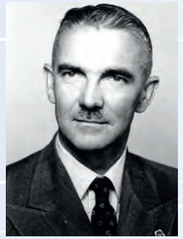
In November 1961, Holt was awarded the Peter Nicol Russell Memorial Medal. He was Queensland Government representative and Chairman of the State Committee of the Standards Association of Australia and a long-term supporter of University of Queensland. He was knighted in 1960 and in 1965 the University of Queensland conferred on him an Honorary Doctorate of Engineering.



Across a wide number of disciplines and projects, Sir James Holt's low key, determined approach was stunningly successful

WATER IN HIS VEINS

SIR RONALD EAST



By taking control of a State's water supply, Sir Ron East underlined his passion that water was for everyone

Ron East was a man of high principles and strong work ethic who's years of public service helped shape the way his home State, Victoria, managed its lifeblood: water.

After brief service as an Air Mechanic in the Australian Flying Corps at the end of World War One, East completed an engineering degree at Melbourne University. He joined the Victorian State Rivers and Water Supply Commission as an engineer in 1922; within 13 years he reached the level of SR&WSC Commissioner, and then Chairman from 1936 until his retirement in 1965.

During this period he increased Victoria's water storage capacity threefold, doubled its irrigated areas, enlarged Eildon Dam, and improved and expanded flood protection and country town water supplies and sewerage.

Under the constitution, water for irrigation was a state responsibility, and sharing the water resources of the Murray River with New South Wales and South Australia was an ongoing issue. The River Murray Commission was established in 1917 to administer a water sharing agreement between the states concerned, while the Commonwealth retained an interest in navigation on the river and at times in sharing the funding of necessary work.

Concurrent with his role of SR&WSC Chairman, East was a River Murray Commissioner from 1936-65, the longest serving of any state representative. In spite of competing state interests, considerable cooperative action was achieved during that period, including the construction of the Murray mouth barrages to arrest salinity, regulating structures such as the Mildura, Torrumbarry and Yarrawonga Weirs, and enlargement of the Hume Dam.



A young Ron East in 1923 highlighting the complete absence of flow of the Murray River, before the river was regulated.

East's interests extended farther afield than simply construction and capacity. It can be argued that he was as much visionary as environmentalist before that latter word was popularised. He planned for present and future needs of Victoria, and took a leading part in drafting legislation and working for soil conservation, water-catchment protection and river improvement.

His efforts included addressing growing issues such as salination, river pollution, water waste, silting, loss of river flow, and housing development below flood levels. He held strong views that water was for the benefit of all and that landowners should not expect to benefit from public expenditure increasing their property value.

East worked energetically within his community, as town councillor, church leader and RSL member, and an active supporter of social welfare and refugees. He received a knighthood on his retirement from the SR&WSC and was awarded the Peter Nicol Russell Memorial Medal in 1957.He published four volumes of family history, edited the Gallipoli diary of sapper Sergeant Lawrence, taught youngsters to make model engines, and was a sought-after public speaker into his old age.



The unique floating bridge across Hobart's Derwent River, soon before its removal in 1964.

A LIFE IN POWER

SIR ALLAN KNIGHT

Tasmania's remoteness and challenging landscape helped inspire some of Australia's finest engineers. Principal among them sits Allan Knight, who across much of the 20th century combined vision and expertise to have a major impact on his home State's development.

Born in Launceston in 1910, Knight would be best known for his revolutionary work on bridges as an emerging engineer, then his lengthy, three-decade tenure in charge of the State's Hydro-Electric Commission.

Graduating from the University of Tasmania, his work as an assistant in the University's Engineering Department included the unique modelling of his Composite Beam Theory. In 1932, the Director of Public Works Department authorised the building of an 11 m prototype Composite Beam bridge to prove the practicability of the theory. Knight measured deflections under static and impact loading with large trucks carrying rock over the bridge. The deflections measured were well within the safety factors required and Knight's confidence and safety were proven. The bridge is still in use on Proctors Road over Vincents Rivulet close to Hobart.

The method was subsequently applied in the construction of a seven-span bridge over the Leven River at Ulverstone, with Knight designing the bridge and also supervising its construction.

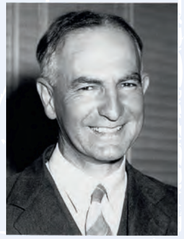
Knight was appointed as a Public Works Department engineer in 1932, three years after more than 150 bridges had been washed away or significantly damaged in Northern Tasmania. There was much to be done to reinstate this infrastructure, including design and construction of the all-welded steel girder bridge at Scamander, Knight's next major project.

At 27, he advanced to the newly created position of Chief Engineer of the Public Works Department. Over the next decade, this bridge activity was his focus; he toured America and Canada for three months to examine design and construction, and cemented a reputation for discipline and thoroughness in his work. He also designed the unique floating bridge across the Derwent River at Hobart.

Immediately after World War Two – having served with distinction on the home front for the Royal Australian Engineers – Knight was appointed Commissioner of the Hydro-Electric Commission. The Commission won international recognition for enormous advances in the technology of dam and power station design and construction. Under Knight's leadership (1946–77), the Commission's installed capacity grew from 172 to 1515 MW and its workforce from 1000 to over 5000.

The HEC set tunnel boring world records which have not been surpassed, led world-wide practise in large rockfill dams with upstream concrete membranes and built the world's sixth highest head hydro-electric power station at Poatina.

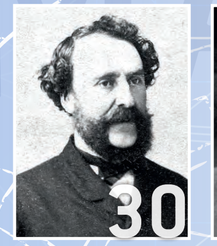
An accomplished sportsman, Knight was honoured many times for his contribution to both engineering and his State of birth. He died in Hobart in 1998.



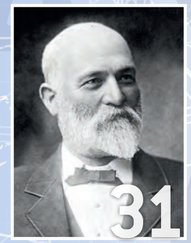
Under Allan Knight's leadership, the Hydro-Electric Commission lit up the state of Tasmania

4 MANUFACTURING AND RESOURCE DEVELOPMENT

In the early 19th century there was a strong dependence on imported machinery to support the primary and secondary industry developing in the new colonies. Copying of imported machinery occurred, sometimes with little regard for the fragmented patent system, but this developed capacity for local manufacturing and in turn inspired local ideas. Manufacturing generated economic advantages via shortened delivery times and spare parts on hand, while volume of production was progressively obtained through capitalising on export opportunities. Mineral discoveries also led to increasing self-sufficiency and inventiveness in mining and metal refining across Australia, and in production of the machinery needed to support mining.



SIR PETER NICOL RUSSELL



MEPHAN FERGUSON



ROBERT STICHT



GUILLAUME DELPRAT



CHARLES POTTER



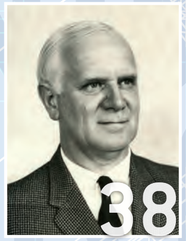
DAVID BAKER



HEADLIE TAYLOR



SIR ERNEST FISK



SIR VICTOR BURLEY CBE

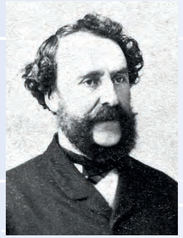


PETER COCKBAIN

4

A PROUD ENGINEERING LEGACY

SIR PETER NICOL RUSSELL



From boilers to steam engines and shipbuilding, Peter Nicol Russell was an engineering pioneer across 19th century decades

Paramount among the engineering honours available in this country is the Peter Nicol Russell Memorial Medal, Engineering Australia's highest recognition of individual engineering achievement. It is quite a legacy for the man after whom the medal is named, Sir Peter Nicol Russell, who built one of the country's most successful design and manufacturing companies through the middle decades of the 19th century.

Of Scottish parents, Russell was one of 11 children to immigrate to Hobart in 1832. His father, Robert, was an iron founder, and the sons would grow their extensive foundry business throughout Sydney in the decade that followed.

But Peter broke away in 1842, purchasing a foundry of his own in a battleaxe block on the east side of George Street, just north of Market Street. Success was immediate and extensive. Russell obtained contracts for cast items from the government of NSW and the City of Sydney for industrial, marine, architectural, and domestic products.

He would move locations as he expanded, manufacturing a veritable catalogue of mid-19th century engineering: steam engines, pumps, gold-stamping batteries, boilers, flour milling equipment and bridges, including the Denison Bridge at Bathurst which still stands today.

In 1855 a new company, P. N. Russell & Co., was formed combining his company with that of his brothers which was reportedly one of the country's largest non-government employers with more than 1000 staff. Four years later Russell married and moved to London where he acted as the company's representative.



P N Russell & Co developed into one of the country's largest, most successful employers.

The subtitle to the company's name was now 'Engineers and Shipbuilders', activity confirmed by the construction of a variety of marine machinery and vessels for the ports and rivers of Australia. In 1863, two armoured vessels were produced for the hostilities in New Zealand; the Koheroa and Rangiriri classed as river gunboats of the Waikato Fleet. Soon after, the company became a standard-bearer for Australian engineering when the British journal 'The Engineer' included in its July issue an item headed "Australian Machinery" with drawings of a P. N. Russell & Co. steam engine and compression unit for refrigeration on the Harrison principle.

Sadly, industrial disputes would be the company's undoing. The Directors were exasperated to the extent that they abruptly closed down the entire business in 1875.

An 1895 visit by William Henry Warren, Professor of Engineering at the University of Sydney, secured from Russell a gift of 50,000 pounds sterling. As a result, the P. N. Russell School of Engineering was established. A second gift of the same amount was received in 1904, the same year in which Russell was knighted, and just a year before his death.

A MASTER IN IRON AND STEEL

MEPHAN FERGUSON

Almost from the moment 11-year-old Mephan Ferguson arrived in Melbourne aboard the Admiral Boxer in 1854, it seemed his ingenuity and work ethic made the Scottish-born ironworker destined to become a ground-breaking success in his field.

Initially apprenticed in regional Ballarat, Ferguson eventually opened his own workshop at Hotham Hill (North Melbourne) in 1875, his first major contract being for the ironwork for the Johnston Street road bridge in Collingwood.

His products soon incorporated pipes, filling orders for Victoria's Board of Land and Works, plus screw couplings for railways, and Ferguson grew out of his workshop, purchasing a foundry in suburban Carlton.

Work continued to flow in, including the iron work for 20 bridges for the North-Eastern Railway and for the Victorian Railway's new workshops at Newport. As more and more pipework orders came in, he added an ironworks in West Melbourne, eventually merging his premises at a larger site in Footscray in the 1890s. From here, the business would operate for 90 years.

On the score of success and longevity alone Ferguson would be considered a success, but a spark of genius one evening in 1896 helped forever change the way pipes were constructed from flat plate. Previously, rivets in the longitudinal joins would impede water flow and compromise the pipe strength; Ferguson applied the concept of dovetail joints in timber joinery and tested them on steel.

The 'lock bar pipe' was born.

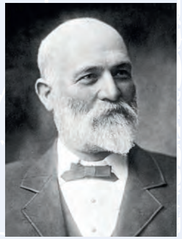
The first major use of this technology – and a substantial test of its suitability – was the pipeline from the Helena River, north of Perth, to Western Australia's Coolgardie and Kalgoorlie goldfield towns. The pipes were a success, and the business's reputation continued to be enhanced. Boiler making was added to their range, and in 1907 Ferguson carried out the fabrication of a number of large riveted girders to support the dome of the new Flinders Street Railway Station in Melbourne.

Three years later, the company was incorporated as Mephan Ferguson Limited with a capital of £150,000. Shortly afterwards, the company filled an order for lock-bar pipe for the O'Shannassy water supply main in Melbourne and a larger order for similar lock-bar pipe from Bombay, India.

Mephan Ferguson died at age 76, on 2 November 1919. The company continued with great success until the Great Depression of the 1930s and in a reduced form until the death of Mephan's son (known as Mr Meph) in 1948. It was sold to Tubemakers of Australia Limited in September 1950, and the Footscray site closed in 1981, ending 90 years of manufacture on the site.



Ferguson's unique lock bar pipe joining concept forever changed the efficiency of water movement.



A moment of genius highlighted Mephan Ferguson's respected career in ironworking

A BURNING DESIRE

ROBERT STICHT



From Colorado to Tasmania, Robert Sticht helped change mining around the turn of the century

When directors of the newly formed Mount Lyell Mining & Railway Co. Ltd, in remote Tasmania, sought expertise to process their copper ore, they turned to the mountains of Colorado and Montana, in far North America. There, Robert Sticht had established a reputation as the foremost authority on pyritic smelting – a process which burns the sulphur in the ore as fuel, thereby reducing the need for expensive coke.

A metallurgist and mining engineer who studied in America and Germany, Sticht was offered the position of metallurgist at the new Queenstown mine. He duly accepted, arriving in 1895 with his wife, and was to become a dominant figure in the west coast community, Tasmanian industry and copper smelting worldwide.

His first task was to persuade the company to abandon its plans for roasting copper ore and, instead, adopt pyritic smelting. He directed the construction of a reduction works, partly of his own design, and the first two blast furnaces were fired in 1896.

The results were spectacular, and *The Economist* nominated Mount Lyell as the best-managed mine in Australasia repaying shareholders all of their investment, and more, in the first two years, but all was not well. The viable ore in its leases was running out and its neighbouring competitor company, North Lyell Co. held the best ore reserves but had followed the advice of a succession of remote consultants and had constructed hugely expensive but unsuitable processing plants which could not produce copper economically. In 1903, owing to its strong financial position the Mount Lyell Mining & Railway Co. took control of its competitor and its future was guaranteed in the near term.



Queenstown's Mt Lyell copper mine was considered the best-managed mine in Australia.

Sticht was a paternalistic manager, believing that employees should be restrained in their behaviour and work in concert with management. However, he was intolerant of union "interference" and confrontation at the mines continued leading up to World War One, culminating in a disastrous fire in 1912 which claimed 42 lives.

When copper prices plunged following World War One and the company faced bankruptcy, Sticht responded by cutting wages, which caused renewed confrontation. His ultimate successor, R M Murray, followed a different strategy: he had previously gained employee respect by implementing a successful company-sponsored employee welfare programme and now advocated the use of the flotation method for mineral concentration.

By 1922, Sticht was in poor health and was succeeded by Murray. The flotation process proved successful at Mt Lyell and the company prospered once again.

Sticht had pioneered a metallurgical technique that paid handsome dividends – in one year the company had earned more revenue than the Tasmanian Government – but his uncompromising belief in pyritic smelting and approach to employee relations meant that he did not adopt new ideas and necessary changes.

A LIFE WELL LIVED

GUILLAUME DELPRAT

It is arguable that Guillaume Delprat had already lived a full professional life before his 1898 arrival in Australia, yet the Dutch-born engineer, metallurgist, and pioneer industrialist would change forever his adopted home through his work with the Broken Hill Proprietary Co. Ltd.

At the age of 16, Delprat started his engineering career as an apprentice on the ill-fated Tay Bridge in Scotland where he insisted on experiencing all aspects of the construction. After further study with exceptional results he moved to southern Spain where he won respect for his geological and mining expertise – particularly for locating and working long-forgotten Roman silver mines – and then on to Norway and Canada.

By the 1890s his curiosity, energy and intelligence had marked him as a worldwide mining authority. A paper on the extraction of ore from wide veins published in 1892 first brought him to the attention of BHP.

In 1897 he accepted the position of Assistant General Manager of BHP and moved to Broken Hill with his family the following year. Two years later, following the resignation of the General Manager he succeeded to that position.

These were hard times for the silver and lead industries and BHP profits were the lowest for decades. Delprat recognised the tremendous wealth locked away in the tailings dumps (waste from previous processing) - if only it could be extracted. With his chief metallurgist, AD Carmichael, he perfected the Potter/Delprat flotation process, the principle of which is still employed today.

He also demonstrated his abilities as an accomplished businessperson through focussed investment at Broken Hill, the patenting of his processes and skilful negotiations with suppliers.

Recognising the eventual exhaustion of the Broken Hill mines, Delprat, in 1911, persuaded BHP's board to consider establishing a steelworks in Newcastle utilising the Iron Knob deposit in South Australia. After an extensive personal investigation, much government lobbying and the selection of an expert manager in David Baker, the works were opened on 2 June 1915. His vision, judgment and timing were vindicated not only by their opening in the early months of World War I, but also by his choice of American rather than the cheaper, but strategically vulnerable, German steel-making plant.

Delprat became an Australian citizen in 1904 and lived here for the rest of his life. He was committed to the development of his adopted country and its people. When he resigned as General Manager in 1921, he passed the baton to the next titan of Australian industry – Essington Lewis.

In a 1920 speech, he stated that he believed that the great wealth taken from Broken Hill had imposed upon BHP a responsibility to reinvest at least a portion in Australia's future, and that investment in steel is a legacy that lives on today.



Deprat's decision to locate steelworks in Newcastkle changed that city forever.



Well-travelled and much respected, Guillaume Delprat brought his expertise and intelligence to BHP

A MIXED AND MALTED CAREER

CHARLES POTTER

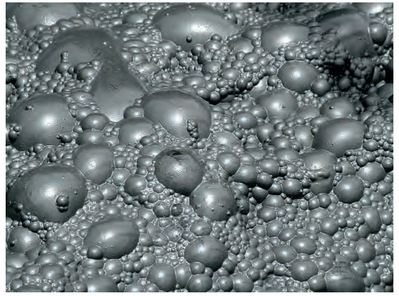
By developing a flotation plant, Charles Potter allowed mining companies to reclaim endless riches

At age 26, and newly married, Charles Potter set out for Victoria from his English home of Kent as the Australian representative of Gillman & Spencer, a company renowned in his homeland as 'brewers and maltsters' and analytical chemists. Working in Adelaide and Melbourne from 1885, he stayed with the company for five years as he found his feet, then established himself in Melbourne as a consulting brewer, chemist and engineer.

It was not only brewing which caught his interest. Over the coming decade, Potter secured Victorian patents for treating cereals for brewing; a fire bar and smoke consumer; a gas engine for a motor car; an oxyhydrogen furnace; a bottle and stopper; a washing compound; a nose-bag; and a paint additive.

Malting remained his primary source of work, but Potter is best remembered for the work he completed in his laboratory at The Avenue, in the Melbourne suburb of St Kilda. There, he investigated the concentration of sulphide ores being mined at Broken Hill in New South Wales.

In 1901, he discovered and patented a process whereby he could make sulphide ore particles float on bubbles generated by a reaction between the ore and a hot bath of one per cent sulphuric acid, in which the ore was placed. At Broken Hill, the Block 14 company experimented with the process, completing a small flotation plant. In 1903-05 it recovered 60 per cent of the zinc and much of the lead and silver from iron ore tailings.



The Potter-Delprat froth flotation method revolutionised the economics of mining.

Such was the problem of reclaiming these minerals, a number of interest groups were working on similar processes. Indeed, Potter fought a five-year legal battle against Guillaume Delprat, General Manager of BHP Co. Ltd, who discovered a similar process in 1902. Although BHP won eventually on the grounds that Potter's process lacked utility, it soon adopted his use of sulphuric acid and the method of recovery became known as the Potter-Delprat process.

This first large-scale flotation process eventually produced six million tonnes of zinc concentrate at Broken Hill.

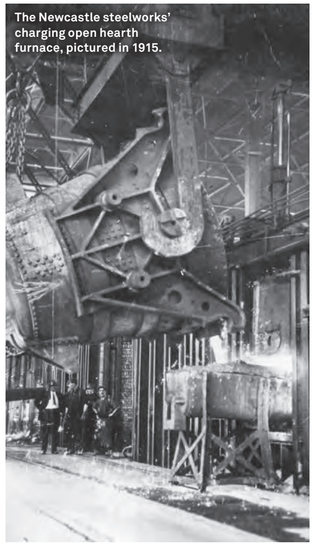
In 1905, the Zinc Corporation was formed under the direction of Herbert Hoover to treat zinc tailings at Broken Hill. They immediately purchased the right to the Potter flotation process but were unable to apply it successfully. Although more effective chemicals have since been found for the process, flotation has continued world-wide to be the method used for treating sulphide ores.

Charles Potter died at his Balwyn home on 27 May 1908. Sadly, having done such pioneering work, his estate's financial position was a debt of £1415, which he had borrowed to invest in his company, Potter's Sulphide Ore Treatment Ltd.

THE MAN OF STEEL

DAVID BAKER

Having been born and eventually died in the United States, it is the 13 years David Baker spent in Australia that marked his status as one of the most influential early contributors to this country's industrial development.



The Newcastle steelworks' charging open hearth furnace, pictured in 1915.

Baker hailed from Boston, Massachusetts, and in 1885 graduated as a mining engineer and metallurgist before working as a blast furnace superintendent with the Pennsylvania Steel Co. In this role he oversaw the establishment of new steelworks at Sparrows Point, and he was soon a published, well respected member of his profession.

Shortly after the turn of the century, Baker formed a partnership with James B. Ladd (later to become BHP's representative in the US) and the pair began to design and install a number of innovative devices for use around blast furnaces.

In April 1912, Baker was selected by Guillaume Delprat, General Manager of Broken Hill Pty Co. Ltd, as a 'tip top' man to advise on establishing steel-making in Australia. Baker spent several months investigating BHP and the Australian market and reported that steel could be manufactured profitably by constructing an integrated steel works at Newcastle, New South Wales, and by focusing on producing steel rails. He prepared a detailed proposal for the facilities and a plan for incremental expansion. In August 1912 he was engaged to oversee construction and management of the steelworks, and in March 1913 he settled with his family in Newcastle. Operations commenced, on schedule, two years later.

As well as specifying modern, but proven, technology he also introduced modern "American" management methods and recruited the most experienced managers available from the US, UK and Australia. When World War One required a massive expansion in production, the plant was able to implement the planned future developments early and successfully.

Baker remained an influential figure in the world iron and steel industry through his membership of international organisations and provided valuable counsel to senior BHP Management. His advice that BHP should not produce all steel products but support related, specialised industries was adopted and served BHP well.

Energetic and capable of making decisions rapidly, Baker expected a high level of commitment and rewarded loyalty, but he oversaw turbulent relationships between management and unions. As BHP was the principal industry in the city, he was a significant community figure and one of his last public statements at Newcastle was advice on the beautification of the historic centre of the city.

By the time ill-health had forced his return to the United States in 1925 – but not before preparing his successor – David Baker had demonstrated his great ability as an engineer and manager in all of his endeavours. His influence was felt throughout BHP Steel for many decades after.



David Baker's time in Australia was brief but impactful

A HEAD FOR PRODUCTION

HEADLIE TAYLOR



From a childhood on the land, Headlie Taylor helped farmers become more commercially

When 14-year-old Headlie Taylor left school to work on his parents' wheat and sheep farm at Emerald Hill farm near Henty, in southern New South Wales, he brought no qualifications except imagination, work ethic and clear thinking.

Convinced that farm machinery could be improved, in his late 20s Taylor lodged his first patent for an improved grain harvester. Next year he set out to design a header-harvester which would handle storm-damaged crops better than the Sunshine harvester designed and commercialised successfully by H V McKay. With family support, working long shifts and teaching himself engineering, he produced his first machine for the 1911-12 harvest.

Though disappointed with the outcome, he pressed on. His next model featured a long-fingered comb which combined with a reciprocating knife and twin spirals that conveyed the cut crop from the comb to the elevators. More evolution followed; by 1914 Taylor produced a third machine at the Henty show which was capable of handling fallen and tangled crops damaged by storms, and weed infested crops.

Interested farmers offered capital to produce it, but he preferred that an existing Australian manufacturer undertake its production. At Taylor's invitation, agricultural machinery manufacturer H V McKay saw the header in action and was so impressed that he



A museum in Henty, NSW, keeps Taylor's story alive.

negotiated for the patent rights. He engaged Taylor to supervise production of the header at the Sunshine works.

Output grew rapidly, from just six machines in 1916, 143 in the 12 months that followed, and 325 in 1918. During 1920, when widespread storms flattened crops, the factory worked day and night to produce 1024 machines equipped with special 'crop lifters'.

The first commercial harvester to combine the reciprocating knife with the Australian stripping-comb, Taylor's header provided the harvesting capacity needed in the broadacre dry farms of the wheat belt.

Taylor went on to produce a string of other innovations. Of them all, the 'Sunshine' engine-powered auto-header, developed in 1924, was the standout, as it greatly increased the speed of harvesting and was the first self-propelled harvester to be manufactured in large numbers. In 1929, Taylor set up a factory in Canada to make auto-headers for the North American market. Production proceeded until the merger of McKay and Massey Harris interests in 1930.

In World War Two, Taylor designed three machines to meet the pressing need for equipment to mechanise the harvesting of flax. Among his final achievements was the modernisation of his 1924 designed Auto Header to accommodate the change to bulk handling of the Australian grain crop, for in 1954 he retired from his position as superintendent of agricultural machinery works at H V McKay Massey Harris Pty Ltd. He died three years later.

A GIANT AMONGST PEERS

SIR ERNEST FISK

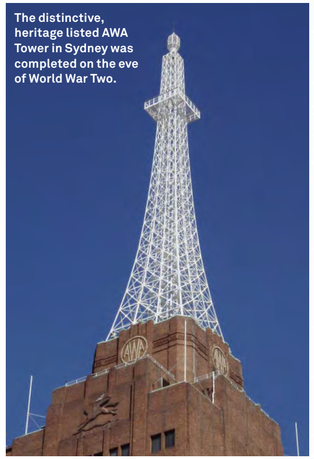
Emerging from a time when formal engineering qualifications were optional, Sir Ernest Fisk stands tall among the Australian engineering fraternity. His drive, natural inquisitiveness, determination, vision, business sense, theosophist philosophy and a wide-ranging mind makes him stand out among his peers across the generations.

Born in Middlesex, England in 1886, his self-taught learning of Morse Code during early work in a post office were the first steps in a career path that took him to the other side of the world. Soon after, famed inventor Guglielmo Marconi developed the long-distance telegraph, and broadcast the first transatlantic radio signal.

At 19, Fisk sought out and in 1905 joined Marconi as a radio operator, then qualified as a radio engineer. Fisk quickly demonstrated his higher-level skills in the company, for he was sent to the United States, Canada and Australia to demonstrate Marconi's products. That latter port was to prove a powerful draw, and in 1911 he returned to Australia as Marconi's Resident Engineer during a period in which the Australian Government was beginning to establish radio communications.

The Government-formed Amalgamated Wireless (Australasia) Ltd. had exclusive rights throughout Australasia to the patents, 'present and future', for both Marconi and German competitor Telefunken, and Fisk was a founding AWA director, plus General and Technical Manager. He would later become Managing Director, then Chairman in 1932.

Through this involvement with AWA, Fisk was instrumental in achieving a major breakthrough in Australian engineering history: the first radio transmission between the United Kingdom and Australia (previously, all communication between Australia and the United Kingdom was via a submarine cable).



The distinctive, heritage listed AWA Tower in Sydney was completed on the eve of World War Two.

In the UK, Marconi set up a long wave station in Caernarfon, Wales, for the initial broadcast to Australia. Fisk set up a receiver in his own house on Sydney's north shore. On 22 September 1918, the first radio message between the UK and Australia was sent by Prime Minister Billy Hughes.

By 1926, the Government sought a direct radio service with the UK, and it commissioned AWA, Fisk's ground-breaking radio communication now evolving into a fully commercial enterprise. He continued to promote the advantages of radio and maintained it was integral to the British Empire, noting: "No scientific discovery offers such possibility for binding together the parts of the far-flung Empire, and for developing its social, commercial and defence welfare."

Fisk was knighted in the Coronation Honours of 1937. He resigned from the company in 1944 to become managing director and chief executive of the Electrical and Musical Industries (His Master's Voice) group in London until his 1952 return to Sydney, where he died in 1968.



A colleague of Marconi, Sir Ernest Fisk introduced Australians to the airwaves

THE CHOCOLATE SOLDIER

SIR VICTOR BURLEY



Sir Victor Burley transformed a factory in the Hobart suburbs into a world manufacturing icon

It is remarkable that the Tasmanian Cadbury factory, situated in the relative isolation of the Hobart riverfront suburb of Claremont, became the iconic 'Factory by Mountain and Sea', and a world leader in the production of chocolate.

And it speaks highly of the man credited with Cadbury's industry-leading status, Sir Victor Burley, who enjoyed a lifetime of engineering and technical achievement. Burley took advantage of that isolation to work away from competitors' scrutiny, becoming a technical adviser and inspiration for the many Cadbury operations built or acquired steadily around the world.

Ten years after joining Cadbury in 1938 as an engineering graduate from the University of Tasmania, Burley was appointed Engineering Director of the Australian Company, a position he filled, among other senior roles, until his retirement in 1978. The Tasmanian factory was built in 1921 to serve a growing Australian confectionery market previously supplied by imports. Soon, thanks to the man they called 'The Chocolate Soldier', the site would become the company's trailblazer.

Burley was deeply interested in the manufacture of the company's flagship product, Cadbury Dairy Milk chocolate, which was made by evaporating milk with cocoa and sugar to produce its uniquely distinctive flavour. Burley developed a revolutionary continuous process plant at Claremont which emerged as the model for much larger developments across the Cadbury world.

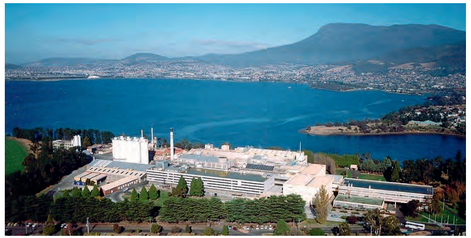
He was considered an expert on all aspects of milk processing and confectionery and was consulted not only by his international Cadbury colleagues but by international machinery manufacturers as well. Burley pioneered the move from metal to plastics for chocolate moulds and his interest in all things engineering incorporated an expert knowledge of steam generation, industrial refrigeration, electricity and hydraulics. He was notable for pioneering work on centrifugal refrigeration compressors and electrode boilers at Claremont.

Dynamic and popular, he inspired an engineering team that continuously advanced the Company's technical innovation and the viability of its Tasmanian operations.

Burley maintained an active role in the University of Tasmania throughout his life, dating from 1937 as President of the Students Union, later a key advisor, and particularly with the Engineering Faculty by mentoring many students through a scholarship program that he established, sponsored by Cadbury.

He served as Chairman of the Institution of Engineers Tasmanian Division, was a member of the Australian Academy of Science, and played a key role as Chairman of the reconstituted National Council of the CSIRO (1978-81) in its transformation.

He was knighted in 1980 and in his retirement Sir Victor became foundation chairman of the Tasmanian Council for Advanced Education where he was instrumental in establishing the Tasmanian College of Advanced Education, which later became part of the University of Tasmania.



The iconic Cadbury factory sits proudly on the Derwent River banks in Claremont, Tasmania.

A SPARK OF INTEREST

PETER COCKBAIN

In 1966, Peter Cockbain was a mature age, part-time engineering degree student attending lectures four nights a week. By day, he was a clerk at Crompton Parkinson, a British electrical manufacturing business in Newcastle, NSW, but an announcement would soon change his life, and the lives of many others.

The company was sold, with the new owner declaring he would cease manufacturing in Australia within two years. It seemed the local market was too small to sustain local manufacturing, and importing electrical componentry was a far superior option.

Having earlier tackled an electrical apprenticeship and trades course, Cockbain gathered a handful of friends – Neville Sawyer, Keith Grant and Tony Stoddart – and they decided to go it alone, believing many customers still preferred to purchase Australian-made products where possible. They formed Ampcontrol on 1 April 1968, working out of a shed during the day, plus nights and weekends, to make switchboards and switchgear.

The partners had complementary skills: Sawyer in marketing and sales, Grant in project management and Stoddart in sales on the road. They needed Cockbain to bring the manufacturing knowledge and he joined full-time after completing his electrical engineering degree in 1969. Ampcontrol took on the agency for selling NHP Electrical Engineering Products and grew from there, winning BHP contracts for six substations, followed by irrigation pumping stations.



Cockbain's belief in homegrown Australian product helped build a worldwide business.

There was still the matter of competition. If they could not be the cheapest, they would outstrip others with performance and innovation.

Under Cockbain's direction, the company established itself in underground mining and grew to be recognised for its design and manufacture of electrical solutions which improved safety and efficiency in the resources sector. Gradually they expanded from the Hunter region to serve state, national and international customers, manufacturing electrical and electronics products not only for mining but also for the renewable, infrastructure and industrial sectors.

In 2019, the company operates in eight countries, including Australia, New Zealand, Russia, Botswana, Hong Kong, United States, United Kingdom and China. Featuring over 1,000 employees, it has now evolved beyond the fluctuations of the resource sector, delving into railways, trams and renewables, with two solar farms already built using their expertise.

A former National Council member and President of Engineers Australia, Cockbain has been a board member of Standards Australia, the University of Newcastle Council and the Prime Minister's Science, Engineering and Innovation Council. In 2015, he received a Member of the Order of Australia honour for his significant contribution to the mining and energy sectors and professional organisations.

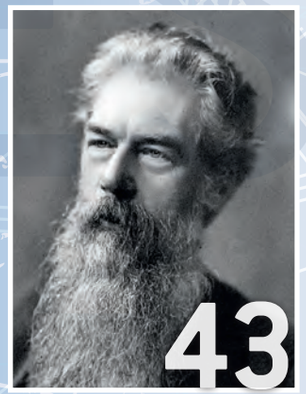


Supporting the local mining industry, Peter Cockbain helped build a worldwide electrical force

5 RESOURCEFULNESS THROUGH ISOLATION



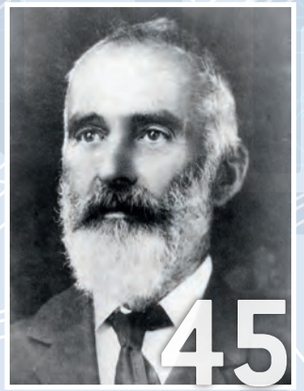
FREDERICK WOLSELEY



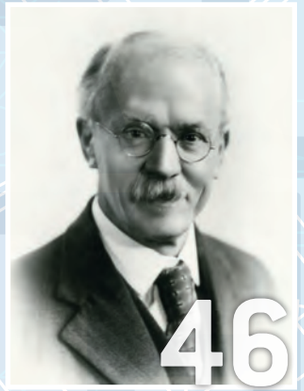
NORMAN SELFE



ROBERT GRAY FORD



LAWRENCE HARGRAVE

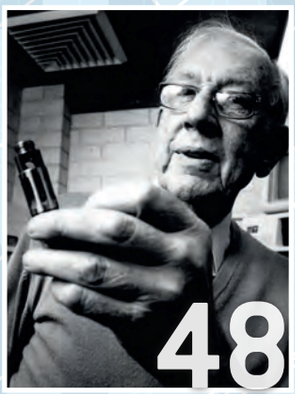


ANTHONY MICHELL



ALF TRAEGER

Isolation in the southern hemisphere, coupled with different climactic conditions and farming methods, led to increasing need for self-sufficiency and resourcefulness. But at times it had the disadvantage of visionaries being removed from existing industries, where innovation could have been introduced by inventive minds, and ideas were sometimes dismissed simply because they arose from 'colonials'.



ARTHUR BISHOP

5

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CUTTING IT CLOSE

FREDERICK WOLSELEY



By inventing the shearing machine, Frederick Wolseley revolutionised one of Australia's primary sources of income

Irish-born Frederick Wolseley arrived in Melbourne in 1854 as a 17-year-old and headed for his brother-in-law's sheep station on the Murray River. He thrived in this new land and after five years became manager and part-owner of the family's properties, a position he held for another twelve years.

By 1868, now an accomplished woolgrower and with finance from his elder brother Garnet, he had begun experiments on a machine for shearing sheep which, by 1872, had evolved into a working model which removed at least part of a fleece. A number of obstacles remained unsolved: a cutter that would not clog in the thick fleece, a handpiece that did not restrict the shearer's movements and a reliable means of transmitting power to the handpiece.

From 1874 he spent two years in Melbourne working with Robert Savage and Richard Park before returning to the land and purchasing Euroka station near Walgett. From 1877 he was granted a number of patents, all of which proved unsuccessful, but he didn't give up.

In 1884 he and Park patented an 'Improved Shearing Apparatus' which became the standard for future developments: an oscillating cutter head, a cog-gear universal joint at the rear of the handpiece and a flexible rotating wire driveshaft. John Howard, now Wolseley's mechanic at Euroka made several improved machines which worked so well



Elements of hand piece designed by Wolseley, which added substantial efficiency to the shearing process.

during the 1885 season that Wolseley decided to commence manufacture.

From 1885 he staged a number of 'demonstrations' throughout the country pitting "gun" hand shearers against his mechanical shears. The hand shearers were faster but the mechanical shears cut closer to the skin and removed more fleece – more money for the grazier! He also worked hard to convert respected hand shearers to become advocates for his shears.

From the first order in 1888 sales grew rapidly but, at the time, Australia did not have the capability to supply the volume or precision of components required so, in 1889, he established the Wolseley Sheep Shearing Machine Co. Pty Ltd in England. The 1890s depression affected sales and competition was fierce and sometimes unscrupulous, mainly from enhancements on his and Park's original arrangement.

Wolseley's health was also failing and in 1893 he returned to England, appointing Howard to run the Australian business and Herbert Austin to manage the English factory. Austin (later of car fame) had been working for Park improving features and manufacturability since 1887 and it was he who diversified the company into bicycle and later motor car production to 'smooth' seasonal variations in production.

Undeterred by his limited practical mechanical experience, Wolseley engaged talented collaborators, though he was inventive and, above all, persevering.
He has the honour of inventing the shearing machine, which revolutionised the wool industry in Australia.

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A PROLIFIC PERFORMER

NORMAN SELFE

Norman Selfe was an engineer, naval architect, inventor, urban visionary and passionate advocate of an independent technical education system. Today, he is best remembered in the name of the suburb of Normanhurst, where his grand house Gilligaloola still stands.

But decades before the existing Harbour Bridge was built, Sydney came close to building a Selfe-designed steel cantilever bridge across the harbour with its northern foot in McMahons Point and he was highly regarded for his docks, boats, precision machinery, his ideas for new transport schemes for Sydney, and for his pioneering developments of engineering and technical education institutions.

After emigrating from England with his family in 1855, Selfe began his career as an engineer by taking articles of apprenticeship to famed Sydney ironmaster Peter Nicol Russell, at whose firm he worked in several departments and eventually became chief draftsman. In 1859, when P N Russell & Co expanded to a site in Barker Street near the head of Darling Harbour, Selfe drew up plans for the new works and the wharf, and oversaw their construction.

In 1861, at the age of 21 he achieved international recognition when leading British journal The Engineer published illustrations of his designs for one of the first refrigerating machines, innovation that allowed the export of meat and dairy products. He eventually wrote a definitive textbook on the subject, published in the US in 1900.

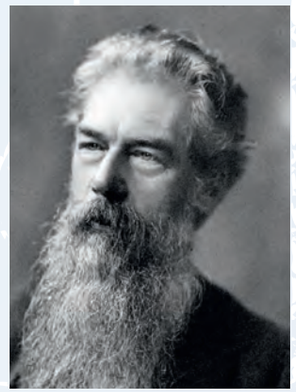
In 1869, Selfe was appointed to the senior post of Chief Draftsman and Scientific Engineer at Mort's Dock and Engineering Company in Balmain where he oversaw the design and construction of the mail ship SS Governor Blackall.

He established his own practice in 1877 and proved to be as prolific as he was versatile. He designed machinery for some 50 steam vessels, including two torpedo boats which he claimed were the fastest boats on the harbour for 20 years, and the SS Wallaby, Sydney Harbour's first double-ended screw ferry.

Selfe introduced the first lifts, patented an improved system of baling wool – which increased capacity fourfold – and oversaw electric light and hydraulic installations. He planned mills, waterworks and pumping stations and designed the inclined coal transfer system, the track of what is now the Scenic Railway attraction at Katoomba in the Blue Mountains.

He was a passionate and outspoken advocate for independent engineering and trades training and often locked horns with politicians and the education 'establishment'. Nevertheless, he helped found the Engineering Association of NSW, a forerunner of Engineers Australia and the Technical and Working Men's College, the foundation of future technical education in NSW.

Across NSW, Norman Selfe's mark is everywhere.



From an early professional age, Norman Self was clearly going to make his mark across his own backyard



Selfe's design entry for the 1902 Sydney Harbour Bridge project.

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BEFORE HIS TIME

ROBERT GRAY FORD



By refining rock boring technology, Robert Gray Ford delivered industrialisation to the back breaking work of mining

Of the thousands of young men heading south from England to the allure of the Australian goldfields, Robert Gray Ford would influence his new home, and industry, like few others. A blacksmith by trade, like his father, Ford arrived in 1852 with good prospects for work, but he soon expanded his horizons thanks to an ingenuity and work ethic that shone all his life.

Ford's first patent was for a lifting apparatus to raise an iron viaduct girder. On the strength of the idea, he was appointed Superintendent for the erection of the ironwork of the Moorabool Viaduct, one of the early Victorian Railways engineering marvels. This viaduct is 396 metres in length and up to 35 m above the Moorabool River valley.

It marked Ford's reputation as an engineer, and although he continued to work on his own projects none would be as ground-breaking – literally – as his rock boring machine. Patented in 1867, 'Ford's Rock Boring Machine' was first demonstrated at Vivian's Foundry in the regional Victorian town of Castlemaine.

More than 20 men from the mining industry, and the Victorian Water Supply Department, witnessed the drill in action, its use of an air pump or compressor, and air receiver, completing a display impressive enough for those assembled to organise a more meaningful test at the nearby Hustler's Reef Mine.

Again, the rock boring machine succeeded. The drill was mounted in a small crosscut, boring slate, sandstone and quartz, and observers knew this was revolutionary change in mining industrialisation.

Ford, however, was not yet satisfied. He turned his attention to the air compressor itself, a typically heavy, cumbersome yet mandatory accessory for the drill, and a new compact yet efficient design soon followed and became the most common in Victoria for the next two decades.

As Engineer for Construction for the Victorian Railways, Ford remained highly influential. He was talented, inventive, incorruptible and conscientious, and his innovative thinking would save the Government a great deal of money, not only in railway construction.

As an example: the deepening of the mouth of the Yarra River in 1878 was a necessary but problematic challenge. Ford invented a large submarine drill. Two were employed, set in 13.7 m towers on twin barges carrying the vertical boiler, air compressor, air receiver and winches. He would also create a compressed air or steam powered Improved Winch and an Improved Patent Gas Compressor.

Ford passed away in East Brighton in 1891. A man without formal qualification, he was remembered as 'a man before his time' who was intellectually head and shoulders above his fellows.



Drilling with compressed air completely changed the miner's speed and workload.

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DEFYING GRAVITY

LAWRENCE HARGRAVE

It is Orville and Wilbur Wright who are rightly credited with man's first powered flight, in a field at Kitty Hawk, North Carolina, in 1903. Yet it is not too much a stretch to suggest the Wright Brothers' story is linked to the work of Lawrence Hargrave, an English-born Australian a decade earlier.

Lawrence Hargrave was a dreamer, yet his dreams were founded on a refined understanding of aeronautics and flight. Hargrave chose to live and experiment with his flying machines in Stanwell Park, a picturesque coastal village north of Wollongong, NSW. Blessed with excellent wind and topography, it remains one of Australia's most revered hang gliding and paragliding venues.

Hargrave conceived, tested and developed many innovations.

In 1892 he discovered that a curved wing surface, particularly those with thicker leading edges, appeared to produce greater lift than a flat supporting surface. Then he turned his attention to research into the behaviour of various types of kites. During the course of his experiments he demonstrated that a curved surface had twice the lift of a flat one, and by 1893 he had discovered that a kite with two separated 'cells' or double planes - the 'box' kite – had the greatest stability and soaring power.

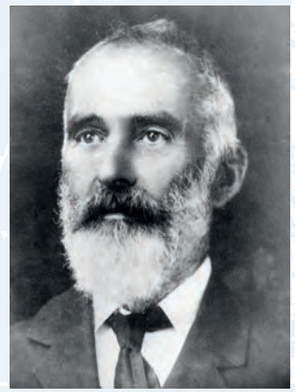
Of great significance to those working toward powered flight, Hargrave successfully lifted himself off the ground under a train of four of his box kites moored via a spring balance to two sandbags.

Hargrave carried an anemometer and clinometer aloft to measure windspeed and the angle of the kite line. He rose 16 ft in a wind speed of 21 mph. This experiment was widely reported and established the box kite as a stable aerial platform, beginning a design lineage later adopted by countless flight pioneers and culminating with the Wrights.

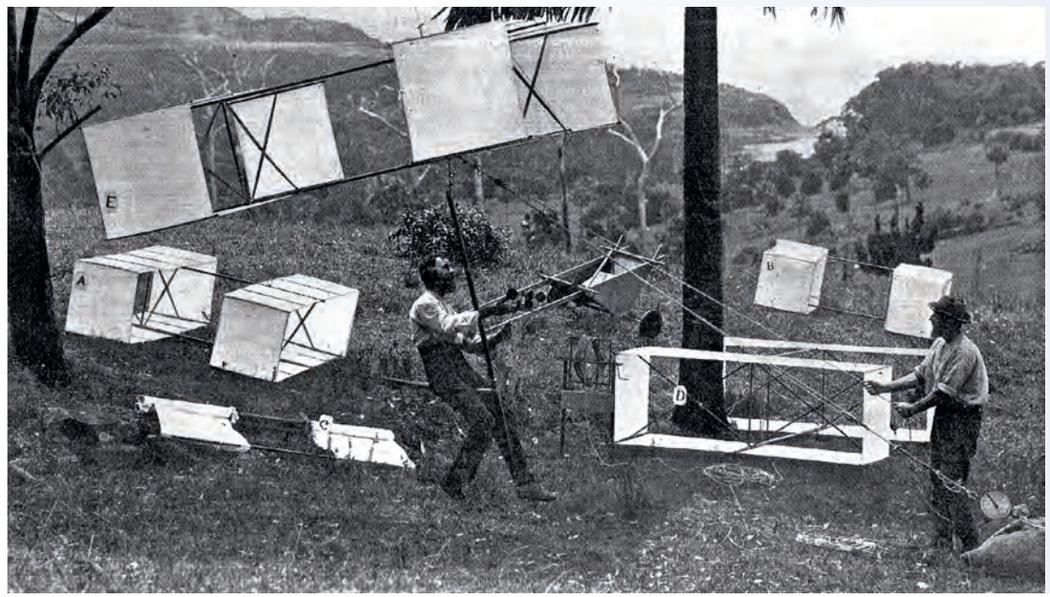
In an attempt to achieve powered flight, he invented a rotary engine, but weight and machining limitations of the time proved insurmountable. Interestingly, in 2002, when Sydney University aeronautical engineering students built a replica aircraft from Hargraves' original 1902 blueprints and fitted a modern engine – it flew!

Many men smiled at his efforts and few had faith that anything would come of them, but Hargrave had the optimism that is essential for an inventor, and the perseverance to move past failures. Modest, unassuming and unselfish, he always refused to patent his inventions, and was only anxious that he might succeed in adding to the sum of human knowledge. Indeed, he published his works in international learned journals from 1895.

Still widely respected in the aeronautical circles around the world for his pioneering research, he has been recognised in Australia through his appearance on Australia's first $20 paper note, which he adorned from 1966-94 and was one of the first to be inducted into Australia's Aviation Hall of Fame.



A pioneer of early Australian flight, Lawrence Hargrave's mind helped man take to the sky

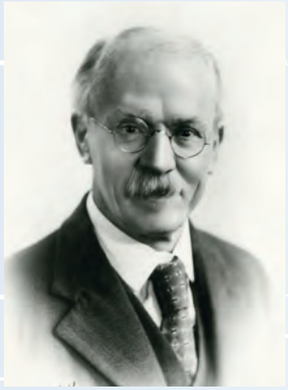


Hargraves experiments with his 'man-lifting' kite.

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A MAN OF BRILLIANCE

ANTHONY MICHELL



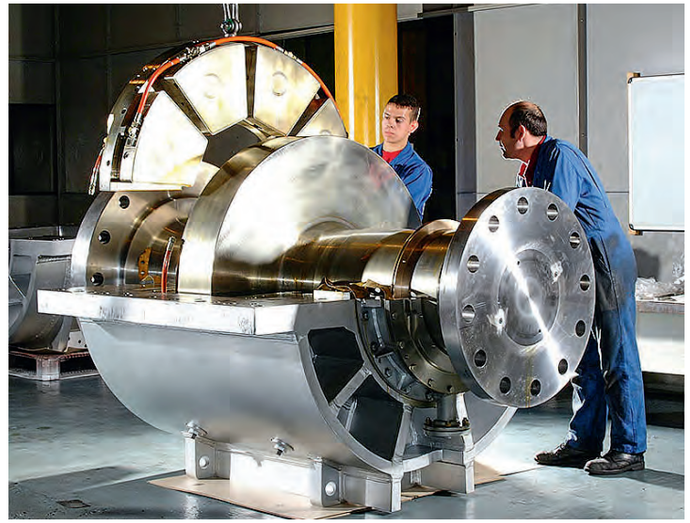
A genius in fluid mechanics, Anthony Michell revolutionised thrust technology through his unique designs

It makes sense that Anthony Michell's Devonshire-born parents both came to Australia as part of the gold rush, for their son inherited the same spirit of adventure and optimism in a highly inventive career in engineering.

Educated in England before returning to Australia in 1890, Michell enrolled at the University of Melbourne and was soon noticed by, and became pupil-assistant of, civil and hydraulic engineer Bernhard A Smith. The pair jointly developed and patented a design for a regenerative pump, and soon after the turn of the century Michell established his consultancy in irrigation, water supply and sewerage.

His reputation was secured when he took out a patent for the Michell thrust-bearing, developed from his research on the mechanical properties of fluids and mathematical studies of fluid motion, viscosity and lubrication. It revolutionised thrust technology, especially in marine propulsion, making possible the building of ships up to the size of the Queen Mary and larger. The Michell thrust-bearing allowed increased pressure more than ten-fold, replacing the massive plane-faced collars which made contact with fixed plane shoes.

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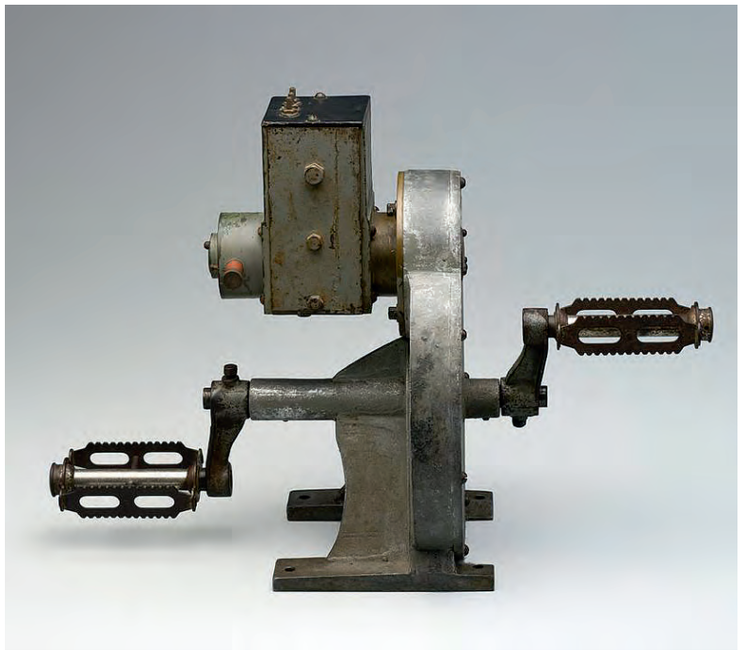
Of "medium height and slight build, with sandy hair and moustache, (and) keen intelligent eyes", Michell received the University of Melbourne's Kernot Medal in 1938, and in 1943 was awarded the James Watt International Medal by the Institution of Mechanical Engineers, London.

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ALL PRAISE PEDAL POWER

ALF TRAEGER



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AN INVENTIVE MIND

ARTHUR BISHOP



Arthur Bishop might be Australia's most prolific inventor

A naturally inquisitive boy, Arthur Bishop began pulling clocks and other machinery apart as a child. By the time of his death, aged 88, he had compiled more than 300 patents in 17 countries, and one in five of the world's cars were using some aspect of his variable ratio, rack and pinion power steering technologies.

It can be argued Bishop was Australia's most successful inventor. Armed with a diploma of mechanical engineering with honours from Sydney Technical College, Bishop served his apprenticeship at his uncle's machine shop, E.G. Bishop, in Chippendale. His first invention came in 1933 when he noticed a soap production line needed women with knives to trim the soap bars.

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After the war, Bishop and two fellow workers formed LBL Products to design and manufacture special purpose machines. An adaptation of one of his wartime patents led to a career in vehicle handling and the manufacture of innovative automobile steering gears.

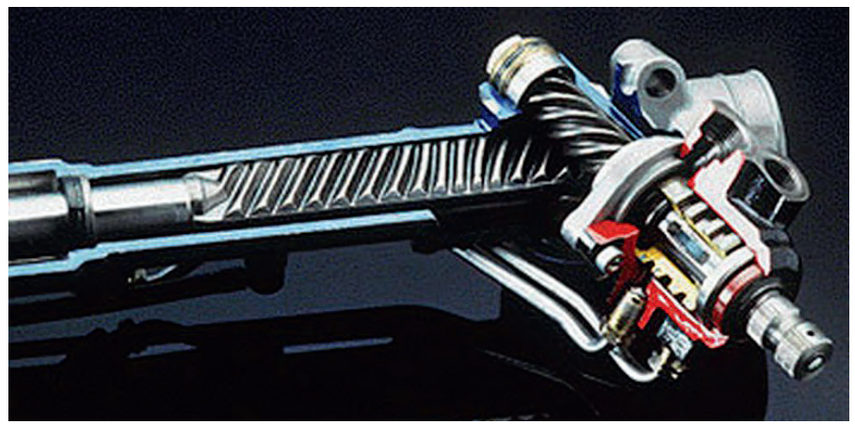
Over the next two decades he worked as a consulting engineer to the motor industry in the US and England, including running his own automotive steering company in Detroit, until in 1970 the lure of the Australian car industry drew him home.

For a man steeped in algorithms and formulae, the search for the perfect steering system was surprisingly subtle. He understood the relationship between human and machines exemplified in the steering mechanism and constantly sought to improve it.

In the 1980s, Bishop sensed an energy crisis was at hand. Investigating people-mover systems, he developed and patented a high speed vehicle-and-track system using fleets of small, electric, driverless vehicles running on narrow-gauge tracks. Ahead of its time, it never progressed to mass acceptance.

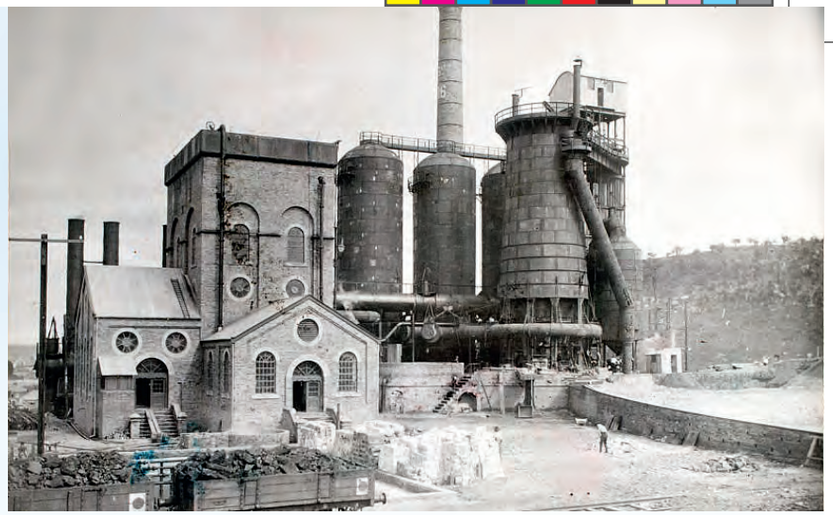
The project typified his intense breadth of interests: not only did he design the machines; he designed the machines to make the machines. Bishop Technology exported manufacturing machines to China, supplied titanium steering racks to two Formula 1 racing teams and produced tooling for biomedical companies such as Cochlear and the developer of an implantable heart.

Royalty payments for his work have recently varied between $8 million and $15 million a year, and the company has annually invested up to $7 million into research and development. Yet Arthur Bishop, who was made a Member of the Order of Australia,never took more than a salary from the company and drove a Honda for many years because he liked the way it steered.



Bishop's lifelong quest for the perfect steering apparatus was finally realised.

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Then and now: ruins of the 1886 blast furnace in Lithgow Blast Furnace Park.

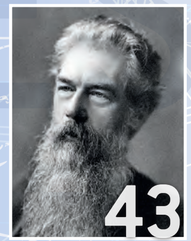
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5 RESOURCEFULNESS THROUGH ISOLATION

Isolation in the southern hemisphere, coupled with different climactic conditions and farming methods, led to increasing need for self-sufficiency and resourcefulness. But at times it had the disadvantage of visionaries being removed from existing industries, where innovation could have been introduced by inventive minds, and ideas were sometimes dismissed simply because they arose from 'colonials'.


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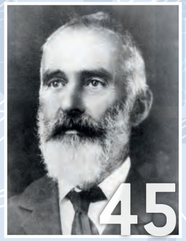
FREDERICK WOLSELEY


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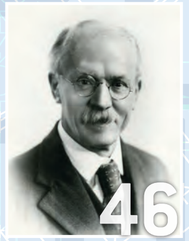
NORMAN SELFE


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ROBERT FORD


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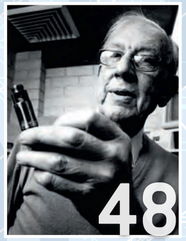
LAURENCE HARGRAVE


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RESOURCEFULNESS THROUGH ISOLATION

5

CUTTING IT CLOSE

FREDERICK WOLSELEY



By inventing the shearing machine, Frederick Wolseley revolutionised one of Australia's primary sources of income

Irish-born Frederick Wolseley arrived in Melbourne in 1854 as a 17-year-old and headed for his brother-in-law's sheep station on the Murray River. He thrived in this new land and after five years became manager and part-owner of the family's properties, a position he held for another twelve years.

By 1868, now an accomplished woolgrower and with finance from his elder brother Garnet, he had begun experiments on a machine for shearing sheep which, by 1872, had evolved into a working model which removed at least part of a fleece. A number of obstacles remained unsolved: a cutter that would not clog in the thick fleece, a handpiece that did not restrict the shearer's movements and a reliable means of transmitting power to the handpiece.

From 1874 he spent two years in Melbourne working with Robert Savage and Richard Park before returning to the land and purchasing Euroka station near Walgett. From 1877 he was granted a number of patents, all of which proved unsuccessful, but he didn't give up.

In 1884 he and Park patented an 'Improved Shearing Apparatus' which became the standard for future developments: an oscillating cutter head, a cog-gear universal joint at the rear of the handpiece and a flexible rotating wire driveshaft. John Howard, now Wolseley's mechanic at Euroka made several improved machines which worked so well



Elements of hand piece designed by Wolseley, which added substantial efficiency to the shearing process.

during the 1885 season that Wolseley decided to commence manufacture.

From 1885 he staged a number of 'demonstrations' throughout the country pitting "gun" hand shearers against his mechanical shears. The hand shearers were faster but the mechanical shears cut closer to the skin and removed more fleece – more money for the grazier! He also worked hard to convert respected hand shearers to become advocates for his shears.

From the first order in 1888 sales grew rapidly but, at the time, Australia did not have the capability to supply the volume or precision of components required so, in 1889, he established the Wolseley Sheep Shearing Machine Co. Pty Ltd in England. The 1890s depression affected sales and competition was fierce and sometimes unscrupulous, mainly from enhancements on his and Park's original arrangement.

Wolseley's health was also failing and in 1893 he returned to England, appointing Howard to run the Australian business and Herbert Austin to manage the English factory. Austin (later of car fame) had been working for Park improving features and manufacturability since 1887 and it was he who diversified the company into bicycle and later motor car production to 'smooth' seasonal variations in production.

Undeterred by his limited practical mechanical experience, Wolseley engaged talented collaborators, though he was inventive and, above all, persevering. He has the honour of inventing the shearing machine, which revolutionised the wool industry in Australia.

A PROLIFIC PERFORMER

NORMAN SELFE

Norman Selfe was an engineer, naval architect, inventor, urban visionary and passionate advocate of an independent technical education system. Today, he is best remembered in the name of the suburb of Normanhurst, where his grand house Gilligaloola still stands.

But decades before the existing Harbour Bridge was built, Sydney came close to building a Selfe-designed steel cantilever bridge across the harbour with its northern foot in McMahons Point and he was highly regarded for his docks, boats, precision machinery, his ideas for new transport schemes for Sydney, and for his pioneering developments of engineering and technical education institutions.

After emigrating from England with his family in 1855, Selfe began his career as an engineer by taking articles of apprenticeship to famed Sydney ironmaster Peter Nicol Russell, at whose firm he worked in several departments and eventually became chief draftsman. In 1859, when P N Russell & Co expanded to a site in Barker Street near the head of Darling Harbour, Selfe drew up plans for the new works and the wharf, and oversaw their construction.

In 1861, at the age of 21 he achieved international recognition when leading British journal The Engineer published illustrations of his designs for one of the first refrigerating machines, innovation that allowed the export of meat and dairy products. He eventually wrote a definitive textbook on the subject, published in the US in 1900.

In 1869, Selfe was appointed to the senior post of Chief Draftsman and Scientific Engineer at Mort's Dock and Engineering Company in Balmain where he oversaw the design and construction of the mail ship SS Governor Blackall.

He established his own practice in 1877 and proved to be as prolific as he was versatile. He designed machinery for some 50 steam vessels, including two torpedo boats which he claimed were the fastest boats on the harbour for 20 years, and the SS Wallaby, Sydney Harbour's first double-ended screw ferry.

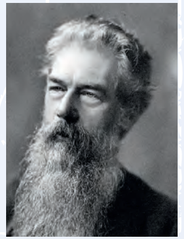
Selfe introduced the first lifts, patented an improved system of baling wool – which increased capacity fourfold – and oversaw electric light and hydraulic installations. He planned mills, waterworks and pumping stations and designed the inclined coal transfer system, the track of what is now the Scenic Railway attraction at Katoomba in the Blue Mountains.

He was a passionate and outspoken advocate for independent engineering and trades training and often locked horns with politicians and the education 'establishment'. Nevertheless, he helped found the Engineering Association of NSW, a forerunner of Engineers Australia and the Technical and Working Men's College, the foundation of future technical education in NSW.

Across NSW, Norman Selfe's mark is everywhere.



Selfe's design entry for the 1902 Sydney Harbour Bridge project.



From an early professional age, Norman Self was clearly going to make his mark across his own backyard

BEFORE HIS TIME

ROBERT GRAY FORD



By refining rock boring technology, Robert Ford delivered industrialisation to the back breaking work of mining

Of the thousands of young men heading south from England to the allure of the Australian goldfields, Robert Ford would influence his new home, and industry, like few others. A blacksmith by trade, like his father, Ford arrived in 1852 with good prospects for work, but he soon expanded his horizons thanks to an ingenuity and work ethic that shone all his life.

Ford's first patent was for a lifting apparatus to raise an iron viaduct girder. On the strength of the idea, he was appointed Superintendent for the erection of the ironwork of the Moorabool Viaduct, one of the early Victorian Railways engineering marvels. This viaduct is 396 metres in length and up to 35 m above the Moorabool River valley.

It marked Ford's reputation as an engineer, and although he continued to work on his own projects none would be as ground-breaking – literally – as his rock boring machine. Patented in 1867, 'Ford's Rock Boring Machine' was first demonstrated at Vivian's Foundry in the regional Victorian town of Castlemaine.

More than 20 men from the mining industry, and the Victorian Water Supply Department, witnessed the drill in action, its use of an air pump or compressor, and air receiver, completing a display impressive enough for those assembled to organise a more meaningful test at the nearby Hustler's Reef Mine.

Again, the rock boring machine succeeded. The drill was mounted in a small crosscut, boring slate, sandstone and quartz, and observers knew this was revolutionary change in mining industrialisation.

Ford, however, was not yet satisfied. He turned his attention to the air compressor itself, a typically heavy, cumbersome yet mandatory accessory for the drill, and a new compact yet efficient design soon followed and became the most common in Victoria for the next two decades.

As Engineer for Construction for the Victorian Railways, Ford remained highly influential. He was talented, inventive, incorruptible and conscientious, and his innovative thinking would save the Government a great deal of money, not only in railway construction.

As an example: the deepening of the mouth of the Yarra River in 1878 was a necessary but problematic challenge. Ford invented a large submarine drill. Two were employed, set in 13.7 m towers on twin barges carrying the vertical boiler, air compressor, air receiver and winches. He would also create a compressed air or steam powered Improved Winch and an Improved Patent Gas Compressor.

Ford passed away in East Brighton in 1891. A man without formal qualification, he was remembered as 'a man before his time' who was intellectually head and shoulders above his fellows.



Drilling with compressed air completely changed the miner's speed and workload.

DEFYING GRAVITY

LAWRENCE HARGRAVE

It is Orville and Wilbur Wright who are rightly credited with man's first powered flight, in a field at Kitty Hawk, North Carolina, in 1903. Yet it is not too much a stretch to suggest the Wright Brothers' story is linked to the work of Lawrence Hargrave, an English-born Australian a decade earlier.

Lawrence Hargrave was a dreamer, yet his dreams were founded on a refined understanding of aeronautics and flight. Hargrave chose to live and experiment with his flying machines in Stanwell Park, a picturesque coastal village north of Wollongong, NSW. Blessed with excellent wind and topography, it remains one of Australia's most revered hang gliding and paragliding venues.

Hargrave conceived, tested and developed many innovations.

In 1892 he discovered that a curved wing surface, particularly those with thicker leading edges, appeared to produce greater lift than a flat supporting surface. Then he turned his attention to research into the behaviour of various types of kites. During the course of his experiments he demonstrated that a curved surface had twice the lift of a flat one, and by 1893 he had discovered that a kite with two separated 'cells' or double planes - the 'box' kite - had the greatest stability and soaring power.

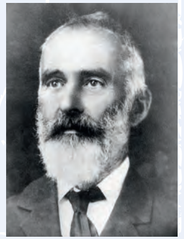
Of great significance to those working toward powered flight, Hargrave successfully lifted himself off the ground under a train of four of his box kites moored via a spring balance to two sandbags.

Hargrave carried an anemometer and clinometer aloft to measure windspeed and the angle of the kite line. He rose 16 ft in a wind speed of 21 mph. This experiment was widely reported and established the box kite as a stable aerial platform, beginning a design lineage later adopted by countless flight pioneers and culminating with the Wrights.

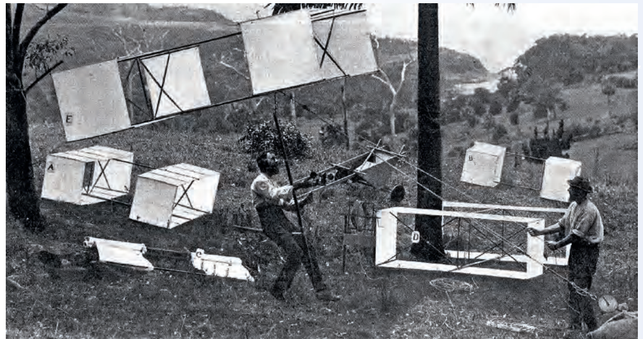
In an attempt to achieve powered flight, he invented a rotary engine, but weight and machining limitations of the time proved insurmountable. Interestingly, in 2002, when Sydney University aeronautical engineering students built a replica aircraft from Hargraves' original 1902 blueprints and fitted a modern engine – it flew!

Many men smiled at his efforts and few had faith that anything would come of them, but Hargrave had the optimism that is essential for an inventor, and the perseverance to move past failures. Modest, unassuming and unselfish, he always refused to patent his inventions, and was only anxious that he might succeed in adding to the sum of human knowledge. Indeed, he published his works in international learned journals from 1895.

Still widely respected in the aeronautical circles around the world for his pioneering research, he has been recognised in Australia through his appearance on Australia's first $20 paper note, which he adorned from 1966-94 and was one of the first to be inducted into Australia's Aviation Hall of Fame.



A pioneer of early Australian flight, Lawrence Hargrave's mind helped man take to the sky



Hargraves experiments with his 'man-lifting' kite.

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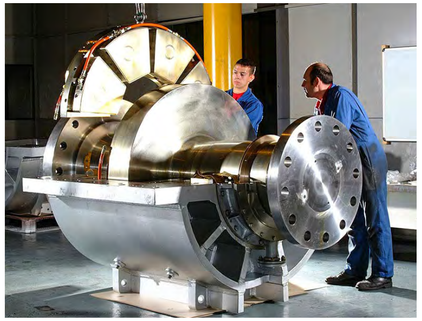
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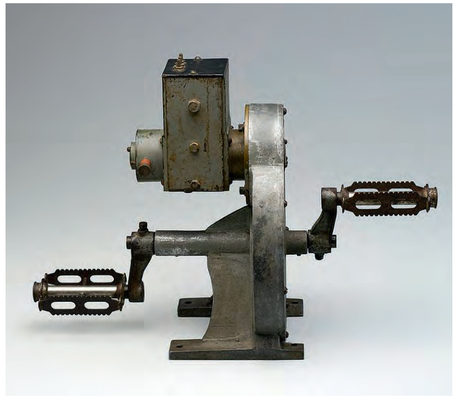
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It can be argued Bishop was Australia's most successful inventor. Armed with a diploma of mechanical engineering with honours from Sydney Technical College, Bishop served his apprenticeship at his uncle's machine shop, E.G. Bishop, in Chippendale. His first invention came in 1933 when he noticed a soap production line needed women with knives to trim the soap bars.

During World War II he worked at the Aircraft Production Annexe in Sydney, which produced the undercarriage for Beaufort bombers. Owing to wartime shortages these facilities had to re-design and manufacture components 'from scratch'. There, still in his early twenties, he improved the plane's steering and landing gear, particularly the 'shimmy' of the tail wheels, innovations taken up by Britain and the United States for many aircraft.

After the war, Bishop and two fellow workers formed LBL Products to design and manufacture special purpose machines. An adaptation of one of his wartime patents led to a career in vehicle handling and the manufacture of innovative automobile steering gears.

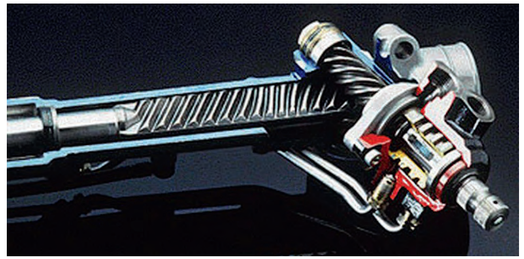
Over the next two decades he worked as a consulting engineer to the motor industry in the US and England, including running his own automotive steering company in Detroit, until in 1970 the lure of the Australian car industry drew him home.

For a man steeped in algorithms and formulae, the search for the perfect steering system was surprisingly subtle. He understood the relationship between human and machines exemplified in the steering mechanism and constantly sought to improve it.

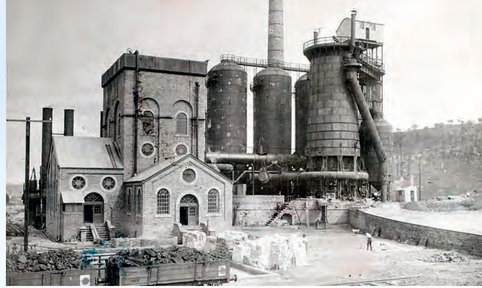
In the 1980s, Bishop sensed an energy crisis was at hand. Investigating people-mover systems, he developed and patented a high speed vehicle-and-track system using fleets of small, electric, driverless vehicles running on narrow-gauge tracks. Ahead of its time, it never progressed to mass acceptance.

The project typified his intense breadth of interests: not only did he design the machines; he designed the machines to make the machines. Bishop Technology exported manufacturing machines to China, supplied titanium steering racks to two Formula 1 racing teams and produced tooling for biomedical companies such as Cochlear and the developer of an implantable heart.

Royalty payments for his work have recently varied between $8 million and $15 million a year, and the company has annually invested up to $7 million into research and development. Yet Arthur Bishop, who was made a Member of the Order of Australia,never took more than a salary from the company and drove a Honda for many years because he liked the way it steered.



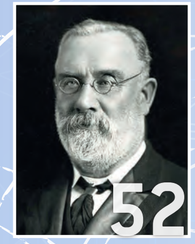
Bishop's lifelong quest for the perfect steering apparatus was finally realised.

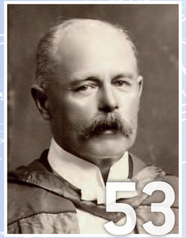


Then and now: ruins of the 1886 blast furnace in Lithgow Blast Furnace Park.

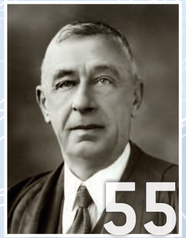
6 A COHERENT PROFESSION

Mid-19th century civil and mechanical engineering skills were generally learned on the job, with little formal recognition or entry requirements for practising as an engineer. Some Australian engineers gained recognition through English institutions, but entry was based more on experience than on education. The need for better educated engineers was recognised through the development of the mechanics institutes and school of arts movement for working men; the schools of mines that were founded in key mining areas; and the progressive inclusion of engineering in universities. State-based organisations merged after the World War One to form the Institution of Engineers Australia in 1919, and the value of standardisation was recognised as a national priority.


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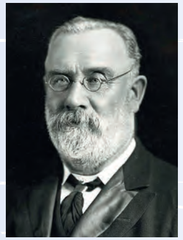

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ERROL MILEVSKIY

A COHERENT PROFESSION

6

AN EARLY PIONEER

WILLIAM KERNOT



William Kernot pioneered higher education for engineers

It is no stretch to suggest that, without the drive and discipline of William Kernot, the early days of engineering education in Victoria would look starkly different.

The English-born Kernot graduated with a Bachelor of Arts in 1864 from the University of Melbourne, which itself was only 11 years from its inception. He had enrolled at age 15, a precocious student who then secured a Master of Arts degree, with units in engineering.

The engineering component was not to degree level as the university did not have the formal authority at the time. But he received the certificate of civil engineering, becoming the first qualified engineer to be produced by the University.

The years that followed revealed to him questionable engineering standards and subsequently steered him back to education as the solution. An early working life was spent in Government water supply, mines, and railways departments in roles which were far from technically challenging. His qualifications were constantly questioned, the engineer-in-chief of the Department of Railways never missing an opportunity to note the "uselessness and undesirability of university training for engineers".

Enjoying part-time lecturer work in surveying and civil engineering, Kernot resigned from the public service in 1875. At age 30, he dedicated his career to improving engineering education, initially within the university framework and later encompassing technical and mining schools as they were established.

In 1882 Kernot became Professor of Engineering, the first at Melbourne University (and a year ahead of William Warren being appointed in Sydney). The first degrees of Bachelor of Engineering were awarded the following year, substantially upgrading some holders of the former certificate.



The striking memorial Kernot window in the University of Melbourne's Old Engineering Building.

When Kernot started at Melbourne University there was little in the way of buildings or equipment, but over 26 years he developed a highly regarded engineering school, while also assisting in the organisation of what later became the Royal Melbourne Institute of Technology.

Beyond the university, Kernot worked on the development of a steerable torpedo, organisation of the International Exhibition of 1880 and on royal commissions and enquiries ranging from railways bridges and locomotives to undergrounding telephone wires. He was published multiple times notably on errors in iron bridge design. His sense of professional dignity and ethics was widely recognised, including an involvement in industrial relations. He was a leading member of professional associations in Victoria, including chair of the Royal Society for 15 years and the Victorian Institute of Engineers as president for 6 years.

Kernot remained Professor of Civil Engineering until his sudden death in 1909. He is honoured by the University's Kernot Memorial Medal for Engineering, which has been awarded to many of Australia's greatest engineers since 1926, and by a memorial window in the Old Engineering Building.

STRIVING FOR EXCELLENCE

WILLIAM WARREN

Having been classically educated in England and Ireland, and admitted in 1877 to the Institution of Civil Engineers, London, William Warren travelled half way around the world to create a legacy that exists to this day.

Warren migrated to Sydney in 1881, beginning work in the Roads and Bridges Branch of the Department of Public Works. Concurrently, he taught applied mechanics at Sydney Technical College in the evenings before being appointed lecturer in engineering in the Department of Physics at the University of Sydney in 1883 and professor from 1884.

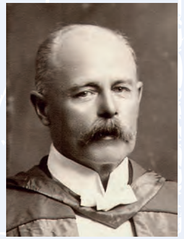
Supported by famed academic W C Kernot in Melbourne, Warren worked to gain recognition for the place of engineering in universities. Popular, but not an outstanding lecturer, he required students to work from technical papers and textbooks, developing their abilities by personal guidance and example. At Sydney, he built up a great engineering school.

He had visited England and the United States of America in 1895 and also established a relationship with Sir Peter Russell, whose gifts to the university led to the foundation of the P N Russell School of Engineering, with facilities unmatched in Australia. In 1900, the first four-year engineering course was approved by the University, and later introduced a requirement of practical experience during their studies – a requirement still demanded by Engineers Australia today – and a decade later, courses in the three major branches of engineering were established in a form that remained essentially unchanged until the 1950s.

Warren was extensively published, especially in his areas of passion: primarily the virtues of Australian timbers, plus iron, steel, masonry, and concrete, all elements of his cutting-edge bridge designs. He served on Royal Commissions into railway bridges and Baldwin locomotives, and for the Adelaide and Melbourne exhibitions, and during World War One was associated with the manufacture of munitions, the calibration of testing machines and the certification of steel.

The acknowledged leader of his profession, with an international reputation and twice President of the Royal Society of NSW, Warren was in 1919 the unanimous choice as first president of the new Institution of Engineers, Australia. His retiring address the next year stressed restrictions on the use of the word 'engineer', registration of engineers with the institution as a qualifying body, a code of ethics and the engineer's duty to his profession. Possessing clear insight, depth of knowledge, wide experience and mental ability, he had the gift of delegating work and authority.

Warren died in 1926 but his legacy lives on at the University of Sydney with the 1983 establishment of the Warren Centre, an independent institute affiliated with the Engineering Faculty with the central objective of "fostering excellence and innovation in advanced engineering in all fields of Australian engineering".



A dedicated educator, William Warren was Engineers Australia's first president.



A testing machine developed under Warren's guidance.

THE EACH-WAY ENGINEER

SIR GEORGE JULIUS



From the creation of the world's first complex computing machine to the establishment of Australia's world-class research organisation

For a man best known for his invention of the racecourse automatic totalizator, George Julius in fact achieved remarkable success across a range of engineering sectors.

Son of a mechanically minded father – and later son-in-law of famed West Australian engineer C Y O'Connor – Julius was born in England, educated in both Melbourne and Christchurch, emerging from Canterbury College with a B.Sc. in mechanical engineering in 1896.

After joining the Western Australian railways as an assistant engineer, and early in the new century publishing works on the physical characteristics and economic uses of Australian hardwoods, in 1907 he moved to Sydney to start work with a major timber company and ultimately started his own successful practice.

Although originally conceived as a vote counting machine, Julius invented the automatic totalizator, which by 1913 was installed at Auckland, New Zealand. These electro-mechanical machines were able to receive multiple bets, calculate and display odds on every horse in the race, as betting proceeded at many places around the course. It is also claimed to be the world's first operational computer.

Commonwealth and State Governments soon sought his broadening expertise on a committee to inquire into electricity supplies in 1925; on a water conservation scheme for the northwest of NSW in 1937; and in regard to the infamous break of gauge in the railways in 1939. Julius widely promulgated his personal views on fiscal policy, unemployment duTring the Depression, industrial standardisation and professional qualifications.



At the CSIRO laboratory in Ryde, NSW, the address commemorates its founding Chairman.

Julius was president of the Engineering Association of New South Wales for three terms in 1910-13 and of the Electrical Association of Australia in 1917-18. A founder of the Institution of Engineers, Australia, in 1919 and president in 1925, Julius fostered the formation of the Australian Commonwealth Engineering Standards Association, inspiring Australia-wide rules for electrical safety in 1926. And he played a key role, as Chairman, in CSIR and subsequently CSIRO, from its inception in 1926 until his retirement in 1945, focusing on the country's primary production threats as yet another example of the varied disciplines in which he excelled.

With "his rather gaunt face, his crop of curly brown hair, and his very luminous blue eyes", Julius was slight in build and spoke in a staccato manner. Considered autocratic and at times impatient, but politically savvy, he was also known for a sense of fair play, quick sense of humour, and objectivity in scientific judgement.

Knighted in 1929, Julius continued to influence a broad range of interests for the remainder of his life, including the establishment of the National Standards Laboratory in the 1930s. Even during World War Two, he served on the Central Inventions Board, the Australian Council for Aeronautics (as chairman) and the Army Inventions Directorate.

A UNIQUE MIND

SIR JOHN MADSEN



An abiding belief in the application of science for the benefit of society drove Madsen to excel in measurement standards, radiophysics and teaching

The achievements of highly respected electrical engineer J P V Madsen were based on broad interests and practical knowledge, which contributed greatly to a distinguished career and lasting legacy to Australian society.

Madsen spent 44 years at the University of Sydney as a student, lecturer, and Professor of Electrical Engineering, the latter role being the first of its type in any Australian university. Graduating in 1900 and 1901 with double degrees of science and engineering, and the University Medal in Mathematics, the unique mind of the man was already apparent.

Madsen was interested in the practical applications of science and encouraged his students, also, to study Science and Engineering. His method of teaching Engineering was to set out a principle and immediately give an example of its practical application; at the same time, he believed students should develop their interaction skills with people of diverse interests, and that high standards and personal presentation were essential to a good engineer.

Madsen argued strongly for the need for physical standards of electrical units as early as 1903, and, more widely in other fields of standardisation in each of the decades that followed, but it was not until 1939 that the National Standards Laboratory was started in the grounds of Sydney University, in what is now the Madsen Building.

During the war, slip gauges were made at the NSL for precision engineering and after the war it reverted to a more traditional role as a testing laboratory. In 1947, Madsen was appointed Vice Chairman and one year later Chairman of the newly formed National Association of Testing Authorities.

Concurrently, he pursued another great interest; that of radio communications, introducing a course and carrying out valuable work on the ionosphere and atmospherics affecting broadcasting stations, which led to war-time radar research and development in Sydney's Radiophysics Laboratory. The production of air warning, Airborne Surface & Vessel radar, naval and shore defence radars emerged from the designs prepared by the RPL and kept Australia at the forefront of this new field. An Ionospheric Prediction Service was operating from Madsen's Department during World War Two, providing accurate radio-frequency forecasts three months in advance.

Continuing to participate at the forefront of knowledge, as Chairman of the Australian National Research Council he was active in developing six recommendations for the Chifley Government relating to Australia's uranium and thorium reserves. In 1951, he chaired a conference on automatic digital and analogue calculating machines, showcasing the digital CSIRAC computer, a turning point in Australia as it marked the beginning of computer science as a new discipline.

And, in 1952, he was President of the International Union of Radio Science congress in Australia, at which he proudly demonstrated Australia's advances in radio astronomy.



The Madsen Laboratory Building at Sydney University.

TRANSFORMING A STATE

GORDON COLEBATCH



Gordon Colebatch developed Tasmania's hydro-electric scheme and shared his knowledge for safer national and international dams

There have been key periods of extensive infrastructure development throughout Australian history, and few can match the marvel that was the evolution of Tasmania's hydro-electric scheme. One of the men most responsible for the decades of literally ground-breaking work was Gordon Colebatch.

South Australian-born and educated, after graduation Colebatch spent four years with the Engineering & Water Supply Department of SA, assisting with the design of Mt Bold Dam and the River Murray Barrages. This experience laid the foundation for him in 1936 joining the Hydro-Electric Commission in Hobart, where he gained experience in canal and pipeline design and model testing for the Tarraleah Power Development.

With the outbreak of World War Two, Colebatch served with the Royal Australian Engineers in the Middle East, Papua New Guinea. He was Lieutenant Colonel in command of the RAE in the 3rd Australian Division in Bougainville, where extensive road and bridge works and mine removal were carried out. For his distinguished services he was awarded the OBE.

On post-war return to the HEC, his star ascended; in 1951 he was appointed Chief Civil Engineer and would hold that position for 23 years, during which he oversaw the commissioning of 19 power stations, including the civil works of 28 large dams and over 40 smaller dams, as well as the associated tunnels, pipelines and villages.

Colebatch and his teams transformed a State, through works which featured incredible planning of construction, manpower and logistics. His engineers thrived under his fair, equitable leadership, establishing a world-wide reputation for expertise in design and construction of dams in particular and also tunnels, pipelines and underground power stations.

Major innovations included the Catagunya concrete gravity dam, only the second in the world to be anchored to its foundation with steel cables and reducing the concrete required by 20%. Colebatch was also hands-on in the development of unique tunnel boring, rock-bolting and penstock design, and the 140m high Gordon Dam was the highest arch dam in Australia.

Colebatch shone for his ability to get talented staff and a skilled workforce to work harmoniously together. When mistakes were made, his attitude was to concentrate on fixing the problem and not on fixing the blame.

Beyond HEC, Colebatch freely shared his experience and drive for technical safety standards with other authorities. From 1960 he represented the HEC on the reconstituted Australian National Committee on Large Dams and followed Sir William Hudson as Chairman of ANCOLD from 1967 to 1969. In 1966 he was elected Vice-President of the International Commission on Large Dams for 3 years.

Colebatch remained active in professional engineering associations until his retirement in 1974, after which he became a key figure in arbitration and engineering mentoring in Australia.



The capacity of the Robbins tunnel boring machine, pictured in 1960, assisted Colebatch power development projects.



Damage from Cyclone Larry pictured in Cairns in 2006.

AGAINST THE WIND

GEOFF BOUGHTON

While studying engineering at the University of Western Australia, Geoff Boughton volunteered to help build an airstrip in a remote Indigenous community in the Northern Territory. On Christmas Day, 1974, he became one of the thousands affected by the devastation caused by Tropical Cyclone Tracy.

Boughton saw first-hand the destruction of people's homes and lives, and stayed to help with the cleanup and recovery. The experience influenced the direction of his career; inspiring him to move from Perth to Townsville with his young family to become the first Research Fellow at the Cyclone Testing Station (CTS) at James Cook University (JCU).

He would begin his PhD on wind loads on houses, and go on to become an internationally respected wind and timber engineer who has made significant contributions to the advancement of the engineering profession – and Australian community – over the past 40 years.

Boughton pre-dated many of the instruments we today take for granted. His motivation to generate accurate, valuable research saw him build his own computer and 64 channel data loggers to record data from the displacement transducers he also made himself. He was also part of a CTS team that constructed a simulated cyclonic load test rig to test a house suitable for use in cyclone-prone Tonga, and hundreds of similar houses have survived many cyclones over the past decades.

A key part of Boughton's work has been investigative, his research into the after-effects of cyclone and severe storm damage across Australia contributing valuable information to local government authorities, Standards Australia and the Australian Building Codes Board. He has been active in improving the Australian / New Zealand wind loading standards as well as a number of Australian and Australian / New Zealand timber standards.

An inaugural member of the Australasian Wind Engineering Society, Boughton has volunteered for the United Nations to assist in the design and construction of low-cost housing for areas of India, the Philippines and the Pacific region, and has been involved in advising governments and engineers in Pacific nations on suitable housing options for the region.

He began a research position at Curtin University in 1986, where a passion for timber emerged, and he has since been an outstanding advocate, educator and consultant for the timber industry. Equally, his enthusiasm for Engineers Australia, Standards Australia and various industry bodies has marked his work, as has extensive pro-bono academic and practical supervision for several undergraduate and post-graduate engineering students.

Ultimately, he has used his engineering skills to make a significant contribution to improving the lives of people by helping to ensure buildings – particularly houses – are designed and built to standards which provide shelter and safety to the people who live and work in them.



By establishing high standards of design for wind-resistant housing, Geoff Boughton has protected countless lives

AN INQUISITIVE PATH

MARLENE KANGA



Leading the engineering profession nationally and internationally

Marlene Kanga's journey to governance started in her small village, in Goa State, India. A bright child who loved science and maths, she read as much as she could before the oil lamps came out at night. Thus her amazement when her father, a prominent engineer, said the village would be electrified and there would be a light in each room.

At that moment, a light of itself – the connection between engineering and the community – shone into Kanga's imagination.

When she studied engineering, there were only 20 females among more than 2000 on campus. And when she arrived in Australia, women engineers were a rarity.

Undeterred, Kanga was among the first women to join Engineers Australia. She applied for jobs advertised for 'men and boys' and eventually joined Esso Australia, the second female engineer employed there.

Later, she started her own engineering consultancy, seeking flexible work to raise her two sons. Specialising in process safety engineering, she drafted the first Land Use Safety Criteria for hazardous industry, which is now embedded in legislation throughout Australia. Later, she co-founded iOmniscient, with world-leading artificial intelligence technology for video analytics.

Kanga was elected President of Engineers Australia in 2013, the second woman in 94 years to chair the organisation; she was on its National Council from 2007-14, and her changes include the modernisation of EA's governance, strategy, and technology.



Kanga pictured at the World Energy Day Conference.

In 2017, she was elected President of the World Federation of Engineering Organisations (WFEO), the peak body for engineering institutions internationally representing some 100 nations and approximately 30 million engineers, while she recently led the proposal for the UNESCO declaration of World Engineering Day, to be celebrated annually on 04 March from 2020 onwards.

She has a busy board portfolio, including Airservices Australia, Sydney Water Corporation and formerly, Innovation Australia, chairing its R&D Incentives Committee from 2013-19 with its $4+ billion industry support programme.

Crucially, her experience in driving diversity and inclusion in engineering has given Kanga valuable perspective on the benefits of personal differences. She often shares those thoughts, an outspoken but considered voice seeking, especially, to increase women's participation in the engineering profession.

Being made a Member of the Order of Australia in 2014 is among her long list of honours, a member of the Australian and ASEAN academies of engineering, Honorary Fellow of two institutions (Engineers Australia and IChemE UK), 2018 EA Professional Engineer of the Year, 2014 FEIAP Professional Engineer of the Year (Asia Pacific region), and inclusion in the Top 100 Westpac Women of Influence and the Top 100 Engineers in Australia.

If engineers need an inspiration, or role model, they need look no further than Marlene Kanga.

STRENGTH OF CHARACTER

ERROL MILEVSKIY

Errol Milevskiy has known challenges in his life. As a baby he received the last rites; he lost his mother when he was 16; five years later, his father was robbed and murdered. As if not tested enough, the North Queensland country boy has suffered from the chronic pain condition Trigeminal Neuralgia for the past 18 years, an illness regarded by many medical experts as the most painful condition known to man.

Yet Milevskiy has not simply endured. He has thrived, becoming one of the leading worldwide marine engineers and surveyors, and preventing serious casualties and disasters through his focus on the details critical to marine surveying.

His working life began as a labourer at the local sugar mill, which soon evolved into an apprenticeship as a fitter and turner. Milevskiy's potential was recognised by BHP, who offered him a cadetship as a marine engineer – he was sent to study in Launceston, the first of a long, distinguished education at such prestigious universities as Harvard and MIT, incorporating law, nuclear science, astrobiology and astronautics.

Milevskiy went to sea as a marine engineer, while continuing to study in the late 1990s and producing his prize-winning thesis, 'Building a Foundation for a Marine Engineer', written as a guiding tool for cadet engineers to use in building their own practical knowledge and techniques, not generally covered in text books.

Joining DNVGL, an international classification society, as a marine surveyor and station manager in Newcastle, the diversity of work rounded out his skill base, be it surveying different types of ships or certifying numerous machinery parts and systems, to being the attending surveyor for the topside construction of ESSO oil platforms.

In 1994, he commenced auditing to certify vessels and companies to the International Safety Management code from the International Maritime Organisation, soon filling the executive role of Dockyard Manager at the largest commercial dockyard in the southern hemisphere, and is understood to have become the world's most highly qualified surveyor with the largest global classification society.



Hull repair after the ship hit the wharf.

While it sounds like an office role, Milevskiy continued critical, sometimes dangerous surveying work, notably identifying significant safety and structural issues on an Australian crude oil tanker in 2003, averting potential loss of the vessel, human life, and catastrophic environmental damage. In recognition of his expertise, he was appointed as a member of the elite group of only 20 worldwide surveyors in 2009, named the 'Flying Squad', tasked with handling demanding situations on vessels internationally.

It is notable that Milevskiy is now a Fellow of four institutions: Engineers Australia (noted as an 'engineering technologist'), The Institute of Marine Engineering, Science and Technology; the Chartered Managers Institute; and the Institute of Managers and Leaders, all achieved at just 34 years of age.



Certifying that acceptable marine standards are met

7 FEDERATING A NATION

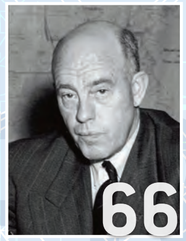
The Commonwealth of Australia came into existence in 1901 after the states agreed to federate. While states retained their infrastructure and most functions, the Commonwealth was faced with setting up its own Parliament, departments, defence force and capital city. The newly formed Commonwealth drew on the engineering resources of the states but also developed its own expertise to handle Federal functions – the former state militias transferred into the Australian Army in 1901, with the Royal Australian Navy being formed in 1911 and the Royal Australian Airforce in 1921. World War Two saw the creation of the Allied Works Council, which involved engineers collaborating in rapidly building defensive infrastructure in strategic locations across Australia, while privately run factories were urgently established for defence production of munitions and aircraft.

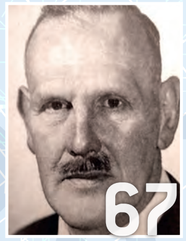

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SIR JOHN BUTTERS

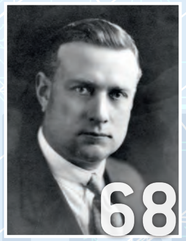

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A CAPITAL IDEA

SIR JOHN BUTTERS



Sir John Butters was a larger than life influence on early Australian development

It is no surprise to hear Sir John Henry Butters being described as 'big, bronzed and direct of speech'. For a man to achieve what Butters did in a single lifetime, he must have enjoyed a substantial presence even among some of Australia's early 20th century pioneers.

A University of London electrical engineering graduate, Butters arrived in Australia in 1909, his posting from his employer, Siemens Brothers, to advise on a hydro-electric station in New Zealand and Adelaide's Municipal Tramways Trust on electrifying its system.

Soon afterwards he was sought by the Hydro-Electric Power and Metallurgical Co. Ltd about proposals to produce electricity in Tasmania. Butters elected to join the project, signing on as engineer-in-chief and manager and assuming responsibility for the design, layout and construction of a masonry dam at the Great Lake. He also tackled intake works on the Shannon River, a power station and transmission line, and an electricity distribution and sub-station complex for Hobart.

In 1914, the newly established Hydro-Electric Department took over the project, and Butters was appointed chief engineer and general manager. Despite testing weather conditions and high altitudes, he forged relentlessly ahead and the first two turbines of the Waddamana Power Station were brought into operation in May, 1916. As Waddamana was expanded, he used cheap power to attract new industries.



The ceremonial opening of the original Parliament House, Canberra.

Butters remained a prominent facilitator of the capacity and reticulation of power across the State until 1924, when he secured the position of full-time chairman of the Federal Capital Commission, a body created under the Federal Seat of Government (Administration) Act, 1924, to expedite the development of Canberra.

For the first time, a single authority had responsibility for the administration, design and construction of Canberra. The new commission was charged with the job of completing Parliament House at the earliest possible date – January 1927 was suggested – by which time office and residential accommodation was also to be ready for parliamentary staff.

He had 30 months. Accessing a workforce of 4000 tradesmen and labourers, and fighting off negativity about the 'bush capital's' location, his enthusiasm, planning and co-operative labour relations saw the task completed to deadline and specification. His achievement was recognised during the visit of the Duke of York for the Parliament House opening, when he was knighted.

It might have been a career high point, but Butters remained active elsewhere, from significant planning roles in Sydney – where he moved after Canberra's relative completion – to President of the Royal Automobile Club of Australia, Chairman of Associated Newspapers, and a directorship of General Motors Holden. He was also active in the Institution of Engineers, Australia, including as President in 1928, and was instrumental in forming the Canberra Division while he was resident there.

FATHER OF THE RAAF

ERIC HARRISON

When the British Government in June 1919 offered free aircraft to any Dominion that would establish an air force independent of their Army and Navy, engineer Eric Harrison stepped forward to accept the challenge, immersing himself in the technical aspects of aviation to ensure that aircraft were designed, built, operated and maintained to quality standards.

It is Harrison's legacy as an engineering leader that embodies the very fabric of the organisations, people, processes and products that today comprise military aviation safety and aerospace engineering, and has led to him being described as a 'Father of the Royal Australian Air Force'.

As a young mechanic in rural Victoria, Harrison dreamed of flying. He studied aeronautics in his spare time, and after an all-night vigil at a deserted station in Altona Victoria, Harrison watched with amazement as Joe Hammond – of the British and Colonial Aeroplane company – wheeled out a Bristol Box-kite and flew it across the plain. Harrison was hooked.

Harrison travelled to Britain in March 1911 and, six months later, having accumulated 30 minutes of flight time with the Royal Aero Club, he was issued pilot's certificate No. 131 on the world register.

At the invitation of the Australian Government, Harrison helped establish the Australian Flying Corps (AFC) and the Central Flying School (CFS) at Point Cook in Victoria. He had acquired Australia's first aircraft before returning to Australia: two Deperdussin monoplanes, two B.E.2 biplanes and a Bristol Box-kite, and he conducted the first flight of an Australian military aircraft. Harrison also trained every student pilot who served in the Australian Flying Corps during World War One.

Without Harrison's tireless work and immense technical knowledge, the AFC would not have got off the ground, literally. He was the design engineer, production engineer, test pilot, maintenance manager, quality inspector and safety investigator.

When the Australian Air Force formed in March 1921, the *Royal* prefix being added in August of that year, Flight Lieutenant Harrison was one of the 21 founding officers.

A lifetime in engineering followed. Harrison championed Australia's fledgling aviation industry and founded the first inspection regimes for the design, test, production and maintenance of military aircraft in Australia. He commanded significant engineering organisations in Defence; established the first air accident investigation capability; ran the Federal Government's resources committee for aircraft, aero engines and motor transport following his promotion to Group Captain; and led the Directorate of Aeronautical Inspection as a civilian engineer responsible for chemical, mechanical and metrological standards at over 150 sites until the cessation of World War two in 1945.

Put simply, Harrison was a young engineer who was passionate about flying who went on to drive significant improvements in what has become the science and practice of Defence aerospace engineering in Australia.



Harrison's early flight experience marked him as a pioneer of Australian air.



Eric Harrison followed his skyward dreams to help create Australia's Air Force

TAKE TO THE AIR

SIR LAWRENCE WACKETT



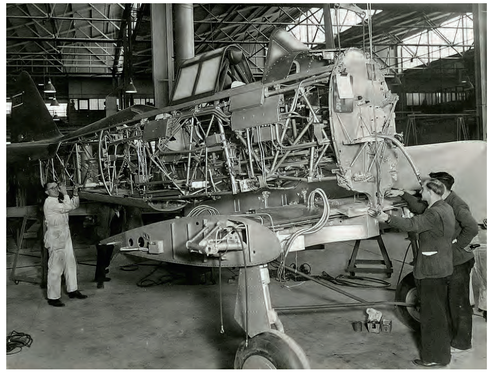
A blend of flying and engineering skills placed Lawrence Wackett at the forefront of Australian aviation

From pioneer aviator and aircraft engineer to chief technical advisor on aviation to government and aircraft industry leader Lawrence Wackett stands out as one of Australia's most significant aviation figures. His determination and reputed forceful personality contributed to a long list of achievements.

Educated in Townsville, he joined the army and trained at the Royal Military College, Duntroon. Wackett qualified as a pilot at Point Cook, Victoria, in October 1915. He was posted to No.1 Squadron, which arrived in Egypt in the following April, and flew on operations that included reconnaissance, bombing, strafing and air-to-air combat.

His aptitude for more than flying was apparent, and Wackett was soon put in charge of repairing and overhauling the Royal Flying Corps' damaged and unserviceable aircraft to increase the number available for the anticipated Gaza offensive. He later perfected a method of dropping ammunition to ground forces by parachute that was used in the battle of Hamel and received the Distinguished Flying Cross for flying hazardous reconnaissance of German trenches.

On return to Australia, he became one of the first 21 officers appointed to the newly formed RAAF and qualified as an aeronautical engineer, followed by two years of advanced instruction from Frank Barnwell, a distinguished British engineer and aircraft designer.



Under Wackett, Australia's aircraft production escalated dramatically.

Wackett moved to Sydney, to command the newly established RAAF Experimental Section where he oversaw the design and construction of a number of experimental aircraft, none of which were adopted for full-scale production. After resigning as a Wing Commander in 1930 he headed the aircraft section of the Cockatoo Island naval dockyard.

When Australia commenced preparations for war in 1936, the Chief of the Air Staff, Sir Richard Williams, nominated Wackett to set up and manage operations of the Commonwealth Aircraft Corporation at Fishermans Bend, Melbourne. Wackett controversially chose to build American, not British-designed aircraft and by the end of World War Two had delivered over a thousand Wirraway, Boomerang, Wackett and Mustang aircraft. Critically, he had built a modern aircraft industry.

Post-war, his influence was crucial in the selection of the American Sabre aircraft, over less suitable alternatives, to replace the RAAF's Meteor fighter. The Australian variant, with the Rolls Royce Avon engine, built by CAC outperformed its American counterpart and gave excellent service.

In December 1960 Wackett retired as CAC's general manager and continued as a director until 1965.

Wackett, widely regarded as the father of the Australian aircraft industry, was knighted in 1954, and among his multiple honours he received the Kernot Memorial Medal from the University of Melbourne five years later. In 1970, a fall left him an incomplete quadriplegic; he used his skills to design improved equipment for himself and others similarly afflicted.

THE WORKER

ESSINGTON LEWIS



A force for change, Essington Lewis steered Australia's biggest company, BHP, and harnessed Australian war-time manufacturing

When Essington Lewis passed away in 1961, a study of his papers revealed three self-penned words which defined a lifetime of achievement in engineering and management: I AM WORK. This work ethic, coupled with astute vision and the skills to execute it, saw Lewis make BHP one of the most efficient steel companies in the world.

Lewis was born in 1881 at Burra, South Australia, and enrolled at the South Australian School of Mines and Industries in 1901. His working life began as a foreman of BHP's sulphuric acid and zinc plants before quickly rising through the ranks at different plants.

Retained in Australia during World War One due to his munitions expertise, Lewis spent increasing time at the Newcastle steel works following its 1915 opening to focus on the steel and munitions business.

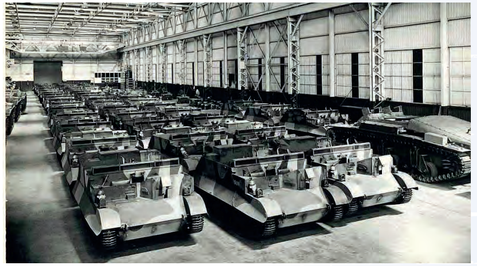
After the War, world steel prices collapsed and BHP faced severe competition from imports. Lewis was prepared to challenge the direction set by BHP's General Manager, Guillaume Delprat, and indeed he succeeded Delprat in 1921 and set about changing the company's direction.

Lewis made decisions on steel-making technology and focussed on efficiency of plant, men and management methods. He also reversed the previous philosophy and established BHP owned 'customer' industries such as nail and wire production, which provided a 'captive' market and increased profits.

During his own travels to Germany and Japan in the 1930s, he recognised the threat posed by these countries and assembled a team of Australia's leading industrialists to start building manufacturing capacity. When war broke out, the Commonwealth Government appointed him Director General of Munitions, a position of immense authority with the responsibility of harnessing the nation's entire manufacturing industry to the war effort, including Government owned factories. Due largely to Lewis' efforts and leadership, Australia's manufacturing capacity trebled in the 10 years to the 1940s and trebled again in the next decade.

Even post-war, Lewis was a force for refinement and change after returning to BHP, eventually ascending to Chairman along with involvement in other national projects such as General Motors-Holden's first all-Australian cars, and the long-range weapons project at Salisbury and Woomera, South Australia.

Lewis refused honours (including a knighthood) and publicity and only ever drew his normal salary. His management style featured discipline and detail, and personally visiting plants, quarries, mills and mines, which gave him an astonishing knowledge of the business. His notebooks were crammed with every conceivable piece of information – he was a strong supporter of staff training, encouraging study and travel tours, a legacy that continued for decades with BHP employees being extremely well trained.



Machine gun carriers built at the NSW Government Railways Workshop at Chullora, under the war-time control of the Director General of Munitions.

THE THIRD GENERATION

KEITH FRASER



Keith Aird Fraser was a champion of railway engineering in NSW and overseas while serving with distinction in the Australian Imperial Forces

As a product of both bloodlines and railway lines, Keith Fraser was a born engineer – both his father, James Fraser, and his maternal grandfather, Thomas Firth, held the position of Engineer-in-Chief for Existing Lines in the NSW Railways.

Yet Keith would make his own mark, crafting a remarkable public service career around honourable service in both World Wars, in the process earning a well-deserved OBE.

Fraser was a Junior Surveyor with the railways when he enlisted with the Australian Imperial Forces in 1915, serving three years in France with the 12th Field Company of Australian Engineers. On his return, he was recognised by the Railways as an assistant engineer, and in February of 1922 he was appointed as one of two Resident Engineers on the massive Sydney City Railway project.

This decade-long construction of six lines of railway and four stations under an existing city at shallow depth was undertaken from many access points and having all the discrete sections align may have made Fraser's surveying skills particularly valuable. Prior to World War Two, he went on to fulfil significant engineering roles across the city and its surrounds, notably in 1939, commencing construction of the bridge at the Hawkesbury River, by far the largest structure on the NSW Railways.



Construction of one of several steel truss multi-span bridges across deep river valleys on the Haifa to Tripoli railway.

War again interrupted Fraser's career trajectory. Now an experienced manager of men and projects, it is fair to deduce that he played a key role in the formation of a Railway Unit for the Australian Imperial Forces. He filled substantial planning and construction roles in railway development around the critical Suez Canal, and in 1942 was tasked with building a challenging 95 km section of the Haifa to Tripoli railway, a route requiring great cuttings and embankments, a long tunnel and many high bridges.

Fraser was given 18 months to complete the job. He did it in 12, leading to an OBE which included a citation that he was "an officer of outstanding merit, who has carried out his duties at all times with exceptional ability and whose quiet confidence impresses all members of his own and other units".

On his 1943 return to Australia, Fraser's energy was directed to the still unfinished Hawkesbury project, which took three more years to complete.

He then undertook a study tour of the United Kingdom and America, and in 1950 he became Chief Civil Engineer before ascending to the role of NSW Commissioner for Railways in 1952. Tragically, his time in this position was brief, for he died suddenly in August of the same year.

A KEEN INTELLECT

CALEB ROBERTS

The son of noted painter Tom Roberts, Sydney-born Caleb Roberts moved to England with his family, where he was educated at the Royal Military Academy. He was commissioned with the Royal Engineers and earned the Military Cross for service in the Great War, before graduating in engineering at University of London.

Roberts returned to Australia on the promise of an interview with William Calder, Chairman of the Country Roads Board of Victoria. This successful application saw him begin employment with the CRB as an assistant highway engineer. It was an entry point for a highly successful, diverse working life in his new home.

Described as "a man of integrity, tremendous energy, and fearless loyalty", Roberts progressed rapidly through the seniority of the CRB. His duties included the modernising of road-making techniques and the introduction of cost saving construction methods, and in 1937 he prepared the board's first 10-year plan for highway development.

Yet war would interrupt his life a second time. An engineer officer (from 1931) with the Citizen Military Forces, he was gazetted Acting Major in 1939 and called up for full-time duty, appointed to the Australian Intelligence Corps. Roberts was soon promoted to Colonel and made director of military intelligence in February, 1942.

He was then appointed controller of the Allied Intelligence Bureau when it was formed in 1942 at Douglas MacArthur's General Headquarters. The AIB was a joint United States, Australian, Dutch and British intelligence and special operations agency of some 2,000 men. It was responsible for operating parties of spies and commandos behind Japanese lines in order to collect intelligence, support local resistance and conduct guerrilla warfare against enemy forces in the South West Pacific.

Roberts relinquished his appointment, seeking the stability of his previous working life, and returned to the CRB in 1944 as chief engineer.

This was an exciting time, for the number of Australian motor vehicles using roads increased enormously immediately after the war. After touring overseas to study best practice methods, his subsequent report constituted a landmark in the analysis of Australia's needs: it recommended fresh approaches to highway planning, to predicting traffic demand, to constructing and repairing roads, and to developing the skills of personnel involved in these activities.

Roberts actively promoted the formation of the Australian Road Research Board, which was established in 1959, and was committed to advancing the engineering profession, lecturing at Swinburne Technical College and the University of Melbourne.

Appointed deputy-chairman (1956) of the CRB, he became its chairman in July 1962, the year before his retirement and just three years before his death.



Native soldiers of the Allied Intelligence Bureau training on the beach, using rifles to discharge grenades.



Known for integrity and loyalty, Caleb Roberts was an impressive contributor in both war and peace

AN EYE TO THE NORTH

SIR JOHN KEMP



A savvy planner and budget manager, John Kemp developed roads across the state of Queensland and defence facilities for the war effort

During the first half of the 20th century, John Kemp emerged as a driving force in developing the infrastructure of his adopted home in Queensland. A Victorian by birth, and educated at the University of Melbourne, Kemp gained experience as a draftsman and Shire engineer before joining the Victorian Country Roads Board, which was a leader in Australian road-making.

His time in Queensland began in 1920, securing the role of foundation chairman of the Queensland Main Roads Board, later to become the Main Roads Commission with Kemp as sole commissioner. He initiated a State-wide road-survey and liaised with local government authorities on long-term planning for the construction and maintenance of declared 'main' roads.

From the outset, Kemp's reputation was anchored on optimising the limited funds at his disposal. He gave priority to the length of roads over their width, and was not averse to private or toll roads if they added miles to the system. As Commonwealth funding began to support State coffers for road-making, he became a powerful advocate for his adopted State and between the wars was a regular figure at national conferences.

Still, in a period when horses provided most of the workpower, he was a familiar sight to road-gangs during his tours of inspection, often conducted in the knee-deep mud of Central Queensland's black-soil plains.



Kemp was responsible for the construction of the Cairncross Graving Dock in Brisbane during World War Two under emergency conditions.

Kemp's persistent efforts to improve professional standards led to increasing numbers of Main Roads engineers being employed by local councils. He encouraged his staff to study for formal qualifications at the Central Technical College and, after 1930, at the University of Queensland where he assisted in developing the curriculum for the faculty of engineering.

With his knowledge of infrastructure requirements, transport economics and local conditions, Kemp became the Queensland Government's chief development adviser in the 1930s, and sat on or chaired landmark reviews of the State's electricity, transport and industry sectors. He headed the Stanley River Works Board – formed to build Somerset Dam – and the Bridge Board, on which his drive contributed to the early completion of Story Bridge.

During World War Two, Kemp was Deputy Director-General of Allied Works, Queensland, and supervised hundreds of defence projects, ranging from airstrips to naval bases, and the critical Inland Defence Road from Ipswich to Charters Towers. A lifetime of juggling manpower, limited resources and tight deadlines was an ideal preparation for such a role, and a later description of him as a "national benefactor" could scarcely have been more accurate.

A recipient of multiple, significant awards, Kemp – who was Knighted in 1951 – died in Brisbane in 1955.

THINKING BIG

SIR LOUIS LODER

It is said that Australia's 'Lost Generation' includes those gifted young men that venture to war, not to return. Fortunately for this country, Louis Loder survived the perils of World War One, for the Sale-born engineer would become an influential figure in Australia's development during the decades that followed.

Enlisted in the Australian Imperial Force and trained as a pilot, Loder served on the Western Front with the Australian Flying Corps and was mentioned in dispatches before returning to his studies and in 1923 graduating from the University of Melbourne with first-class honours.

That year he also worked as a designing engineer with Johns & Waygood Ltd before joining the Victorian Country Roads Board in November. At the CRB, Loder was involved in the design and construction of bridges, including a 90 m timber structure at Echuca, and another of steel and timber, some 91 m in length, at Stratford.

Promoted to highway engineer – later Chief Engineer, then Chairman of the Board – he oversaw the development of hundreds of miles of relatively low cost, bituminised roads suitable for heavy traffic. Notably, during World War Two, when the Allied Works Council was formed to bring together the resources of Commonwealth, State and local Governments and the Civil Construction Corp, Loder became its Co-ordinator of State Instrumentalities.

Complying with the council's request, in 1942-45 the CRB surfaced with bitumen 787 miles (1,267 km) of the Stuart Highway in the Northern Territory.

In 1944, Loder was appointed overall control as Director-General of Allied Works. After the war this evolved to the substantial role of Director-General of the Commonwealth Department of Works, with responsibility for the design, costing, supervision and execution of all architectural and engineering works for the Federal government.

He would oversee the completion of the Captain Cook Dry Dock in Sydney Harbour (1945), the building of the rocket range at Woomera, South Australia (from 1947), and the 1961 start of construction of the 'beef' roads programme in northern Australia. Loder also chaired the joint Commonwealth-States technical committee which reported on the proposed Snowy Mountains project.

A teetotaller, Loder was a tall, sparsely built man with a resonant voice, a streak of athleticism, and a finely tuned sense of propriety. Clearly, he was born to support projects of grand scale, soon chairing the committee which investigated the West Australian comprehensive water-supply scheme, and representing the Commonwealth on the River Murray Commission.

Having begun as a part-time lecturer in 1937, Loder remained a member of the engineering faculty of the University of Melbourne until 1961. He was awarded the Peter Nicol Russell memorial medal for 1954; was Kernot Medallist in 1955; and was Knighted in 1962.



Highway and airstrip construction were key achievements under Loder's tenure.



From highways to rocket ranges, projects steered by Louis Loder were of a scale that changed a nation

IN COMMAND

SIR JAMES ROWLAND



A life in the military formed the foundation of a remarkable career of public service

In the catalogue of notable Australian engineers, many excelled in both civilian and military careers. While many were civilian engineers who took on military duties when required, Air Marshal Sir James Rowland is an example of a military engineer who progressed to a remarkable civilian career.

Educated in Sydney, Rowland enrolled in aeronautical engineering at the University of Sydney. World War Two put a hold on Rowland's engineering studies – he enlisted in the RAAF in May 1942, leading to a remarkable and quite heroic time in Europe.

Rowland became part of the Empire Air Training Scheme, undergoing further training in Canada and being commissioned as a pilot officer in July of 1943. Posted to Britain, he converted to Handley Page Halifax and Avro Lancaster bombers. Considered an exceptional pilot, Rowland was posted to the elite Pathfinder Force in RAF Bomber Command, marking out bombing targets with flares ahead of the main bomber squadrons. For this service, Rowland received a Distinguished Flying Cross in recognition of his 'great determination and devotion to duty'.

In January 1945, he was the sole survivor of a mid-air collision over Frankfurt, was captured and interrogated. Following his repatriation and return to Australia, Rowland resumed his aeronautical engineering studies and rejoined the RAAF in 1947, serving in the newly formed Technical Branch. Emerging as Chief Test Pilot, he led test programs on many of the RAAF's early jets, such as the Gloster Meteor, de Havilland Vampire, and CAC Sabre. This led to promotion to the rank of Squadron Leader and the award of the Air Force Cross.



Rowland was the RAAF technical representative in France, overseeing the introduction of the French-designed, Australian-built Mirage III interceptors.

It also further enhanced a sparkling military career, including commanding the Aircraft Research and Development Unit in the 1950s, and fulfilling Commanding Officer duties at the RAAF Base at Amberley. In 1972, Rowland was promoted to Air Vice-Marshal with the role of Air Board Member for Technical Services, thus responsible for all technical matters relating to RAAF aircraft and support facilities. Appointed as Chief of Air Staff in 1975, he was the first engineer to hold this position and was knighted in 1977 for 'diligent, long service to the community'.

In his book, Lancaster Men, Peter Rees describes Rowland as, "straightforward, interested, [and] ready to laugh" and notes that he could talk to just about anyone. Rowland was therefore a natural recommendation for the Governor of NSW when it became vacant in 1980, and his tenure in this role would twice be extended beyond the customary four years, such was the respect in which he was held.

Rowland's contribution to the development and understanding of Australian air power was formally recognised in 2016, when the RAAF's Air Power Development Centre and the UNSW Australian Centre for the Study of Armed Conflict and Society jointly established the highly respected annual Sir James Rowland Air Power Seminar.

BY RAIL OR SEA

DONALD WILLIAMS

Donald Williams was born in 1937 in Fremantle, where his father worked for the Western Australian Government Railways (WAGR) as the Chief Civil Engineer. While he would expand his interests and career in a range of sectors, his initial link with the railways would prove an irresistible force throughout his lifetime.

Williams began his railway career as an engineering cadet for the WAGR, and by 1959 had graduated from the University of Western Australia as a civil engineer. He then undertook post-graduate studies in bridge design at Rice University in Texas and Imperial College London, gaining a PhD in 1969.

On his return to Australia he worked for Redpath Dorman Long, a British company which was redesigning and reconstructing Melbourne's West Gate Bridge following its collapse during construction. He was Project Engineer for the rebuilding, gaining great credit for his work, but left in March 1977 before the bridge was officially opened.

The railways were calling. Williams took a role as Assistant GM Engineering and Planning of the Australian National Railways Commission, ascending to Chief Executive and creating AN's first corporate plan, setting a goal to become profitable within 10 years.

As well as introducing a new corporate identity he invested in a new standard gauge mainline from Tarcoola to Alice Springs, and standardised the line from Port Pirie to Adelaide. New buildings and railway infrastructure were constructed, and new locomotives and rolling stock were introduced.

While remaining Chairman of ANR, Williams also became the first CEO of the newly formed Australian Submarine Corporation, charged with delivering the $3.9 billion contract to build six new Collins Class submarines for the Royal Australian Navy. These were to be the first submarines constructed in Australia, prompting widespread improvements in Australian industry and defence capabilities.

A lasting legacy of Williams' efforts was his relentless efforts to improve quality standards through his insistence on accreditation of suppliers to ASC, resulting in a large increase in quality-accredited support companies and the subsequent growth in the capabilities of Australia's defence-related industries.

In late 1993, Williams again returned to the railways, working for the Indian Railways and China Railway Corporation. He later joined Kinhill Engineering, developing the engineering program and establishing funding for the construction of the Alice Springs to Darwin railway line, and became GM for FreightLink, the company that would operate freight trains over the new railway line.

Williams was a constant supporter of local communities located along the Trans-Australian Railway line and was a strong supporter of railway preservation in South Australia, and the National Railway Museum in Port Adelaide.



Production of the Collins Class Submarine was a major step in the country's defence capacity.



A life on the lines was interrupted by a stint with subs, but Donald Williams remained a railway man for life committed to national projects

A UNIFORM FIGURE

JOHN SANDERSON



Describing John Sanderson as a respected military achiever only begins to tell his tale

When John Sanderson entered the Royal Military College, Duntroon, it began a lifetime of military and social service which profoundly impacted those around him. Commissioned into the Royal Australian Engineers after his 1961 graduation, and completing his Fellowship Diploma in Civil Engineering at RMIT, Sanderson entered an era of significant Australian military influence in south east Asia.

His early career involved military training and construction that included a period as second in command of 10 Field Squadron. He was then posted to Sabah, Malaysia as Troop Commander and Construction Officer of 21 Construction Squadron.

Promoted to Captain, Sanderson spent 18 months on the staff of the Office of the Engineer in Chief before being posted to England, returning after two years (on promotion to Major) as commander of 23 Construction Squadron. He was deployed to Vietnam in late 1970 to take up command of 17 Construction Squadron.

Sanderson's ongoing military rise through the years that followed was, if not linear, impressive in its vision. It included Director of Army Plans (1983) and a year-long attendance at US Army War College before returning as a Brigadier, taking command of the 1st Brigade at Holsworthy.



Pictured in his time in Cambodia, Sanderson became a respected figure in the United Nations.

That climb also featured key peace-keeping roles: from October 1991, he became engaged directly in the United Nations process to bring peace to Cambodia, first as adviser to the Secretary General of the United Nations, then as Lieutenant General and Commander of the 16,000 strong international military component of the United Nations Transitional Authority in Cambodia (UNTAC).

Sanderson became Chief of the General Staff in June 1995 (later renamed Chief of Army), and continued in this position until his 1998 retirement from the Army.

Two years later, Sanderson became Western Australia's 29th Governor, rounding out a career which began in traditional military engineering but became highly respected for its peace-keeping influence in the region. An engineer at heart, he developed a long-term interest in the philosophy and practical dimensions of international intervention and is extensively published on these subjects.

Following from his command of the United Nation Force in Cambodia, Sanderson lectured extensively on peace building and is a strong advocate of human rights as the basis of national and international reconciliation.

He has advised successive WA governments on their relationship with Aboriginal people, including as Chair of the Indigenous Implementation Board up to February 2011, and received numerous honours and awards, both foreign and Australian, for a body of work ultimately focused on social justice and equality.

A CAREER OF FIRSTS

JULIE HAMMER

As an indication of the challenges that confronted Julie Hammer during her emergence as one of Australia's most recognised engineers in her field of electronics, consider this: after she joined the Royal Australian Air Force in 1977, her 1981 transfer to the Engineer Branch was possible only because such a role had just been opened up to women.

Hammer was no token appointment. She had been placed eighth in the State of Queensland in the Senior Public (Matriculation) Examination, and completed a B.Sc. (Hons) in Physics at the University of Queensland.

In her early junior officer days, she was a staff member at the Engineer Cadet Squadron, instructing in electronics at the School of Radio. Yet she also managed deep level maintenance on F-111, Iroquois, Chinook and Canberra aircraft at Amberley, and worked at Headquarters Support Command in the engineering management of avionics equipment for the RAAF fleet.

By 1985, Hammer was promoted to Squadron Leader. This marked her for greater things; she studied at RAF Cranwell in the UK, completing a M.Sc. in Aerosystems Engineering before returning to Canberra and serving as a technical intelligence analyst in the Joint Intelligence Organisation.

She subsequently worked on a major electronic warfare project, the P3C Orion Electronic Support Measures Project, first as project engineer and then, after promotion to Wing Commander, as project manager. In 1992, she assumed command of the Electronic Warfare Squadron in Adelaide, the first woman to command an operational unit in the RAAF.

By now, her star was ascendant, rising on the strength of her intellect and leadership. Hammer was soon promoted to Group Captain and posted into major projects, this time as the Project Director of a number of command and control projects, interrupted only by secondment to the Science and Technology Team of the Defence Efficiency Review, and a stint as the sole Australian student at the prestigious Royal College of Defence Studies in London.

Returning to Australia, she assumed Air Commodore duties as Director General Information Services, responsible for the operations and support of Defence's fixed communications networks and computer systems throughout Australia. This made her the first serving woman in the history of the Australian Defence Force to be promoted to One Star level.

Indeed, it has been a decorated career of 'firsts' for Hammer. On 26 January 2004, Air Vice Marshal Julie Hammer was appointed a Member of the Order of Australia for exceptional service in the fields of electronics engineering in Defence, and military education as the Commandant of the Australian Defence Force Academy.

She also managed to fit in being the first female National President of Engineers Australia in 2008.



Wing Commander Hammer in charge of the Electronic Warfare Squadron in Adelaide.



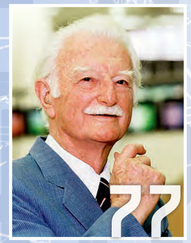
The first woman in Australia to command an operational defence unit, Julie Hammer rose all the way to Air Vice Marshall

8 DEVELOPMENT THROUGH CONSULTING AND CONTRACTING

After World War Two there was a surge in immigration and national development, with private consultants and contractors carrying out significantly more work for Government and private enterprise. Over time, Commonwealth and State instrumentalities engaged more consultants, delivering works by contract, leading in some cases to corporatisation or sale to the private sector.



SIR WILLIAM HUDSON



JOHN CONNELL



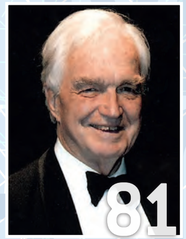
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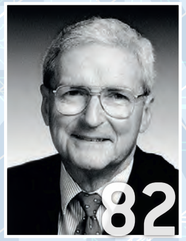
SIR JOHN HOLLAND



CARLO SALTERI



HAROLD CLOUGH



BRUCE SINCLAIR



JOHN NUTT

8

THE FATHER OF THE SNOWY

SIR WILLIAM HUDSON



By skill, experience and an understanding of workforce, Bill Hudson delivered the Snowy Mountains Scheme

Such was the strength of reputation of William (Bill) Hudson when he applied for the role of Commissioner of the Snowy River Scheme statutory authority, that no other candidate was genuinely considered. True, the Chifley Cabinet required three names to be assessed, but the Federal Minister pointedly sent Hudson's name three times.

Born and initially educated in his native New Zealand, then London and post-graduate study in hydroelectric engineering at University of Grenoble, France, Hudson cut his engineering teeth back in his native land on railway and dam construction.

Crossing the Tasman in 1927, he worked briefly in NSW before assuming responsibility as engineer-in-charge of construction of Scotland's Galloway power scheme, the largest of its kind in Britain at the time. The five years he spent on the Galloway scheme enhanced his knowledge and reputation as an efficient and dedicated leader whose approach in dealing with staff and contractors in the remote location led to completion of the project a year ahead of schedule.

Returning to Sydney in 1937, Hudson was again recruited by the water board as resident engineer for the Woronora Dam project, where his capacity to build dams on time and at fixed prices was further entrenched. So, when the ambitious Snowy Scheme gained momentum – and necessity – immediately after World War Two, Hudson was a clear candidate to steer it.

From his headquarters in Cooma, over the next 18 years Hudson developed and managed a project consisting of 16 dams, 13 major tunnels extending over 145 kms, seven power stations (including two deep underground), a pumping station, and eight switching stations and control centres that were spread across the Australian Alps.

The scale of the project was unprecedented, involving employment of over 100,000 people from 30 countries and major contracts with overseas and Australian firms, while driving innovation in surveying, hydrology, electrical and civil engineering and construction practices. This was all achieved without political or industrial problems thanks to a motivated and cohesive workforce, and with admirable safety standards given the potential hazards and remoteness of the project.

The outcome changed a nation, providing increased power and water supplies for three States, and arguably changing the cultural landscape of a nation.

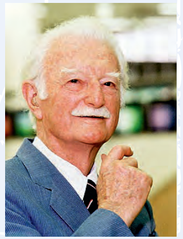
Known as the 'Father of the Snowy', Hudson had his contract extended twice, but retired in 1967 at age 71, before the scheme's completion. He had been knighted in 1955 and elected a fellow of the Royal Society in 1964 as well as receiving a long list of Australian awards. He died in 1974 and was buried in Cooma.



Pressure pipelines at the Tumut3 power station, a core elements of the Snowy Scheme.

THE CONVENOR

JOHN CONNELL



For more than half a century, John Connell maintained one of the country's prominent engineering firms

In many eyes, Dr John William Connell ranks among Australia's most distinguished engineers. Entering the profession as a junior draftsman in 1939 with the firm of Cyril Hudspeth and Associates in Melbourne, Connell then served with distinction with the 57/60 Infantry Battalion in the Goon Valley, near Port Moresby.

He rose to the rank of Major, early evidence of an organised mind and capacity for leadership, before returning to Hudspeth and resuming his structural engineering studies at RMIT. A decade later, Cyril Hudspeth died suddenly and Connell – who was thinking of setting up his own practice – went out on a limb financially to acquire the practice from the estate.

By 1958, John Connell and Associates was born. Under his leadership, it became one of the most successful consulting engineering firms in Australia, with widely diverging fields of practice. He brought in engineering experts from around the world to join the firm and help it grow, and established one of the first computer aided design divisions (Consuldata) in such an engineering practice.

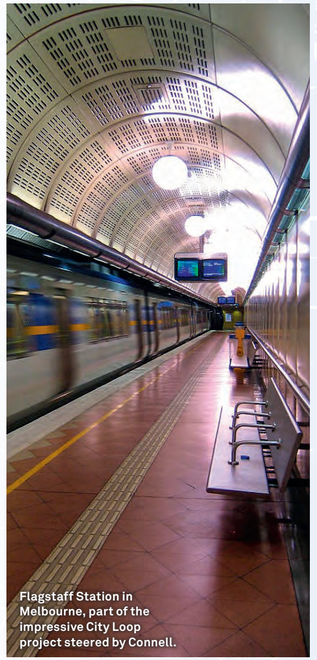
The civil works projects completed by Connell were significant, often through pioneering joint ventures, perhaps none larger than the Eastern water purification plant for the Melbourne Metropolitan Board of Works built in 1975, or the design and supervision of the $500 million Melbourne Underground Rail Loop in the 1970s and the Victorian Arts Centre, completed in 1984.

At the core of these projects was Connell's keen awareness of drawing together broad multi-disciplinary talent from all corners of the world. He welcomed international engineers and their ideas, believing that a good idea was worthy no matter where it came from, of from who.

And he remained a hands-on engineer at heart. Many colleagues recall his daily attendance at the remarkable rebuilding of the Melbourne Age Newspaper building, a project that demanded the presses kept running as development took place around them. He was a man dedicated to his work.

Connell had vision on a grand scale. He would merge with MacDonald Wagner to form Connell Wagner in 1989. In 2009, Connell Wagner was one of the three consulting firms that merged to form the engineering giant Aurecon.

Until his 2016 death, aged 102, Connell retained a revered place in Australian engineering history. Among his multiple honours, he was awarded the prestigious Kernot Medal by the University of Melbourne, while the most important recognition given to eminent structural engineers by Engineers Australia is the John Connell Gold Medal. In 1987, he was awarded Member of the Order of Australia in recognition of his service to civil engineering and to the community.



Flagstaff Station in Melbourne, part of the impressive City Loop project steered by Connell.

A LIFE OF SERVICE

SIR BERNARD CALLINAN



A born leader, Sir Bernard Callinan achieved distinction in everything he touched

When Bernard Callinan departed St Kevin's College in suburban Melbourne, he could scarcely have dreamed of the life that lay ahead. From a burgeoning civil engineering career, to a decorated military career, then back to civilian life and great success, Callinan carved a prominent place in Australian society.

Upon graduating in 1935, he joined the embryonic consulting practice of Gordon Gutteridge, which soon after became Gutteridge, Haskins and Davey and is now known as GHD. A promising young engineer, war bluntly intruded on his ascension, but in some ways it made the man: Callinan was commissioned as a Lieutenant in the Citizens Military Force in June 1940, being appointed to the Royal Australian Engineers, and in March 1941 he volunteered for overseas service.

Promoted to a Captain in the Second Australian Imperial Force, and later second-in-command to the 2/2nd Independent Company, he led commandos in the revered Sparrow Force raids of Japanese-held Timor late in 1941. Callinan clearly had the leadership skills to command such a unit and understood, early in his career, that a small group of highly cohesive and highly motivated troops could disrupt and delay much larger enemy forces.

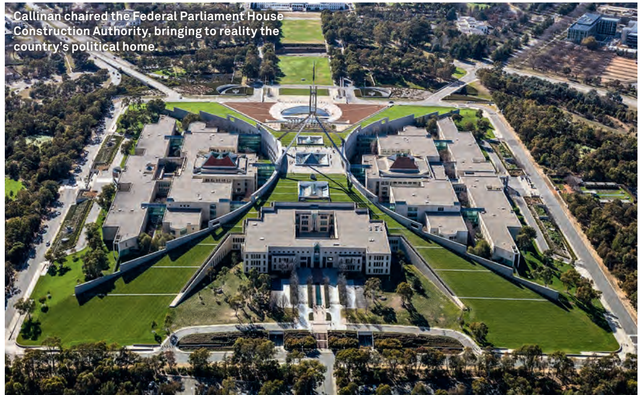
He would later serve with distinction in West Papua (now Indonesia), and in 1945 he assumed command of the 26th Battalion in the Bougainville Campaign. For his wartime service he was awarded the Distinguished Service Order and Military Cross for outstanding leadership and gallantry.

Returning to GHD after service, Callinan developed the practice in Victoria and Tasmania. Climbing to Managing Director by the early 1970, he was a great believer in diversifying GHD's work, particularly in urban planning, and helped it develop a global footprint that now features 200 offices across five continents.

His natural leadership shone through in his multi-faceted business interests, be it directorships and chairman roles with entities such as CSR and British Petroleum, as commissioner of the Australian Broadcasting Commission and the State Electricity Commission of Victoria (SEC), and even president of the Melbourne Cricket Club.

Yet his heart remained in engineering. Callinan was president of the Institution of Engineers Australia, and immediately after retiring from GHD he accepted the chairmanship of the new Federal Parliament House Construction Authority (1979-85), the role in life of which he was most proud.

Callinan was presented with the Peter Nicol Russell Memorial Medal from the Institution of Engineers Australia. In 1977, he became Sir Bernard, knighted for services to engineering after 44 years of service with GHD.



Callinan chaired the Federal Parliament House Construction Authority, bringing to reality the country's political home.

A WIDE FOOTPRINT

SIR JOHN HOLLAND

When World War Two broke out in 1939, Clifton Vaughan Holland – known as John from an early age – joined the Australian Army's engineering corps and served in the Middle East, Greece and with Z-force in the South -West Pacific.

Having studied civil engineering pre-war at the University of Melbourne, Holland returned to his job at the Commonwealth Oil Refineries once he was 'demobbed'. When he then set up his own business in 1949, he sought to utilise the talents of the young men he had served with and who had lost up to six years of their professional working lives.

Many ex-servicemen helped Holland develop a very large and versatile construction enterprise which changed the face of building in Australia. An extract of the company's projects under Holland's direction is impressive: the Sidney Myer Music Bowl in Melbourne (1959); the Talbingo Diversion Tunnel (1964) and Jindabyne Pumping Station (1966) on the Snowy Mountains Scheme; and the West Gate Bridge in Melbourne (1970).

Holland's firm played a significant role in the rebuilding of Darwin after Cyclone Tracy (1974), and went on to construct the Sydney Entertainment Centre (1983), take joint construction responsibility for the new Parliament House in Canberra (1988), and complete the Great Southern Stand at the Melbourne Cricket Ground (1992) and the Adelaide to Darwin Railway (2003).

Across it all sat the same man and his abilities, be it managing director, chairman or president from 1949 until his death in 2009. And he retained an open-minded, world view – if specific expertise was not available in Australia, he made a point of teaming with overseas companies and learning from them.

In his early days, Holland interviewed every man he employed, and he was renowned for taking a personal interest in their ongoing careers. His integrity and vision drove the company – and the country – forward, such that when Holland was made an Honorary Fellow of the Australian Academy of Technological Sciences and Engineering, the President of the Academy observed that it may never be again possible for one person to so shape an entire profession and an industry in Australia such as Holland had done for half a century.

The Civil College Board of Engineers Australia have honoured him by naming its annual award for Civil Engineer of the Year the 'Sir John Holland Civil Engineer of the Year'.

John Holland was knighted in 1973 for services to engineering, and made a Companion of the Order of Australia (AC) in 1988 for service to the community, particularly to youth and in the field of medical research through a lifetime of substantial philanthropy.



Work envisioned by John Holland and continued through his team represents a versatile, impactful portfolio across Australia



Construction of the MCG's Great Southern Stand – to the right in this image – was part of Holland's long list of major achievements.

FAMILY MAN, ENGINEER

CARLO SALTERI



Beginning with an offshore posting on the other side of the world, Carlo Salteri built an empire

As a young boy in Milan, Italy, Carlo Salteri's grandfather, an engineer, presented him with a 5 centimes coin stating, "Remember, to make a million you have to start with this..." Salteri carried the coin with him for the rest of his life, a constant inspiration during his subsequent engineering and business career.

A student as World War Two broke out, Salteri was called to military duty as a junior artillery officer. Only after service did he return to complete his engineering degree. The first company with which he gained employment, Societa Anonima Electtriificazione (SAE), had been awarded a contract to build powerlines in Australia.

Thus, a life was changed. Salteri was appointed in charge of the team of 25 workers who arrived in Sydney in August 1951. At contract's end, five years later, Salteri and his deputy, Franco Belgiorno-Nettis, left the company and set up their own, called Transfield.

With an office in North Sydney and industrial site in Seven Hills, the business prospered as it tackled large scale engineering projects. They backed their expertise and hard work as it grew in size, revenue and prestige through work on bridges, tunnels, dams, hydro-electric and coal-power stations, oil rigs, concert halls, sugar mills and power lines.

Belgiorno-Nettis was the networker, marketer and business visionary. Salteri made things happen on site, his keen engineering mind ensuring construction and spending remained on plan. Salteri was known as a fiend for fine detail – though he was equally loved for his humility and humanity.

By 1980, Transfield had 3000 employees and an annual turnover of $350 million. As the 1980s unfolded, it had grown to be the biggest engineering firm in South East Asia and, after winning the tender to build six frigates for the Australian Government, the largest defence company in Australia.

Sadly, in May of 1995, the two founders fell out, and the long-time partners would never talk freely again. After long negotiations, Transfield, valued at $733.2 million, was split into two, Salteri taking the defence component of the business and renaming it Tenix. The company prospered and had an annual revenue of $1.7 billion before selling its defence business to BAE Systems in 2008.

Salteri reduced his involvement to consulting, focusing on giving back to the society in which he made his wealth. The Tenix Foundation provides assistance for education, research and underprivileged children. Salteri received the Order of Merit of the Italian Republic and was appointed a Companion of the Order of Australia for service to industry and the community

Before his 2010 death, he was asked how he would like to be remembered. "Uomam de famlia, ingegnere," he replied: family man, engineer. A proud Italian became a great Australian.

A bridge constructed by Transfield in Indonesia; the company had become the largest engineering firm in the region.



SHAPING THE WILD WEST

HAROLD CLOUGH

There was always an impressive scale to the projects managed by Perth-born engineer Harold Clough. A mechanical engineer who studied at the University of Western Australia during World War Two, Clough would come to represent the vision which helped make his state of birth so successful.

First, he travelled in Australia and, after the award of a Fulbright Scholarship, to the University of California, Berkeley (USA), where he obtained a Master of Science in Industrial Engineering.

Joining his father's building company, his initial large project was a high rise building in Perth, the National Mutual office building in St Georges Terrace. In a joint venture with a Danish company, Christiani & Nielsen, the business constructed Perth's first Narrows Bridge (1957–1959), with Clough now Managing Director. Next, the joint venture constructed the Ord River Diversion Dam (1961–1963).

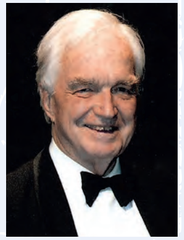
When the Pilbara region of WA was opened up to iron ore mining in the 1960s, and later natural gas development, Clough's negotiating skills resulted in the formation of a joint venture, combining Clough Engineering's local knowledge with Royal Netherlands Harbour Works' marine design and construction experience. Iron ore export jetties were completed for Hamersley Iron at Dampier, for Cliffs Robe River at Cape Lambert, and the LNG export jetty for Woodside. Another joint venture with ETPM of France resulted in laying the 135 km undersea pipeline from Woodside's processing plant at the Burrup Peninsula to the North Rankin platform.

Expansion into South East Asia oil and gas projects followed, culminating in the award in 1992 of Clough Engineering's largest contract to date, the design and construction of a $200 million oil and gas processing plant on Pagerungun Island, Indonesia.

Clough Engineering independently constructed Perth's other two major bridges, the Stirling Bridge at East Fremantle and the Mt Henry Bridge at Mt Pleasant, utilising much of the experience gained and equipment used on the Pilbara projects.

Clough transitioned from engineering roles to more business-related aspects of development and construction, and his involvement with trade and diplomatic missions in the Asian region continued until the company's sale, and his retirement, in 2005. In that same year, he was awarded the Sir Edward 'Weary' Dunlop Medal for commitment to enhancing the quality of life in the region and improving Australian-Asia relations. While he helped his home state prosper, his interest and work in South East Asia was important in improving the circumstances and lives of people in the region through his roles in trade and local development.

Clough held various key roles, including President of the Australian Chamber of Commerce and Industry, and was awarded both an Officer of the Order of the British Empire (1979) and Officer of the Order of Australia (1990). He was also awarded the Peter Nicol Russell Medal (1993) and the Sir William Hudson Award (1997).



Men like Harold Clough tamed some of Australia's most remote and challenging areas



Perth's Narrows Bridge, here under construction in 1958, links the city's northern and southern suburbs.

THE NETWORKER

BRUCE SINCLAIR



A highly talented engineer who thought on a large scale, Bruce Sinclair also used his people skills to prosper

Like so many before him, Andrew "Bruce" Sinclair commenced in Government service. Sinclair joined the NSW Public Works Department as a trainee engineer, providing him with on-site engineering experience during University of Sydney holidays.

After graduating with honours in civil engineering in 1948, he was assigned to the Manly Hydraulic Laboratory where he gained experience in hydrology, coastal and river engineering on projects including the Oberon Dam, Port Kembla Harbour works and Eucumbene Dam. In 1951, he applied for and undertook a summer course at the Massachusetts Institute of Technology as one of the first Fulbright Scholars.

Becoming concerned about the narrowness of his experience at the PWD, Sinclair resigned in 1955 and joined W D Scott and Co, management consultants. There he learnt about time and motion studies before a move to Rankin & Hill consulting engineers, where he established a civil engineering department with projects predominantly in Canberra and Sydney.

Sinclair hit it off with a colleague at Rankin & Hill, Jack Knight. Their own company, Sinclair Knight, was established in 1964, the blend of Sinclair's networking with Knight's attention to detail proving effective from its earliest stages.

During his 23 years as CEO of the company, Sinclair established it as a major technical and professional consultancy in Australia and Southeast Asia. Creating employee shareholding ownership (a philosophy he gained from W D Scott and Co) assured loyalty and commitment in his employees, and the consultancy developed a reputation for reliability.



Sinclair worked on multiple large scale projects around the world, including the Olympic Stadium in Athens, Greece.

They were also thorough, carrying out projects in a range of countries including Malaysia, India, Thailand, the Pacific, South America and Africa, many under the auspices of AusAID, the World Bank, the Asian Development Bank and the European Bank for Reconstruction and Development. Over 35 years, some 300 development projects were completed by staff in developing countries.

Sinclair had been involved with the Institution of Engineers Australia (now Engineers Australia) since 1945. He became a Member of Council, Vice President and, finally in 1979-80, President. To devote his time fully to the institution, he stood down temporarily from Sinclair Knight, leaving its operation in Knight's hands before returning to team leadership on SE Asian projects until 1990.

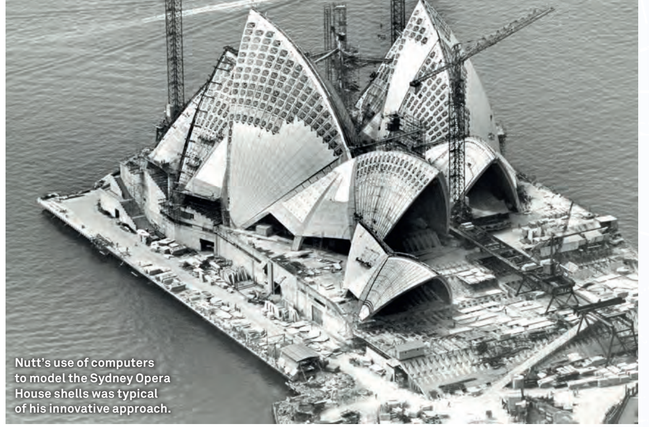
Sinclair Knight merged with Merz Australia in 1990 and Sinclair became an independent consultant and Canberra representative of SKM. In 2003, SKM was bought out by the Jacobs Engineering Group of the USA.

Notably, Sinclair's extra-SKM activities included reviving RedR (Registered Engineers for Disaster Relief) as Chair from 1992-96, restoring its worldwide reputation as Australian and United Nations 'go to' organisation for civil disasters.

Sinclair was awarded an AM in 1982, the Peter Nicol Russell Medal in 1996 and was a proud recipient of an honorary doctorate from the University of Canberra in 2013.

THE SHELL GAME

JOHN NUTT



Nutt's use of computers to model the Sydney Opera House shells was typical of his innovative approach.

The seamless elegance of the Sydney Opera House shells hides a complex web of design and engineering achievement, woven by engineers such as Dr John Nutt, with his pioneering use of computers in structural design and analysis.

Townsville-born and educated in Brisbane and Manchester, Nutt joined consulting firm Ove Arup & Partners in London in 1961; he returned to Australia to lead Arup's Opera House design group, while helping found its Australian practice. He later set up Arup's first office in the USA in New York, and was Australian Chairman and Managing Partner with Peter Thompson from 1973 through to 1998.

Nutt specialised in the structural design and analysis of high-rise buildings. While the pioneering use of computers was his great contribution to the design of the Opera House, he was involved in many tall buildings in Australia including Melbourne's National Australia Bank and Westpac Plaza, plus Governor Phillip Tower and Governor Macquarie Tower in Sydney, this he was continually reshaping Australian skylines.

Nutt constantly sought innovative approaches to high rise construction and in particular, ways to build quicker by performing separate activities simultaneously. His keen analytical skills provided a platform for exceptional and often courageous designs, while his philosophy of tightly linking architect and contractor generated better design and construction outcomes and saved money. Both architects and builders liked to work with him, a rare combination.

That commitment to make the workplace operate more efficiently stemmed from dealing with his own inspirations, Sir Ove Arup and Sir Jack Zunz. In turn, Nutt inspired those around him and the entire engineering profession, with his integrity, energy and intellect, rightly making him one of Australia's great consulting engineers.

As Chairman of the Australian Standards Loading Code Committee for 15 years, he was instrumental in producing the Wind Loading Code, and the Earthquake and Snow Load Codes, as well as heading a task force to Review Australian building regulations, from which the Australian Building Codes Board emerged.

Nutt was made a Member of the Order of Australia for services to engineering and awarded the Centenary Medal. He received Honorary Doctorates from Macquarie University, the University of Technology, and Sydney University. Engineers Australia awarded him the Peter Nicol Russell Memorial Medal, its highest honour, followed by the John Connell Gold Medal for his leadership in the field of structural engineering.

Nutt was tireless in his drive to encourage learning at all levels, from current university students to seasoned professionals; both the industry and Arup benefited enormously from this dedicated approach. Active in the Australian Academy of Technological Science and Engineering, he served as a Governor of the ATSE Clunies Ross Awards, of which he received a Lifetime Achievement Award in 2014.



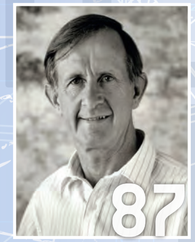
As innovative as he was efficiency, renowned consulting engineer John Nutt sculptured Sydney's skyline

9 THE CHANGING FACE OF ENGINEERING

In the 21st century there has been a broadening of engineering's focus, with increasing community awareness that resources are not limitless, and what we do affects the environment in which we live. In parallel, there has been social change where racial and gender equality have seen major progress since the days of the white Australia policy and the expectation that a woman's place is in the home. There has also been a marked broadening of engineering disciplines, particularly in the humanitarian and biomedical fields and a trend towards teamwork with many other professions.



FLORENCE McKENZIE



GRAEME KELLEHER



LOUIS CHALLIS



ANTHONY FANE



ELSE SHEPHERD



JOHN O'SULLIVAN



BILL LAWSON



PETER FARRELL



ELIZABETH TAYLOR



VEENA SAHAJWALLA



BEN LANGE



MARITA CHENG

A CAREER OF 'FIRSTS'

FLORENCE McKENZIE



An innate understanding of electricity sparked a lifetime of achievement for Florence McKenzie

It would have been easy to underestimate Florence McKenzie. Barely five feet (153 cm) tall, McKenzie had a studious and determined appearance that contrasted with her friendly and unassuming manner, but perhaps above all determination marked her ground-breaking career.

Born as Florence Violet Granville in 1890, McKenzie could not afford the ongoing tuition fees at Sydney University, leaving to complete electrical engineering at Sydney Technical College. To support herself, she bought a radio sales and repair shop in Royal Arcade, Sydney, an interest that came from "fooling around with the wiring" at home, and when she graduated in 1923 with a diploma she was possibly the first woman in Australia to have received such a qualification.

It began a career of 'firsts'. She became Australia's first female certificated radio telegraphist, the first female member of the Wireless Institute of Australia, and the first woman in Australia to hold an amateur wireless licence.

In 1934, she founded the Electrical Association for Women (Australia) where women could learn to use an electric kitchen and modern appliances, and attend meetings and lectures. A prolific writer, she published the EAW Cookery Book (1936) – the first women's guide to cooking with electricity – a children's educational book on electricity, and even corresponded with Albert Einstein, to whom she sent a didgeridoo and information on Aborigines.



A WRAN telegraphist trained by McKenzie transmits naval communications during World War Two.

McKenzie joined the Australian Women's Flying Club, becoming responsible for training women pilots in Morse code. With World War Two approaching, she foresaw a need for trained female wireless telegraphists, initially to replace men in civilian roles but eventually to serve in the forces. McKenzie was the only female electrical engineer in NSW at the time, and early in 1939 she formed the Women's Emergency Signalling Corps, by war's end training 3000 women and 12,000 men in Morse code, visual signalling and international code.

While the Air Force was resistant to recruit her female graduates, in April 1941 she persuaded the Naval Board in Melbourne to accept 14 of her operators. These women formed the nucleus of the Women's Royal Australian Naval Service.

After the war, her focus shifted to the Department of Civil Aviation. Although she was an official examiner for the department, the school never received official status though 'Mrs Mac' was highly respected, and received an OBE in 1950.

She closed her school in 1955 and became patroness of the Ex-WRANS Association in 1964, then pursued leisure activities including scientific study, reading, gardening and jam-making. She died at Greenwich on 23 May, 1982.

A VALUABLE FOOTPRINT

GRAEME KELLEHER

Engineers' ambitions can be grand, but few have painted so large and impressive a picture as Graeme Kelleher. With a vision and drive to protect the natural environment on a world stage, the once Canberra-based Department of Works engineer truly found a calling in life.

Kelleher was trained as a Civil Engineer with an early career focus on the structural design and construction of major civil engineering projects including dams and bridges in Australia and Canada.

He received a Churchill Fellowship in 1971, which allowed him to travel to the USA to work with the Environmental Protection Authority and move from structural engineering to environmental management, mainly in Australia but also internationally.

In 1976 he became a Commissioner on the Ranger Uranium Environmental Inquiry, which determined Aboriginal land ownership and defined the Kakadu National Park. The Commission also carried out a global assessment of the risks of the proliferation of nuclear weapons and provided policy advice for the Australian Government on minimising the risks of nuclear proliferation.

Kelleher was the Chairman and Chief Executive of the Great Barrier Reef Marine Park Authority, Australia (GBRMPA) for 15 years, his tenure ending in 1994.

The Authority pioneered the application of the concept of ecologically sustainable development to the management of a large marine ecosystem in an area whose economic value annually exceeds a billion dollars.

Dollar figures do not, of course, do justice to the magnificence of this region, but Kelleher's determination to combine the science of marine conservation with his astute political and people management skills placed him at the forefront of the business of saving the environment.

In 1992, he was instrumental in organising the establishment of a co-operative Research Centre on Sustainable Development of the Great Barrier Reef, involving private industry with University, government and research organisations. GBRMPA achieved the declaration by the International Maritime Organisation of part of the Great Barrier Reef as the world's first Particularly Sensitive Sea Area, enabling Australia to regulate shipping for its protection.

Kelleher was a key member of the International Union for Conservation of Nature, and as its vice chairman of the World Commission on Protected Areas from 1986-99 he championed the creation of a global representative system of marine protected areas, and assisted a number of countries in designing such areas.

As a result, Kelleher took Australia to the international forefront of marine conservation.

He is a Fellow of the Australian Academy of Technological Science and Engineering, the Environment Institute of Australia and New Zealand and of the Institution of Engineers, Australia, and has received countless awards and honours for his commitment to the world in which he lives. He now proudly bears the title of Australia's only Ocean Elder.



By committing his efforts to Australia's environmental wonders, Graeme Kelleher has been a force for saving the world's oceans



Kelleher's passion and commitment secured critical protection for the Great Barrier Reef, and made it visible to the public through the aquarium in Townsville.

SOUND IDEAS

LOUIS CHALLIS



An acoustics specialist who is remembered for clear communication

While acoustics may be perceived as a fairly narrow field of engineering, Louis Challis countered this perception by his involvement in a broad range of acoustic endeavours, ranging from traffic lights to monumental public buildings, while achieving widespread public recognition on the side as a reviewer of home audio systems.

The son of eastern European immigrants, Challis emerged from the University of Sydney with first a Bachelor of Electrical Engineering Degree, then a Master of Architectural Science. He landed a job in underwater acoustics for the Royal Australian Navy before joining the Overseas Telecommunications Commission, which had inherited facilities and resources from Amalgamated Wireless Australasia Limited.

A Wing Commander in the Royal Australian Air Force Reserve as a specialist advisor in acoustics, he would eventually start his own consulting firm, Louis A Challis & Associates, in 1966, and over the coming four decades become a pre-eminent figure in his field.

Challis's most significant project was his eight-year involvement in the architectural acoustic design and supervision of Parliament House in Canberra, which opened in 1988. Over a three-month period, he tested the acoustical properties of prospective materials using a 1:10 scale model of the House of Representatives chamber – constructed in the living room of his home!



Challis spent eight years refining the acoustics of the remarkable Parliament House project.

Other landmark public buildings and infrastructure projects included the Parliament Houses of New South Wales, Queensland and Papua New Guinea; the Olympics 2000 project at Homebush Bay; and the Sydney Harbour Tunnel.

Major architectural and engineering projects were not his only forte, for in the 1970s Challis designed and developed an audio-tactile push-button signalling system, so pedestrians who are sight- and / or hearing-impaired can easily determine whether the signal is displaying 'Walk' or 'Don't Walk' simply by touching the button. The system he designed is used worldwide.

Notably, the NSW Department of Main Roads offered Challis the privilege to patent his development, which he declined – his humanitarian view was that this development should be made as generally available as possible at the lowest possible cost.

Challis acted as specialist adviser on forensic assessment of tapes for ASIO, the New South Wales Independent Commission against Corruption and the New South Wales Crime Commission. Yet his interests were broader, too: he became known as one of the country's foremost audio equipment reviewers, and spent time on committees to develop acoustical standards.

Throughout his career Challis won many Engineering Excellence Awards from Engineers Australia and Consult Australia, and in 2005 was awarded a Member of the Order of Australia. At his death, it was also stated that Challis's aim was to make unwanted noise and vibration inaudible and good noise crystal clear.

THE HIGH WATER MARK

ANTHONY FANE

A graduate of Imperial College, London, in 1961, Tony Fane worked for some time in R&D at the Distillers Co before returning to the college to do a PhD in distillation column design. An interest had been sparked in an emerging discipline, one that would take him to the other side of the world.

Fane and his wife travelled to Australia, arriving in Sydney in late 1968. The following year he took up a position as a Research Scientist with the Australian Atomic Energy Commission, working on fluidised bed processing of nuclear fuels.

Just four years later, he turned to academia, commencing a celebrated life as one of the most respected teachers in his field, first as a Lecturer in the School of Chemical Engineering at the University of New South Wales.

Fane's knowledge and curiosity helped establish him as a world leader in membrane process engineering and membrane fouling. His research interests have been in membrane science and technology as it relates to water and waste-water applications; membrane bioreactors and water reclamation; desalination by reverse osmosis and water treatment by microfiltration and ultrafiltration; membrane fouling and cleaning.

In the early 1980s, Fane worked with Professor Chris Fell and other colleagues at UNSW on novel membrane technology that led to the 1983 formation of Memtec Ltd, now part of an international membrane company in the water industry. He became an Associate Professor, and five years later ascended to the role of Professor. This same year, he was awarded the Whiffen Medal of the Institution of Chemical Engineers (IChemE) for developments in membrane technology.



Pictured with a membrane test facility, Fane is a leader in his specialised field of engineering.

All the time he took increasingly senior roles at the University, travelled extensively, and was prolifically published in more than 500 publications on membranes, and 40 in other aspects of chemical engineering.

The UNESCO Centre for Membrane Science and Technology was founded in 1988 as a Commonwealth Special Research Centre. Fane was co-Director from 1991-2005.

Since 2002 he has led membrane research in Singapore, where he was a Temasek Professor at the Nanyang Technological University between 2002-06. A competitive appointment aimed at eminent researchers, Fane was tasked with raising the research profile in membranes for sustainable water. The subsequent formation of the Singapore Membrane Technology Centre sees more than 80 researchers engaged in fundamental and applied research into membranes for the water cycle.

Fane has spent the last decade on wide-ranging advisory boards, including the World Health Organisation's Desalination Guidelines steering committee, and Sydney Water's Technical Advisory Committee (Water) reverse osmosis reclamation plant. A winner of multiple honours, he is a Fellow of the Australian ATSE, IChemE and IEAust.



In the field of membrane research, Anthony Fane is a world renowned figure

ENTERING A MAN'S WORLD

ELSE SHEPHERD



Else Shepherd swiftly dealt with gender challenges to 'control' power in Queensland

As an indication of the changed attitude to women in engineering, Engineers Australia named Else Shepherd the 2000 Queensland Professional Engineer of the Year. Yet when she joined the Institution committee in the 1960s, she could not attend their meetings, as they were held at the local Men's Club.

It seems a quaint story, but it perceptively outlines the barriers Shepherd and a handful of female engineering colleagues confronted as they emerged from University into the workforce. It seemed a logical career path: as a child, she was always drawn to maths and physics, so while she was encouraged by her father to pursue medicine, she chose her own path.

Hence, Shepherd and another student were the first women to earn engineering degrees from the University of Queensland, in 1965.

What she has achieved since belittles any conversation on gender: Shepherd has had an outstanding career as an operational researcher, teacher, entrepreneur, and major company chair. That's a lengthy, winding path from her first job as a sugar industry process control engineer in Mackay, Queensland.

While teaching lured her to the Queensland Institute of Technology, she then co-founded a company specialising in the research and development of innovative communications, particularly custom-designed modems, and another making microwave filters using novel materials, including high temperature superconductors and ceramics used in mobile phones.

Now highly respected in both academic and professional fields, Shepherd became Chair of Powerlink Queensland, a role she would hold for 17 years. Powerlink was established by the Queensland Government to oversee the State's electricity transmission system following the break-up of the Queensland Electricity Commission.

From 1994, as the first female Chair of Powerlink, she oversaw the building, operation, and maintenance of the State's 1700 km high-voltage electricity transmission network. Shepherd also worked with the CEO on strategic issues and served as the company's liaison to the Government as Powerlink revenues grew from $1.4 billion to nearly $5.4 billion. Under her guidance, the firm developed a reputation as an early adopter of new technology and cost-effective practices.

For many years, she also sat on the National Electricity Market Management Company Board, the Brisbane City Works Advisory Board and the International Electrotechnical Commission Council Board, while holding directorships of a range of engineering companies, not-for-profit and music organisations.

Shepherd received Engineering Australia's 2007 Peter Nicol Russell Medal. She is currently Adjunct Professor and CEO in Residence in the Science and Engineering Faculty at QUT. She received an honorary doctorate from UQ as a role model for women in non-traditional fields, and is an accomplished musician, conductor and co-founder of the Australian National Choral Association.



Under Shepherd, Queensland's power network and associated commercial success expanded dramatically.

THE WI-FI GUY

JOHN O'SULLIVAN

There are unquestionable benchmarks in most engineering disciplines, leaders in their fields whose work will resonate and impact for decades, and often longer. Among those held in such esteem is Dr John O'Sullivan.

If it is fair to suggest that O'Sullivan did not invent Wi-Fi, it is equally credible to state that he was the leader of teams which made Wireless Local Area Network technology not only possible, but fast, stable and reliable. Upon this innovation, Wi-Fi was born.

O'Sullivan completed his PhD in 1974 at Sydney University, then taking an appointment in the Foundation for Radio Astronomy in the Netherlands. He ascended to lead its engineering group, making major contributions in the electronics and signal and image processing areas. Working with J P Hamaker and J E Noordam, the trio's key published paper presented a technique for sharpening and improving picture clarity in radio astronomy images.

On his return to Australia in 1983, O'Sullivan pursued the ongoing improvement of this technology during his work with the CSIRO. Charged with setting up a new Signal Processing group at the Division of Radiophysics, his team set out to find applications in areas such as image processing for medical and geophysical applications, underground mine safety, communications systems and radar processing systems.

It was not only the technology itself, but its commercial application, which would prove so successful.

In 1996, his team patented the use of a related technique for reducing multipath interference of radio signals transmitted for computer networking. This was a breakthrough of significance: one of the great problems with the Wi-Fi concept was that radio waves would essentially 'bounce' off hard surfaces, the signal therefore being jumbled and distorted.

Endless resources around the world were seeking a solution to 'unsmear' the signal. It was O'Sullivan's team (including Graham Daniels, Terry Percival, Diet Ostry and John Deane) that solved the problem in the course of doing broader research – reportedly seeking to detect exploding mini black holes the size of an atomic particle – and thus they are credited with inventing Wi-Fi as it is known today.

This technology is a part of all Wi-Fi implementations, aligning with the 802.11 standards for radio frequencies and earning billions of dollars for CSIRO through royalties and a range of lawsuits.

Among O'Sullivan's recognition sits the CSIRO Chairman's Medal and the Australian Prime Minister's Prize for Science, and his breadth of work well and truly exceeded his Wi-Fi breakthrough. From computer chip speed development to radio telescope design, his scientific influence has been profound. But in 2016, when Australia chose a contribution to the exhibition A History of the World in 100 Objects, it was the WLAN Test Bed that was chosen.



By helping make wireless technology fast, stable and reliable, John O'Sullivan changed the world



A BEACON OF HOPE

BILL LAWSON



Bill Lawson looks to impact as much on people as he does on infrastructure

Engineers have a remarkable capacity to impact upon the society in which they live, delivering everything from roads to railways, electricity to communications, and a quality of life to the Australian community. While much of it is visible, the Bill Lawsons of the world – perhaps without the profile – can arguably make the biggest difference.

Lawson graduated from the University of Tasmania in 1970, joining the Public Works and Main Roads Departments to work on structural design and road and bridge construction. While he would establish his own consulting firm and grow to 70 staff, his later work with Sinclair Knight Merz proved that, when you meet a fork in the road, some people can take both roads and succeed.

While he continued to thrive as an experienced engineer, one of his roles became the development of SKM's performance in the indigenous sector, aligning with its Corporate Social Responsibility program. As an example of his impact, Lawson was mainly responsible for Engineers Australia adopting the policy of paying a 'tribute to country' at the beginning of meetings, conferences and events.

That social responsibility work also opened the door to return to another passion of his: eradicating welfare dependence. Lawson had been an honorary probation officer and was involved with neighbourhoods full of welfare-dependent families, with unemployment identified as a root cause.



Lawson, pictured left, with some local trainees in Kununurra in 2006.

He established the Beacon Foundation in 1988, aiming to alleviate youth unemployment in Tasmania. Initial success was encouraging: at Brooks High School in Launceston, he and the headmaster tackled those leaving school after Year 10 by connecting them with employers through the Launceston Rotary Club. The annual welfare rate of 33% dropped to 13% and then to 2%. The school subsequently took it over and it fell to zero.

By 2000, Beacon Foundation activity was rolled out across Australia. Funded by the private sector, it will this year engage more than 15,000 young people from more than 109 schools in career education development activities.

That success complemented Lawson's work-related focus, too, including indigenous support at Tennant Creek (NT) to advise on the construction of an art gallery and an Interpretive Centre in the shape of a lizard. In the Kimberley he set up a precast concrete factory employing young Aborigines to build houses, a project that won a national award.

Fittingly, both aspects of Lawson's admirable work have been recognised: in 2003, Engineers Australia recognised him as the National Professional Engineer of the Year, and three years later he was awarded an Order of Australia for his Beacon Foundation commitment.



Farrell's ResMed success has both assisted sleep apnoea sufferers and built a worldwide business.

A SLEEPING GIANT

PETER FARRELL



By investing his own time and money into helping sleep apnoea sufferers, Peter Farrell changed countless lives for the better

Like so many moments of discovery, Dr Peter Farrell recognised potential that would change his life, and those of millions of sleep disorder patients around the world.

Farrell graduated from the University of Sydney with honours in chemical engineering and Doctor of Science from the University of New South Wales. Having then extensively studied biomedicine in the United States, an opportunity to shift back to Australia emerged in the 1980s and he returned to his previous school, the University of NSW, as Foundation Director of the Graduate School of Biomedical Engineering.

Soon after, Farrell was establishing a research and development arm in Sydney on behalf of the multinational healthcare giant, Baxter. He was on the lookout for investment opportunities, his line of work exposing him to a range of research and innovation that made him an ideal candidate for filtering good ideas from bad.

As part of this process, Farrell visited an obstructive sleep apnoea patient being treated with what he described as a "Darth Vader-like mask" that was hooked up to a machine that made the "noise of a freight train". While the description suggests primitive, the device in itself was brilliant.

The ungainly but effective mask allowed nasal continuous positive airway pressure (CPAP) to occur. At the time, Sullivan was treating about 100 patients suffering from sleep apnoea. This occurs when the airway temporarily collapses during sleep, preventing or restricting breathing for up to 10 seconds, sometimes more. Clinical studies have also linked untreated sleep apnoea to chronic diseases, including stroke, heart failure, hypertension, diabetes, and obesity.

Although Baxter initially invested money in developing the continuous positive airway pressure treatment, it wasn't as enthused as Farrell about its potential. The company's direction turned elsewhere, and Farrell decided to invest his own money.

Farrell developed the technology to be a highly successful non-invasive treatment which involves either wearing a discreet mask or nasal pillow that is connected to a small, quiet portable air pump. The air pressure, which may be constant or variable, is strong enough to keep the airway open while the patient sleeps. The treatment is quiet, highly effective and widely accepted with worldwide distribution in the medical field.

The business – known as ResMed – focused on developing innovative therapies that increased patient comfort and convenience while improving health and reducing healthcare costs.

That 1989 decision proved highly successful commercially. Within six years the California-based medical equipment company ResMed was listed on the American technology exchange, the NASDAQ, before dual-listing on the New York Stock Exchange and the ASX in 1999.

THE VOICE, NOT THE ECHO

ELIZABETH TAYLOR



In an inspired career of notable leadership, Elizabeth Taylor believed in the value of standards

Elizabeth Taylor is an acknowledged leader of Australia's engineering profession, be it in the areas of education, accreditation, the participation of women, professional practice, and in humanitarian aid.

After a successful and productive decade as a practising engineer, Emeritus Professor Taylor shifted her focus in 1988 and started a career as a curriculum innovator, her first role being Coordinator of the Women in Engineering Unit at the University of Technology, Sydney (UTS).

Her development of the Engineering Practice Program at UTS focussed on the culture, interdisciplinary understanding and practice of engineering. Her publication, 'Managing Workplace Learning', is used in a number of workplaces and universities throughout Australia to improve the effectiveness of engineering teaching and learning practices.

Taylor is also a champion for women in engineering. In 1991, she was elected as Foundation Convenor of the newly formed National Women in Engineering Committee of Engineers Australia. As Convenor, she was a member of the National Council, the decision making body of Engineers Australia, and the sole female among 50 members.

In 1998, she was recognised by the Australasian Association for Engineering Education for 'outstanding and sustained contribution to engineering education in Australasia'. It was a fitting honour, for Taylor's work has directly contributed to greater diversity in the engineering tertiary education sector, arguably changing the culture of the sector.



Taylor's long-term commitment to RedR has helped engineers provide relief in times of need for disaster struck countries.

From 2002 to 2011, as Chair of the Board of Professional Engineers of Queensland, Taylor was responsible for the implementation and operation of the Professional Engineers Act 2002. She then joined the Accreditation Board of Engineers Australia, responsible for accrediting engineering courses, and was later invited by Engineers Australia Council to take on the role of Chair. In this capacity she ensured that accreditation facilitates innovation, diversity and inclusion while maintaining the international standing of Australian engineering education.

At a 2015 meeting of the International Engineering Alliance, Taylor was elected Deputy Chair and is now Chair of the Executive Committee of the Washington Accord, a multilateral agreement between bodies responsible for accreditation or recognition of tertiary-level engineering qualifications who have chosen to work collectively to assist the mobility of professional engineers.

Taylor has made significant contributions to the wider community. She is a long-term Board member (and now Chair) of RedR (Registered Engineers for Disaster Relief) Australia, providing engineers and other experts to aid organisations supporting nations suffering in times of disaster.

Taylor's work has directly contributed to creating much greater diversity in the engineering education sector. In 2004 she was made an Officer in the Order of Australia for her services to engineering education, and for enhancing the status of women in engineering. She has followed her own philosophy, that professionalism is "about being a voice, not an echo".

CARING FOR THE PLANET

VEENA SAHAJWALLA

More than two centuries of engineering have changed the Australian manufacturing landscape. Yet the by-products of such activity create problems of their own, precisely the arena into which Professor Veena Sahajwalla is effecting substantial change.

Sahajwalla studied for her engineering degree at Kanpur, India, before a Masters in Engineering in Canada and Material Science doctorate from the US.

As Founding Director of the University of New South Wales' Centre for Sustainable Materials Research and Technology, Sahajwalla and her team work closely with industry partners to deliver technologies that aim to redirect many of the world's most challenging waste streams away from landfills and back into production, with savings in cost and to the environment.

Sahajwalla is revolutionising what she calls "micro-recycling science" to enable industries to safely use toxic and complex wastes as low cost alternatives to virgin raw materials and fossil fuels. This ground-breaking work effectively 'mines' waste stream destined for landfill to harness useful elements such as carbon and hydrogen, and materials like silica and titania. By using precisely controlled high temperature reactions that selectively break and reform bonds between different elements within waste mixes, she is producing previously unimaginable value-added new materials.

Yet the commercial imperative remains front of mind. Sahajwalla's research in partnership with the steel industry resulted in a world-first, patented 'green steelmaking' process that enables non-renewable coke to be partially replaced with waste tyres and/or waste plastics in electric arc furnace steelmaking. The process has been commercialised in Australia, Thailand, Korea, the UK and Norway, resulting in quality steel and the diversion of millions of waste tyres away from landfill.

Likewise, her unique micro-factory model is safely recycling toxic e-waste to produce high value products, such as filaments for 3D printers, as well as transforming problematic glass waste such as windscreens, textiles and packaging waste, into engineered ceramics and other green materials.

From her undergraduate days in India to the worldwide recognition for her achievements, Sahajwalla has been a pioneer for women in a traditionally male field. In 2012, her 'green steel' technology was recognised by the US Society for Manufacturing Engineers' as an innovation that could 'change the way we manufacture'; she has been recognised by the Indian Prime Minister and many times as one of Australia's most influential engineers and academics.

In addition to her research work she is tireless in her encouragement for girls to pursue careers in science and technology, speaking at schools, public events and through different media. She has challenged the way we think of 'waste' and the role of women in 'dirty' engineering jobs, and as the Director of the NSW Circular Economy Innovation Network she brings together stakeholders across industry, Government and research organisation.



UNSW's world first e-waste microfactory, transforming discarded electronic components.



Balancing waste management with the bottom line helped Veena Sahajwalla craft a ground breaking engineering career

FAMILY TIES

BEN LANGE



A product of the far north, Ben Lange has emerged as a role model for indigenous engineers

To say that engineering is in Ben Lange's blood has dual meaning: his father was a civil engineer, who met his mother while working in Arnhem Land, Northern Territory, while drilling for uranium deposits. And as Australia's first Aboriginal electrical engineer, those bloodlines have special meaning.

Lange went to a regional school north of Cairns, North Queensland, "in the middle of a cane field", and spent his holidays with his mother's family on Groote Eylandt, in the Gulf of Carpentaria. As a youngster, he would watch the mechanical skills of his multi-lingual grand-father, who could fix almost anything as a result of working for the mission on Groote Eylandt and the defence forces in World War Two.

Lange was as inspired as he was captivated, and that passion was fuelled in 1999 when he travelled to Sydney to attend a week-long summer school at the University of New South Wales, organised and funded by Engineering Aid Australia. EAA is a charitable organisation whose principal aim is to encourage indigenous secondary school students entering Years 11 and 12 to consider a career as a professional engineer.

From 2000, Lange undertook his Bachelor of Electrical Engineering at the University of NSW, initially under a Cooperative Scholarship and then a cadetship with the NSW Department of Energy, Utilities and Sustainability. Lange did well in power engineering subjects, completing a thesis on the psychological and environmental effects of wind farms.



Lange's wide ranging interests includes playing the didgeridoo with Opera North West.

He also became involved in the indigenous tutoring program, and co-wrote a paper that appeared in the renowned scientific journal Nature on the acoustics and science of playing the didgeridoo.

After stints with Bovis Lend Lease, he joined Ausgrid in 2006, volunteering for a graduate placement in the Upper Hunter, where he rode on the skids of helicopters in order to carry out pre-bushfire aerial checks of power lines. His job now entails planning and developing multifaceted responses to major unplanned network outages and serious incidents.

Lange's career goals have a community focus that stretch back to his indigenous roots. He wants to one day be a part of delivering better infrastructure to indigenous communities, including Groote Eylandt, and further emerge as a role model and mentor to a number of indigenous people.

As part of that activity, he has been involved in the indigenous pre-apprenticeship program at Ausgrid, which grew from a handful to an expanded group of indigenous apprentices graduating into line workers, electricians, and another electrical engineer. He is currently on the Board of Engineering Aid Australia where he takes a leadership role, including local NAIDOC and reconciliation events with day care and schools. And among other talents he performs on the didgeridoo with organisations such as Opera North West.

NO ORDINARY GAL

MARITA CHENG

The motivation, drive and activism of Marita Cheng were evident from her tertiary education days. Noticing the low number of girls in her engineering classes at the University of Melbourne, she rounded up her fellow engineering peers and they went out to schools to teach girls robotics, as a way to encourage girls into engineering.

While on an academic exchange in 2009 at Imperial College, London, and a Churchill Fellowship in 2011, Cheng expanded Robogals throughout Australia, the UK, the USA and Japan. The group runs robotics workshops, career talks and various other community activities, with a focus on female participation.

Impressive enough, but this was built on a foundation of technology entrepreneurship. Cheng is the founder and CEO of Aubot, which makes a telepresence robot, Teleport (a remote controlled wheeled tablet), enabling kids with cancer in hospital to attend school, people with a disability to attend work and to monitor and socialise with elderly people.

Teleports have been sold to offices, museums, co-working spaces, hospitals and security firms. As well as telepresence robots, Aubot undertakes research and development in robotic arms, virtual reality and autonomous mapping and navigation.

In 2015, Cheng attended Singularity University's 10-week flagship Graduate Studies Program, held at NASA Ames Research Center in Mountain View, California, funded by a $40,000 scholarship from Google. While there, she cofounded Aipoly; its first application recognises objects in real time on a smartphone, and relays them to people who are visually impaired. Since launching at the technology trade show CES in January 2016, Aipoly is now available in 23 languages and has been downloaded over 500,000 times.

Cheng was named the 2012 Young Australian of the Year for demonstrating vision and leadership well beyond her years. Robogals workshops have now influenced 90,000 girls from 11 countries, raising Cheng's profile such that she is a regular presenter at global technology events. Indeed, Cheng was referred to as "the coolest girl at CES 2014" by VentureBeat magazine, while the company has been recognised through the 'Forbes 30 Under 30 Asia' list in 2016.

That's a significant leap for a girl from Cairns, in northern Queensland, who grew up in a housing commission apartment with her brother and single-parent mother. What was immediately obvious in Cheng was her intellect and passion for technology, and she graduated from high school in the top 0.2% in the country before securing a Bachelor of Engineering (Mechatronics) / Bachelor of Computer Science.

Cheng has served on the boards of Robogals Global, the Foundation for Young Australians, and RMIT's New Enterprise Investment Fund – where she helps decide on startup investments – the Victorian State Innovation Expert Panel, and the Clinton Health Access Initiative's Tech Advisory Board.



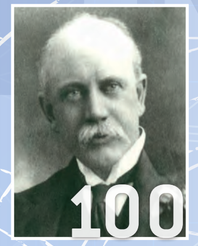
Cheng's influence with prospective young engineers has earned her recognition throughout her brief career.



Marita Cheng's keen mind and entrepreneurial drive helped bring life-changing robots to life

10 ENDLESS LEADERSHIP POSSIBILITIES

There are many examples of engineers advancing their career through purely technical aspects such as research or design, while others choose or are led to a path of management within their parent organisation or discipline. Other engineers have made their mark of leadership in business and society, including high ranking Government and viceregal appointments. Engineering skills and a disciplined approach to problem solving and management are highly valued across the board.



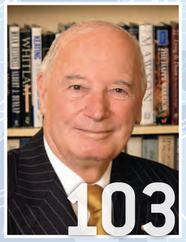
GEORGE SWINBURNE



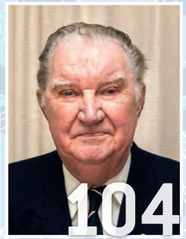
SIR WARREN McDONALD



SIR IAN McLENNAN



SIR ERIC NEAL



SIR ARVI PARBO



KEN MICHAEL



SIR ROD EDDINGTON



ALAN FINKEL



MARY O'KANE



SUSAN MURPHY



KATHRYN FAGG

AN EDUCATION BENEFACTOR

GEORGE SWINBURNE



Best now known for a university named after him, George Swinburne was an early influencer in the growth of Victoria

It was clear from his earliest days that George Swinburne had an appetite for learning matched only by that of hard work. Born in 1861 in North East England, Swinburne was apprenticed to a chemical merchant by age 13, the early termination of his formal education proving no barrier to success as he became one of Melbourne's most influential champions of a growing city's infrastructure.

Following his engineer uncle John Coates to London in 1882, Swinburne was employed in the gas and hydraulic engineering business and was soon sent to Vienna, in charge of seven English workmen, to install a gas-holder and plant. He had self-taught German, night-class engineering theory and 18 months' experience to support his innate energy, intelligence and tact, and was successful in his task.

Perhaps the travel broadened his horizons. Coates left for Melbourne late in 1885 – Swinburne was left in charge in London but a year later he followed his uncle again to join him in business.

Their first initiative was the Melbourne Hydraulic Power Co (1887), supplying power to city buildings for hydraulic lifts. Prospering through the difficult 1890s, it launched him on a successful business career and he became superintendent, managing director and finally Chairman of Colonial Gas (Australasia) and director of a range of other industrial companies. Along the way he gained formal qualifications, becoming a member of the Institution of Mechanical Engineers (1897) and of the Institution of Civil Engineers (1914).

He was interested in electric power development and equally in politics, and by 1902 he was Mayor of the inner eastern suburb of Hawthorn. He entered the Victorian Legislative Assembly that year on an 'economy and reform' ticket.

Swinburne was appointed minister of water supply in 1904 and his Water Act (1905) placed all State water supplies under the control of a new statutory, independent authority: the State Rivers and Water Supply Commission. In his other portfolio, agriculture, he promoted agricultural colleges and high schools, demonstration farms and departmental publications.

Swinburne eventually could not abide the leadership style of Premier Sir Thomas Bent, and left the Legislative Assembly to take on more than a decade of government posts, mainly federal, including Chair of the Interstate Commission. Through this he created the Advisory Council of Science and Industry, the germ of the future Commonwealth Scientific and Industrial Research Organization and contributed to the war effort before being a foundation member and champion of the State Electricity Commission.

He re-entered politics at age 67 but died after serving just four months in the chamber of the Legislative Council. The legacy of his life-long interest in education was the creation of what would become Swinburne University; though he funded it, Swinburne protested against the use of his name.



Swinburne University in Melbourne proudly carries the name of its founder.

A CIVIL BANKER

SIR WARREN McDONALD

Born in Penguin, Tasmania, in 1901, Warren McDonald believed a career in medicine awaited him. Yet it would be as engineer, industrialist, soldier and banker that Warren would carve an incredible life, earning a knighthood for his contribution to his country.

While waiting to commence a scholarship with the University of Tasmania, the 17-year-old took a role as cadet-engineer with the Tasmanian Hydro-Electric Department. He was, by all accounts, immediately hooked: "As an engineer you see what you have done," he wrote. "It's in concrete; it's there. I enjoy travelling over some bridge I have built ... for the fellow who built it, it has its own personality."

In the mid-1920s, McDonald moved to Camperdown, Victoria, as assistant engineer of Hampden Shire, resigning within 12 months to join his father, William, in a building and engineering contractor business.

He came to Canberra, accompanied by his father, William McDonald, and secured his first large contract, to build 100 homes in Forrest, and a contract to build a section of the Federal Highway between Canberra and Goulburn followed. After his father's death in 1936, he took over the family business.

War would dramatically intrude on a seemingly linear rise. McDonald performed gallantly as a sapper, climbing through the ranks to become a senior officer in the 7th Divisional Engineers, and serving in the Middle East and the Papuan campaign.

On return to Australia he began to build strong political connections, and in 1952 the Menzies government appointed him to the Australian National Airlines Commission, which operated Trans-Australia Airlines. He became Vice-Chairman of TAA in 1956 and Chairman in February 1957.

These roles typified the diversity of McDonald's ongoing professional interests, such that his 1964 knighthood noted 'public service in many fields'.

He was appointed foundation chairman of the Commonwealth Banking Corporation in 1959, providing "inspired direction" in the success of the Commonwealth Development Bank of Australia.

He also strongly supported the development of northern Australia, where his company was constructing 'beef roads' in the cattle country of north Queensland and building an iron ore railway from the Hamersley Range to the coast in Western Australia.

McDonald was a driving force in the campaign to increase Australian exports; director of the English Electric Company of Australia, and Imperial Chemical Industries ANZ; vice-chairman of Perpetual Trustee Company; and a member of the council of the Australian National University from 1953-64.

In 1960, he took the lead in establishing the National Heart Foundation of Australia and was its first President. The Foundation's Warren McDonald Research Fellowship commemorates him.



A diversity of interests and influences ensured Warren McDonald left his mark across many sectors



McDonald's stewardship of TAA was a highlight among many in his illustrious professional life.

A STEELY CONSCIENCE

SIR IAN McLENNAN



By guiding BHP through challenging waters, Ian McLennan steered an incredibly successful ship

Born and educated in Victoria, Ian Munro McLennan graduated in Electrical Engineering in 1932 and set his sights on BHP. He was accepted as a cadet the following year and gained experience at BHP's operations at Whyalla and elsewhere before returning to Melbourne head office.

Recognised for his abilities, McLennan was sent to Newcastle steelworks as a 'special cadet' and quickly rose through the ranks during the frenetic wartime period to the position of assistant manager of the steelworks, aged just 32. Even then he had considerable influence and recommended that BHP should establish a flat products plant at Port Kembla.

By 1947, he had been appointed Assistant General Manager BHP and two years later ascended to Acting GM of Australian Iron & Steel at Port Kembla – then a subsidiary of BHP – where he had direct responsibility for the massive Flat Products Development. This development to produce structural plate, hot rolled strip, tinplate and roofing steel was by some measures more significant than the Snowy Mountains Scheme being carried out concurrently.

It was also a time of tremendous stress for the steel industry. Initiated by McLennan's predecessor, Essington Lewis, the continuing industrialisation of Australia to meet wartime requirements needed ever greater steel output and strained raw materials and workers.



Under McLennan's encouragement, the Port Kembla Flat products division became a significant addition to the BHP portfolio.

By 1953, McLennan was Managing Director of BHP and, with Lewis as his Chairman, led the company through three decades, rising to new challenges and developing plans to address them.

BHP continued to expand the steel plants, utilising the most modern technology. Recognising that it lacked necessary expertise, McLennan entered into joint ventures to open up the Pilbara iron ore deposits and partnered with Esso to develop the Gippsland oil and gas reserves.

He entered into partnerships with universities (including the establishment of Wollongong University College), established Central Research Laboratories, offered scholarships, provided in-house technical training, advised Government on immigration policy and employed vast numbers of immigrants.

In 1971, McLennan was appointed Chairman and Director of Administration, BHP, and remained until reaching compulsory retirement age in 1977. He also took on Chairman and Directorships for ANZ Bank, ICI, Henry Jones (IXL) and others and numerous Government, business and charity bodies. He became a Fellow of the Australian Academy of Science, was awarded the Peter Nichol Russel Medal by the Institution of Engineers Australia and was knighted in 1979 for services to youth, community and industry.

It has been claimed that during this time BHP was an 'engineers' company': too financially conservative and too focussed on technology and production at the expense of shareholder returns. Yet there remains no doubt that, under McLennan, the company contributed greatly to Australian society.

A LIFE OF SERVICE

SIR ERIC NEAL

If circumstances foreshortened Eric Neal's early education, it no doubt redoubled his passion for learning over the years that followed, a passion that launched one of the great success stories of Australian engineering and business.

At age 16, Neal commenced an apprenticeship by day and engineering studies at the South Australian School of Mines by night. He secured his first appointment in 1950, aged 25, with the Broken Hill and Suburban Gas Company Limited. In his first six years he rebuilt the works, and by 1956 he was appointed Manager.

In 1959, now managing the Ballarat Gas Company in Victoria, he introduced butane air-mix as a gas for industry – prior to use of natural gas some years later – and trebled annual sales.

When the company was taken over by Boral Limited, Neal became Assistant General Manager of Boral Gas (now Origin Energy), with whom he had a long and successful career. Highlights included: converting nine Queensland coal gas companies to using LPG; designing and constructing four seaboard tank terminals in PNG in 1964, initiating the contract which led to Boral's first sea tanker ownership; and devising a mini-tanker domestic gas distribution system which required the development of new regulations. The mini-tanker system later became a standard delivery method.

After becoming the General Manager of Boral Gas he oversaw the setting up of operations in Fiji, the Solomon Islands, New Hebrides, Tonga, Cook Islands and US Samoa.

He was a logical choice for the Chief Executive role at Boral Limited in 1974, expanding his responsibility to encompass quarrying, pre-mixed concrete, road surfacing, reinforcing steel, brick manufacture and contracting. He retired as Managing Director from Boral Limited in 1987.

In recognition of his outstanding career in industry, Neal was knighted in 1982, and later appointed a Companion in the Order of Australia. Neal has been an active supporter of the Institution of Engineers, Australia for 70 years.

In 1992, he was awarded the USA Department of Defense Medal, for Distinguished Public Service for chairing the joint US and Australian committee which organised the 50th anniversary commemoration of the Battle of the Coral Sea.

He served on a number of major company boards, until retiring from those roles in 1996 to take up office as the 32nd Governor of South Australia. Eight years as Chancellor of Flinders University followed, where he reactivated the Engineering Faculty.

Neal commenced his final role in public office in 2009, Chairing the SA Veterans Advisory Council. He also co-chaired a committee to raise funds for Australia's first memorial to Aboriginal and Torres Strait Servicemen and Women. After completion of the Anzac Centenary Memorial Walk in 2016, he stepped down after 76 years of public and industry service.



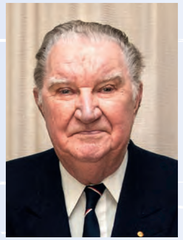
Neal's leadership helped make Boral and its divisions a household name across Australia and the Pacific.



Sir Eric Neal led an expanding gas industry through diversification to a role as State Governor

THE MINING MAGNATE

SIR ARVI PARBO



The remarkable journey of Arvi Parbo, from war-time refugee to leading some of Australia's biggest resource development companies

Among the hundreds of thousands of post-World War Two emigrants to arrive in Australia, young Estonian Arvi Parbo surely carved his mark as substantially as any. Parbo's career as mining engineer, surveyor and eventually mining magnate generated untold income and employment in his adopted home, a far cry from the German refugee camp in which he finished the war.

Having studied mining engineering in Germany, he enrolled in evening classes at the University of Adelaide in 1951, working in Broken Hill mines during his holidays to make ends meet and gain on the ground – and in the ground – experience.

It was perhaps good fortune that saw him secure a job at the Western Mining Corporation (WMC), a small but vigorous gold-mining company, but there was no luck in his progression. His first position was as an underground surveyor at Bullfinch, in the Yilgarn region of Western Australia, and Parbo's star was clearly on the ascent in a business, and industry, that was rapidly expanding.

WMC added bauxite mining in WA's Darling Ranges to its gold interests. In the process Parbo worked with staff of the Aluminium Company of America (ALCOA) on a feasibility study which led to the formation of ALCOA of Australia, today one of the world's largest integrated bauxite mining, alumina refining and aluminium smelting operations.

Nickel was soon discovered at Kambalda, just south of Kalgoorlie, and Parbo's expertise led to his 1968 appointment as General Manager. Within three years, he was Managing Director, evidence of not only his firm grasp of the industry, but his sense of strategy, business sense and management. Parbo believed in being accessible, his faith in openness and a lack of confrontation underlying his highly respected resolution skills.

In 1974, Parbo was appointed chairman and Managing Director of WMC. Three years later he also became chairman of ALCOA of Australia. Under his leadership, WMC discovered and commenced mining of the huge copper and uranium ore body at Olympic Dam in South Australia.

Parbo was knighted for his services to industry in 1978 and made a Companion of the Order of Australia in 1993, acknowledgement of the diversity of the roles he now filled. These ranged from influential roles with some of Australia's largest entities, including Alcan, Zurich, Hoescht, and Chase AMP, and he eventually filled the role of Chairman of BHP (1989-92).

Notably, he was elected as the inaugural president of the Business Council of Australia, President of the Australasian Institute of Mining and Metallurgy and the Australian Academy of Technological Sciences and Engineering. Parvo died in Melbourne in 2019, aged 93.



Parbo helped make ALCOA one of the world's largest mining entities.

THE ROAD TO GOVERNMENT HOUSE

KEN MICHAEL

Ken Michael is the son of migrants from the island of Castellorizo in Greece. His father arrived in Australia in the 1890s as a young boy and served with the Australian Imperial Forces in the First World War; his mother arrived in the mid-1930s. After his father passed away when he was eight years old, Michael received support from Perth Legacy and the then-Department of Repatriation, which gave him the opportunity to pursue his education.

Arguably this instilled two key values in his life: knowledge and community support. Michael became a distinguished engineer in his own right but is better known for his tireless and respected contribution to many aspects of Government, business and community activity within Western Australia.

A student at the University of Western Australia, Michael secured a Bachelor of Engineering with First Class Honours in Civil Engineering in 1961. He started his career as a bridge design engineer with the Main Roads Department before studying at Imperial College in London, culminating in the award of a PhD degree in engineering from the University of London in 1968.

He then returned to WA, continuing his work on bridge design before moving to Geraldton in the mid-1970s, broadening his career into road design, construction and management. After a few years, he returned to Perth, and embarked on a number of varied and significant roles, eventually rising to Commissioner of Main Roads. He became a respected international figure and was Australia's First Delegate to the Permanent International Association of Road Congresses.

Michael retired as Commissioner in 1997 and decided to enter private practice. His interests in the time that followed became even more diverse, from formal roles in gas pipeline and rail access regulation; to Chairmanship of the WA Museum Board of Trustees and Chancellor of the University of Western Australia from 2001 to 2005.

Michael's community interests also thrived. Among many positions were President of the Rotary Club of Perth and the Hellenic Australian Chamber of Commerce and Industry, while also serving on the Board of the Cancer Council of WA.

His contribution has been recognised by the Institution of Engineers, Australia in 2002 with the award of the Peter Nicol Russell Memorial Medal 'in recognition of the outstanding service rendered to engineering and Australia'. He became a Companion in the Order of Australia in 2006 for wide ranging community service of lasting benefit.

Michael was a natural appointment as Governor of WA in 2006 for a three-year term, later extended by a further two years before retiring from the role in 2011. He has since remained active as Chair of the Western Australian Cricket Association and the International Centre for Radio Astronomy Research.



As passionate about those around him as his unstinting leadership, Ken Michael has lived an admirable life of service



Government House, in Perth, was Michael's home for five years, his Governorship being the highlight of his public service.

A HIGH FLYING LEADER

SIR ROD EDDINGTON



Through Infrastructure Australia Rod Eddington helped guide Australia's future development

Rod Eddington was born in country Western Australia in 1950, later graduating from the University of Western Australia with First Class Honours in engineering. He continued with post-graduate studies at UWA, securing the degree of Master of Engineering Science.

A clearly gifted student, Eddington was named the Rhodes Scholar for WA and moved to Oxford University in England, where he completed a DPhil in Engineering Science.

He joined the Swire Group in 1979, working with its subsidiary Cathay Pacific Airways in South Korea and Japan. In 1992, Eddington became Cathay's Managing Director, based in Hong Kong, before returning to Australia to become Chairman of Ansett Australia, which was then a subsidiary of News Corporation. News Corp sold Ansett in 1999, by which time he had been appointed Deputy Chairman of News Limited, and a member of the Board of News Corporation.

In May 2000, he took the role of Chief Executive Officer of British Airways, leading the company through difficult times for the airline industry, including the 11 September 2001 attacks on New York and Washington, the Iraq War, and the tragic loss of an Air France Concorde aircraft in 2003, leading to his controversial decision to retire British Airways' fleet of that aircraft. Under his leadership, British Airways transformed from a loss-making airline to a profitable business, and he was knighted for his services to British civil aviation.

Eddington headed back to Australia in late 2005.

Upon his return, he took on many senior corporate roles, including non-executive directorships of companies including Rio Tinto, China Light & Power Holdings, 21st Century Fox, and John Swire and Sons Pty Ltd (Australia). He is Chair of J P Morgan's Asia Pacific Advisory Council, and Chair of Lion Corporation. His international business experience has resulted in him being invited to chair the APEC Business Advisory Council and take on the role of President of the Australia Japan Business Cooperation Committee.

Eddington has worked to improve the public and political understanding of the importance of strategic infrastructure to the economic and social wellbeing of Australia. His advice has been sought by governments keen to engage his expertise and he was appointed the inaugural Chair of Infrastructure Australia, serving from 2008-14.

In addition, he authored the 2006 Eddington Transport Study for the UK Government on how transport contributes to productivity and competitiveness, and he led a two-year study, completed in 2008, of transport requirements for Melbourne into the 2030s, which recommended implementation of several major projects.

Eddington was appointed an Officer of the Order of Australia "for distinguished service to business and commerce" in 2012 and is a Fellow of the Australian Academy of Technological Sciences and Engineering.



A Chairman role for Ansett Airlines sat among Eddington's multiple senior positions for airlines worldwide.



The Stile education concept features teachers who seek to ensure subjects are as interesting as they are challenging.

THE SCIENCE OF ENGINEERING LEADERSHIP

ALAN FINKEL

As Australia's Chief Scientist, Alan Finkel - neuroscientist, engineer, entrepreneur and philanthropist - is surely at the pinnacle of a remarkable career. During his distinguished public life, Finkel has worked tirelessly with a wide range of organisations to improve the outcomes of Australian research and the interface with engineering.

With a doctorate in Electrical Engineering from Monash University in 1981, he returned decades later as Chancellor of that University (2008-2016).

While serving as a postdoctoral research fellow in neuroscience at the Australian National University, he designed equipment to support research programs and soon realised the commercial possibilities, leaving academia to found Axon Instruments.

Based in California (USA), Axon made precision scientific instruments used at pharmaceutical companies and universities for the discovery of new medicines. Finkel also developed a commercially successful device that substantially sped up drug research.

Axon was sold in 2004, a turning point that saw him return to a career in Australia that rapidly broadened. Finkel led the amalgamation that formed the Florey Neuroscience Institutes; he became Chair of the Australian Centre of Excellence for All-Sky Astrophysics and was a director of the ASX-listed diagnostics company Cogstate Limited. He was Chair of Manhattan Investment Group, Chief Technology Officer of Better Place Australia and Chair of Speedpanel Australia.

At the same time, he followed his interest in education, co-founding Cosmos Magazine which, in addition to magazine publishing, operated a secondary schools science education program.

A winner of the Clunies Ross Award for facilitating international neuroscience research, Finkel is committed to science education and in 2012 he founded Stile Education, a Melbourne-based science education company. In 2008, as a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE), he led the development and implementation of the STELR program for secondary school science, which has been adopted in more than 600 Australian schools. In 2011 Finkel was elected President of ATSE, a role he held for five years.

Finkel's acceptance of the role of Australia's Chief Scientist in 2016 sees him providing high level policy advice to the Australian government, including leading the development of the national hydrogen strategy at the request of the Council of Australian Governments Energy Council. He also led the National Research Infrastructure Roadmap, the Review into the National Electricity Market (The 'Finkel Review') and the STEM Industry Partnership Forum report.

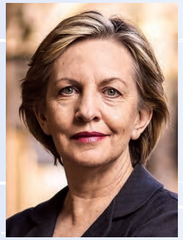
How does he achieve and sustain the breadth of his involvement in differing fields of science and engineering? He is constantly supported by and has his assumptions challenged by Elizabeth, his wife of 36 years (scientist, author and journalist) and an interview with Good Weekend magazine revealed that whenever he hits a problem he gets on with it, believing there's always a solution.



With broad interests and broader capabilities, Alan Finkel has been a standout scientific contributor

APPETITE FOR KNOWLEDGE

MARY O'KANE



While speech recognition research was her forte', Mary O'Kane has been influential in wide-ranging societal issues

When Mary O'Kane was appointed by then-NSW Premier Nathan Rees as the State's first Chief Scientist & Engineer, the range of topics she would investigate underscored her capacity and span of intellect.

Notably, her work included conducting an independent review of coal seam gas related activities, focussing on human health and environmental impacts. She would examine a range of other contentious issues at the request of government, including the state's energy security, the decline of koala populations, rail coal dust emissions, and road tunnel air quality.

O'Kane was born in 1954 in Mount Morgan, Queensland, and educated in Toowoomba. She studied at the University of Queensland, graduating with a Bachelor of Science, majoring in mathematics and physics. She received her PhD from the Australian National University in 1982.

Her research focused on automatic speech recognition for speaker-independent, naturally-spoken continuous speech. Her research group attracted significant financial support from industry and from government grants. O'Kane was thus a pioneer in the design, collection and establishment of a database of spoken Australian English.

Returning to Australia, she received a lectureship appointment in Artificial Intelligence and Theory of Computation at the Canberra College of Advanced Education (later University of Canberra), where she was Dean of the Faculty of Information Sciences and Engineering from 1989-93, one of many formal University leadership roles she would fill in the years that followed. This included her appointment as Vice-Chancellor and President of the University of Adelaide from 1996 to 2001.



Celebrating National Science Week with a school group at the Maritime Museum.

O'Kane established her own consulting practice that undertook work for Government and private sector clients. The company completed reviews of the Co-operative Research Centres and the Bureau of Meteorology.

Prominent among her awards, O'Kane has received the Peter Nicol Russell Memorial Medal, the most distinguished engineering prize in Australia; the Pearcey Medal for Lifetime Achievement in ICT; the Erna Hamburger Prize, awarded by the Ecole Polytechnique Federale de Lausanne in Switzerland to acknowledge leading women scientists who are transforming their field and executing change; and the inaugural UNSW Ada Lovelace Medal for an Outstanding Woman Engineer. O'Kane is a Fellow of the Academy of Technological Sciences and Engineering and an Honorary Fellow of Engineers Australia.

In 2016, O'Kane was appointed a Companion of the Order of Australia for "eminent service to science and engineering, as a contributor to national policy development and governance, the promotion of technology research and future energy supply, higher education, and as a role model for young scientists".

She is now Chair of the Independent Planning Commission of NSW, a statutory body established to review a wide range of planning issues referred by the government for public consultation and determination.

A LEADING CHIEF EXECUTIVE

SUSAN MURPHY

It is telling that, when Sue Murphy elected to study engineering at the University of Western Australia, she found herself the only female in a civil engineering class of over 300, such was the male influence and dominance of that vocation. It is equally telling, therefore, that Murphy would emerge as one of the most successful in her class, and indeed any class, in contemporary Australian engineering.

After winning a Clough Scholarship and graduating with honours in 1980, Murphy joined Clough Engineering, commencing what would be a 25-year career with that organisation. Her distinguished early career was spent in the field in construction roles as a site engineer and project manager.

While working on the construction of the Port Bonython jetty in 1982, she likened running a marine construction project to organising a dinner party. Her (mostly male) colleagues presented her with a copy of the Women's Weekly cookbook, re-covered in stainless steel and labelled Every Girls' Guide to Jetty Construction.

After 12 years in the field, Murphy was appointed to corporate roles with a focus on human resources, safety and engineering design management. In 1998, she was the first female to be appointed to the board of the Clough Engineering Ltd and CEO of its Minerals and Infrastructure division.

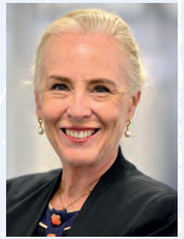
Murphy was the National Winner of the Telstra Business Woman of the Year in the private sector category in 2000, in recognition of her work at Clough Engineering. She later joined the Water Corporation of Western Australia, where she served as General Manager of Planning and Infrastructure with responsibilities for delivery of capital projects and planning, and ascended to Chief Executive Officer in 2008.

It was here that Murphy shone, ensuring that sustainable water services were maintained for all sectors of the community at a demanding and complex time of declining rainfall and increasing competition for water supplies.

Under her leadership, Water Corporation delivered Perth's second major seawater desalination plant, setting a benchmark for energy efficiency while also delivering a 35% reduction in per person water usage through community-wide programmes, plus launching a nation-leading trial of groundwater replenishment.

In other leadership roles, Murphy is a member of the University of Western Australia Senate and Board Member of the University of WA Business School, and has most recently been appointed a Director of Monadelphous Group and the Western Australian Treasury Corporation. She was the Deputy Chairman and Board Member of the Rottnest Island Authority, and a Board Member of the AFL Fremantle Dockers Football Club.

She was elected to join the Fellowship of the Australian Academy of Technological Sciences and Engineering (ATSE) in 2009, and in 2013 named by Engineers Australia as the Sir John Holland Civil Engineer of the Year.



Emerging from a male-dominated environment, Sue Murphy outstripped those boundaries in a life of achievement



The Southern Seawater Desalination Plant, in Binningup, WA, is typical of the forward thinking under Murphy's watch.

PASSION TO LEAD

KATHRYN FAGG



Graduating from the oil fields of Bass Strait, Kathryn Fagg evolved into one of Australia's most versatile managers

Kathryn Fagg commenced her professional career as a petroleum engineer with Esso Australia (now Exxon Mobil), after completing her chemical engineering degree at the University of Queensland. Her work was focused on optimising oil and gas production from the fields in Bass Strait, yet it was clear her strengths and interests extended beyond those responsibilities.

Fagg moved into management consulting with McKinsey & Co., working on engagements in strategy and change management. She then joined the ANZ Banking Group, including as General Manager, Retail Banking New Zealand, and Managing Director, Banking Products for the Group.

It would seem a career progression was well defined in the financial sector. But, again, she took a diversion, returning to her industrial roots and joining BHP Steel. It was here that her blend of industry knowledge and management experience shone. Her senior executive roles with what became BlueScope Steel included President, Australian Building and Logistics Solutions, and President Asia, the latter in Singapore with responsibility for BlueScope's operations across the Asia region.

It became clear that Fagg was an outstanding manager above all else. She spent three years at Linfox as President Fast Moving Consumer Goods (FMCG), providing logistics services to nine of the world's 10 largest FMCG companies in Australia, New Zealand and Asia.



The Turrum Field Marlin B Platform in Bass Strait, Victoria, was typical of Fagg's early workplace.

She has filled numerous directorships, including for the Reserve Bank of Australia and Breast Cancer Network Australia. She has completed terms as President of Chief Executive Women, Chairman of the Melbourne Recital Centre and Chairman of Parks Victoria. Fagg is currently on the board of the CSIRO. In addition to her commercial boards, Fagg previously served as a board member for the Australian Centre for Innovation and now serves on the Boards of The Grattan Institute, The Myer Foundation and Male Champions of Change.

She has been a vocal advocate for management progression for females, including women in senior executive roles and succession planning.

In some sense, it was a reversion to her original passion, that of forward thinking engineering.

Indeed, Fagg started as an engineer but made a successful transition to being a professional board member and board chair, an ideal example of the flexibility in thinking which enables – and encourages – engineers to succeed in other areas of enterprise.

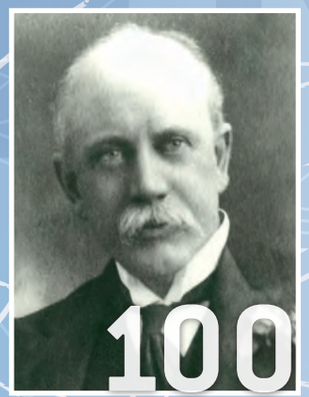
Alongside her engineering degree, Fagg has added a Master of Commerce in Organisation Behaviour from the University of New South Wales, was a recipient of the University of Queensland's Vice-Chancellor's Alumni Excellence Award, and honorary doctorates from the University of Queensland and the University of New South Wales.

Fagg was appointed an Officer of the Order of Australia (AO) in 2019 for "distinguished service to business and finance, to the central banking, logistics and manufacturing sectors, and to women".

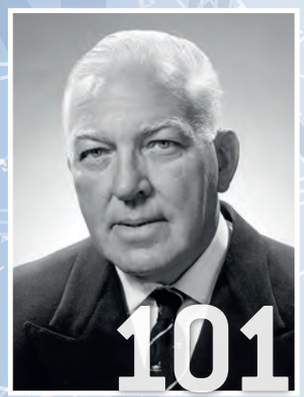


Box coil at the hot strip mill in the Port Kembla Steelworks.

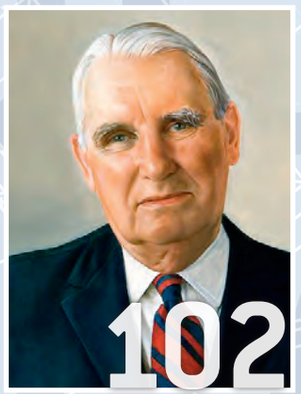
10 ENDLESS LEADERSHIP POSSIBILITIES



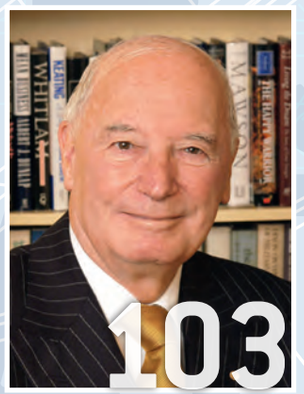
GEORGE SWINBURNE



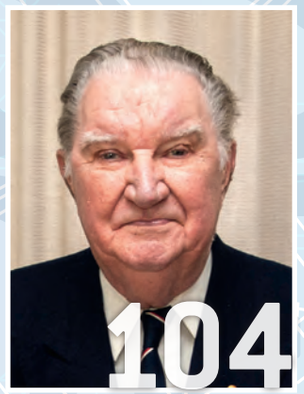
SIR WARREN McDONALD



SIR IAN McLENNAN



SIR ERIC NEAL



SIR ARVI PARBO



KEN MICHAEL

There are many examples of engineers advancing their career through purely technical aspects such as research or design, while others choose or are led to a path of management within their parent organisation or discipline. Other engineers have made their mark of leadership in business and society, including high ranking Government and viceregal appointments. Engineering skills and a disciplined approach to problem solving and management are highly valued across the board.



SIR ROD EDDINGTON



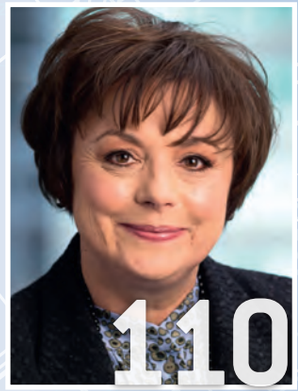
ALAN FINKEL



MARY O'KANE



SUSAN MURPHY



KATHRYN FAGG

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AN EDUCATION BENEFACTOR

GEORGE SWINBURNE



Best now known for a university named after him, George Swinburne was an early influencer in the growth of Victoria

It was clear from his earliest days that George Swinburne had an appetite for learning matched only by that of hard work. Born in 1861 in North East England, Swinburne was apprenticed to a chemical merchant by age 13, the early termination of his formal education proving no barrier to success as he became one of Melbourne's most influential champions of a growing city's infrastructure.

Following his engineer uncle John Coates to London in 1882, Swinburne was employed in the gas and hydraulic engineering business and was soon sent to Vienna, in charge of seven English workmen, to install a gas-holder and plant. He had self-taught German, night-class engineering theory and 18 months' experience to support his innate energy, intelligence and tact, and was successful in his task.

Perhaps the travel broadened his horizons. Coates left for Melbourne late in 1885 – Swinburne was left in charge in London but a year later he followed his uncle again to join him in business.

Their first initiative was the Melbourne Hydraulic Power Co (1887), supplying power to city buildings for hydraulic lifts. Prospering through the difficult 1890s, it launched him on a successful business career and he became superintendent, managing director and finally Chairman of Colonial Gas (Australasia) and director of a range of other industrial companies. Along the way he gained formal qualifications, becoming a member of the Institution of Mechanical Engineers (1897) and of the Institution of Civil Engineers (1914).

He was interested in electric power development and equally in politics, and by 1902 he was Mayor of the inner eastern suburb of Hawthorn. He entered the Victorian Legislative Assembly that year on an 'economy and reform' ticket.

Swinburne was appointed minister of water supply in 1904 and his Water Act (1905) placed all State water supplies under the control of a new statutory, independent authority: the State Rivers and Water Supply Commission. In his other portfolio, agriculture, he promoted agricultural colleges and high schools, demonstration farms and departmental publications.

Swinburne eventually could not abide the leadership style of Premier Sir Thomas Bent, and left the Legislative Assembly to take on more than a decade of government posts, mainly federal, including Chair of the Interstate Commission. Through this he created the Advisory Council of Science and Industry, the germ of the future Commonwealth Scientific and Industrial Research Organization and contributed to the war effort before being a foundation member and champion of the State Electricity Commission.

He re-entered politics at age 67 but died after serving just four months in the chamber of the Legislative Council. The legacy of his life-long interest in education was the creation of what would become Swinburne University; though he funded it, Swinburne protested against the use of his name.



Swinburne University in Melbourne proudly carries the name of its founder.

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A CIVIL BANKER

SIR WARREN McDONALD

Born in Penguin, Tasmania, in 1901, Warren McDonald believed a career in medicine awaited him. Yet it would be as engineer, industrialist, soldier and banker that Warren would carve an incredible life, earning a knighthood for his contribution to his country.

While waiting to commence a scholarship with the University of Tasmania, the 17-year-old took a role as cadet-engineer with the Tasmanian Hydro-Electric Department. He was, by all accounts, immediately hooked: "As an engineer you see what you have done," he wrote. "It's in concrete; it's there. I enjoy travelling over some bridge I have built ... for the fellow who built it, it has its own personality."

In the mid-1920s, McDonald moved to Camperdown, Victoria, as assistant engineer of Hampden Shire, resigning within 12 months to join his father, William, in a building and engineering contractor business.

He came to Canberra, accompanied by his father, William McDonald, and secured his first large contract, to build 100 homes in Forrest, and a contract to build a section of the Federal Highway between Canberra and Goulburn followed. After his father's death in 1936, he took over the family business.

War would dramatically intrude on a seemingly linear rise. McDonald performed gallantly as a sapper, climbing through the ranks to become a senior officer in the 7th Divisional Engineers, and serving in the Middle East and the Papuan campaign.

On return to Australia he began to build strong political connections, and in 1952 the Menzies government appointed him to the Australian National Airlines Commission, which operated Trans-Australia Airlines. He became Vice-Chairman of TAA in 1956 and Chairman in February 1957.

These roles typified the diversity of McDonald's ongoing professional interests, such that his 1964 knighthood noted 'public service in many fields'.

He was appointed foundation chairman of the Commonwealth Banking Corporation in 1959, providing "inspired direction" in the success of the Commonwealth Development Bank of Australia.

He also strongly supported the development of northern Australia, where his company was constructing 'beef roads' in the cattle country of north Queensland and building an iron ore railway from the Hamersley Range to the coast in Western Australia.

McDonald was a driving force in the campaign to increase Australian exports; director of the English Electric Company of Australia, and Imperial Chemical Industries ANZ; vice-chairman of Perpetual Trustee Company; and a member of the council of the Australian National University from 1953-64.

In 1960, he took the lead in establishing the National Heart Foundation of Australia and was its first President. The Foundation's Warren McDonald Research Fellowship commemorates him.



A diversity of interests and influences ensured Warren McDonald left his mark across many sectors



McDonald's stewardship of TAA was a highlight among many in his illustrious professional life.

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A STEELY CONSCIENCE

SIR IAN McLENNAN



By guiding BHP through challenging waters, Ian McLennan steered an incredibly successful ship

Born and educated in Victoria, Ian Munro McLennan graduated in Electrical Engineering in 1932 and set his sights on BHP. He was accepted as a cadet the following year and gained experience at BHP's operations at Whyalla and elsewhere before returning to Melbourne head office.

Recognised for his abilities, McLennan was sent to Newcastle steelworks as a 'special cadet' and quickly rose through the ranks during the frenetic wartime period to the position of assistant manager of the steelworks, aged just 32. Even then he had considerable influence and recommended that BHP should establish a flat products plant at Port Kembla.

By 1947, he had been appointed Assistant General Manager BHP and two years later ascended to Acting GM of Australian Iron & Steel at Port Kembla – then a subsidiary of BHP – where he had direct responsibility for the massive Flat Products Development. This development to produce structural plate, hot rolled strip, tinplate and roofing steel was by some measures more significant than the Snowy Mountains Scheme being carried out concurrently.

It was also a time of tremendous stress for the steel industry. Initiated by McLennan's predecessor, Essington Lewis, the continuing industrialisation of Australia to meet wartime requirements needed ever greater steel output and strained raw materials and workers.



Under McLennan's encouragement, the Port Kembla Flat Products division became a significant addition to the BHP portfolio.

By 1953, McLennan was Managing Director of BHP and, with Lewis as his Chairman, led the company through three decades, rising to new challenges and developing plans to address them.

BHP continued to expand the steel plants, utilising the most modern technology. Recognising that it lacked necessary expertise, McLennan entered into joint ventures to open up the Pilbara iron ore deposits and partnered with Esso to develop the Gippsland oil and gas reserves.

He entered into partnerships with universities (including the establishment of Wollongong University College), established Central Research Laboratories, offered scholarships, provided in-house technical training, advised Government on immigration policy and employed vast numbers of immigrants.

In 1971, McLennan was appointed Chairman and Director of Administration, BHP, and remained until reaching compulsory retirement age in 1977. He also took on Chairman and Directorships for ANZ Bank, ICI, Henry Jones (IXL) and others and numerous Government, business and charity bodies. He became a Fellow of the Australian Academy of Science, was awarded the Peter Nichol Russel Medal by the Institution of Engineers Australia and was knighted in 1979 for services to youth, community and industry.

It has been claimed that during this time BHP was an 'engineers' company': too financially conservative and too focussed on technology and production at the expense of shareholder returns. Yet there remains no doubt that, under McLennan, the company contributed greatly to Australian society.

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A LIFE OF SERVICE

SIR ERIC NEAL

If circumstances foreshortened Eric Neal's early education, it no doubt redoubled his passion for learning over the years that followed, a passion that launched one of the great success stories of Australian engineering and business.

At age 16, Neal commenced an apprenticeship by day and engineering studies at the South Australian School of Mines by night. He secured his first appointment in 1950, aged 25, with the Broken Hill and Suburban Gas Company Limited. In his first six years he rebuilt the works, and by 1956 he was appointed Manager.

In 1959, now managing the Ballarat Gas Company in Victoria, he introduced butane air-mix as a gas for industry – prior to use of natural gas some years later – and trebled annual sales.

When the company was taken over by Boral Limited, Neal became Assistant General Manager of Boral Gas (now Origin Energy), with whom he had a long and successful career. Highlights included: converting nine Queensland coal gas companies to using LPG; designing and constructing four seaboard tank terminals in PNG in 1964, initiating the contract which led to Boral's first sea tanker ownership; and devising a mini-tanker domestic gas distribution system which required the development of new regulations. The mini-tanker system later became a standard delivery method.

After becoming the General Manager of Boral Gas he oversaw the setting up of operations in Fiji, the Solomon Islands, New Hebrides, Tonga, Cook Islands and US Samoa.

He was a logical choice for the Chief Executive role at Boral Limited in 1974, expanding his responsibility to encompass quarrying, pre-mixed concrete, road surfacing, reinforcing steel, brick manufacture and contracting. He retired as Managing Director from Boral Limited in 1987.

In recognition of his outstanding career in industry, Neal was knighted in 1982, and later appointed a Companion in the Order of Australia. Neal has been an active supporter of the Institution of Engineers, Australia for 70 years.

In 1992, he was awarded the USA Department of Defense Medal, for Distinguished Public Service for chairing the joint US and Australian committee which organised the 50th anniversary commemoration of the Battle of the Coral Sea.

He served on a number of major company boards, until retiring from those roles in 1996 to take up office as the 32nd Governor of South Australia. Eight years as Chancellor of Flinders University followed, where he reactivated the Engineering Faculty.

Neal commenced his final role in public office in 2009, Chairing the SA Veterans Advisory Council. He also co-chaired a committee to raise funds for Australia's first memorial to Aboriginal and Torres Strait Servicemen and Women. After completion of the Anzac Centenary Memorial Walk in 2016, he stepped down after 76 years of public and industry service.



Sir Eric Neal led an expanding gas industry through diversification to a role as State Governor

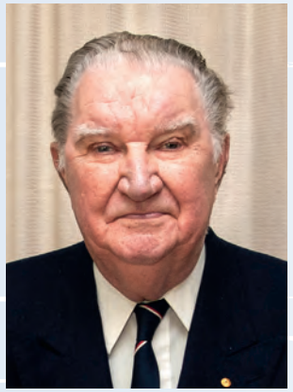


Neal's leadership helped make Boral and its divisions a household name across Australia and the Pacific.

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THE MINING MAGNATE

SIR ARVI PARBO



The remarkable journey of Arvi Parbo, from war-time refugee to leading some of Australia's biggest resource development companies

Among the hundreds of thousands of post-World War Two emigrants to arrive in Australia, young Estonian Arvi Parbo surely carved his mark as substantially as any. Parbo's career as mining engineer, surveyor and eventually mining magnate generated untold income and employment in his adopted home, a far cry from the German refugee camp in which he finished the war.

Having studied mining engineering in Germany, he enrolled in evening classes at the University of Adelaide in 1951, working in Broken Hill mines during his holidays to make ends meet and gain on the ground – and in the ground – experience.

It was perhaps good fortune that saw him secure a job at the Western Mining Corporation (WMC), a small but vigorous gold-mining company, but there was no luck in his progression. His first position was as an underground surveyor at Bullfinch, in the Yilgarn region of Western Australia, and Parbo's star was clearly on the ascent in a business, and industry, that was rapidly expanding.

WMC added bauxite mining in WA's Darling Ranges to its gold interests. In the process Parbo worked with staff of the Aluminium Company of America (ALCOA) on a feasibility study which led to the formation of ALCOA of Australia, today one of the world's largest integrated bauxite mining, alumina refining and aluminium smelting operations.

Nickel was soon discovered at Kambalda, just south of Kalgoorlie, and Parbo's expertise led to his 1968 appointment as General Manager. Within three years, he was Managing Director, evidence of not only his firm grasp of the industry, but his sense of strategy, business sense and management. Parbo believed in being accessible, his faith in openness and a lack of confrontation underlying his highly respected resolution skills.

In 1974, Parbo was appointed chairman and Managing Director of WMC. Three years later he also became chairman of ALCOA of Australia. Under his leadership, WMC discovered and commenced mining of the huge copper and uranium ore body at Olympic Dam in South Australia.

Parbo was knighted for his services to industry in 1978 and made a Companion of the Order of Australia in 1993, acknowledgement of the diversity of the roles he now filled. These ranged from influential roles with some of Australia's largest entities, including Alcan, Zurich, Hoescht, and Chase AMP, and he eventually filled the role of Chairman of BHP (1989-92).

Notably, he was elected as the inaugural president of the Business Council of Australia, President of the Australasian Institute of Mining and Metallurgy and the Australian Academy of Technological Sciences and Engineering. Parvo died in Melbourne in 2019, aged 93.



Parbo helped make ALCOA one of the world's largest mining entities.

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THE ROAD TO GOVERNMENT HOUSE

KEN MICHAEL

Ken Michael is the son of migrants from the island of Castellorizo in Greece. His father arrived in Australia in the 1890s as a young boy and served with the Australian Imperial Forces in the First World War; his mother arrived in the mid-1930s. After his father passed away when he was eight years old, Michael received support from Perth Legacy and the then-Department of Repatriation, which gave him the opportunity to pursue his education.

Arguably this instilled two key values in his life: knowledge and community support. Michael became a distinguished engineer in his own right but is better known for his tireless and respected contribution to many aspects of Government, business and community activity within Western Australia.

A student at the University of Western Australia, Michael secured a Bachelor of Engineering with First Class Honours in Civil Engineering in 1961. He started his career as a bridge design engineer with the Main Roads Department before studying at Imperial College in London, culminating in the award of a PhD degree in engineering from the University of London in 1968.

He then returned to WA, continuing his work on bridge design before moving to Geraldton in the mid-1970s, broadening his career into road design, construction and management. After a few years, he returned to Perth, and embarked on a number of varied and significant roles, eventually rising to Commissioner of Main Roads. He became a respected international figure and was Australia's First Delegate to the Permanent International Association of Road Congresses.

Michael retired as Commissioner in 1997 and decided to enter private practice. His interests in the time that followed became even more diverse, from formal roles in gas pipeline and rail access regulation; to Chairmanship of the WA Museum Board of Trustees and Chancellor of the University of Western Australia from 2001 to 2005.

Michael's community interests also thrived. Among many positions were President of the Rotary Club of Perth and the Hellenic Australian Chamber of Commerce and Industry, while also serving on the Board of the Cancer Council of WA.

His contribution has been recognised by the Institution of Engineers, Australia in 2002 with the award of the Peter Nicol Russell Memorial Medal 'in recognition of the outstanding service rendered to engineering and Australia'. He became a Companion in the Order of Australia in 2006 for wide ranging community service of lasting benefit.

Michael was a natural appointment as Governor of WA in 2006 for a three-year term, later extended by a further two years before retiring from the role in 2011. He has since remained active as Chair of the Western Australian Cricket Association and the International Centre for Radio Astronomy Research.



As passionate about those around him as his unstinting leadership, Ken Michael has lived an admirable life of service



Government House, in Perth, was Michael's home for five years, his Governorship being the highlight of his public service.

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A HIGH FLYING LEADER

SIR ROD EDDINGTON



Through Infrastructure Australia Rod Eddington helped guide Australia's future development

Rod Eddington was born in country Western Australia in 1950, later graduating from the University of Western Australia with First Class Honours in engineering. He continued with post-graduate studies at UWA, securing the degree of Master of Engineering Science.

A clearly gifted student, Eddington was named the Rhodes Scholar for WA and moved to Oxford University in England, where he completed a DPhil in Engineering Science.

He joined the Swire Group in 1979, working with its subsidiary Cathay Pacific Airways in South Korea and Japan. In 1992, Eddington became Cathay's Managing Director, based in Hong Kong, before returning to Australia to become Chairman of Ansett Australia, which was then a subsidiary of News Corporation. News Corp sold Ansett in 1999, by which time he had been appointed Deputy Chairman of News Limited, and a member of the Board of News Corporation.

In May 2000, he took the role of Chief Executive Officer of British Airways, leading the company through difficult times for the airline industry, including the 11 September 2001 attacks on New York and Washington, the Iraq War, and the tragic loss of an Air France Concorde aircraft in 2003, leading to his controversial decision to retire British Airways' fleet of that aircraft. Under his leadership, British Airways transformed from a loss-making airline to a profitable business, and he was knighted for his services to British civil aviation.

Eddington headed back to Australia in late 2005.

Upon his return, he took on many senior corporate roles, including non-executive directorships of companies including Rio Tinto, China Light & Power Holdings, 21st Century Fox, and John Swire and Sons Pty Ltd (Australia). He is Chair of J P Morgan's Asia Pacific Advisory Council, and Chair of Lion Corporation. His international business experience has resulted in him being invited to chair the APEC Business Advisory Council and take on the role of President of the Australia Japan Business Cooperation Committee.

Eddington has worked to improve the public and political understanding of the importance of strategic infrastructure to the economic and social wellbeing of Australia. His advice has been sought by governments keen to engage his expertise and he was appointed the inaugural Chair of Infrastructure Australia, serving from 2008-14.

In addition, he authored the 2006 Eddington Transport Study for the UK Government on how transport contributes to productivity and competitiveness, and he led a two-year study, completed in 2008, of transport requirements for Melbourne into the 2030s, which recommended implementation of several major projects.

Eddington was appointed an Officer of the Order of Australia "for distinguished service to business and commerce" in 2012 and is a Fellow of the Australian Academy of Technological Sciences and Engineering.



Through Infrastructure Australia Rod Eddington helped to guide Australia's future development.

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The Stile education concept features teachers who seek to ensure subjects are as interesting as they are challenging.

THE SCIENCE OF ENGINEERING LEADERSHIP

ALAN FINKEL

As Australia's Chief Scientist, Alan Finkel - neuroscientist, engineer, entrepreneur and philanthropist - is surely at the pinnacle of a remarkable career. During his distinguished public life, Finkel has worked tirelessly with a wide range of organisations to improve the outcomes of Australian research and the interface with engineering.

With a doctorate in Electrical Engineering from Monash University in 1981, he returned decades later as Chancellor of that University (2008-2016).

While serving as a postdoctoral research fellow in neuroscience at the Australian National University, he designed equipment to support research programs and soon realised the commercial possibilities, leaving academia to found Axon Instruments.

Based in California (USA), Axon made precision scientific instruments used at pharmaceutical companies and universities for the discovery of new medicines. Finkel also developed a commercially successful device that substantially sped up drug research.

Axon was sold in 2004, a turning point that saw him return to a career in Australia that rapidly broadened. Finkel led the amalgamation that formed the Florey Neuroscience Institutes; he became Chair of the Australian Centre of Excellence for All-Sky Astrophysics and was a director of the ASX-listed diagnostics company Cogstate Limited. He was Chair of Manhattan Investment Group, Chief Technology Officer of Better Place Australia and Chair of Speedpanel Australia.

At the same time, he followed his interest in education, co-founding Cosmos Magazine which, in addition to magazine publishing, operated a secondary schools science education program.

A winner of the Clunies Ross Award for facilitating international neuroscience research, Finkel is committed to science education and in 2012 he founded Stile Education, a Melbourne-based science education company. In 2008, as a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE), he led the development and implementation of the STELR program for secondary school science, which has been adopted in more than 600 Australian schools. In 2011 Finkel was elected President of ATSE, a role he held for five years.

Finkel's acceptance of the role of Australia's Chief Scientist in 2016 sees him providing high level policy advice to the Australian government, including leading the development of the national hydrogen strategy at the request of the Council of Australian Governments Energy Council. He also led the National Research Infrastructure Roadmap, the Review into the National Electricity Market (The 'Finkel Review') and the STEM Industry Partnership Forum report.

How does he achieve and sustain the breadth of his involvement in differing fields of science and engineering? He is constantly supported by and has his assumptions challenged by Elizabeth, his wife of 36 years (scientist, author and journalist) and an interview with Good Weekend magazine revealed that whenever he hits a problem he gets on with it, believing there's always a solution.



With broad interests and broader capabilities, Alan Finkel has been a standout scientific contributor

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APPETITE FOR KNOWLEDGE

MARY O'KANE



While speech recognition research was her forte', Mary O'Kane has been influential in wide-ranging societal issues

When Mary O'Kane was appointed by then-NSW Premier Nathan Rees as the State's first Chief Scientist & Engineer, the range of topics she would investigate underscored her capacity and span of intellect.

Notably, her work included conducting an independent review of coal seam gas related activities, focussing on human health and environmental impacts. She would examine a range of other contentious issues at the request of government, including the state's energy security, the decline of koala populations, rail coal dust emissions, and road tunnel air quality.

O'Kane was born in 1954 in Mount Morgan, Queensland, and educated in Toowoomba. She studied at the University of Queensland, graduating with a Bachelor of Science, majoring in mathematics and physics. She received her PhD from the Australian National University in 1982.

Her research focused on automatic speech recognition for speaker-independent, naturally-spoken continuous speech. Her research group attracted significant financial support from industry and from government grants. O'Kane was thus a pioneer in the design, collection and establishment of a database of spoken Australian English.

Returning to Australia, she received a lectureship appointment in Artificial Intelligence and Theory of Computation at the Canberra College of Advanced Education (later University of Canberra), where she was Dean of the Faculty of Information Sciences and Engineering from 1989-93, one of many formal University leadership roles she would fill in the years that followed. This included her appointment as Vice-Chancellor and President of the University of Adelaide from 1996 to 2001.



Celebrating National Science Week with a school group at the Maritime Museum.

O'Kane established her own consulting practice that undertook work for Government and private sector clients. The company completed reviews of the Co-operative Research Centres and the Bureau of Meteorology.

Prominent among her awards, O'Kane has received the Peter Nicol Russell Memorial Medal, the most distinguished engineering prize in Australia; the Pearcey Medal for Lifetime Achievement in ICT; the Erna Hamburger Prize, awarded by the Ecole Polytechnique Federale de Lausanne in Switzerland to acknowledge leading women scientists who are transforming their field and executing change; and the inaugural UNSW Ada Lovelace Medal for an Outstanding Woman Engineer. O'Kane is a Fellow of the Academy of Technological Sciences and Engineering and an Honorary Fellow of Engineers Australia.

In 2016, O'Kane was appointed a Companion of the Order of Australia for "eminent service to science and engineering, as a contributor to national policy development and governance, the promotion of technology research and future energy supply, higher education, and as a role model for young scientists".

She is now Chair of the Independent Planning Commission of NSW, a statutory body established to review a wide range of planning issues referred by the government for public consultation and determination.

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A LEADING CHIEF EXECUTIVE

SUSAN MURPHY

It is telling that, when Sue Murphy elected to study engineering at the University of Western Australia, she found herself the only female in a civil engineering class of over 300, such was the male influence and dominance of that vocation. It is equally telling, therefore, that Murphy would emerge as one of the most successful in her class, and indeed any class, in contemporary Australian engineering.

After winning a Clough Scholarship and graduating with honours in 1980, Murphy joined Clough Engineering, commencing what would be a 25-year career with that organisation. Her distinguished early career was spent in the field in construction roles as a site engineer and project manager.

While working on the construction of the Port Bonython jetty in 1982, she likened running a marine construction project to organising a dinner party. Her (mostly male) colleagues presented her with a copy of the Women's Weekly cookbook, re-covered in stainless steel and labelled Every Girls' Guide to Jetty Construction.

After 12 years in the field, Murphy was appointed to corporate roles with a focus on human resources, safety and engineering design management. In 1998, she was the first female to be appointed to the board of the Clough Engineering Ltd and CEO of its Minerals and Infrastructure division.

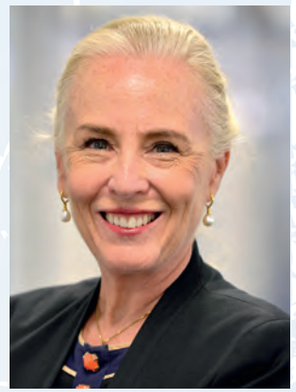
Murphy was the National Winner of the Telstra Business Woman of the Year in the private sector category in 2000, in recognition of her work at Clough Engineering. She later joined the Water Corporation of Western Australia, where she served as General Manager of Planning and Infrastructure with responsibilities for delivery of capital projects and planning, and ascended to Chief Executive Officer in 2008.

It was here that Murphy shone, ensuring that sustainable water services were maintained for all sectors of the community at a demanding and complex time of declining rainfall and increasing competition for water supplies.

Under her leadership, Water Corporation delivered Perth's second major seawater desalination plant, setting a benchmark for energy efficiency while also delivering a 35% reduction in per person water usage through community-wide programmes, plus launching a nation-leading trial of groundwater replenishment.

In other leadership roles, Murphy is a member of the University of Western Australia Senate and Board Member of the University of WA Business School, and has most recently been appointed a Director of Monadelphous Group and the Western Australian Treasury Corporation. She was the Deputy Chairman and Board Member of the Rottnest Island Authority, and a Board Member of the AFL Fremantle Dockers Football Club.

She was elected to join the Fellowship of the Australian Academy of Technological Sciences and Engineering (ATSE) in 2009, and in 2013 named by Engineers Australia as the Sir John Holland Civil Engineer of the Year.



Emerging from a male-dominated environment, Sue Murphy outstripped those boundaries in a life of achievement



The Southern Seawater Desalination Plant, in Binningup, WA, is typical of the forward thinking under Murphy's watch.

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PASSION TO LEAD

KATHRYN FAGG



Graduating from the oil fields of Bass Strait, Kathryn Fagg evolved into one of Australia's most versatile managers

Kathryn Fagg commenced her professional career as a petroleum engineer with Esso Australia (now Exxon Mobil), after completing her chemical engineering degree at the University of Queensland. Her work was focused on optimising oil and gas production from the fields in Bass Strait, yet it was clear her strengths and interests extended beyond those responsibilities.

Fagg moved into management consulting with McKinsey & Co., working on engagements in strategy and change management. She then joined the ANZ Banking Group, including as General Manager, Retail Banking New Zealand, and Managing Director, Banking Products for the Group.

It would seem a career progression was well defined in the financial sector. But, again, she took a diversion, returning to her industrial roots and joining BHP Steel. It was here that her blend of industry knowledge and management experience shone. Her senior executive roles with what became BlueScope Steel included President, Australian Building and Logistics Solutions, and President Asia, the latter in Singapore with responsibility for BlueScope's operations across the Asia region.

It became clear that Fagg was an outstanding manager above all else. She spent three years at Linfox as President Fast Moving Consumer Goods (FMCG), providing logistics services to nine of the world's 10 largest FMCG companies in Australia, New Zealand and Asia.



The Turrum Field Marlin B Platform in Bass Strait, Victoria, was typical of Fagg's early workplace.

She has filled numerous directorships, including for the Reserve Bank of Australia and Breast Cancer Network Australia. She has completed terms as President of Chief Executive Women, Chairman of the Melbourne Recital Centre and Chairman of Parks Victoria. Fagg is currently on the board of the CSIRO. In addition to her commercial boards, Fagg previously served as a board member for the Australian Centre for Innovation and now serves on the Boards of The Grattan Institute, The Myer Foundation and Male Champions of Change.

She has been a vocal advocate for management progression for females, including women in senior executive roles and succession planning.

In some sense, it was a reversion to her original passion, that of forward thinking engineering.

Indeed, Fagg started as an engineer but made a successful transition to being a professional board member and board chair, an ideal example of the flexibility in thinking which enables – and encourages – engineers to succeed in other areas of enterprise.

Alongside her engineering degree, Fagg has added a Master of Commerce in Organisation Behaviour from the University of New South Wales, was a recipient of the University of Queensland's Vice-Chancellor's Alumni Excellence Award, and honorary doctorates from the University of Queensland and the University of New South Wales.

Fagg was appointed an Officer of the Order of Australia (AO) in 2019 for "distinguished service to business and finance, to the central banking, logistics and manufacturing sectors, and to women".

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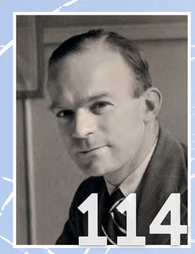


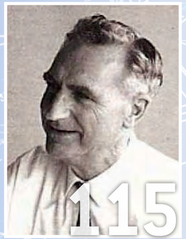
Partially rolled coil at the hot strip mill at Port Kembla Steelworks.

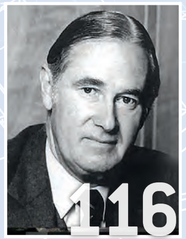
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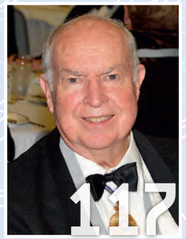
11 GLOBALISATION

A move toward free international trade with reduced tariff barriers, the digital communications revolution, and a large measure of entrepreneurial spirit in promoting good engineering have enabled Australians to participate and succeed in a global market, generating significant export income. Some engineers have also received noteworthy international recognition by their peers for ideas and technology developed in Australia. Where doors may at first seem to be closed, there are ways in a globalised world of getting around barriers and living one's dreams.


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BILL BRADFIELD


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CHARLES WARMAN


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DOUG PRICE


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BRIAN O'KEEFFE


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GRAEME JAMESON


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ANDREW THOMAS

GLOBALISATION

11

THE AIR APPARENT

BILL BRADFIELD



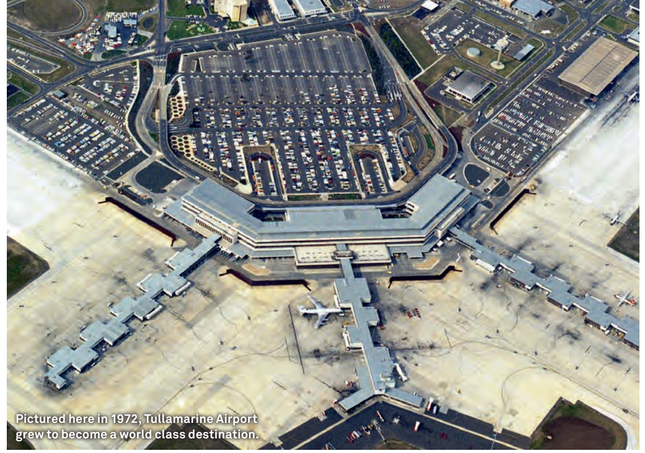
Designing some of Australia's major airports and setting aviation standards sit among Bill Bradfield's crowning accomplishments

Selected as the NSW Rhodes Scholar for 1935, Bill Bradfield travelled to the United Kingdom to study Engineering Science at Oxford University. His doctoral thesis on methods of stress analysis in mathematically indeterminate frameworks, such as aircraft structures, hinted at what became a landmark career in aviation.

Dr Bradfield joined the Oxford University Air Squadron, a branch of the RAF, and learned to fly on Avro Tutors, and later Hawker Harts. He completed his scholarship working for Norman and Dawbarn of London, the first English firm of consulting engineers and architects to specialise in airport planning and design.

Returning to Australia in 1939, he joined the Department of Civil Aviation just as war escalated, and there was a rush to develop aerodromes throughout Australia. Now working for the Queensland Main Roads Department and later with the Commonwealth Department of Civil Aviation, Bradfield's first assignments were to design aerodromes at Bowen, Mackay, Rockhampton and Bundaberg.

Post-war, he was appointed the Australian representative on the first International Civil Aviation Organisation (ICAO) Council. Quickly establishing his leadership traits, Dr Bradfield was elected Vice-President of the Council during a period of civil aviation in which crucial foundations were laid for global international standards for safety, navigation and communications.



Pictured here in 1972, Tullamarine Airport grew to become a world class destination.

Dr Bradfield was appointed Director of Airports for the Department of Civil Aviation (DCA) and across his 33-year career there was responsible for designing expansions of Essendon Airport in Melbourne as the second international airport in Australia. He was later personally responsible for the principal design work on the expansion of the airport at Mascot (Sydney) and development of the new Tullamarine Airport (Melbourne). His design for Tullamarine was criticised by some in NSW for giving Melbourne an 'unfair advantage'.

Dr Bradfield returned to ICAO for another term on the Council from 1968-72, formulating provisions on aircraft noise and the introduction of new aircraft such as the Boeing 747 and Concorde.

He also served as Chairman of the South Pacific Air Transport Council, and in 1960 was a member of the West Indies Civil Aviation Commission, established to advise the West Indies Government on the question of civil aviation in the West Indies, British Guiana and British Honduras.

In keeping with such an illustrious career, Bill Bradfield received many awards and honours including the Award of Merit of the Commonwealth Professional Officers' Association (1963), the Order of the British Empire (1966) and the Medal of the Civil Aviation Council of Arab States (1971). In 1991 Dr Bradfield became the 25th recipient of the prestigious ICAO Edward Warner Medal, the highest award in civil aviation.

MINING HIS INTELLECT

CHARLES WARMAN

As a culture to be raised in as a budding mining engineer, Kalgoorlie was as rich with knowledge as it was with minerals. There, in 1910, one of Australia's most innovative contributors to the industry was born.

At age 14, Charles Warman won a scholarship to attend the Western Australian School of Mines. In the early 1930s, he worked as a draftsman at a gold mine in his home town, where he recognised that improvement in slurry pump technology, where pumps are used to transport fluids containing high levels of solid, often abrasive, particles, was needed. Warman set out to improve design, and his first patent – for a ball thrust bearing – was taken out in 1934.

He continued to refine his ideas, improving the pump seal so that it was simple to replace and required little maintenance. His introduction of a replaceable rubber lining and impeller was revolutionary, greatly extending the life of the pump and having major commercial implications.

Warman created a private consulting practice while continuing to upgrade his pump design. It wasn't until after World War Two that manufacturing began in earnest at a Kalgoorlie plant, but as early as 1948 his pumps were being used in the USA, Malaya, India and China.

A key reason for the growth of the Warman Pump was its extreme reliability.

As demand increased, offices were set up in Sydney and Perth. By the end of the 1950s, the pumps accounted for 90 per cent of the WA slurry pump market, but that was only the beginning – they soon had manufacturing licences across the globe, and the Warman Series "A" Pump was considered the world leader ... a position retained to this day

Still, Warman retained its roots through expansion at its Sydney manufacturing facility, developing it into the only plant in the world where slurry pumps are designed, totally manufactured and tested in the one self-contained site. Manufacturing expanded in the USA, UK and Brazil and through licensees in Japan, China, the Philippines and India. Expansion continued through the 1980s and sales increased by 75 per cent despite a global financial dip.

A graduate and past lecturer of the WA School of Mines, Warman was one of its most accomplished graduates and was named by Engineers Australia as one of the top ten Australian Engineers of the century. He has supported and contributed to education, postgraduate scholarships, the Warman Design & Build Competition for students, and has been awarded the prestigious AGM Michell Medal (in 1980) and the Peter Nicol Russell Memorial Medal (1989).

In 1997, he was made a Member of the Order of Australia for service to engineering, the mining industry and the community. Charles Warman passed away in 2008, aged 98.



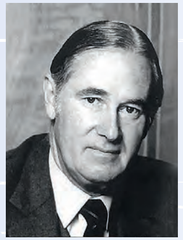
Staff celebrate the 80th birthday of Warman Pumps.



From West Australian mines to supplying slurry pumps to the world

THE SNOWY GRADUATE

DOUG PRICE



A life in engineering and construction led Doug Price to the head of a worldwide consulting firm

Doug Price, who became known as the father of SMEC, had a rapid transition from being a senior engineer in a major project to leading a global consulting organisation. The Snowy Mountains Authority (SMA) under Sir William Hudson was a design and construction authority for a major Australian project. Emerging from SMA, Snowy Mountains Engineering Corporation (SMEC) was an international consulting organisation from the outset.

Born in Campbelltown, New South Wales, in 1927, Price received his bachelor's degree from the University of Sydney in 1950. The young engineer came to the attention of Sir William Hudson, commissioner of the Snowy Mountains Hydro-Electric Authority, and was invited to join the recently-established organisation.

Price worked on hydrology studies in Cooma before being appointed Liaison Officer in Sydney for the geology and diamond drilling group, advancing to the Field Construction Division. In 1954, he was sent with other trainees to US Bureau of Reclamation to learn as much as possible about materials control, contract documentation, and construction supervision.

When Price returned to Cooma, he worked on the contract supervision of the early stages of the Tumut Pond Dam and then on the earth and rockfill Tooma Dam.



The earth and rockfill Tooma Dam, completed under Price's contract supervision.

He then joined the first of several Australian overseas aid projects by the SMA. This involved site investigations for big dams on different parts of the Mekong River and road building at Khon Kaen in north-east Thailand. He was named the SMA's assistant commissioner in 1967 before becoming assistant director in 1970.

SMEC was established in 1970 to make use of the engineering skill and expertise brought together on the Snowy Mountains Scheme. It took on infrastructure projects not only in Australia but Asia and elsewhere around the world. It was initially owned by the Australian Government but in 1985 the government amended its legal status, installing a board of directors. From being the sole director, answerable only to the relevant government minister, Price became managing director of SMEC, answerable to a board. This move foreshadowed corporatisation and the eventual privatisation in 1993.

Price was Chief Executive Officer and Managing Director of SMEC from 1972 until his retirement in 1988, shaping it into a highly successful multinational, multidisciplinary consultancy with offices around the world. He was in 1984 awarded the Peter Nicol Russell Memorial Medal for Career Achievement, Engineers Australia's most prestigious award.

The business was bought by Singapore-based Surbana Jurong in 2016 for $400 million, but retains its Australian Name and identity.

Price retired from SMEC in 1988, well before its privatisation, but continued a close involvement with the organisation through the establishment of the SMEC Foundation in 2001, which is still working today providing small-scale grant assistance to communities in need.

A SAFE APPROACH

BRIAN O'KEEFFE

From a start investigating navigation aids, University of Queensland graduate Brian O'Keeffe evolved into arguably one of the most influential Australians in world aviation safety through a career that spanned five decades.

O'Keeffe first applied his electronics engineering knowledge to radio installations, converting ex-World War Two equipment for the Department of Civil Aviation. It was modest but important work, laying a foundation for the design of the new Instrument Landing System (ILS) which became the standard for Australia for many years.

Working with the Air Navigation Group at Sydney University, a model range and new glide path antenna were developed and incorporated into the ILS to be adopted at airports in Australia to enable pilots to conduct an instrument approach to landing if they are unable to establish visual contact with the runway. During this period, O'Keeffe was one of the co-developers of a high accuracy optical-electronic tracking system, which became a vital part of testing in a Microwave Landing System (MLS) project that beginning.

In 1967 O'Keeffe presented a paper on a new landing system to the International Civil Aviation Organisation (ICAO). He proposed that the ILS be replaced and then took a leading role in the development of the MLS.

He led the Department of Transport (successor to DCA) MLS program, bringing together research and manufacturing bodies across Australia to produce and test a complete MLS system which became known on commercialisation as INTERSCAN. This more accurate landing system was adopted by ICAO as one of the world standards for assisted landing in 1978.

O'Keeffe remained a key member of a range of ICAO panels and committees. He took a leading role in – and was elected Chairman of – the ICAO Committee that worked to have an integrated system of communication, navigation, surveillance and air traffic management accepted at a world-wide ICAO meeting in 1991. He was subsequently elected First Vice President of the ICAO General Assembly in 1992.

Within the Department of Transport, O'Keeffe succeeded to a number of key strategic and operational roles and task forces. By 1982, he was appointed First Assistant Secretary Airways Operation Division, Canberra, an all-encompassing role responsible for Air Traffic Controllers, Flight Service Officers, Airport Rescue and Fire Fighters, Aviation Security and Aircraft Noise. Notably, he was the first engineer appointed to such a position.

In 1988, he was appointed General Manager, Advanced Systems Development for the newly created Australian Civil Aviation Authority until his retirement in 1997. In recognition of his international contribution, O'Keeffe received many awards, including being inducted into the Hall of Fame at the Smithsonian's Air and Space Museum in Washington DC in 1997, and the Edward Warner Award, ICAO's highest honour, in 2004.



O'Keeffe's INTERSCAN trial antennas were installed at Sydney Airport in 1980 to collect data for the International Civil Aviation Organisation, as featured on the cover of this Engineers Australia publication.



Deploying his skills in electronics engineering, Brian O'Keeffe helped keep the world's skies safe

THE BUBBLES EVOLUTION

GRAEME JAMESON



By refining a century-old concept, Graeme Jameson brought new, untold riches to the mining industry

The ever-evolving nature of innovation is exemplified by the work of Graeme Jameson, a name that few people in the general public may know but one that has had an incredible influence on the mining sector, generating immense additional wealth for the country in the last 25 years.

Laureate Professor Jameson works in the field of froth flotation that is used for extracting valuable minerals from ores. The flotation process was first applied practically in Broken Hill in the early 1900s and is widely used in the minerals industry – but it has limitations. He recognised that he could make improvements using his knowledge of fluid and particle mechanics and came up with a new device called the Jameson Cell. More than 350 Cells are now in use in 25 countries, extracting copper, coal, zinc, nickel, lead, silver, gold and platinum. The value of products recovered by the Cell for export is now more than $40 billion.

The flotation process involves grinding mineral ores into small particles, suspending them in water and placing them into stirred tanks. A large mine can treat 10,000 tonnes an hour – that's more than an Olympic swimming pool full of rock being reduced to dust every hour.

The Cell works by blowing small air bubbles up through the liquid and using reagents to make mineral particles stick to them. The bubbles form a mineral-rich froth on the surface, which is then scraped off.



A modern Jameson Cell in operation.

As well as annually recovering billions of dollars' worth of minerals, the Cell has been used for industrial and environmental applications like removing blue-green algae from waterways in inland Australia.

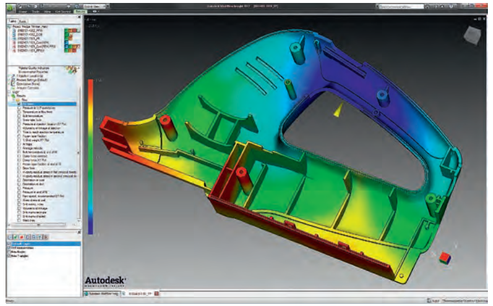
Finely-ground particles that were once too small to recover and previously were dumped into rivers, or buried, can now be processed. Old mines now have a longer life, and the environmental damage caused by the need to open more new mines is reduced.

Yet the work is not done for this softly spoken graduate from the University of New South Wales, PhD student at Cambridge University and 40 years at the university of Newcastle (Australia). He is still fine-tuning and improving the Jameson Cell. His Concorde Cell for recovering ultrafine particles was recently licensed to an equipment manufacturer and his NovaCell for coarse particles is under option. This device will increase the upper particle size limit of flotation and drastically reduce the mining industry's energy and water requirements.

Jameson's work has been recognised by many awards, national and international. He received an Order of Australia Medal in 2005, the NSW Scientist of the Year Award in 2013, and the 2015 Prime Minister's Science Prize for Innovation. He is a Foreign Member of the US National Academy of Engineering and a Fellow of the Royal Society.

RE-SHAPING THE MOULD

COLIN AUSTIN



Austin's understanding of injection moulding and software delivered unprecedented efficiency to the production process.

That Colin Austin became Australia's most successful exporter of technical software speaks volumes for the ingenuity of his vision, but also his capacity to convert that vision into a hugely successful global business.

More than 48 countries have used Austin's software, which was designed to take the guesswork out of injection moulding. Indeed, prior to his development of predictive software and expansion of his business, the manufacturing process had largely been based on trial and error, and gut instinct. The potential of the injection moulding industry was huge, with the growing number of every day plastic components required from toys to electrical products to automobiles.

An engineering graduate from Sheffield University, Austin identified the opportunity to vastly improve the moulding process while working in Melbourne as R&D Manager with Johns Hydraulics making injection moulding machines, and subsequently lecturing at Royal Melbourne Institute of Technology where he started simulating the moulding process with automated calculations.

Austin mortgaged his house to buy a first-generation microcomputer and formed Moldflow in 1978. His aim was to simulate the flow of plastic into a mould, potentially helping to predict design flaws before production,

Moldflow provided the world-first ability to visualise filling patterns and predict temperatures and pressures throughout the mould to improve the design of the mould and the manufacturability and strength of the product. This eliminated much of the uncertainty in product development, reducing costly re-designs of parts and moulds.

By 1992 Moldflow had been installed in more than 1,000 sites worldwide, adopted by manufacturing giants in the USA, Korea, Germany, Japan and the United Kingdom. The software covered plastic flow, mould cooling and shrinkage, warpage and structural analysis for thousands of polymer grades, allowing engineers to optimise product design, mould cavity layout, material selection and mould processing conditions.

Austin's company won many awards between 1980-97, including honours for technical innovation, the Governor of Victoria Export Award, the Department of Trade in Association with Confederation of Australian Industry's Export Award for outstanding achievement, and the international Fred O. Conley Award for outstanding achievement in plastics engineering and technology.

Moldflow was acquired in 2008 by multi-national giant Autodesk for $US297M. Austin moved on from his plastics focus, re-directing his energy to his environmental interests of soil and water - developed the wicking bed system which is now used universally.

He became concerned with the underlying causes of the modern health epidemics including diabetes, obesity, strokes and dementia, realising that the systems that regulate our bodies are being compromised by our modern food production. His ongoing work is on regenerative agriculture to improve gut biology.

Austin firmly believes that innovators must take responsibility for the social results of their innovations to prevent technology dominating our lives.



Colin Austin pioneered computer programming to bring efficiency to injection moulding in a world market

THE FAST CAT TRACK

ROBERT CLIFFORD



Crossing the seas of the world, Robert Clifford brought innovation and efficiency to ferry travel

Robert Clifford built his first boat in his parent's lounge room. The craftsmanship on that timber dinghy was so good most erroneously suspected his father had helped. 'Bob' explained that, in fact, his father did play a role: he took his mother to the cinema while Bob removed the front window to get the boat out of their house in Tasmania.

This amusing anecdote is a foundation story in one of Australia's most iconic water transport stories. Clifford, a keen yachtsman and sometime fisherman, would form the Sullivans Cove Ferry Company in 1972, and he soon became enamoured of catamaran hull fast ferries as an opportunity to revolutionise transport by sea.

When he presented a model catamaran to the Survey Authority, he was told the services of a naval architect would be required. He took the model to Phillip Hercus in Sydney who conducted extensive calculations and tank tests. The outcome was the Jeremiah Ryan (later the Derwent Explorer), an 18 m steel-hulled catamaran capable of carrying 145 passengers at 22 knots.

This was his prototype, the first of many of his craft which would grace the world's waterways. As travelling at high speed on rough water made for a bumpy ride, the concept of a wave-piercing catamaran was adopted, and by the late 1980s Clifford's focus had expanded to passenger ferries which incorporated vehicle transport.



From simple beginnings, Clifford's 'cats' grew in scale as quickly as his business.

His new business, Incat Tasmania, took his dream to the next level. As managing director, Clifford recruited naval architects, designers, engineers, electronics and electrical technicians, fitters, welders, fabricators and a range of other tradespersons. Incat became a high profile Tasmanian entity supplying craft around the world, a world that took notice when the 74 m long Hoverspeed Great Britain broke the Transatlantic crossing record in 1990 – INCAT vessels still hold the world record three decades later.

Under Clifford's management across five decades, Incat has produced 90 catamaran ferries ranging in length from 22 to 111 m, in speed from 22 to 57 kn, and with a capacity anywhere between 145 to 1200 passengers, plus hundreds of cars and trucks.

Notably, as the only captain in the company, Clifford was responsible for putting the completed ferries through their sea trials usually with the owners on board. He has then delivered many of these ferries, crossing the major oceans of the world to the customers' home ports.

Clifford remains as Chairman, but stepped down as MD in 1999. Four years earlier, he became an Officer of the Order of Australia for service to the shipbuilding industry, particularly through the development and design of high-speed catamarans. He was awarded an honorary Engineering degree (dEng.) from the University of Tasmania.

WHERE THERE'S SMOKE

MARTIN COLE

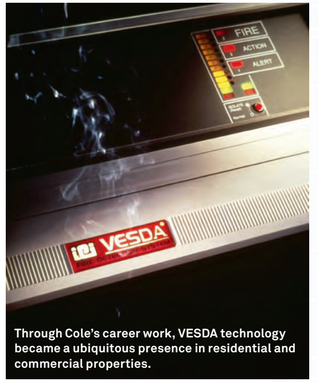
Martin Cole's interest in electronics started as a hobby from age 12, building amplifiers and radios and soon, operating electronic equipment for his High School Drama Club.

School holiday employment at Monash University provided computer and laboratory experience, and funded his building of a large oscilloscope, shortwave radios and test equipment. A qualified Amateur Radio Operator by 18, at age 20 he gained holiday research experience in microwave communications at Telecom Research.

While still studying at RMIT Electronic Engineering, he registered Cole Electronics in partnership with a fellow student. Operating from Cole's parents' home, they developed a range of laboratory and industrial equipment including a novel weld-energy controller for Dunlop Batteries, a batch controller for Email Ltd, a selective-calling system for Yellow Cabs and many other devices using the then-new technology of integrated circuits.

Products exhibited at the International Electronics, Automation, Control & Computers show in 1969 generated great prospects, and Cole lodged his first patent applications during this period. It began a pioneering career, and business, through his new company IEI Pty Ltd (Integrated Electronic Industries). Overcoming many setbacks, the company engaged in research, development, manufacturing and worldwide marketing of electronic safety and security equipment, establishing offices in London, Boston and around Australia and NZ.

Having invented, patented and developed numerous products, Cole's focus shifted toward fire prevention. Under his leadership IEI accepted the challenge to turn a CSIRO-PMG idea and prototype into a reliable commercial product. This required designing and manufacturing a sensor to detect the faintest traces of smoke and provide very early warning of overheating (other alarms didn't detect until flames erupt – often too late!). From 1979 the ever-improving VESDA™ Aspirated Smoke Detector (ASD) appeared everywhere from computer rooms to museums to hospitals to shops to mines (NASA, Boeing, BHP, IBM, defence, Channel Tunnel), pioneering today's billion dollar ASD industry.



Through Cole's career work, VESDA technology became a ubiquitous presence in residential and commercial properties.

Meanwhile, after designing the Engineers Australia hexagon logo in 1987, he improved EA's branding, EA's governance & representation structure, EA members' professional standing, and Chartered status. He was elected National President for 2000 and 2001.

Cole continued to innovate, conducting fluid dynamics research (and earning a Master's degree and PhD), while growing his business and even designing a world-class automated manufacturing complex for IEI in suburban Clayton (Vic.).

Selling the VESDA technology in 1995, he later continued to develop and market the third generation ASD, Monitair™, which was recognised by an EA National Engineering Excellence Award in 2005.

The role played by Cole and his CSIRO and PMG collaborators in pioneering the ASD industry was recognised in 2017 with the US National Fire Protection Association's award of the DiNenno Prize, recognising significant technical developments that enhance fire safety worldwide. He now follows his passion for writing sci.fi-adventure novels.



Martin Cole turned a CSIRO idea into a highly successful global business

THINKING BIG

JOHN GRILL



In his highly successful professional life, John Grill expanded his business to manage international projects of enormous scale

John Grill sits comfortably among Australia's most successful engineers, having taken his small 1970s firm, Wholohan Grill and Partners, and converted into the 'big league' via acquisitions to form the imposing Worley.

Grill graduated with a Science degree and a degree in Engineering with first class honours from the University of Sydney and joined Esso Australia in 1968 before becoming Chief Executive of Wholohan Grill and Partners, a specialist structural engineering firm which built a name for itself strengthening existing offshore oil and gas platforms in Victoria and WA.

Always thinking big, in 1987 they acquired engineering company Worley Engineering and expanded both its industry sector and geographic footprints through an astute philosophy of diversification. From its roots in the hydrocarbon 'space' they entered the power, minerals and metals, infrastructure and environmental sectors.

By the millennium, the company had grown globally to 30 offices and 3,000 personnel, allowing it the scale and capability to again start thinking big ... and even bigger, listing on the ASX in 2002. In 2004 the Worley Group acquired Parsons E&C Corporation, a US-based global services company, and in time amalgamated with various other parties to form WorleyParsons.



The remarkable Hebron platform, off the Newfoundland coast, broke new ground in scale and construction techniques.

As Chief Executive, Grill brought extensive project delivery experience, having worked on many of the world's largest oil and gas, mining and infrastructure projects. Under his leadership WorleyParsons evolved into a truly global enterprise providing design and project management services in the chemical, mechanical, electrical, civil, structural, environmental, geotechnical and coastal fields.

Some project scale is astonishing: for example, the Hebron project, involving the design and construction management of the topsides of a 46,000 tonne living and production platform in 92 metres of water, 350km off the Newfoundland coast in sub-arctic conditions. The gravity- based structure is capable of storing 1.2 billion barrels of oil.

Other projects reveal social benefit: a Worley team has carried out critical geophysical investigations for drinking water needed by refugee camps in Bangladesh and Uganda. Or project management of the Lake Turkana Wind Farm, Africa's largest wind power project in a remote part of Kenya, involving 365 turbines.

Grill was named Engineers Australia Professional Engineer of the year in 2006 and was awarded an honorary doctorate by Sydney University in 2010 in recognition of his contribution to the engineering profession. He stepped down as WorleyParsons CEO in 2012, and donated $20 million to the University of Sydney to establish what is now known as the John Grill Institute of Projects.

An Officer of the Order of Australia, Grill is Chairman of the Growth Centre Advisory Committee for the Department of Industry, Innovation and Science and Chairman of the Mindgardens Neuroscience Network, a partnership of four organisations addressing neurological, mental health and substance abuse disorders.



Wilson Transformers have become widely used in power systems around the globe.

TRANSFORMING AN AGE

ROBERT WILSON



Challenged early in his professional life, Robert Wilson emerged to successfully lead and inspire a global business

Robert Wilson is Executive Chairman of Wilson Transformer Company (WTC), a leading specialist in the delivery of transformer solutions. The company was founded in 1933 by Jack Wilson, Robert's father, who was a man of vision with the ability to turn ideas into reality.

Jack's passion for the industry and professionally engineered products encouraged Robert to expand the Company to become the largest Australian manufacturer of power and distribution transformers, with operations in Australia and overseas.

'Wilson junior' joined WTC in November 1970 after graduating from Monash University with honours in Mechanical Engineering. Sadly, his father died in March, 1972. At age 23, with only 16 months of work experience, Robert was appointed a Director, Engineering Manager and Chairman of the Technical Committee.

Both the WTC Board – and Robert himself – thought he needed to gain experience and management training to be capable of leading a company with 330 people. He took extensive overseas trips visiting transformer factories and suppliers around the world, and completed a management training program at the University of Western Ontario in Canada.

Following his overseas investigations, Wilson focused on improving product designs, updating manufacturing equipment, reducing costs and improving productivity. He was appointed Managing Director at age 30, and immediately tackled a review of manufacturing techniques. He also started work developing a new distribution transformer factory in Wodonga, Victoria. Building distribution and power transformers in the same factory in suburban Glen Waverley was no longer efficient and the company needed to increase its capacity and productivity.

By the late 1990s, the Wodonga factory was producing approximately 40% of WTC's sales, supplying pole and ground mount transformers, and package substations to most utilities and major industries across Australia.

The 1990s was a decade of readjustment. Local transformer demand fell, but export success was achieved in SE Asia, with joint ventures established there and the Middle East, and an office was opened in the United Kingdom. Dynamic Ratings, a WTC subsidiary, opened a facility in the USA and has become a world leader in providing monitoring, control, and communication solutions for electrical power apparatus.

WTC now manufactures a wide range of transformers from 16kVA to 550MVA for 400kV transmission, and others for industry. Innovations such as fault current limiters, quad booster and power skids for the renewable sector have also been developed.

Wilson is passionate about supporting Australia's energy industry and the local community. WTC is an active member of multiple industry organisations, participates in university programs, supports student development and co-hosts TechCon Aus-NZ, a major electrical industry conference that celebrated its 20th anniversary in 2019.

Wilson's passion and values continue into the future as the business transitions to the next generation of WTC leaders.

SKY'S NOT THE LIMIT

ANDREW THOMAS



Adelaide engineer Andy Thomas broke new ground – and gravity – in his trailblazing path to space

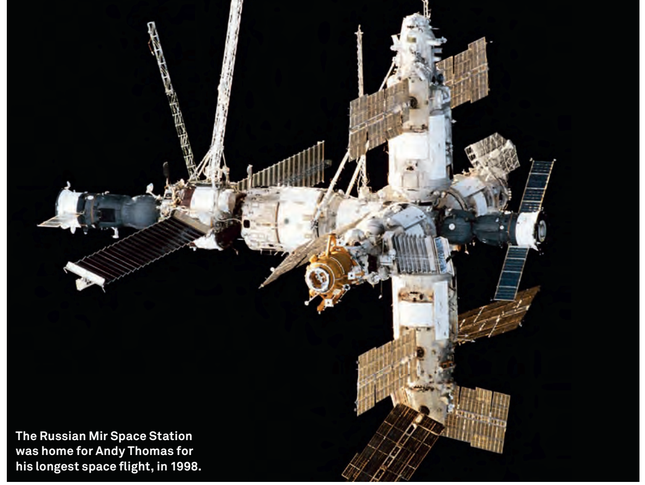
As a child, young Adelaide boy Andy Thomas was fascinated by space, building model rockets from cardboard and plastics. Notably, Thomas is the great-great-grandson of Frederick Waterhouse, first curator of the South Australian Institute Museum.

His path was at first more traditional, securing a Bachelor's Degree and later PhD in mechanical engineering before in 1977 joining the Lockheed Aeronautical Systems Company in Marietta, Georgia (USA) as a research scientist. Thomas was focused on advanced aerodynamics, and became manager of the Flight Sciences Division before moving to the Jet Propulsion Laboratory in California in 1989.

There, he led the program for microgravity materials processing in space, as well as technology studies to support the development of space flight hardware for shuttle missions. Thomas joined the National Aeronautics and Space Administration (NASA) in 1992. After a year of training, he qualified for assignment on space flight crews and was appointed a member of the astronaut corps.

He made his first flight in space in the Space Shuttle Endeavour in May 1996 as part of the 10-day STS-77 mission. During this flight, he carried an old steel flint, a memento carried by his great-great-grandfather as naturalist on the McDouall Stuart expedition.

This crew deployed two satellites, tested a large inflatable space structure in orbit and conducted a variety of scientific experiments in a Spacehab laboratory module carried in Endeavour's payload bay. The flight, launched from the Kennedy Space Center, completed 160 orbits 283 km above earth while logging 240 hours and 39 minutes in space.



The Russian Mir Space Station was home for Andy Thomas for his longest space flight, in 1998.

Following a year of training as a cosmonaut in Russia, Thomas again boarded Endeavour for his second flight in January, 1998, this time as part of the STS-89 crew to dock with the Russian Mir Space Station, where he served as Flight Engineer 2 during a 140-day flight. He returned to earth with the crew of STS-91 aboard Space Shuttle Discovery in June of 1998, after completing 2,250 orbits of the earth.

Thomas would visit space a third time with the STS-102 mission in 2001, including a 'spacewalk' of over six hours to assist in the assembly of the International Space Station. His fourth and final flight was on the STS-114 mission in 2005, also to the International Space Station.

He served as Deputy Chief of NASA's Astronaut Office, as well as Lead of the Lunar Exploration Team and the Mars Exploration Team until his retirement from NASA in February 2014, having logged more than 177 days in space.

Thomas received an Officer of the Order of Australia, the Russian Medal of Merit, the NASA Exceptional Service Medal, the NASA Distinguished Leadership medal, and the 2001 Centenary Medal. He is a Life Member of the Space Industry Association of Australia.



The brilliant Interscan system revolutionised airline safety across the world.

EVERY ENGINEER

Coming from a range of backgrounds, engineers have many traits in common

This book has introduced us to 99 remarkable people demonstrating a tremendous range of individual talents and achievements.

Some delivered iconic projects, some developed new technologies, some received acclamation, and many have remained relatively unknown.

They came from different backgrounds and, after their education, followed a multitude of pathways – many left "traditional" engineering roles to contribute in other fields where they applied aspects of their engineering training. They possessed a wide variety of skills and experiences, faced a range of challenges and their achievements span all facets of society.

And yet, there are similarities.

All have contributed in a meaningful way to Australian society. All accepted the challenges presented to them and found ways to overcome them or saw a possibility to do something better and did it.

This book has shown that whatever the challenge, in most instances it took an engineer to meet it.

Today, we live in a society in which practically every human-made object we see or process we use every day of our lives has required the expertise of an engineer – from initial idea, design, construction, operation and eventual disposal.

Hundreds of thousands of Australian engineers continue to work steadily to keep our complex society functioning. From the structures that provide us shelter, the food we eat and water we drink, the clothes we wear, our health, transport and communications, engineers are involved.

Who are these engineers?

Today's engineers will be found in almost every field of society, applying their unique knowledge and experience. While the challenges and technologies may have changed, they share the same, intangible, qualities demonstrated by their forebears. All have mastered fundamental scientific and engineering principles required to practise as an engineer but that is just the start. They have an ability to recognise a problem or an opportunity and the knowledge, discipline and determination to resolve it.

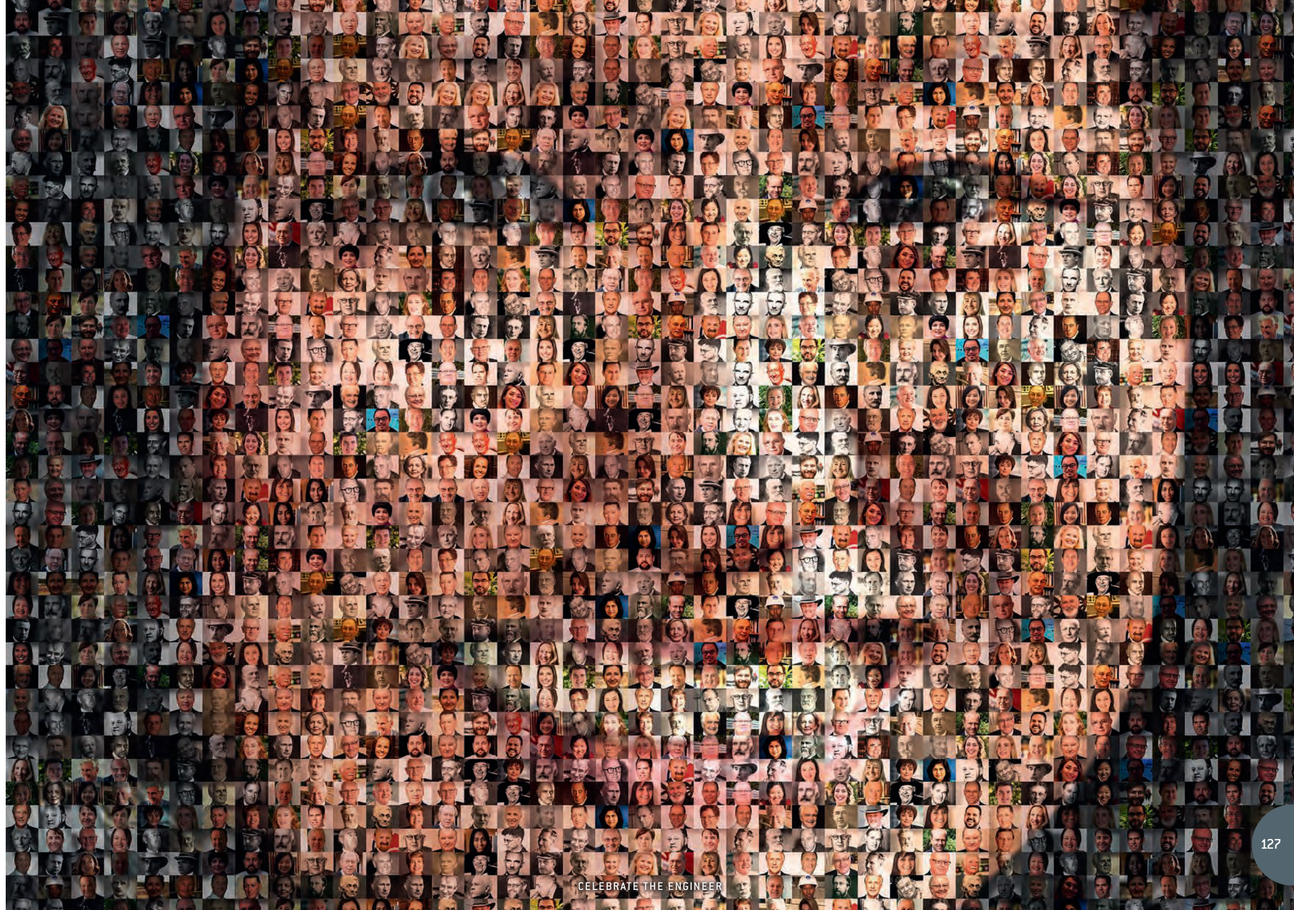
They increasingly represent the diversity of society as a whole and bring new ideas to enrich the profession and produce better solutions.

Typically, engineers are innovative, whether through developing or applying new ideas or by applying their knowledge and experience in a different field. They understand complexity and the need for planning, management and leadership and increasingly work in diverse teams requiring co-operation and communication. Generally, they are known for competence, thoroughness and ethical conduct.

Every engineer can be proud of the legacy left by their forebears and can be confident in their own contribution, be it keeping the wheels of society functioning every day, solving the myriad problems that arise, large or small, or creating the technologies of the future.

While change has been substantial in technology, society and methods of work, the enduring spirit of engineers has been unwavering.

This book is therefore a celebration of the contribution of every engineer, included here or not, and their capacity to continue to shape a nation and its people.



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