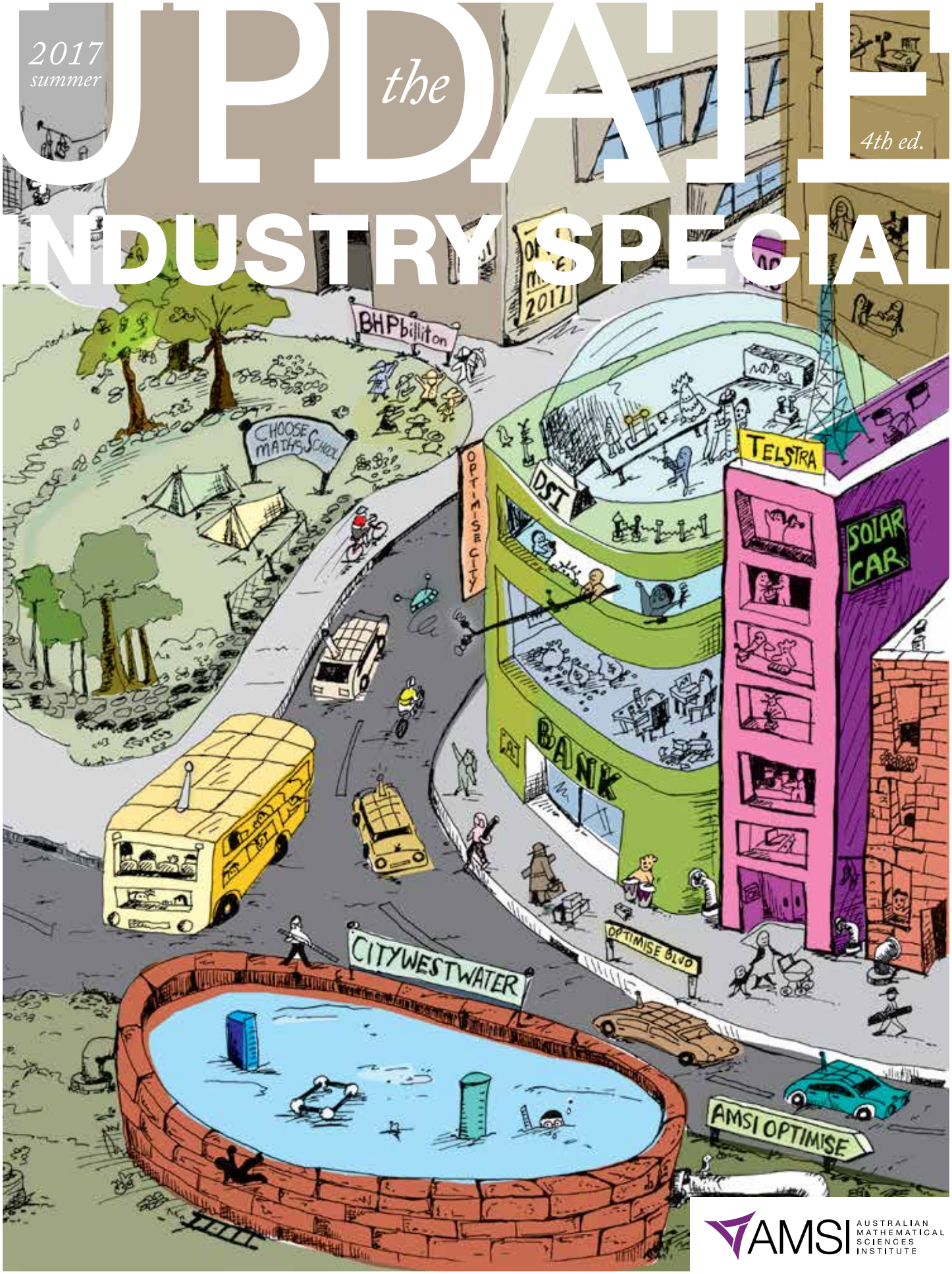
2017 summer

the UPDATE

4th ed.

INDUSTRY SPECIAL



AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

HYPERGEOMETRIC MOTIVES & CALABI-YAU DIFFERENTIAL EQUATIONS

8 - 28 JANUARY
MATRIX@MELBOURNE, CRESWICK

AMSI VACATION RESEARCH SCHOLARSHIPS 2016/17

AMSI CONNECT

8 - 9 FEBRUARY
THE UNIVERSITY OF MELBOURNE

AMSI ANZIAM LECTURER

MARIA VLASIOU

13 - 24 FEBRUARY
SEE WEBSITE FOR LOCATION DETAILS

APPLIED PROBABILITY @ THE ROCK

17 - 21 APRIL
AYERS ROCK RESORT

HARMONIC ANALYSIS & PDE

17 - 21 JULY
MACQUARIE UNIVERSITY

AMSI RESEARCH

SCIENTIFIC EVENTS 2017

AMSI.ORG.AU/SCIENTIFIC

AMSI 17 WINTER SCHOOL

JULY 2017
QUEENSLAND UNIVERSITY OF TECHNOLOGY

WORKSHOP ON MATHEMATICAL MODELLING OF RISK & CONTIGUOUS TOPICS

27 NOV - 1 DEC
MATRIX@MELBOURNE, CRESWICK

AMSI 17 OPTIMISE MATHEMATICAL INNOVATION

NOVEMBER
SEE WEBSITE FOR LOCATION DETAILS

mathsfest AUSTRALIA 2017

NOVEMBER
SEE WEBSITE FOR LOCATION DETAILS

AMSI 17 BIOINFO SUMMER

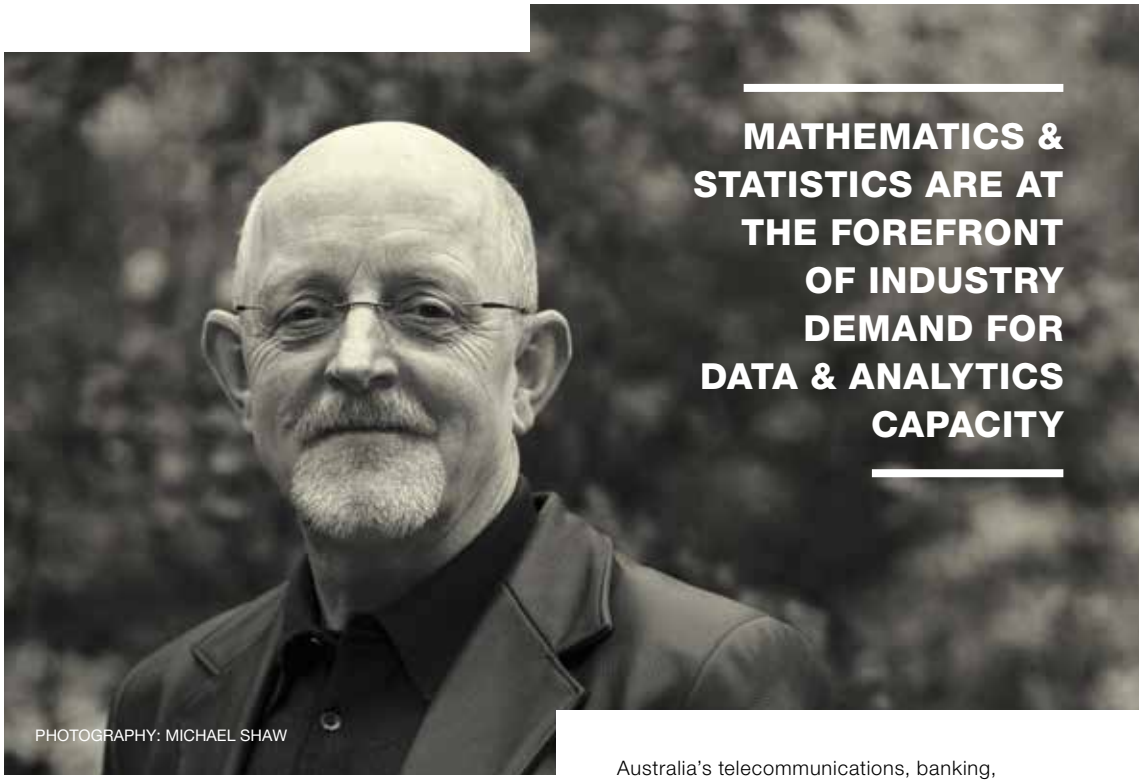
DECEMBER
SEE WEBSITE FOR LOCATION DETAILS

AMSI VACATION RESEARCH SCHOLARSHIPS 2017/18

DECEMBER
SEE WEBSITE FOR LOCATION DETAILS

AMSI 18 SUMMER SCHOOL

JANUARY 2018
MONASH UNIVERSITY



PHOTOGRAPHY: MICHAEL SHAW

MATHEMATICS & STATISTICS ARE AT THE FOREFRONT OF INDUSTRY DEMAND FOR DATA & ANALYTICS CAPACITY

WELCOME TO THE FOURTH EDITION OF THE UPDATE. AS WE PREPARE TO SIGNIFICANTLY RAMP UP AMSI'S NATIONAL ALL-SECTOR, ALL-DISCIPLINE INTERNSHIP PROGRAM, WE HAVE DEDICATED THIS ISSUE TO INDUSTRY AND HOW MATHEMATICAL SCIENCES RESEARCH IS HELPING AUSTRALIAN INDUSTRY INNOVATE ITS WAY ONTO THE GLOBAL STAGE.

The Australian government is committed to increasing collaboration between industry and universities along with an uptake in the private sector employment of PhD graduates. With the mathematical sciences at the forefront of industry's demand for data and analytics capacity AMSI and its membership are freshly engaged with the national innovation agenda.

The chair of AMSI's Industry Advisory Committee, Mark Lawrence, discusses the agenda of the committee's newly formed Industry/University Mathematical Sciences Engagement Task Force. This provides a platform for employers of our mathematics and statistics graduates to communicate their skills needs to AMSI's members and for both groups to work together on the careers awareness campaign we need to grow capacity.

Spanning the mathematical pipeline from classroom to industry, we also hear from AMSI industry partners applying mathematics and statistics at the frontline of Australia's telecommunications, banking, utilities, defence and mining industries. As well as their personal success, they reveal the impact of mathematical sciences on innovation and technological development within some of Australia's most critical sectors.

Taking an academic perspective, we catch up with the Mathematics in Industry Study Group Director, Peter Pudney, to discuss research-industry engagement and why this initiative has been so successful in strengthening research-industry collaboration.

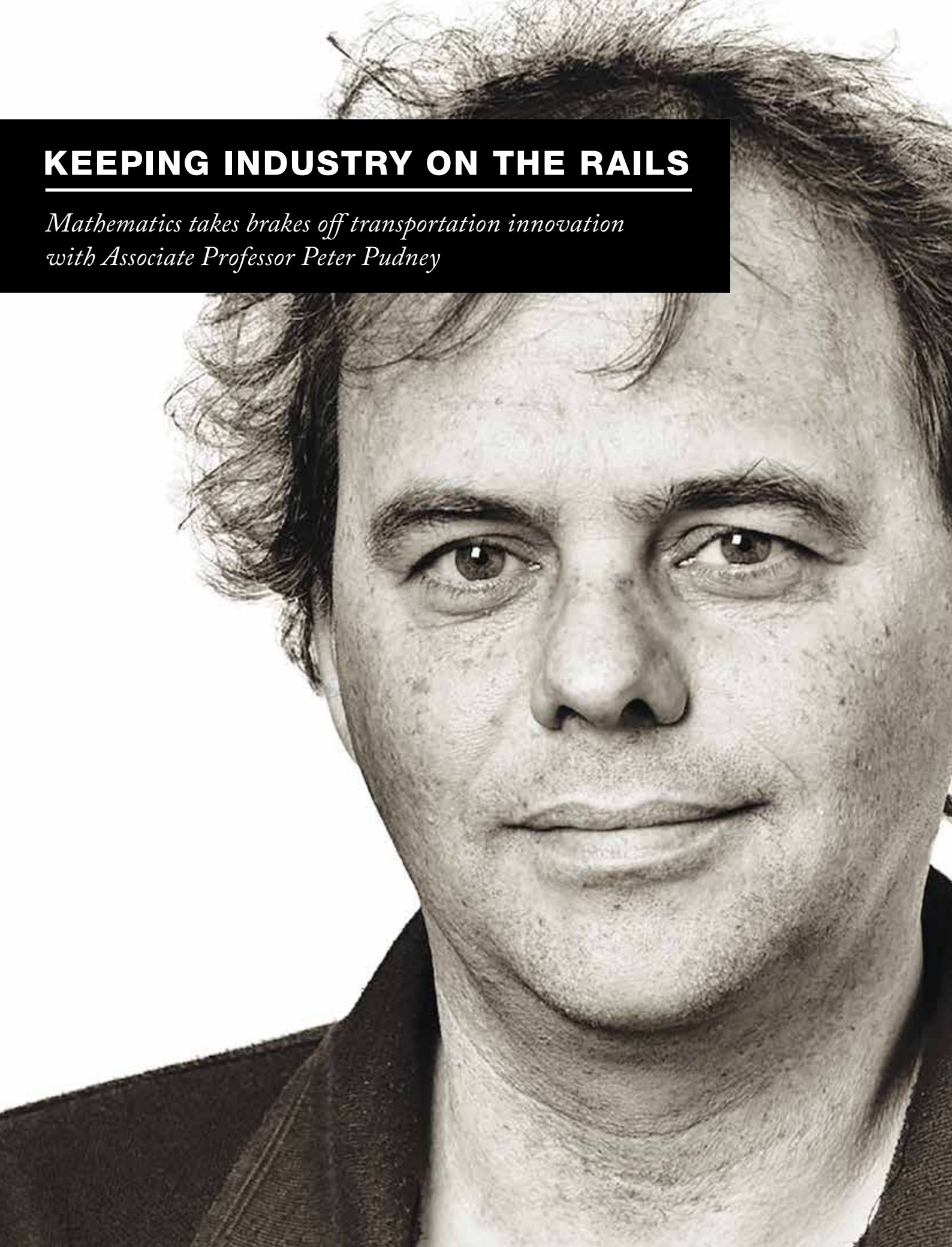
From the human genome to the spread of disease and the social webs we weave online, networks surround every aspect of our lives. In our feature on the annual International Worksop on Complex Systems and Networks we explore this exciting and modern field of mathematics and discover why this evolution of mathematical graph theory has caught the interest of researchers and industry alike.

Read on and update yourself on the rapidly changing face of industrial applications of mathematics and statistics. □

Professor Geoff Prince FAustMS

KEEPING INDUSTRY ON THE RAILS

Mathematics takes brakes off transportation innovation with Associate Professor Peter Pudney



PHOTOGRAPHY: UNIVERSITY OF SOUTH AUSTRALIA

DEPUTY DIRECTOR OF UNIVERSITY OF SOUTH AUSTRALIA'S CENTRE FOR INDUSTRY AND APPLIED MATHEMATICS AND DIRECTOR OF THE MATHEMATICS IN INDUSTRY STUDY GROUP, ASSOCIATE PROFESSOR PETER PUDNEY TAKES US TO THE FRONTLINE OF INNOVATION. HE TALKS TRANSFORMING TRANSPORT, SOLAR CAR RACING AND RENEWABLE ENERGY WITH MATHEMATICS AND THE CHALLENGE OF CONVINCING INDUSTRY THAT RESEARCH HAS THE ANSWERS.

HOW HAS MATHEMATICS HELPED YOU IN YOUR CAREER AND RESEARCH?

I did my undergraduate degree in Computer Studies, before it was a science or information technology. I then did a Masters degree, working with engineers and applied mathematicians and the South Australian transport authority to develop a system for saving energy on suburban trains by telling drivers the optimal locations to power, coast and brake. I realised during that project that it was the applied mathematicians who were solving the interesting problems. I eventually did a PhD in applied mathematics, investigating the optimal control of a solar racing car.

Most of my research has been with the rail industry, developing more advanced driver advice systems, and train scheduling systems for large rail networks. Apart from rail research, I have worked with solar racing teams on driving strategies and solar array design, with engineers building electric vehicles, with the AutoCRC looking into the impact that electric vehicles will have in Australia, and most recently with the CRC for Low Carbon Living looking at how renewable energy systems and energy storage can be used to reduce greenhouse gas emissions.

IS YOUR RESEARCH RESPONSIVE TO OR DOES IT SHAPE INDUSTRY NEED? WHAT IS THE LEAD-TIME FOR IMPACT?

The idea of using control theory to tell train drivers how to drive more efficiently came from an academic engineer, Ian Milroy. He had the foresight to get potential end users involved early. This ensured that the project was focussed on achieving practical outcomes, and also provided us with experts and equipment for testing our ideas.

Over the years we have had a few brilliant ideas that industry did not care about. Ultimately, I find it more satisfying to work on projects with practical outcomes.

We have an industry partner that we have been collaborating with since 2000. They like us to be responsive to their needs, which can often change during the period between applying for a grant and having it awarded. The key to our continuing successful collaboration is that we design our research programs to include on-going long-term research that anticipates future industry needs, as well components that address their immediate and short-term requirements.

Lead-time varies enormously, from weeks to decades. Some of the ideas we started working on 30 years ago are just starting to be implemented. This is partly because the problems we were working on took a long time to become critical—energy costs stayed low, and problems could be solved by adding tracks and trains rather than by operations research and optimisation. We also had to wait for GPS and mobile data communication to become readily available. However, since deploying our first driver advice systems in the UK in 2012 the rail industry has seen the potential of the technology to provide better real-time coordination of trains on congested networks, and to start developing new standards for interoperability with driver advice systems. We have also moved the technology from dedicated hardware to tablets, integrated our software with automated driving systems, and started new research into the underlying scheduling and control methods that will be needed to update schedules in response to real-time events.

When industry partners recognise that they have a problem, they often want a solution as quickly as possible. It is important that we react quickly, perhaps with interim solutions while we work on getting a better understanding of the problem and long-term solutions. ⇨

AT TWO TO THREE PER CENT AUSTRALIAN UNIVERSITY RESEARCH-INDUSTRY ENGAGEMENT IS LOW. WHAT ARE THE BARRIERS DRIVING THIS AND HOW CAN WE OVERCOME THEM?

Not everyone wants to work with industry. Those who do are usually constrained by other demands on their time, and so are often unable to deliver outcomes as quickly as industry would like. Working with industry may lead to outcomes that are useful for the industry partner, but perhaps not publishable.

PhD research and three-year grants with industry need to have some early useful outcomes, and be flexible enough to adapt to the changing needs of industry.

A difficulty we face in applied mathematics is that industry may not recognise their problems could be solved by working with a mathematician. We have relatively few students, and so there are relatively few mathematical science graduates in industry. Perhaps we need greater engagement with students and researchers from other disciplines within our universities to increase our visibility from outside.

HOW CAN INDUSTRY BETTER PROMOTE DEMAND FOR MATHEMATICS AND STATISTICS?

Successful engagement between academics and industry will increase industry demand for graduates with the mathematical science, research and general problem-solving skills required by industry.

To help industry recognise the value of research, academics need to deliver research outcomes in a form that can be applied by industry. This will sometimes require the solution of sub-problems that are more mundane that the primary research question, or require a different set of skills. You need to be persistent. Collaboration with researchers from other disciplines can help bridge the gaps between research and application, and at the same time raise the profile of the applied mathematical sciences.

Attracting students to the mathematical sciences will become easier as we generate more stories about how mathematics is being used by industry. The AMSI Maths Adds booklets are useful when talking to high school students about careers.

ACADEMICS-INDUSTRY ENGAGEMENT WILL INCREASE INDUSTRY DEMAND FOR GRADUATES SKILLED IN MATHEMATICAL SCIENCE & RESEARCH

CAN YOU GIVE ME A QUICK OVERVIEW OF THE MATHEMATICS IN INDUSTRY STUDY GROUP (MISG) AND ITS IMPACT ON RESEARCH ENGAGEMENT?

Every year, 80–120 applied mathematicians from universities and industry get together for a week to work on four to six industry problems. Most delegates are from Australia and New Zealand, but we also have delegates from elsewhere around the world. Students are encouraged to attend.

On the first day, industry representatives describe their challenges. The delegates then form into groups—one per problem. Each group works with the industry representative over the next three days to tackle the problem. Groups are assigned a pair of moderators who are tasked with coordinating the work and collating results. On the last day of the week, each group presents its progress. Beyond the workshop, the moderators produce a short report and then a longer technical report that is published in the ANZIAM Journal.

It is a lot of fun. But it is also a great opportunity for industry participants to have a diverse group of experienced researchers working on their problem, for applied mathematicians to make valuable contacts with industry, and for training the next generation of applied mathematicians.

The next MISG is in February 2017*.

HOW CAN AMSI MAXIMISE EFFECTIVENESS OF AMSI OPTIMISE?

AMSI Optimise is a great opportunity to raise the profile of optimisation within industry. I would like to see plenty of time allocated to industry to allow them to talk about how they would like to engage with academics and the problems they would like to work on. Presentations from academics should be relevant to industry delegates who may not yet have had much engagement with universities, perhaps with focus on examples of how optimisation has been applied successfully to industry problems.

WHAT ROLE CAN INDUSTRY PLAY IN FOSTERING SUPPLY OF MATHEMATICS RESEARCHERS? HOW IMPORTANT ARE PROGRAMS SUCH AS AMSIINTERN?

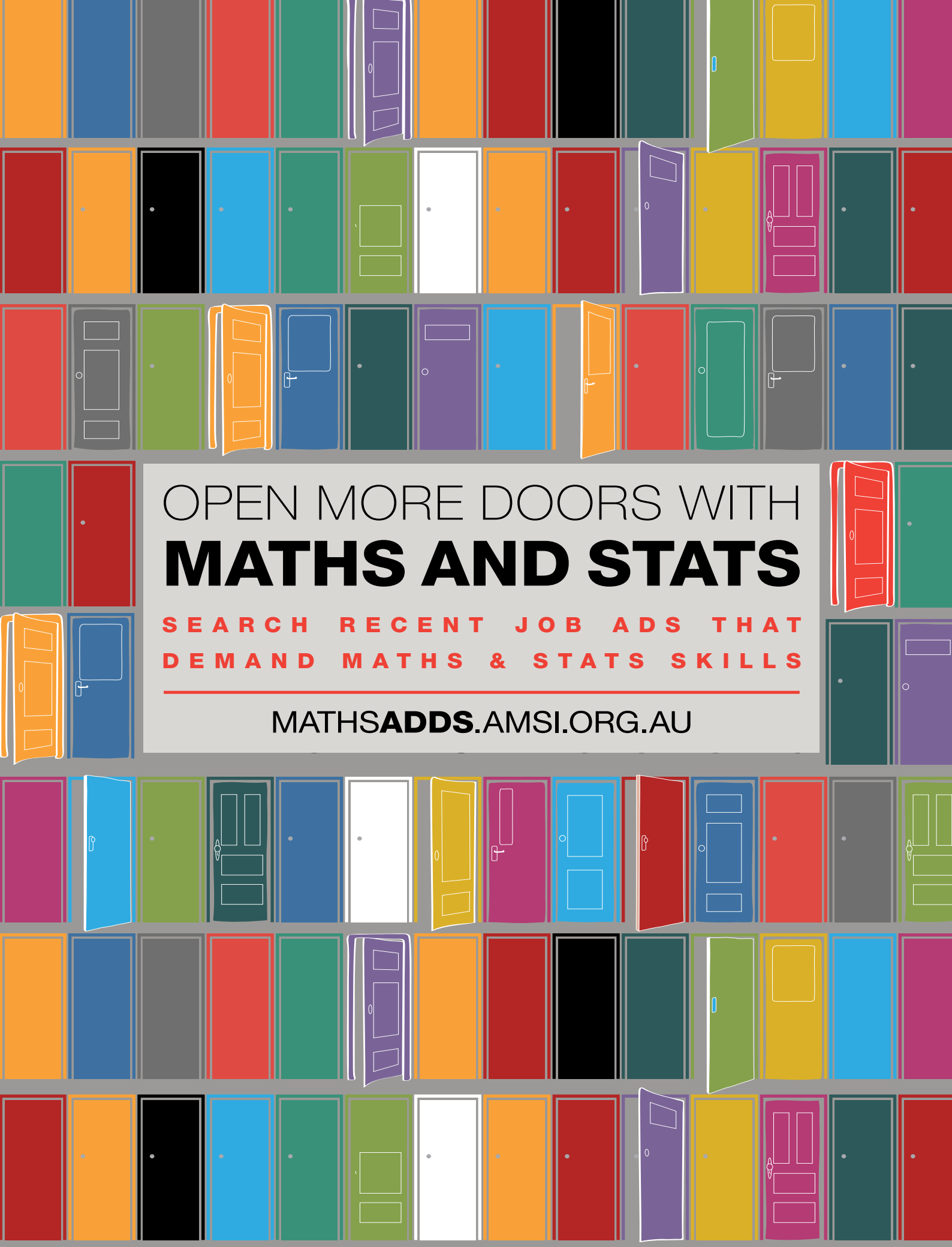
By engaging with university researchers to help solve their problems, industry can find innovative solutions to their problems and at the same time guide universities to produce graduates with the research, problem-solving and technical skills required for an career in industry or for a research career serving industry.

I have supervised a couple of AMSI interns. The program makes it easy for industry to engage with researchers through an AMSI internship, and also gives the interns valuable experience working with industry, particularly when they are working on-site.

Another, complimentary, approach is the ATN's Industry Doctoral Training Centre program. (I was the interim Director for six months). The IDTC program has PhD students working for four years on industry-sponsored research. The IDTC program includes professional and technical coursework and cohort events (including MISG) in addition to the traditional three-year PhD research program.

Most of our PhD graduates will have careers in industry. If we can equip them with industry experience and professional skills beyond their technical skills then we will improve outcomes for both students and industry. □

An ANZIAM program supported by AMSI, MISG aims to strengthen industry linkages with the mathematical sciences and statistics. An annual event, research leaders work in teams to drive innovative solutions to complex real world industry problems.
**Visit - mathsinindustry.com.*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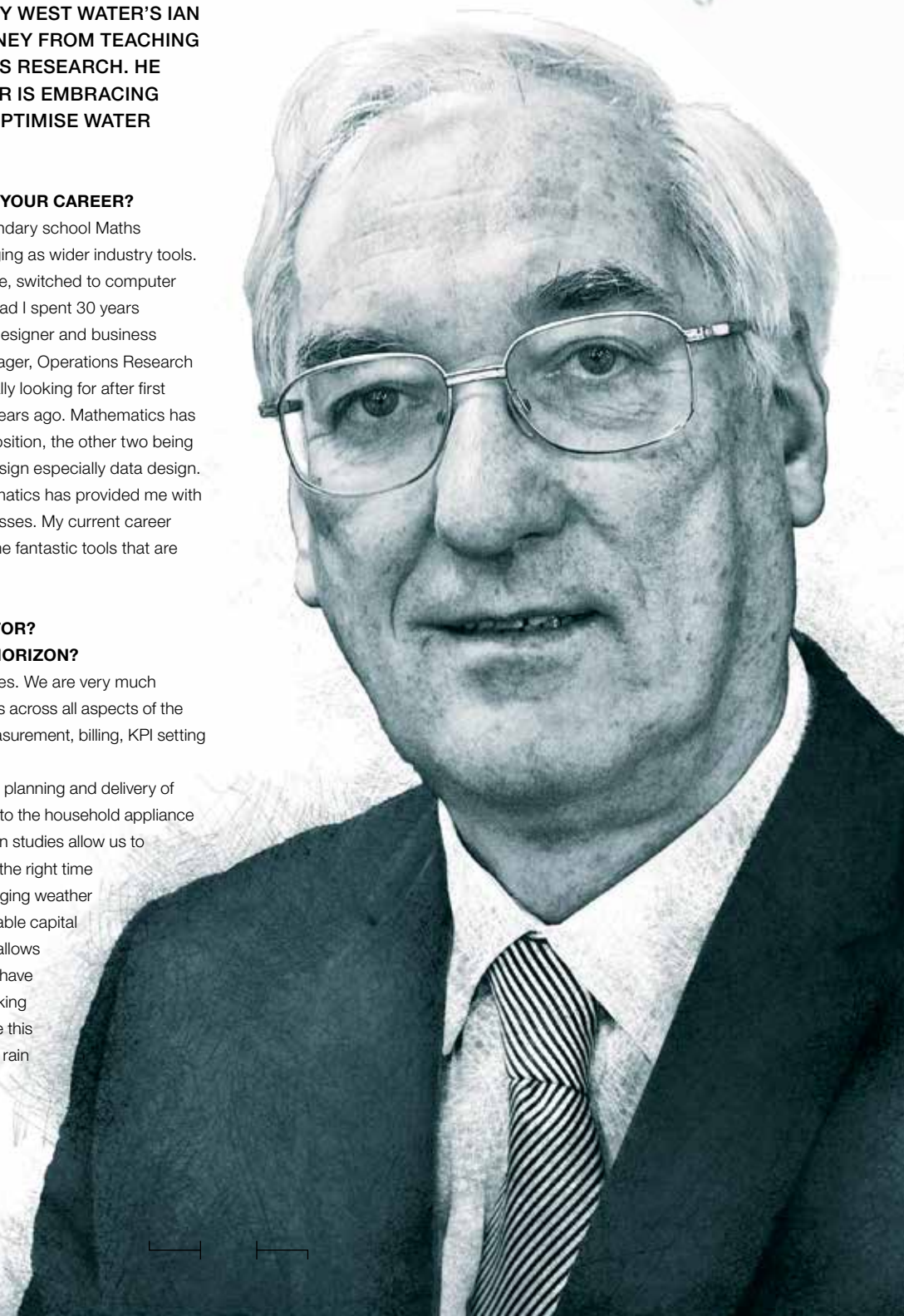
MATHSADDS.AMSI.ORG.AU

SMART WATER FOR SMART CITIES

Optimising water management a numbers game with Ian Monks

MATHEMATICS HAS TAKEN CITY WEST WATER'S IAN MONKS ON A CAREER JOURNEY FROM TEACHING TO I.T. AND NOW OPERATIONS RESEARCH. HE TELLS US HOW THE UTILITIES SECTOR IS EMBRACING BIG DATA AND THE DIGITAL AGE TO OPTIMISE WATER MANAGEMENT AND METERING.



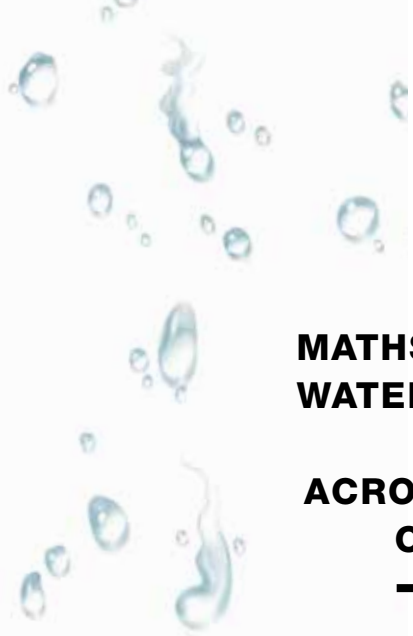
HOW MATHEMATICS HAS HELPED YOU IN YOUR CAREER?

I've had three careers. My first was as a secondary school Maths teacher. This was just as computers were emerging as wider industry tools. I took a computer course and, to gain experience, switched to computer programming. I never returned to teaching, instead I spent 30 years working in various I.T. roles including database designer and business analyst before being offered the position of Manager, Operations Research at City West Water – a dream job that I was initially looking for after first graduating. So my third career started just five years ago. Mathematics has been one of the three key skills for my current position, the other two being business analysis and computer applications design especially data design. Throughout my careers a background in mathematics has provided me with an ability to establish an understanding of processes. My current career allows me to apply mathematics and use all of the fantastic tools that are available today.

HOW IS MATHS USED IN THE WATER SECTOR? WHAT DO YOU SEE ON THE INNOVATION HORIZON?

Engineering maths is critical to water authorities. We are very much construct and operate companies. Maths extends across all aspects of the business, demand forecasting, consumption measurement, billing, KPI setting and monitoring, reporting and analysis.

Segmentation of our customers enables better planning and delivery of services. Modelling of the water cycle right down to the household appliance level enables us to plan for the future. Optimisation studies allow us to put the right sized infrastructure into operation at the right time during strong customer growth periods and changing weather patterns. We can then make the best use of available capital expenditure. Increased use of image processing allows us to measure and report image based data. We have built a rain-event estimation model based on tracking and projecting weather radar images. We can use this same technique to infill the spaces between fixed rain gauges to identify rain patterns in potential storm water harvesting sites.



ENGINEERING MATHS IS CRITICAL TO WATER AUTHORITIES... MATHS EXTENDS ACROSS ALL ASPECTS OF THE BUSINESS

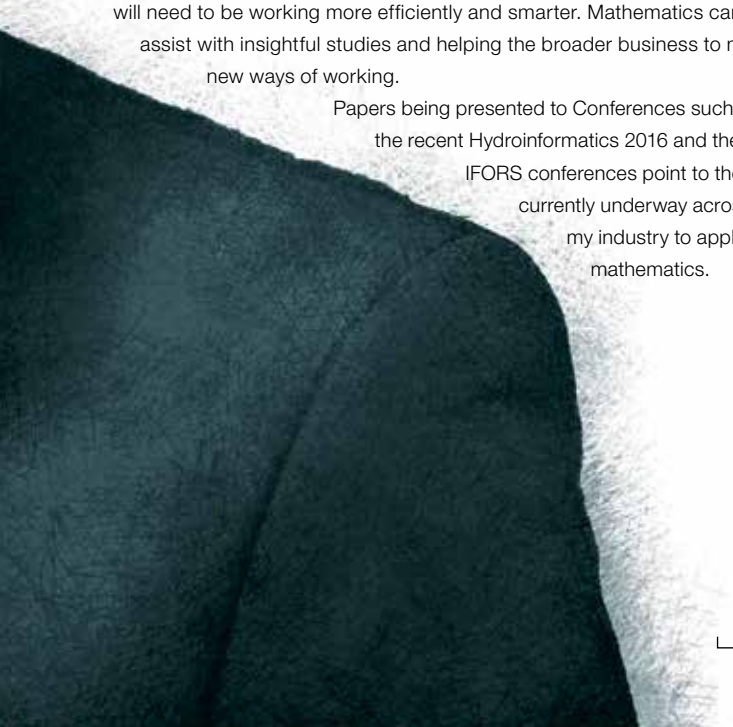
Data mining allows us to know the normal operating bounds of our network components at different times of day and seasons. Real-time monitoring allows us to detect abnormal operation and undertake early intervention before failure of the component. We are highly regulated and so water quality and many other aspects of our operation have to be reported. Statistical sampling and analysis is critical. For "data junkies" who want to interrogate and understand how the world works by the numbers, it's pretty good.

The push is for Smart Cities and Smart Water is a part of that. Digital disruption is already occurring and influencing our product offering and systems. Water Authorities have always had their monitoring sites, their customer, asset and GIS databases and have collected other data from external bodies. The data has not been exploited to its full extent. Over the next five to ten years I expect water authorities will move to a more strategic use of their total data holding. Wider use of digital metering will provide even more data from which new insights and innovation will come. Some social media mining is occurring in some water authorities for monitoring major events such as floods to inform the community response. Improved longer term rainfall forecasting is of interest to many water authorities and the impact of weather and operational disruption (dryness-network bursts) will be quantified and proactively managed.

Water authorities can expect to "have to do more with less" and so they will need to be working more efficiently and smarter. Mathematics can assist with insightful studies and helping the broader business to model new ways of working.

Papers being presented to Conferences such as the recent Hydroinformatics 2016 and the IFORS conferences point to the work currently underway across my industry to apply mathematics.

PHOTOGRAPHY: CITY WEST WATER



HOW DOES CITY WEST WATER ENGAGE WITH UNIVERSITY RESEARCH?

My team's research and development (R&D) is highly focussed on our company's needs. Water meters are required to comply with National Metering Guidelines, which nominates acceptable tolerances. We have developed new methods for detecting failing water meters and for detecting customers who may have leaks at their properties or who may have oversized meters installed. RMIT University assisted this study. As part of the "Greening the West" urban liveability initiative coordinated by City West Water, we've worked with university researchers to develop a method of measuring the tree canopy cover in our service area year-to-year from aerial photographs.

The weather impact studies are providing new insights. Our modelling of water end-use in residences and business and modelling of integrated water cycle management will enable us to do long term simulations for demand and supply response. Overall our engagement with universities is restricted by our budget and the short-term nature of our studies. Given our team's size and composition we tend to be self-sufficient for our R&D. But we do work with the Cooperative Research Centre for Water Sensitive Cities (based at Monash) and many industry groups such as VicWater and the Australian Water Association who in-turn engage universities on special projects.

HOW WILL YOU KEEP PACE WITH INNOVATION AND TECHNOLOGICAL ADVANCEMENT?

Membership of industry bodies, attendance at conferences, ongoing education, product upgrades, renewal of our skill base through recruitment of new graduates, participation in industry trials and, lastly, salesmen knocking on our doors. Through all these ways and by engendering a culture of innovation water authorities will keep pace with broader advancements in technology and methods.

CAREERS AWARENESS CONTINUES TO BE A CHALLENGE FOR MATHEMATICS. HOW CAN INDUSTRY BETTER PROMOTE OPPORTUNITIES AND DEMAND FOR THESE SKILLS?

Communication is the key. That means pitching the message at the right level to each age group. The breadth of opportunities needs to be presented through real-life examples. But it will need to be coordinated and really well presented using the right technologies and through the best channels. When I chose to study maths there seemed to be only three "careers" – teaching, statistician and actuary. Now the opportunities are vast but still somewhat hidden. I find most employed maths grads don't describe themselves as statisticians or mathematicians. I think that is mainly a modesty but also a deference to business titles. For example, my team have role titles such as Statistical Analyst, Data Scientist, Modelling Analyst and Applications Analyst. Others in the business are titled Data Analyst, Customer Information Analyst and Water Efficiency Analyst. The broad thrust of each position is the application of mathematics to business problems by assembling, investigating and interpreting or projecting data. □

City West Water is partnering with AMSI member RMIT to empower students' employability and skills by proposing placements, sponsoring student awards and contributing to the program advisory committee for mathematical sciences.

MATHEMATICS PROVES BEST WEAPON

Defence in the digital age with Dr Regina Crameri

FOR DEFENCE SCIENCE INSTITUTE (DSI) ASSOCIATE DIRECTOR, DR REGINA CRAMERI, MATHEMATICS IS A SECRET WEAPON OF CHOICE. SHE REVEALS HOW KEEPING PACE WITH THE CHANGING LANDSCAPE OF DEFENCE IN THE DIGITAL AGE IS PROVING A NUMBERS GAME.

HOW HAS MATHEMATICS HELPED YOU IN YOUR CAREER?

I have had numerous positions at Defence Science and Technology (DST) group, including investigating the health, human performance and injury management of deployed soldiers during the Afghanistan conflict. I have also worked within the Technology Forecasting and Futures Team assessing the potential impact of emerging and disruptive technologies for Defence. Maths is pervasive. It is in almost everything you do from programming to statistics to logistics.

HOW IS MATHEMATICS USED IN DEFENCE INNOVATION? WHAT DO YOU SEE ON THE HORIZON?

Modelling behaviour, advanced algorithms for processing big data are routinely used by many of the people working in DST group.

Modelling and simulation of which mathematics is a major component is considered one of the core capabilities required for any defence force and the ADF is no different. It is considered one of the top potential game changers for how technology will evolve particularly when it comes to autonomy. Reducing the risk that people are placed in by replacing humans with semi-autonomous/autonomous technology will change how defence works into the future.

Defence spends a significant amount of time assessing the potential impact of technology developments with all the three services in the ADF having a futures plan out to 2035. DST group also has a team of scientists that investigate future technologies and their potential for advancing defence technologies.

WHAT ROLE IS DEFENCE PLAYING IN FOSTERING SUPPLY OF RESEARCH READY GRADUATES?

As the Associate Director of the DSI, my major activity is in encouraging academics to work with DST scientists and the defence industry to improve the R&D of defence-related technologies. The DSI has a strong grounding in facilitation and we use multiple and diverse strategies to encourage collaboration. These include using grants, workshops and AMSI**Intern** programs to encourage more people into the defence ecosystem.

DST Group runs scholarship and placement programs to provide industry experience to students looking for a career in science and technology.

The major programs include the Industry Experience Placement Program, the Summer Vacation Placement Program, the DST Group Cadetship Program, and the Graduate Industry Placement Program.

DST group also encourages women to pursue careers in science and engineering via the Undergraduate Scholarship Program for Female Students.

HOW IMPORTANT ARE PROGRAMS SUCH AS AMSIINTERN? HOW CAN INDUSTRY BETTER PROMOTE DEMAND FOR MATHEMATICS AND STATISTICS SKILLS?

The AMSI**Intern** program is essential in filling what has been a gaping hole in training for graduates with a PhD. Once a PhD graduate would invariably go on to a position at a university and follow a traditional academic career. The paradigm is, however, shifting with more PhD graduates than ever seeking other avenues to utilise the skills that they have developed in particular in seeking positions in industry. Unfortunately, our traditional PhD program is not keeping up with this trend and the AMSI**Intern** allows those students who would prefer to work in industry after completion of their PhD to gain the necessary skills to make them job-ready.

Case studies of how people have used their degree in their employment are essential in a field like mathematics, as it does not have a traditional career path like medicine or dentistry for example. At school more needs to be done to show that a degree in maths can lead to many different careers and you are only limited by your imagination. □

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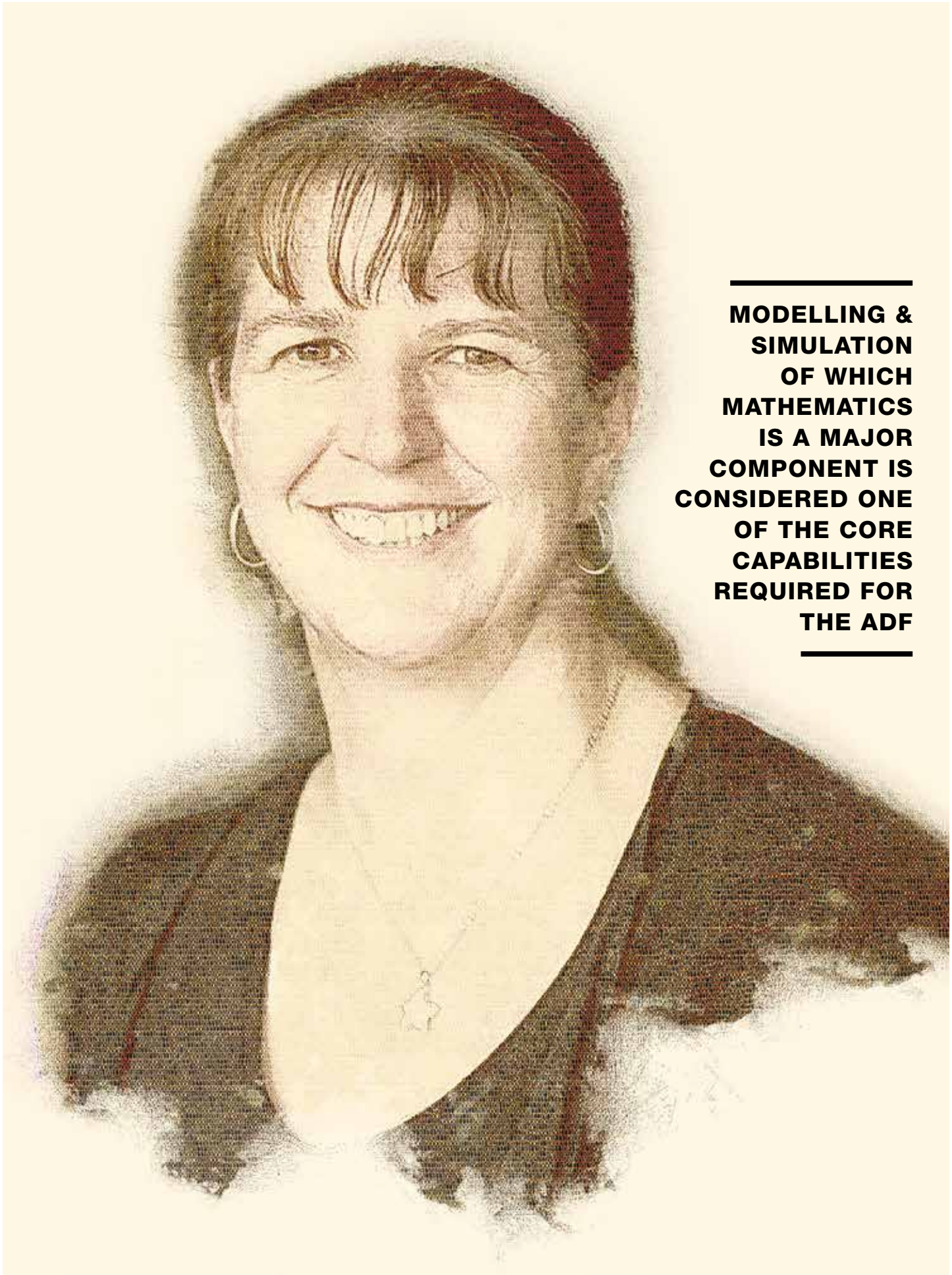
*The Defence Science Institute is a proud AMSI**Intern** collaborator, co-funding placement of PhD students to give SMEs the cutting edge and advance defence innovation in response to real-world industry challenges. Visit - amsiintern.org.au/dsi*



MODELLING & SIMULATION OF WHICH MATHEMATICS IS A MAJOR COMPONENT IS CONSIDERED ONE OF THE CORE CAPABILITIES REQUIRED FOR THE ADF

PHOTOGRAPHY: MICHAEL SHAW

THE UNIVERSITY OF SYDNEY - **ACP SALES** LA TROBE UNIVERSITY - **ADALTA** RMIT UNIVERSITY - **AEROCHUTE INTERNATIONAL PTY LTD** MONASH UNIVERSITY - **AGILENT TECHNOLOGIES AUSTRALIA PTY LTD** RMIT UNIVERSITY - **AGRITECHNOLOGY PTY LTD** THE UNIVERSITY OF QUEENSLAND - **ANTEO DIAGNOSTICS** DEAKIN UNIVERSITY - **ANZ BANKING GROUP** LA TROBE UNIVERSITY - **ANZ BANKING GROUP** MONASH UNIVERSITY - **ANZ BANKING GROUP** RMIT UNIVERSITY - **ANZ BANKING GROUP** RMIT UNIVERSITY - **ASSURANCE PTY LTD** DEAKIN UNIVERSITY - **AUS PITS** DEAKIN UNIVERSITY - **AUSTRALIAN INFORMATION SECURITY ASSOCIATION** UNIVERSITY OF TECHNOLOGY SYDNEY - **AUSTRALIAN NATIONAL COURIERS** THE AUSTRALIAN NATIONAL UNIVERSITY - **AUSTRALIAN PRUDENTIAL REGULATION AUTHORITY** QUEENSLAND UNIVERSITY OF TECHNOLOGY - **AUSTRALIAN TOURISM DATA WAREHOUSE** RMIT UNIVERSITY - **BAE SYSTEMS** RMIT UNIVERSITY - **BARDEN FABRICATIONS** RMIT UNIVERSITY - **BASS COAST SHIRE COUNCIL** LA TROBE UNIVERSITY - **BIARRI NETWORKS** RMIT UNIVERSITY - 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WHERE CAN AMSIIntern TAKE YOU?

DRIVING **INDUSTRY & UNIVERSITY** COLLABORATIONS

MAKING A DATA SCIENTIST

*Maths passion to industry with AMSI**Intern***

SPECIALISED ACADEMIC KNOWLEDGE IS ONLY PART OF THE INDUSTRY RESEARCH PUZZLE WHERE SOFT SKILLS COUNT. WHEN MURRAY NEUZERLING BEGAN AN INTERNSHIP WITH ANZ HE DISCOVERED THE STATISTICS FOR SUCCESS AS HE TOOK THE FIRST STEPS INTO A CAREER IN BIG DATA.

ACADEMIC STUDY DOESN'T EQUIP STUDENTS FOR STAKEHOLDER ENGAGEMENT ... MY INTERNSHIP HAS TAUGHT ME ESSENTIAL SKILLS SUCH AS HOW TO CONSULT ON A BUSINESS PROBLEM & DISTILL IT INTO A QUESTION SOLVABLE WITH STATISTICAL TECHNIQUES

"I think I'm a data scientist now," it was with these words La Trobe University PhD student Murray Neuzerling announced his first steps from academic to industry researcher.

Thanks to an AMSI**Intern** placement with ANZ, stepping over the industry threshold has opened the door for Murray to turn passion into a career. With a fresh perspective and inspired by new challenges "the possibilities of data science within banking and finance."

While Murray's story is becoming more common, the rate of industry led collaboration with university research in Australia remains well below the OECD average at only two to three per cent. Something we urgently need to address if we want to ride the innovation wave to prosperity.

As well as selling research as a commercial innovation pathway, equipping researchers with the skills to navigate industry environments remains one of the biggest challenges. While powerful repositories of theoretical knowledge universities alone do not produce 'job-ready' graduates, something Murray is quick to acknowledge.

"Academic study doesn't equip students for stakeholder engagement or with the skills to present the same material to different audiences with differing perspectives and levels of mathematical knowledge." he says.

At the frontline of this challenge, AMSI**Intern** is proving a powerful partner for many of our leading universities. The national internship program opens vital university-industry pathways and sells research and development as an opportunity too valuable for industry to ignore. Importantly, for students the program offers a perfect platform to plug soft skills gaps and get a taste of what is possible.

"My internship has taught me essential skills, such as how to consult on a business problem and distill it into a question solvable with statistical techniques. It provided exposure to environments where I can develop these soft skills, although I imagine it will take many years to become expert at them," says Murray.

Additionally, the program's inclusion of industry-experienced senior academics as project mentors has proven effective in building and fostering university-industry relationships and future research opportunities. For the student, it is like having the ultimate 'phone a friend', essential for locking in answers in challenging moments.

"I have been fortunate to be supported by Luke Prendergast. It is comforting to have an experienced statistician only an email or phone call away when you find yourself stuck or a model isn't quite working," says Murray.

The benefits run two ways with industry partners from SMEs to big business, reaping the benefits of access to specialised skills needed to overcome innovation barriers.

"Mentors and students offer high-level skills and a new perspective on key business challenges. There is enormous value in a fresh set of eyes with years of experience encountering problems and hunting down solutions," he says.

As AMSI**Intern** gets set to expand, it can only be a good thing for Australian industry and students like Murray looking to make academic passions such as pure mathematics add up to future success. □

A Mathematics PhD at La Trobe University, Murray Neuzerling blogs about his mathematical experiences at - mdneuzerling.com

AMSI & INDUSTRY – ENGAGED

Paving Australia's mathematical pathway to global innovation with Professor Geoff Prince

AMSI DIRECTOR, PROFESSOR GEOFF PRINCE, EXPLAINS WHY MATHS IN INDUSTRY ADDS UP AND REVEALS HOW A PLANNED EXPANSION OF AMSIINTERN** WILL RAMP UP EFFORTS TO FOSTER CRITICAL RESEARCH-INDUSTRY PATHWAYS TO OPTIMISE INNOVATION.**

Education, research and industry remain at the heart of AMSI's policy agenda and mission to transform Australia's mathematical sciences capability. These key strands intertwine to inform and shape the future of mathematics education and research.

Australia has one of the lowest rates of industry-university collaboration and private sector employment of PhD graduates in the OECD. There is broad bipartisan parliamentary support for immediate national action to reverse these trends, with AMSI deeply involved with a number of bold initiatives in partnership with government and industry.

AMSIINTERN

AMSI**Intern** matches the advanced skills sets of our PhD students with private and public sector partners to work on focussed research projects for four to five months.

Mentored by a PhD supervisor, the internships open new avenues for industry-university collaboration, solve problems with immediate impact and have a transformative effect on the student. AMSI has placed more than 160 interns across all disciplines and industry sectors with particular strength in the mathematical sciences. Following a pre-election promise by the Coalition to place 1400 interns through AMSI**Intern** through till 2020 with an emphasis on STEM and women, we are preparing for an anticipated 2017 launch. This will be a truly effective means of delivering collaboration through some of the nation's brightest and most innovative minds.

CHOOSEMATHS

Gender inequity is a deepening issue within the mathematical sciences. Our CHOOSE**MATHS** partnership with the BHP Billiton Foundation is in part driven by the shortage of women in the STEM workforce and the challenges that this creates. The CHOOSE**MATHS** Career Awareness campaign being rolled out now aims to break down adverse gender stereotyping but also to grow more general interest in maths-based career opportunities. BHP Billiton Chief of Staff and Geosciences Head, Laura Tyler shares her insights on maths in mining in this edition of *the Update.* ⇨

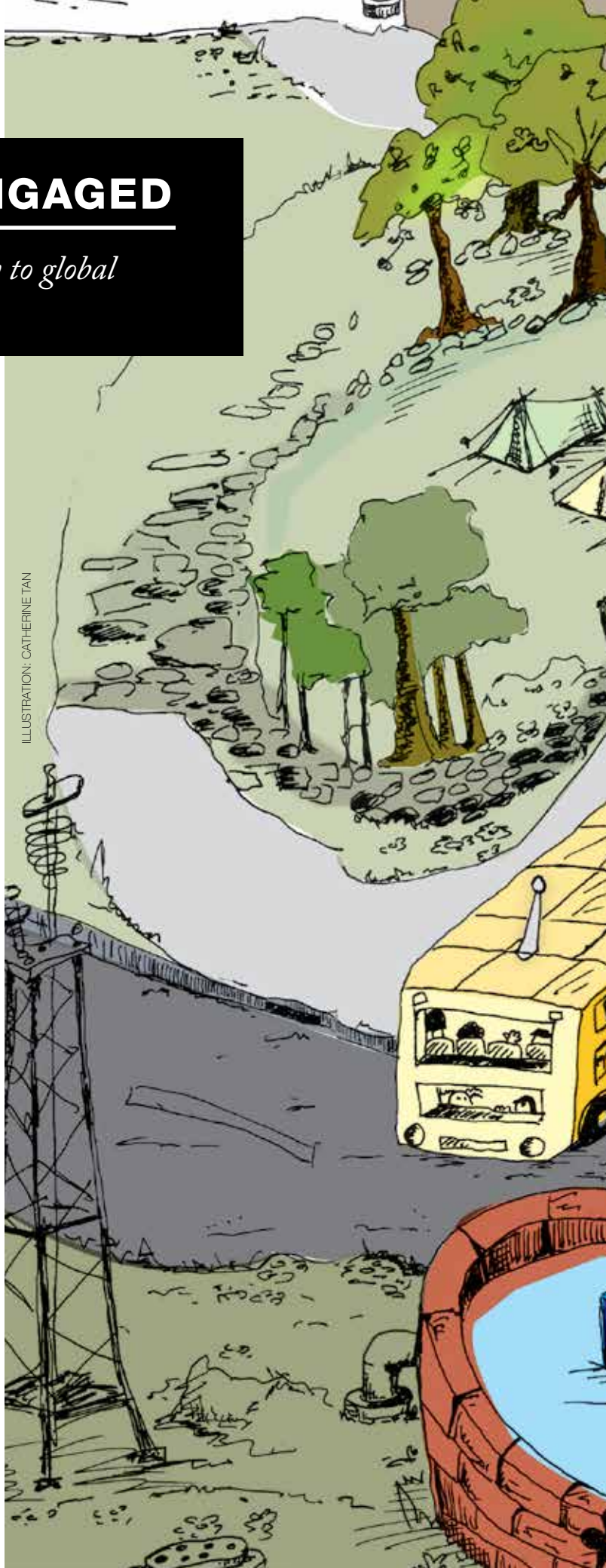
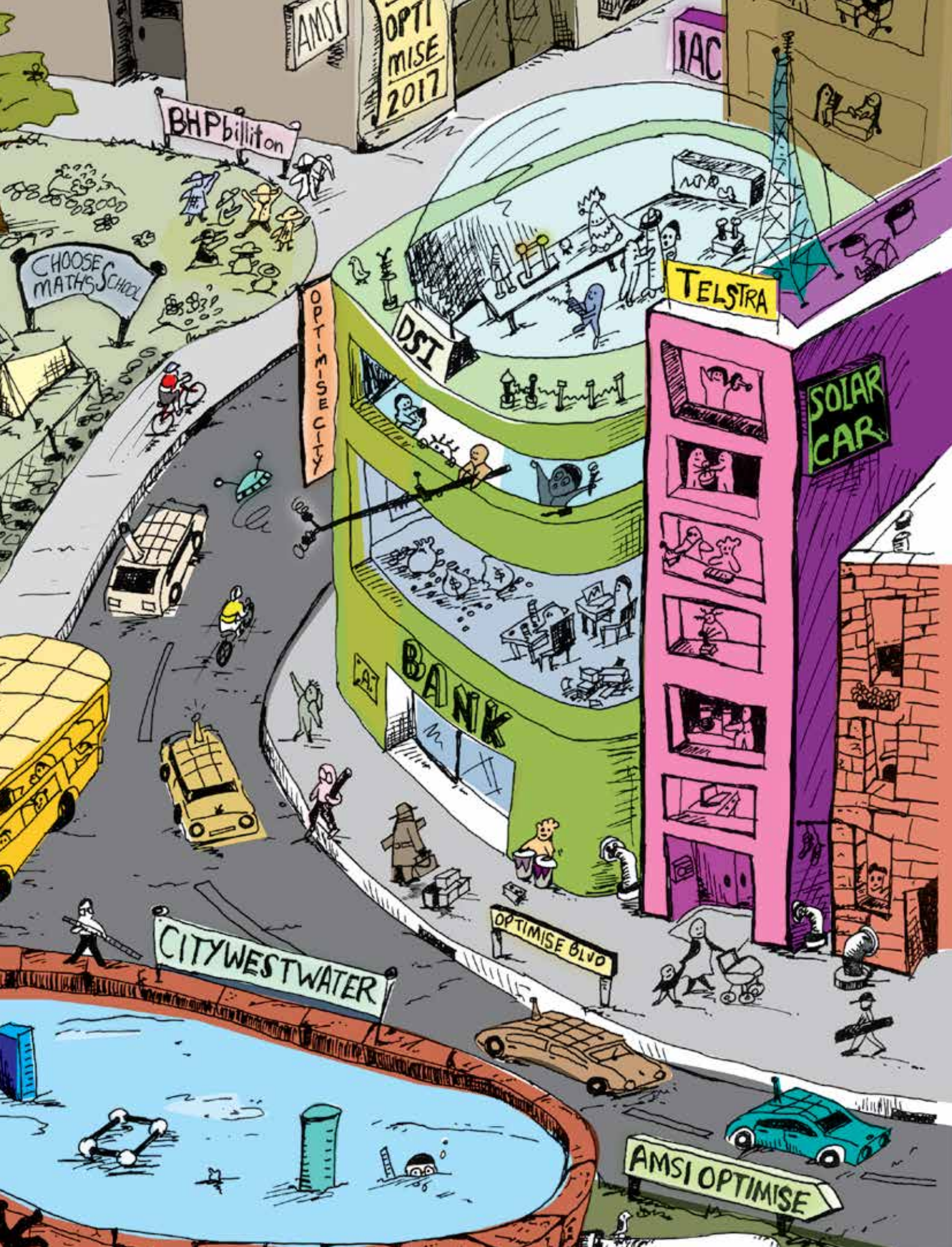


ILLUSTRATION: CATHERINE TAN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MATHEMATICS AND STATISTICS IN INDUSTRY

The Mathematics and Statistics in Industry Study Group (MISG) is a long standing part of the Australia and international research sector-industry engagement landscape. For a number of years AMSI has been supporting the Australian and New Zealand Industrial and Applied Mathematics division of the Australian Mathematical Society in the delivery of MISG and we believe that the program has a major role to play in the new industry engagement environment. In particular, the Australian Research Council's engagement and impact measuring exercise will bring fresh university attention, and we hope extra funding, to MISG. You can read our interview with current MISG Director, Peter Pudney (University of South Australia), including details of the next MISG in February 2017 on page three of this *Update*.

NEW INDUSTRY HORIZONS

With a new era of industry engagement comes new challenges. The lead times to project funding through Australia's research agencies are long and for the mathematical sciences, with our low capital costs, the processes impede collaboration. For this reason AMSI has proposed to the Commonwealth's National Collaborative Research Infrastructure Strategy (NCRIS) workforce that a new collaboration platform be created to allow university researchers to quickly find and utilise mathematical, statistical and computational sciences support in their engagement with industry and agency partners. While the provision of physical data and computational science infrastructure has long been central to NCRIS, engagement with mathematical scientists has been overlooked until now. As illustrated by this industry special *Update*, frontier research in our discipline is critical to innovation and the engagement of our specialists with end users generates genuine, two way research partnerships. You can find AMSI's submission to NCRIS at amsi.org.au.

Under the leadership of Board member, Dr Mark Lawrence, AMSI's Industry Advisory Committee has been extraordinarily active in fostering industry engagement. The industry-university task force has attracted the attention of a number of leading representatives of the Australian business community who have added their voice as champions of the mathematical sciences within innovation. The alignment of government, industry and discipline goals presents an unprecedented but not unplanned opportunity to deliver on AMSI's goal of 'the radical improvement of mathematical sciences capacity and capability in the Australian community'! □

PLANNING FOR THE FUTURE

Dr Mark Lawrence, AMSI board member & IAC chair

AT TWO TO THREE PER CENT, AUSTRALIA HAS ONE OF THE LOWEST RATES OF INDUSTRY-RESEARCH ENGAGEMENT IN THE OECD. RATHER THAN A BARRIER, WE NEED TO VIEW THIS CHALLENGE AS A CALL TO ACTION AND AN OPPORTUNITY FOR REFORM AS WE SEEK TO SECURE OUR PLACE ON THE GLOBAL INNOVATION STAGE.

It is this challenge that has led AMSI's Industry Advisory Committee (IAC) to partner with Australian industry to establish the Industry/ Mathematical Sciences Engagement (IMSE) Task Force. The Task Force will respond to key priorities identified through IAC consultation with industry and government agency executives, which began with over 25 interviews in 2015. This ongoing consultation process has deepened AMSI's understanding of current and projected mathematical and statistical skill requirements across key industry sectors. In particular, the consultation process revealed that there is currently a substantial shortage of suitably qualified Australian graduates with the combination of both 'hard' quantitative and critical thinking skills, together with the 'soft' communication skills that industry needs. This shortage is expected to worsen over the next few years and reach a critical level in certain industries. The IMSE Task Force, including eight industry leaders and eight senior mathematical scientists from AMSI's member universities, is leading urgent action to address the following objectives:

- Raising careers awareness in schools and the community – maths 'opens doors' to a wide range of exciting and challenging careers
- Strengthening industry engagement with the mathematical sciences
- Increasing the supply of industry-ready mathematical science graduates

At a time when the government's National Innovation and Science Agenda (NISA) is top of mind for Australia's universities, AMSI is particularly pleased to be engaging so deeply with Australian business. There is no doubt that the combined voices of major Australian companies and the discipline itself will focus enormous attention on the opportunities and challenges our nation faces in rising to embrace a data-driven economy.

As is evidenced by the feature interviews in this special industry *Update*, industry demand for critical thinking and problem solving skills, and data analysis is increasing strongly. Task Force findings indicate a shortage of industry-ready maths graduates is leading Australian businesses across a wide range of industries to seek these skills overseas, in order to ensure their competitiveness.

University programs alone do not produce work-ready graduates. It is clear that pathways to equip students, such as Murray Neuzerling who features in this issue, with the transferable skills critical for structuring and solving real-world problems are essential.

AMSI is taking a lead role in the national response to this challenge through its national all-discipline, all-sector postgraduate internship program, AMSI**Intern**. This provides students with a platform for work integrated learning opportunities (WIL) to increase understanding of the priorities and requirements of the commercial environment. Equally, industry needs to strengthen the mathematical and quantitative skills of existing staff through professional development to help meet demand.

With the mathematical sciences set to take a lead role, these insights will provide a critical roadmap for AMSI's ongoing engagement with government initiatives such as the NISA. Industry knows that secure access to a steady supply of high-level mathematical and statistical skills is essential to ensure future competitiveness and that without access to these skills our ascent onto the global innovation stage is not assured.

Dr Mark Lawrence is Chair of AMSI's Industry Advisory Committee and Chair of the IMSE Task Force. □

The IAC provides guidance and direction to AMSI, its members and industry regarding strategic initiatives to raise the quantitative capacity and capability of Australian industry and to strengthen its innovation capacity through engagement between industry and the mathematical sciences.

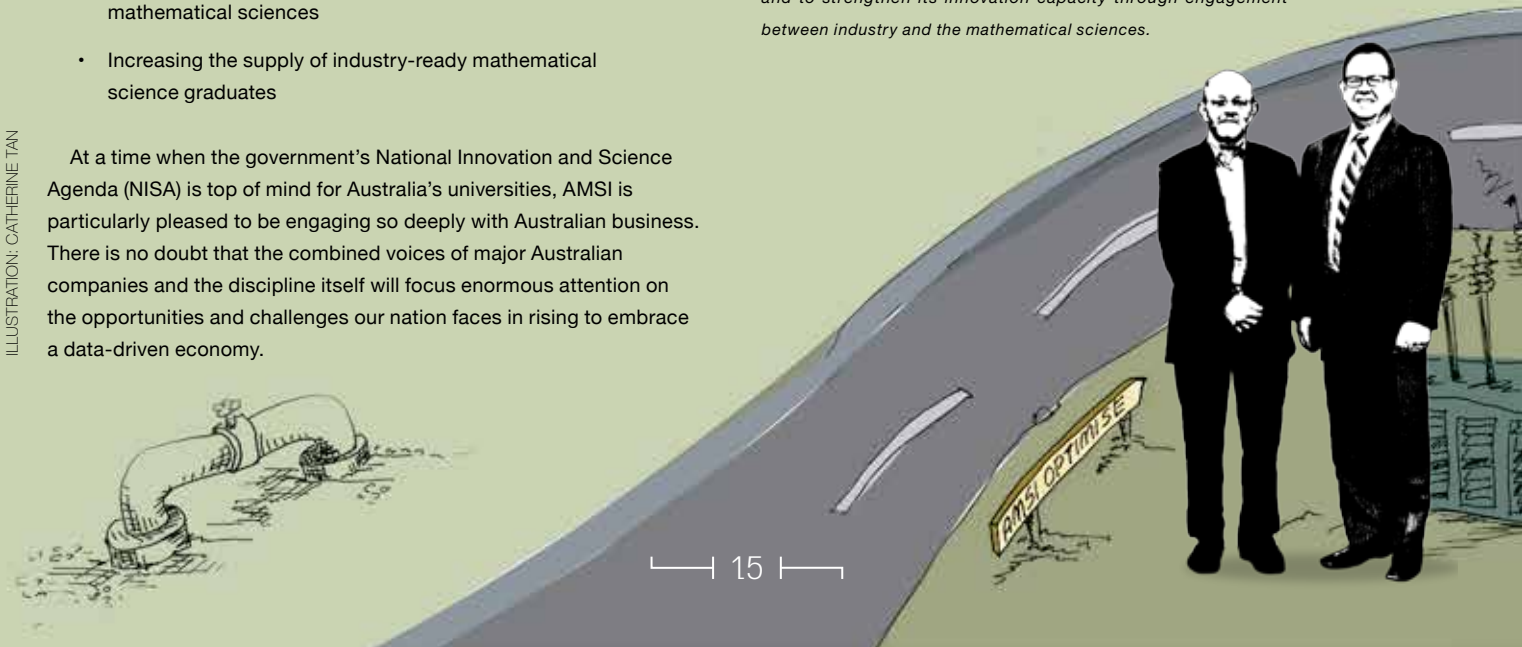


ILLUSTRATION: CATHERINE TAN

FORECASTING INNOVATION

Mathematics of finance with Dr Adam Cagliarini

AS DEPUTY HEAD OF RESEARCH AT RESERVE BANK OF AUSTRALIA (RBA), MATHEMATICS IS AN ESSENTIAL IN DR ADAM CAGLIARINI'S TOOLBOX. FIND OUT WHY HE FORECASTS A BRIGHT FUTURE FOR MATHEMATICS AT THE FRONTLINE OF FINANCE AND BANKING.

HOW HAS MATHEMATICS HELPED YOU IN YOUR CAREER?

Economics and finance have become more technical and mathematical over time. A mathematical mindset has really helped me think about how to solve problems and think about real-world phenomenon. Mathematics is a way of thinking and a great language. It helps us not only formalise our ideas, but is a mechanism to ensure people are precise and clear about the assumptions they make about problems and the world. I use mathematics almost daily, as do many of my colleagues in my department. As well as modelling different phenomenon, we also use modern statistical techniques to take these models to the data to test our assumptions and theories. The mathematical sciences are very important for what we do here at the RBA, and my background in mathematics and statistics has provided me with a set of tools and skills to think about a wide range of issues.

HOW IS MATHEMATICS USED IN THE FINANCE SECTOR? WHAT DO YOU SEE ON THE INNOVATION HORIZON?

I think the opportunities are great. Increasingly, there is greater demand for people with strong mathematical and quantitative skills. Increased access to data means skills to analyse the data, understand patterns in the data and then model the phenomenon are extremely important. Applications include modelling credit risk, modelling asset prices, and modelling the economy. A lot of modern statistical techniques are being applied to understanding the behaviour of households and firms as well, so these quantitative skills are an advantage.

I've been in forecasting long enough to know that whatever I say will be wrong, almost surely. I know that trends in policy circles are increasingly for mathematical and statistical techniques to be applied to a wider range of policy matters – from monetary policy, to financial stability, to the production and distribution of bank notes. Thinking about how to model banks' exposures to each other through network theory, modelling tail risks in finance, thinking about how to make new technologies more secure (such as the distributed ledger and other technologies that might change the way the financial system works) and a whole lot of other policy issues will require people with a mathematical background to help us make progress on these matters. While policy makers are not always doing the innovating, they are often the regulators. They need people with the backgrounds to understand issues well enough before they arise and to design policies to address these issues.

HOW DOES RBA ENGAGE WITH UNIVERSITY RESEARCH?

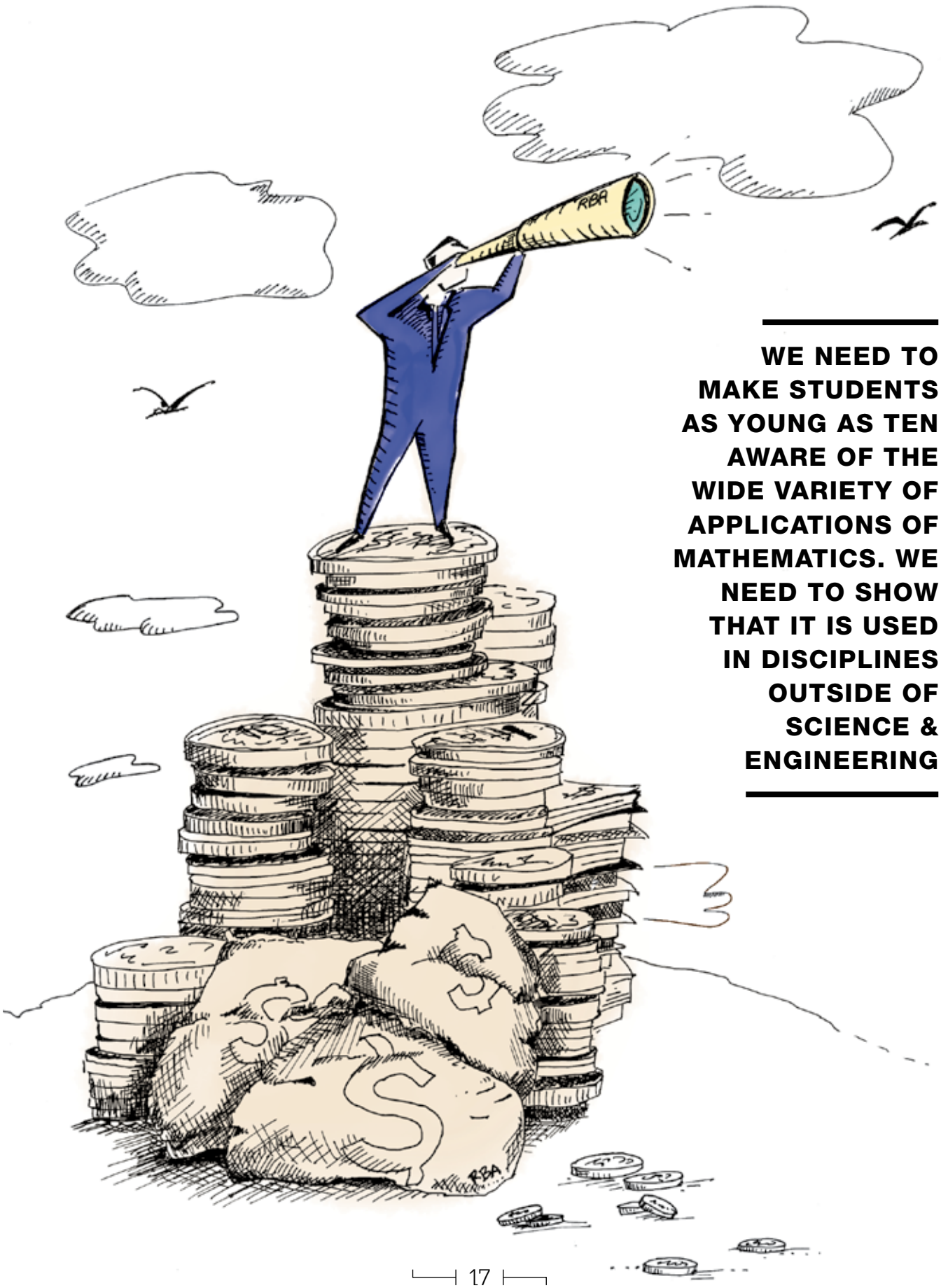
We engage with academia (mainly in economics and finance) quite a bit. We hold a conference each December that has an academic focus – and the papers presented there are very mathematical – we have academics visiting regularly, we have visiting scholars from Australian and overseas universities. The Bank highly values its interactions with academia. It helps expose us to new ideas, new ways of thinking, allows us to engage with these ideas and our staff learn a lot from these interactions.

On research, I might be biased, but the very way we think about monetary policy and economics in general has been shaped by decades of research. Much of that research is based on mathematical and statistical techniques, so these have been integral in the development of the field. Thinking about a range of economic and financial issues are ongoing and research done internally and externally continues to influence the way people think about a variety of issues. A lot of what we do at the Bank is research oriented. Some of the work is of a short-term nature, some of it is medium to long-term, and it is how we get to deepen our understanding of how Australia and global economies and financial markets work.

HOW CAN INDUSTRY BETTER PROMOTE DEMAND FOR MATHEMATICS AND STATISTICS SKILLS?

I think more awareness of the value of these skills and studying mathematical sciences. The ability to think about a wide range of issues, being able to formalise that thinking is extremely useful in any industry. We need to make students as young as ten aware of the wide variety of applications of mathematics (this may require educating teachers of the applications). We need to show that it is used in disciplines outside of science and engineering. There are many students that want to study economics and finance and don't realise that the knowledge, skills and methods learned studying mathematical sciences are essential to do very well in these fields (and other fields as well). It teaches people how to think rigorously. Ultimately, though, I think if there is excess demand for these skills, that should be reflected in the salaries of people with these skills and this information should filter down to students at universities and high school – but that is if I'm looking at the issue with my economist's hat on. □

RBA is an AMSI Member. Dr Adam Cagliarini recently spoke at AMSI Summer School 2016 as part of the Careers Afternoon session.



WE NEED TO MAKE STUDENTS AS YOUNG AS TEN AWARE OF THE WIDE VARIETY OF APPLICATIONS OF MATHEMATICS. WE NEED TO SHOW THAT IT IS USED IN DISCIPLINES OUTSIDE OF SCIENCE & ENGINEERING

ILLUSTRATION: CATHERINE TAN

THE FUTURE OF OUR INDUSTRY DEPENDS ON OUR ABILITY TO GET STEM GRADUATES INTO BUSINESS CRITICAL ROLES. WE ARE EFFECTIVELY IN COMPETITION AGAINST AIRLINES, IT, THE ARMY - YOU NAME IT

PHOTOGRAPHY: BHP BILLITON

MINING BY NUMBERS

Innovating mining & resources with Laura Tyler

LAURA TYLER TALKS TO AMSI ABOUT LIFE AS BHP BILLITON'S CHIEF OF STAFF AND HEAD OF GEOSCIENCE AND WHY THE GLOBAL MINING AND RESOURCES LEADER IS CHOOSING MATHEMATICS TO LEAD ITS NEXT TRANSFORMATION.

HOW HAS MATHEMATICS HELPED YOU IN YOUR CAREER? HOW IS IT USED IN MINING?

Without maths I wouldn't be where I am today. I am a geologist by training and studied chemistry, biology and pure mathematics with mechanics to go to university. Applied science was very appealing to me although my father had doubts I would land a job with such a subject! Earlier in my career my roles focused heavily on technical skills for geoscience—engineering geology, geostatistics and ore deposits generation—all of which use applied maths.

Although my day to day job is now less hands on with the technical aspects of geoscience, I use maths every single day in different and wonderful ways—whether in reviewing a technical report, reviewing performance data or trying to understand and solve a business-related problem. It does not need to be specifically about geology for me to apply the science, technology, engineering mathematics (STEM) skills I have developed.

WITH THE HIGH DEMAND FOR STEM SKILLS, WHAT OPPORTUNITIES EXIST FOR MATHEMATICS GRADUATES ACROSS THE MINING AND RESOURCES SECTOR?

There is enormous variety for STEM graduates in the mining and resources sector. As with any big company, BHP Billiton employs people in all sorts of finance, science and engineering roles all around the globe.

There are lots of roles available in the scientific fields but my passion has always been geoscience.

Geoscientists use maths every day; whether in the geostatistics that define the value of the resources we will mine, or in the geomechanics that predict how the rock may behave and how we can keep our people safe or in the performance measures we monitor and evaluate to understand our performance. Our geoscientists are all applied mathematicians and an amazing and passionate cohort of scientists. There are roles that engage science in mining, which might surprise you. For example, the metallurgists who work with the process engineers to maximise recovery from ore and minimise the deleterious materials that reduce value. Or a field specialist collecting flora and fauna data for rehabilitation at a mine site, would likely have continued maths and stats from high school into university to get a degree in Environmental Science.

Environmental surveying is one of those amazing jobs where you get to work in remote and beautiful places. Of course there are the roles that we haven't even dreamt of yet. The resources industry has a proud history of invention and innovation – much of it led by the scientists and engineers of the day. A great present day example of this is at our remote operating centres. These centres use real time data monitoring to centralise control across our operations – often from many, many kilometres away. The system architecture that sits behind them is remarkable and the idea that we could have done this even or 20 or 30 years ago is unthinkable. Just imagine then what the possibilities could be in another 20 or 30 years. STEM graduates will be vital to the future of the industry and to our way of life. The opportunities are endless.

WHAT DO YOU SEE ON THE MINING INNOVATION HORIZON?

Our priority is always to keep our people safe. Nothing is more important. To help us create and maintain a safe work environment, innovation is key. In another decade from now, I believe we will see more robotics, more automation and more technologies that remove the operator from

danger. We are already doing this with our remote centres. We will also become more productive and at lower cost – as the ore body grades fall innovation will show us the way to discover, extract and process better than ever before.

I expect that in ten years we will have made the next round of breakthroughs in how we recover and treat resources to get the commodities the world needs to support our lifestyles and improve those of the developing world. We will become more inventive in how we find new ore bodies or oil and gas fields, cleverer in how we extract the minerals (hopefully reducing our environmental footprint as we do so), and we will get better at recovering more of the resources we need with lower impact and improved health and safety conditions.

Our workplaces will evolve to become more engaging and diverse – we will see more women in technical and leadership roles. Our world is becoming more connected and faster at developing new and interesting technologies. I am excited to think my children will have a very different experience of work than my parents had. Even in my lifetime the changes have been amazing and Australia can continue to be at the forefront of this transformation through investment in the STEM workers of tomorrow.

I USE MATHS EVERY SINGLE DAY IN DIFFERENT & WONDERFUL WAYS— WHETHER IN REVIEWING A TECHNICAL REPORT, REVIEWING PERFORMANCE DATA OR TRYING TO UNDERSTAND & SOLVE A BUSINESS-RELATED PROBLEM

HOW IS BHP BILLITON IMPACTING THE PIPELINE TO FOSTER MATHEMATICS AND STEM SKILLS SUPPLY?

Australian industry knows that STEM professionals are vital to our future prosperity, national productivity and global competitiveness. For the resources industry this is especially true.

The resources industry is a huge part of the Australian economy and will continue to remain so in decades to come. If we don't have the critical STEM skills we need, not only will the mining and resources sector suffer, but Australia will too.

Industry therefore has a responsibility to spark curiosity in the minds of students and graduates and to promote the value of a STEM career. We need numerate and curious scientists, engineers and accountants to keep Australian industry tackling the challenges before us.

Through the BHP Billiton Foundation, we are committed to supporting the advancement of education through:

- Supporting activities that promote improved graduation rates and employability of marginalised and disadvantaged groups;
- Increased profile, interest and uptake of STEM amongst primary, secondary and tertiary students; and
- The application and deployment of new science and engineering technologies.

Our STEM investments not only focus on improving academic achievement but also promote the recognition of students and teachers who excel in STEM such as through CHOOSE**MATHS**.

We do this in part because we have a fundamental commitment to supporting the communities where we operate and because we see value in investing in a diverse talent pipeline for the future of our industry and our country.

HOW CAN INDUSTRY BETTER PROMOTE DEMAND FOR MATHEMATICS AND STATISTICS SKILLS?

The future of our industry depends on our ability to get STEM graduates into business critical roles. We are effectively in competition against airlines, IT, the army - you name it. They all need STEM graduates! We must increase the pool of people considering STEM careers.

So while we are all about job creation, we also understand that we have a responsibility to communicate and promote career pathways in STEM and that starts at school. That's why we are investing in programs like CHOOSE**MATHS** and the CSIRO Science and Engineering Awards. It's about raising awareness of the value and potential of a STEM career.

I think one of the best ways is by simply telling stories like mine, or like the thousands of BHP Billiton employees who studied maths or science or engineering and now find themselves in enormously rewarding roles - doing jobs they never thought possible in places they had only ever dreamt of.

For instance at school I was one of six girls in maths in a class of over 30. At uni I was one of ten girls in a geology cohort of about 75. And when I started out I was often the only woman on a site. But that didn't stop me from my pursuing my interests and passions in STEM, and as a result my career has taken me all around the world. From the UK to Australia to North America and back again, I am now based in our global head office in Melbourne and am still enjoying a wonderful STEM-filled career!

Sharing those kinds of stories I think helps students connect the sometimes dry and difficult subject matter that they study at school with the amazing practical applications that can equal a wonderful and rewarding life. It is equally important to ensure that kids are also getting the support they need to keep them engaged. I recently met some of the amazing teachers, working hard every day to inspire students in STEM, at the CHOOSE**MATHS** awards. It gave me real hope for the future and reinforced in me the importance of industry lending our support to these amazing people. □

*A national collaboration between AMSI and the BHP Billiton Foundation, CHOOSE**MATHS** is empowering Australian students to pursue mathematics. Working across the pipeline from the classroom to university and industry, this initiative aims to strengthen capability, improve public perception and increase engagement of women and girls. Visit - choosemaths.org.au*

CHOOSE MATHS AWARDS

AN AMSI SCHOOLS PROJECT

DELIVERED BY

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

SUPPORTED BY

bhpbilliton Foundation

CONGRATULATIONS TO ALL THE CHOOSEMATHS 2016 AWARD WINNERS

STUDENT AWARD WINNERS

BEST SENIOR VIDEO

Danebank Anglican School for Girls
NEW SOUTH WALES

BEST JUNIOR VIDEO

Toorak College
VICTORIA

AWARDS FOR EXCELLENCE

Australian Islamic College
WESTERN AUSTRALIA

Beaconhills College
VICTORIA

Huntingtower School
VICTORIA

John Monash Science School
VICTORIA

AWARDS FOR DISTINCTION

Armidale High School
NEW SOUTH WALES

Burwood Girls High School
NEW SOUTH WALES

Georges River College - Hurstville Boys Campus
NEW SOUTH WALES

Methodist Ladies' College
VICTORIA

TEACHER AWARD WINNERS

MENTORING GIRLS IN MATHEMATICS AWARDS

Peter Chandler
Penrhos College
WESTERN AUSTRALIA

Stacey King
Mabel Park State High School
QUEENSLAND

TEACHER EXCELLENCE AWARDS

Greg Anderson
St Leonard's College
VICTORIA

Lisa Hogan
Mary Mackillop Catholic Regional College
VICTORIA

Terry Jacka
St Hilda's School
QUEENSLAND

Jacki McMahon
Makybe Rise Primary School
WESTERN AUSTRALIA

Norah Parsons
Moura State High School
QUEENSLAND

Cassandra Portelli
Hunter School of the Performing Arts
NEW SOUTH WALES

Janine Stewart
St Columba Anglican School
NEW SOUTH WALES

Eddie Woo
Cherrybrook Technology High School
NEW SOUTH WALES

CHOOSEMATHSAWARDS.ORG.AU

I'VE HAD GREAT SUCCESS WITH AMSIINTERN... OTHER AREAS OF TELSTRA HAVE BEEN ABLE TO BENEFIT... BY SEEING NEW APPROACHES SHOWCASED SO ENTHUSIASTICALLY

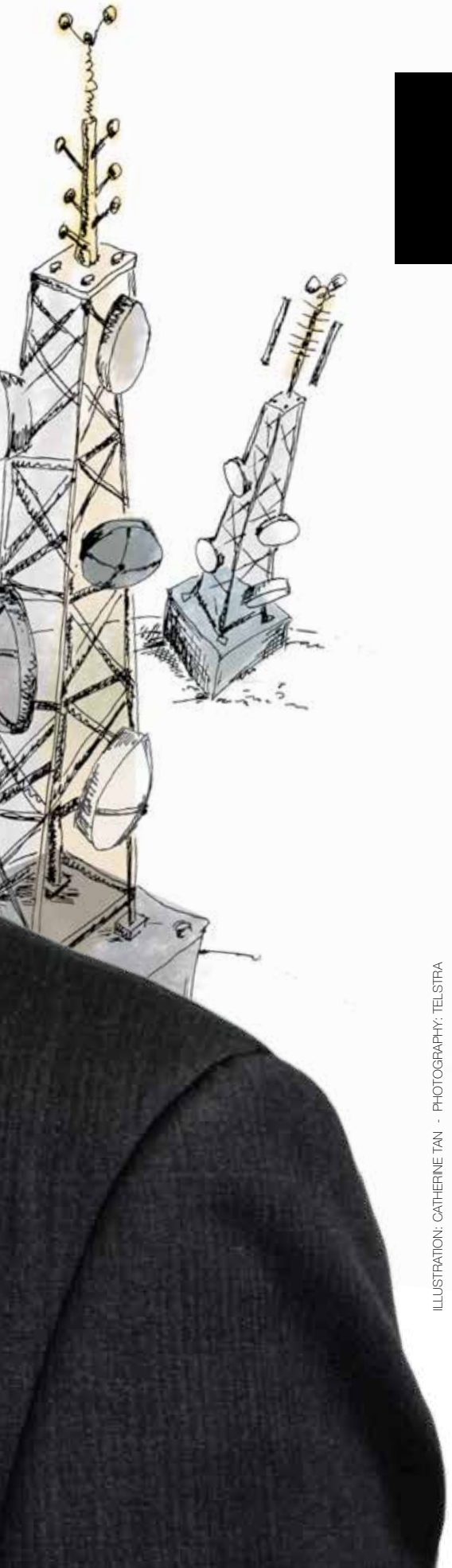


ILLUSTRATION: CATHERINE TAN - PHOTOGRAPHY: TELSTRA

BIG DATA DOWN UNDER

The future of big data with Steve Morris

WE CATCH UP WITH TELSTRA'S GENERAL MANAGER, TECHNOLOGY & ANALYSIS – BIG DATA, STEVE MORRIS, TO CHAT MATHEMATICS, BIG DATA, INNOVATION AND THE FUTURE OF TELECOMMUNICATIONS. READ ON TO DISCOVER WHAT'S ON THE HORIZON FOR ONE OF AUSTRALIA'S BIGGEST PROVIDERS.

HOW HAS MATHEMATICS HELPED YOU IN YOUR CAREER?

I'm an engineer by background, so I have always been interested in seeing real world behaviours following mathematical principles. Over time, my interest has broadened from the mathematics of well controlled scenarios into more complex models, and in recent years its practical business application.

HOW IS MATHEMATICS USED AT TELSTRA? WHAT DO YOU SEE ON THE INNOVATION HORIZON?

Our purpose is to enable our customers to thrive - using analytics to deliver improved customer experiences.

We are champions of the network effect of data, which is data from different sources coming together.

We have a number of innovative projects underway in areas relating to improving specific customer experiences, reducing fraud, and optimising network investment.

Telstra's data is measured in Petabytes, and we deal with streaming network sources that can deliver us a million records a second. In these cases the size of the data set and/or processing capacity becomes part of the computation challenge.

Whilst the results from advanced analytics or machine learning will grab attention, sitting behind each result is a team of quiet achievers dealing with complex open source platforms, network connections, and even routine data quality challenges.

There are many exciting opportunities in the telecommunications sector including 5G, Internet of Things, Network Function Virtualisation / Software-Defined Networking, and security. Data underpins them all.

HOW IMPORTANT ARE PROGRAMS SUCH AS AMSIINTERN? HOW HAS IT BENEFITED TELSTRA?

Our broader team, the Chief Technology Office, has a long history with research engagement and innovation. We regularly see academics and industry groups working and presenting at our Gurrowa Innovation Lab here in Melbourne.

I've had great success with the AMSI program, it gives our staff an opportunity to see the talent coming out of universities, and gives the interns some practical experience in a big corporate environment.

We have been fortunate enough to hire three former AMSI Interns as Telstra staff, and have one ex-intern is working as a part-time contractor.

What makes me particularly proud is that other areas of Telstra have been able to benefit – not only directly by hiring, but indirectly, by seeing new approaches showcased so enthusiastically. □

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*Telstra is an AMSI**Intern** industry partner. Successful engagement with the program has resulted in a number of internships and employment of interns post placement. Visit - amsiintern.org.au*

UNRAVELLING A MATHEMATICAL WEB

International Workshop on Complex Systems & Networks

Professor Michael Small, University of Western Australia

WE DISCOVER WEBS OF A DIFFERENT KIND, AS CSIRO-UWA CHAIR OF COMPLEX ENGINEERING SYSTEMS, MICHAEL SMALL, GIVES AMSI THE INSIDE SCOOP ON THE RECENT SUCCESSFUL INTERNATIONAL WORKSHOP ON COMPLEX SYSTEMS AND NETWORKS.

From the complex webs of social media and human interaction to power-grid substation interconnections, networks surround every facet of our lives. Linking all these systems are complex structures characterised by interconnected components or nodes connected by edges. Understanding the way in which these nodes connect is instrumental to understanding and eventually controlling system behaviour. In societies, studying connections between individuals allows us to better map the spread of disease and engineer control strategies. Modelling the structure of electrical power distribution networks is essential to building systems robust to cascading outages.

An emerging field and evolution of mathematical graph theory and of particular interest to statistical physicists, networks are widely studied as a paradigmatic model of interaction. As computational resources and data become more plentiful, many of the theoretical results related to large interconnected systems can now be applied to real physics systems - from the human genome to the internet or global social and communication networks. Advances in data intensive science have placed complex systems theory at the forefront of basic mathematics where it is being adapted and applied to large, complex, real-world systems.

While interaction at an individual level may be simple and well understood, one of the most interesting aspects of these systems is how little is understood about their collective behaviour. In an increasingly interconnected world, examples of such systems are now everywhere. In the natural world, individual and presumably simple interactions between neighbouring birds in a flock lead to spectacular and complex murmurations - a phenomenon which has application to crowd control, traffic management and the design of autonomous vehicles and drones.

The Internet itself has emerged as the medium underpinning global trade and communication. It is a vast web of interconnected components each following very simple rules to transmit data. Understanding how this system functions allows us to develop the network into a more efficient and robust system.

Levels of networks exist on top of the Internet, each suggesting new applications for complex systems theory - from the World Wide Web, to social networks and even communication among distributed organisations attempting to evade detection on the so-called “dark web”.

Run annually, the International Workshop on Complex Systems and Networks fosters engagement across the pipeline from global field experts and emerging academic and student researchers to industry stakeholders. As Australia’s resources industry hub, Perth was an ideal setting to explore engineering challenges facing remote operations and the role of complex systems in engineering best practice through reliability engineering, virtual networks and complex engineering systems. With speakers leading discussion on physics, engineering, mathematics, social networks, granular systems, electronic systems, robotics and guidance systems, and business and innovation, this year’s program provided an ideal platform for exploration of complex systems and networks.

Australian scientists are increasingly contributing to the development of complex systems science, with a strong focus on problems related to complex networks and their applications. At RMIT, Professor Xinghuo Yu leads a large and very successful group investigating control of dynamical systems embedded on networks. Sydney has several key researchers looking at engineering applications of complex systems - for example in power grids.

Over in Western Australia, Curtin University’s Professor Ba-Ngu Vo is currently driving development of tracking systems and robotics to improve multi-agent systems management. At the University of Western Australia, Professor Melinda Hodkiewicz is leading investigation into application of current understanding of system failure and lifetime prediction to problems of system reliability in engineering operations - particularly in the resource sector in WA. Integration of system-level information will enable development of better models to demonstrate impacts of component interdependence on overall system performance. And her colleague Professor Michael Small, who was chair of this conference, leads a joint initiative between CSIRO Mineral Resources and UWA Faculty of Engineering, applying the mathematics of Complex Systems theory to problems in Engineering for Remote Operations.

Australia is also fostering international collaborations within the field, with University of Adelaide’s Dr Lewis Mitchell working with Dr Dion O’Neale, from the University of Auckland, to apply theoretical modelling to the understanding of social systems. □

IMAGERY SUPPLIED BY: PROFESSOR MICHAEL SMALL

Global Leaders @ the meeting

Professor Celso Grebogi

A Brazilian physicist, Professor Grebogi is renowned for his work in the area of Chaos Theory - in particular chaos control. The Sixth Century Chair in Nonlinear and Complex Systems at the University of Aberdeen, he is a Fellow of The Royal Society of Edinburgh, as well as a Fellow of the Brazilian Academy of Sciences, the World Academy of Sciences (TWAS/UNESCO), the American Physical Society, and the Institute of Physics (UK). His work has attracted over 30,000 citations. Notably his collaboration with Edward Ott and James Yorke, has resulted in a numerical example illustrating the conversion of a chaotic attractor to a range of possible time-periodic attracting motions using only small time-dependent perturbations of an available system parameter. This is known as the OGY Method, after each of the three authors.

Professor Jürgen Kurths

A mathematician and physicist with the Potsdam Institute for Climate Change Research, Professor Kurths also holds chair positions at Humboldt University, Potsdam University, and the University of Aberdeen. He is a Fellow of the American Physical Society, a Member of the Macedonian Academy of Sciences and Arts, and recipient of multiple honorary doctorates, professorships and awards. He has had more than 60 PhD students from about 20 countries with 30 now in tenured positions. Highly cited, he has published over 500 articles and eight books and is currently on the editorial board of more than 10 scientific journals. Professor Kurths' research on the basics of complex systems theory has had application to the Earth system, the human brain, the cardio-respiratory system and other systems characterized by a high degree of complexity and nonlinearity.

Professor Guanrong Chen

Professor Chen has held a chair professorship in electrical engineering, at the City University of Hong Kong since 2000. He is widely lauded for his work in chaos theory and complex systems. Notably he proposed a double scroll chaotic, Chen's attractor, in 1999. Professor Chen is a Member of Academia Europe and a Fellow of IEEE, Highly published, his work has attracted over 70,000 citations, and he is currently Editor-in-Chief of International Journal of Bifurcation and Chaos.

Preferential attachment

Construct a network as follows. At each step add a new node with m edges, each of those m edges connects to existing nodes with probability proportional to the number of edges that that node already has. Over time, the network will evolve a scale-free structure - the probability of a node having k edges is given by $P(k) \propto k^{-\gamma}$ for $k \geq m$ and a positive constant γ. This means that there is a finite non-zero probability of nodes having an arbitrary large number of connections.

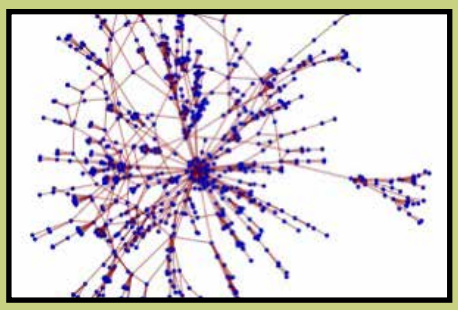

Figure 1 A scale free network with exponent $\gamma < 2$. Such things exist and can be generated (with techniques proposed by Prof. Small), but are not a consequence of preferential attachment.

Controllability

Consider a network of N nodes coupled through an adjacency matrix A ($a_{ij} = 1$ iff node-i and node-j are connected, 0 otherwise) and construct the following coupled dynamical system:

$$\frac{dx_i}{dt} = f(x_i) + c\sum_{i=1}^{N} a_{ij} H x_j$$

where H is an input matrix. Under what conditions (on A and c) do the states of the nodes synchronise? Or do clusters synchronise? How does one control this system to achieve a particular state?

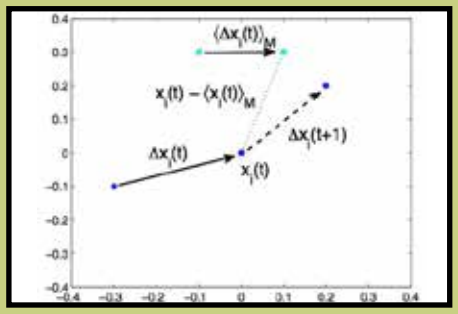

Figure 2 State estimation and update according to a discrete filtering scheme of Prof. Small.

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