2018 summer

the UPDATE

6th ed.

BRIDGING THE GAP

Top Teacher Makes Indigenous Impact

FUTURE INVESTMENT

Government Backs PhD Internships

OPTIMISE

Embracing the Next Industrial Revolution

OH THE PLACES WE'LL GO

The Mathematics of Collaboration

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

2018 SCIENTIFIC EVENTS

18-23 MARCH	***MICROLOCAL ANALYSIS*** *& ITS APPLICATIONS IN* ***SPECTRAL THEORY, DYNAMICAL SYSTEMS***	MURRAMARANG RESORT, NSW
23-27 APRIL	***TOPOLOGY*** *IN AUSTRALIA & SOUTH KOREA 2018*	POHANG, SOUTH KOREA
4 - 8 JUNE	***INDEX THEORY*** *& APPLICATIONS TO* ***POSITIVE SCALAR CURVATURE*** *& RELATED AREAS*	ADELAIDE UNI
MID-YEAR	AMSI **OPTIMISE** 18	RETURNS 2018
28 JUNE - 6 JULY	***MULTICELLULAR VIRTUAL TISSUES:*** *TOWARDS DRUG DISCOVERY & IMPROVED THERAPIES*	MELBOURNE UNI (CRESWICK)
2 - 13 JULY	AMSI **WINTER** SCHOOL 18	QUEENSLAND UNI
8 - 12 JULY	*2018 ANNUAL MEETING OF THE SOCIETY FOR* ***MATHEMATICAL BIOLOGY***	SYDNEY
15-20 JULY	*AGENT-BASED* ***SPATIO-TEMPORAL STOCHASTIC*** *SYSTEMS IN BIOLOGY*	MELBOURNE UNI (CRESWICK)
26-30 NOVEMBER	*WORKSHOP ON* ***NONLINEAR WAVES*** *IN THE* ***OCEANS***	SOUTHERN QLD UNI (TOOWOOMBA)
28-30 NOVEMBER	***AUTHENTICATION*** *FOR THE FUTURE* ***INTERNET OF THINGS***	DEAKIN (MELBOURNE)

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AMSI RESEARCH

THE UPDATE CREATIVE TEAM

MARKETING & COMMUNICATIONS MANAGER
Mari Ericksen - mari@amsi.org.au

PUBLICATIONS OFFICER
Melissa Trudinger - melissa@amsi.org.au

MEDIA & COMMUNICATIONS
Laura Watson - laura@amsi.org.au

MULTIMEDIA MANAGER
Michael Shaw - mshaw@amsi.org.au

ART DIRECTION
Paul Murphy - paul@amsi.org.au

DESIGN
Agnes Tam - agnes.tam@amsi.org.au
Catherine Tan

AMSI CONTACTS

If you wish to use any content in this publication please contact: **MEDIA@AMSI.ORG.AU**

E - enquiries@amsi.org.au
T - +61 3 8344 1777
W - www.amsi.org.au
F - facebook.com/DiscoverAMSI
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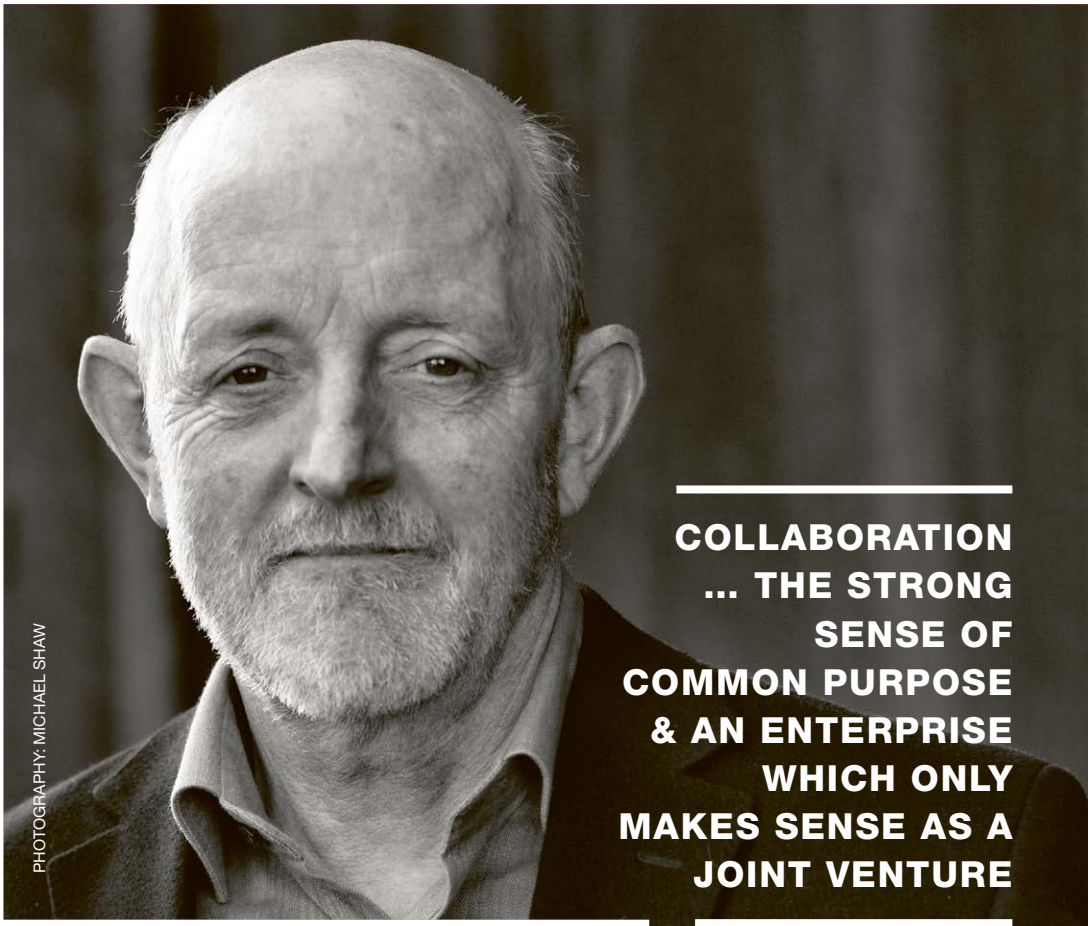
COVER ILLUSTRATION: AGNES TAM



PHOTOGRAPHY: MICHAEL SHAW

COLLABORATION ... THE STRONG SENSE OF COMMON PURPOSE & AN ENTERPRISE WHICH ONLY MAKES SENSE AS A JOINT VENTURE

Collaboration is the focus of this summer's Update magazine. The cover art sums it up beautifully – the strong sense of common purpose and an enterprise which only makes sense as a joint venture.

This edition showcases some of AMSI's collaborations – ChooseMaths and the APR.Intern rebrand, and we feature the latest addition to our flagship research training and industry engagement events, AMSI Optimise. The Minister for Education, Simon Birmingham explains the importance of the Commonwealth's ongoing collaborations with AMSI to securing a 21st century mathematical workforce.

Steve Wright, an eminent Australian expatriate mathematician, talks about his work in optimisation across engineering, computational biology and data science. Steve beats homesickness by visiting often and it was a pleasure to have him at AMSI Optimise.

RMIT's own Asha Rao talks about a life in mathematics, from being a mentor to young mathematicians to engaging with industry. I love her line: "...I believe that if an industry feels that it does not need mathematicians, it means that industry has not really looked for deep solutions to its problems."

We also feature the recent revelations about ancient trigonometry by UNSW mathematicians Daniel Mansfield and Norman Wildberger.

Enjoy a summer read! □

Professor Geoff Prince FAustMS

‘OH THE PLACES WE’LL GO’

Accelerating Mathematics Through Collaboration

By Professor Geoff Prince

National Collaboration in the Mathematical Sciences. We first hit on this messaging during our 2005 rebrand. Reflecting our aspirations, this continues to underpin AMSI’s mission as well as guide my directorship of the Institute.

Behind the phrase is the recognition that our membership can achieve more through collaboration than we can individually. In many cases, AMSI’s partnerships have delivered outcomes that would not have been possible otherwise, for example, Schools initiatives and annual events. In other cases, like the workshop program, these linkages have added a powerful accelerant.

Not surprisingly, we have seen the most impact from our enduring collaborations such as our high-level funding streams. After our engagement with the Commonwealth Department of Education and Training through the International Centre of Excellence for Education in Mathematics in 2004, it became an AMSI collaborator again in 2012 when we co-funded our research training flagship events program with them for four years. This partnership has blossomed with the renewal of the flagship project in 2016 and confirmation of significant funding for the National Research Internship Program being delivered by AMSI’s APR.Intern. It has marked a sea change for the Institute - from applying to existing grant schemes, often successfully, to a genuine partnership where we established a case for action and worked with the funder to deliver solutions.

Collaborations are not always about funding but the power of the collective. While in another category, our collaboration with the Australian Mathematical Society and its ANZIAM division gives us some clues about where to pursue our mission next. Of course, we have a lot of common interests with the Society and we could have divided up the territory and operated independently. However, in 2010 we decided to support each other, equally sharing some activities and leading and following on others. Eight years later and about to renew our vows, we have a rich collaboration which respects our key difference: AMSI has institutional membership and the Society has individual membership. So, for example, the Society provides the objective views of the expert discipline to government and its agencies while AMSI represents the interests of the collective teaching and research enterprise.

While smaller in scale, AMSI continues to grow its partnership with the Statistical Society of Australia. This doesn’t mean that AMSI’s advocacy and support for statistics has been undeveloped but rather that we are still identifying engagement pathways to increase impact. There is no shortage of collaborators of this type: members such as the Mathematics Education Research Group of Australasia, the Academies of Science and of Technology and Engineering, Science and Technology Australia, the Australian Computer Society, the Institute of Physics, Engineers Australia. The opportunities with the peak bodies are surely around bringing coherence to the very noisy STEM environment, whereas the cognate professional and scientific societies bring the opportunity to strengthen the cross-over areas such as theoretical physics, data science and optimisation.

AMSI’s policy priorities extend across the entire mathematical pipeline, as do its partnerships. ChooseMaths, our $22 million partnership project with BHP Billiton Foundation, is a powerful example of industry investment in the classroom. Together, we are working to strengthen Australian’s mathematical capability and foster the engagement of girls and women through mentoring and careers awareness. These national-scale campaigns would not be possible without this funding and the collaboration of many industry and academic partners who continue to lend their time and brand to promote the value of mathematics. Equally, STEM-based industry partners such as Boeing have enabled AMSI to produce a range of multi-media resources to support its education policy objectives.

As I have mentioned, our funding partnership with the Commonwealth Government has been instrumental to the success of a number of our programs. None more so than APR.Intern (formerly AMSI Intern), a program with collaboration at its very core. Working with industry partners, such as Defence Science Technology (DST) Group (see page 11) and Telstra, and our university membership, this program actively creates industry innovation capability in new generations of graduate researchers. At the same time, it builds productive, sustaining collaborations between our university-based researchers and those at innovation’s commercial frontier. With 1400 PhD internships between now and the end of 2020 this partnership will have national impact.

Our greatest collaboration, of course, is with our membership of 30 universities, five agencies and six learned societies. They deliver our flagship events and our research programs and staff our advisory committees and our Board. Their very presence enhances our advocacy and informs our policy base. Whether we are seeking to strengthen learning, discovery or innovation, collaboration is essential to the health and capability of Australia’s mathematical sciences. □

Professor Geoff Prince is the Director of the Australian Mathematical Sciences Institute.

ILLUSTRATION: AGNES TAM

COLLABORATION IN SCHOOLS

Strengthening Maths in the Classroom

By Laura Watson

Arguably M is the most important letter in STEM, with mathematics underpinning our capability to drive science, technology and engineering. Maths is also essential to industry innovation and optimisation to make sense of the opportunities offered by the age of big data.

It is little wonder then that mathematics education is a number one priority for many of our industry leaders. Their impact in the classroom is felt through funding investment, outreach initiatives and mentoring to champion the engagement of a new generation.

Collaboration with partnering schools, education sector stakeholders, community leaders, academia and industry plays a powerful role in delivery of AMSI Schools initiatives. In particular industry investment has significantly bolstered the program's impact at the education frontline, including investment by Boeing to deliver multimedia learning resources and the BHP Billiton Foundation's support of the ChooseMaths project. Partnerships with industry and academia have also been instrumental in the roll out of the project's Careers Awareness campaign and Women in Maths Network.

At a regional level, local industry champions are helping to foster mathematics engagement and careers awareness through their participation in school-based outreach events, such as ChooseMaths Days. These events help students, particularly girls, to make critical connections between mathematics in the classroom and real-life application, highlighting its value as a career pathway.

PHOTOGRAPHY: MICHAEL SHAW

MATHS MENTOR PILOT ENGAGING GIRLS

Australian maths professionals have joined forces with AMSI Schools in a pilot program aimed at strengthening engagement of girls and women.

The 70 mentors are working with 100 Year 9 students across five states as part of the first stage of the Women in Maths Network. Industry leaders represented in the first cohort include BHP, IBM, and the Australian Bureau of Statistics.

Assigned to groups or 'circles' of 10-15 students, the volunteer maths champions are running fortnightly video-conferencing sessions to support learning and foster careers awareness. Access to an online, interactive learning platform is further stimulating discussion as a platform to ask questions, seek advice and explore career avenues.

While still in the early stages, the pilot is already resulting in unexpected collaborations beyond the classroom. The program is proving a powerful support engine for junior mentors who are benefiting from collaboration with their more experienced peers.

COLLABORATION ... PLAYS A POWERFUL ROLE IN DELIVERY OF AMSI SCHOOLS INITIATIVES

Mentoring is a key AMSI policy recommendation as Australia responds to the urgent need to bolster mathematical capability, including through increased engagement of women and girls. In 2016, just 7 per cent of Year 12 girls who participated in advanced maths compared to over 12 per cent of boys.

As the Mentoring program rolls out more widely in 2018, it is hoped more schools will come on board to enable their students to benefit and help tackle the gender divide at the classroom frontline.

CHOOSE**MATHS** Careers Awareness/Awards project officer Susan James with students at a GEM day.

MATHS ON THE MOVE: PUTTING MATHS CAREERS IN THE SPOTLIGHT

Our transport and digital careers awareness campaign set social media alight, as followers reported sightings of AMSI branded trams and buses in their capital city. The push was a follow up of the launch of the ChooseMaths Careers Awareness campaign.

It was exciting to see so many people engage with the campaign, with website visits spiking as Australians discovered how to be 'more than a number with maths'. The powerful adverts featured the inspiring stories of women in maths from health research and computer coding to astronomy, mining and fire management. With at least 75 per cent of Australia's growth employment sectors requiring STEM, keeping your doors open makes a whole lot of sense.

Part of the Australian Mathematical Sciences Institute's $22 million national ChooseMaths project funding by BHP Billiton Foundation, the transport and media advertising was a fun way to keep the careers discussion alive. ⇨

PHOTOGRAPHY: DAVID GERAGHTY / NEWSPIX

St Francis Xavier College students Angelica Fortinez, Sarah Castricum and Toni Solaki take a selfie in front of a tram carrying a sign advertising the CHOOSE**MATHS** careers campaign in Melbourne, Victoria.

CHOOSE
MATHS

AN **AMSI** SCHOOLS PROJECT

DELIVERED BY AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

SUPPORTED BY bhpbilliton Foundation

I am more than a number

I never thought that I would be working in Medical Research, but at University I discovered a world of new areas that interested me. It wasn't an easy road but if you really want something, you'll surprise yourself with how far a bit of hard work and passion can get you.

My name is

Lyndal Henden

Read my story at

CHOOSEMATHS.ORG.AU

PHOTOGRAPHY: BIANCA TURRI

ELDERS VISIT CAPS OFF YEAR OF EXCELLENCE

Indigenous students at Newton Moore Senior High School in Bunbury WA radiated excitement and pride as they demonstrated their latest maths and STEM projects to Head Elder, Dennis Jetta. The visit capped off an exciting year for the school, following Head of Maths, Ashley Stewart's top ChooseMaths Award for Mentoring Girls.

The award including $10,000 for professional development and $10,000 for the school's maths program, honoured Ashley's outstanding work empowering indigenous girls in maths through interactive learning.

Since receiving her award, Ashley has been busy investing in new projects to benefit her students and enhance learning. Her Year 8 indigenous boys benefited from a coding for drawing class delivered by specialists from Perth. She also used part of her prize to run a STEM project with her Year 7 indigenous girls conducting experiments and creating a bike phone charger, as well as individual solar power chargers.

Ashley recently led a STEM project with the Education Support school that is run on the Newton Moore campus. Focused on sustainability, students researched the impact of food waste on the environment, as well as creating biogas digesters to use the food waste. This was presented to the school's principal and administration team as a suggested approach manage school food waste.

The award additionally helped fund a training trip to Malaysia in November, where Ashley and a colleague completed a session with Dr Sheryl Sorby on Developing Student Spatial skills. This will help Ashley and the maths department bridge a gap for girls in relation to STEM skills.

The money also helped bring the Robogals to Newton Moore for a robotics and coding session. This was attended by 30 girls from the school's top two Year 8 maths classes.

Ashley Stewart was one of three main ChooseMaths Teacher Award winners in 2017, with NSW teacher, Keith Barnet winning Outstanding Primary Teacher and Queensland's Patricia Hosking winning Outstanding Secondary Teacher. □

SINCE RECEIVING HER AWARD, ASHLEY HAS BEEN BUSY INVESTING IN NEW PROJECTS TO BENEFIT HER STUDENTS AND ENHANCE LEARNING

A full list of the 2017 Award winners can be found at choosemaths.org.au/2017-award-winners. Further information about the project and its initiatives are at choosemaths.org.au.

OPENING DOORS TO RESEARCH

Hitting the Innovation Fastlane with APR.Intern

By Cate Ballard

Collaboration has always been at the heart of AMSI Intern and its mission to strengthen ties between innovation neighbours research and industry. As the program relaunches as Australian Postgraduate Research Intern, or APR.Intern, National Program Manager Cate Ballard reflects on the program's evolution and impact.

Since its beginnings in 2009 as a small program aimed at giving mathematics PhDs experience in industry, AMSI's intern program has undergone an extraordinary journey of growth and reinvention to emerge as critical player in shaping PhD research - industry engagement.
We have always believed in the program's potential and the value of research-industry collaboration. The challenge for us, as it has been for many others, has been to change how academic research is valued as a pathway to innovation, economic growth and future sustainability and prosperity. This dynamic has changed considerably since our early days.

Our first challenge was to convince industry of the commercial innovation value of mathematics. This meant building confidence in our model and PhD research engagement as a gateway specialist research and development capability, a significant challenge at a time when we had little to offer by way of funding incentives and industry was sceptical about the value of PhDs and the usefulness of this skill repository.

To make our first placements we sold AMSI's convictions, our belief in the program and its merits as a platform to stimulate innovation and commercial linkages to the mathematical sciences. We delivered the impossible and laid the foundations for what would become APR.Intern.

Over time, increased access to a range of funding schemes has changed our structure and scope, and increased the potential of the program. We have built significant partnerships with federal and state governments, funding schemes, and innovation leaders such as Australian Centre for Financial Studies, Australian Sporting Goods Association, CRC for Spatial Information, and the Defence Science Institute. A sign of public sector and commercial confidence in the program, this investment sends a signal about the future innovation workforce and its critical role in securing long-term innovation capability.

Today there is wider recognition of the value and impact of accessing specialist academic research capability. Postgraduates are being seen as a real and critical innovation investment, as companies seek to expand in-house capability. Equally, universities are also turning towards industry and the opportunity to drive high-impact innovation within SMEs and big business.

In an Australian first, a three-year co-investment partnership recently saw us join forces with some of Australia's leading universities. Strengthening industry collaboration, this academic endorsement has led to increased rates of repeat business and long-term collaborations that have seen individual industry partners take on as many as 17 students.

If our journey so far is a guide, the next six years is going to be exciting to watch as we strengthen industry pathways for PhD researchers, enabling the transfer of knowledge, and bringing to light the value of science, technology, engineering and mathematics in realising Australia's global innovation aspirations.

TODAY THERE IS WIDER RECOGNITION OF THE VALUE & IMPACT OF ACCESSING SPECIALIST ACADEMIC RESEARCH CAPABILITY

Providing a taste of what's ahead, our recent partnership with Defence Science and Technology Group will see the placement of 100 interns over four years. These internships will form part of the 1400 placements expected as we deliver the $28.2 million National Research Internships Program. Positioning us as a leader in research-industry internships, this funding signals the Federal Government's confidence in the program and its capacity to expand on a national scale.

For the first time, we are employing people from mathematics departments across the country as Business Development Officers. Deputy Program Manager, Glen Sheldon will also continue to steer key stakeholder relationships within government, industry and academia. Our expanded STEM focus and strengthened collaboration has now positioned us to drive placements from within the mathematical sciences at a time when these skills are needed most in industry. As APR, we will finish what we started in 2009, as we work with industry and academic partners to strengthen industry and community understanding of the importance of mathematics as the foundation of commercial innovation. ⇨

APR]NTERN

RACHEL GEDDES

From big business to SMEs, APR.Intern Business Development Officer, Rachel Geddes has the magic touch when it comes to innovation, research capability and matching specialist research PhDs.

TELL ME ABOUT YOUR ROLE WITH APR.INTERN?

As a Business Development Officer my role is to connect to industry, promote the program and ultimately set up internship opportunities. Generating business opportunities, or the chase as I often deem it, requires face-to-face engagement through symposiums, conferences and networking events. Building industry interest is only half the work. My role also focuses on shaping possible research projects, sourcing appropriate candidates and ensuring the project remains on track. Since I joined the program, I have noticed an increase in industry interest as organisations seek to recruit more skilled postgraduate students into their workplaces, and the opportunities that occur after that are endless.

WHAT ARE YOUR CURRENT AREAS OF FOCUS?

I work heavily in the defence sector, which is booming at the moment in light of significant government investment and the need for constant advancement/reinvention. Other sectors include banking, telecommunications and mining – particularly in data analytics. On a large-scale I am implementing our recent partnership with Defence Science and Technology (DST) Group, which will place up to 100 interns over the next four years. I also continue to engage with long-term partners including ANZ, Telstra and Aurecon, who are now setting up projects outside our usual divisions. Strengthening the program's national reach, a number of my emerging internships are based outside of Victoria. I am also pleased to see some of our bigger industry partners, both corporate and government, committing to larger numbers of interns and on a more regular basis—this is paramount for the future success of the program.

OUR HIGH RATE OF REPEAT PLACEMENTS IS A REFLECTION OF THE PROGRAM'S QUALITY & OUR STRONG RELATIONSHIP MANAGEMENT FOCUS

HOW DO YOU GENERATE NEW OPPORTUNITIES?

The value of the Intern program is that it is a leveraging platform for industry. The program is designed to provide an easy, self-enticing model that removes the barriers that may be holding back organisations from innovating. I often advise our industry partners and academics that APR is the way to pull parties into the research innovation space. Typically, new internships are generated through either word of mouth or as a referral from either a student/academic or university business developer. Our high rate of repeat placements is a reflection of the program's quality and our strong relationship management focus. The program trades on reputation. We have significant repeat business with our industry partners, which is why it is paramount to deliver great service not just until they sign the contract but through the life of the internship. Sometimes discussions with potential industry partners can take a year or more—timing is a factor as is an organisation's resources—so I try to maintain a positive relationship throughout because you never know when they may come around wanting to go ahead.

WHAT ARE THE BENEFITS?

The program allows industry to access expertise otherwise out of reach, and also provides a platform to test potential employees and how well they rise to new challenges. It is also a perfect model for academics keen to expose PhD students to industry challenges. One thing I have noticed from my time at AMSI is that the opportunity to see research applications and/or relevance is key in this transitioning world of research. And at the end of the internship, in addition to receiving the above benefits, we have now formed an industry-university collaboration that paves the way for strengthening engagement in whatever direction the research may lead, be it ARC linkage grants, consulting or more internships! I have also been fortunate to see a number of my interns go on to secure full-time work on the back of their placement. ⇨

PHOTOGRAPHY: MICHAEL SHAW

ADVANCING DEFENCE WITH APR

- PhDS & INNOVATION WIN IN NEW PARTNERSHIP -

The first placements have commenced under the Australian Mathematical Sciences Institute's (AMSI) four-year partnership with Defence Science and Technology (DST) Group The three to six month projects will give 100 of the nation's best and brightest PhDs a career head start at the frontline of national security, with opportunities aimed at demonstrating the value and breadth of defence industry-research innovation. For many of these outstanding PhDs, this chance to build essential industry skills will end in employment.

"Highlighting the breadth of DST Group's research to students and universities, this partnership will help source required capability while generating collaboration," says APR.Intern Business Development Officer Rachel Geddes.

The first PhDs placed will have an opportunity to apply their specialist knowledge and research skills while developing essential industry research experience, with projects based in Adelaide and Melbourne.

As the first of the internships on offer demonstrate, these placements span a range of specialist fields. Current projects include application of Riemann manifold Langevin Monte Carlo methods in risk analysis, machine learning for narrative generation, and the research and development of multiple semi-autonomous systems.

DST GROUP HAS LONG VIEWED APR.INTERN AS THE 'GO TO' FOR ACCESS TO EMERGING SPECIALIST RESEARCH LEADERS

Announced by the Minister for Defence Innovation, the Hon. Christopher Pyne MP, the new partnership is based on a history of collaboration. DST Group has long viewed APR.Intern as the 'go to' for access to emerging specialist research leaders. Previously the defence innovation leader has accepted 17 PhDs to help drive essential research and development projects.

AMSI Director, Professor Geoff Prince who co-signed the memorandum of understanding with Chief Defence Scientist, Dr Alex Zelinsky said the partnership was an important signal of the government's commitment to fostering innovation capacity for the future.

"This partnership will equip some of the nation's brightest minds to drive future commercial innovation. This workforce is essential to secure defence capability and position Australia as a STEM leader."

With a focus on gender equity, the internships are open to eligible STEM PhD students who are Australian citizens. Supported by the Department of Education and Training through the Supporting more women in STEM careers: Australian Mathematical Sciences Institute (AMSI)—National Research Internship Program, the placements will contribute to the 1400 placements expected under this funding agreement.

For more information and to apply for current opportunities, visit aprintern.org.au/dst-internships/

MARK OVENS

APR.Intern Business Development Officer, Mark Ovens talks, industry, research, innovation and placing the nation's brightest PhDs at the NSW innovation frontline.

CAN YOU TELL ME ABOUT YOUR ROLE AND ACHIEVEMENTS AS BUSINESS DEVELOPMENT OFFICER WITH APR.INTERN?

Mainly based in NSW, my role is to identify industry partners with R&D projects and find students to fill those or have university academics match students to their industry partner's projects using the AMSI agreement. It has taken some time in NSW to engage industry partners/ universities to utilise our innovative model placing talented PhD students in R&D projects but we are gaining traction and repeat business. Awareness of our Federal Government funding is helping. My biggest achievements include bringing CBA, Atlassian, MLA, Cisco, CSR and Dolby on board as industry partners. I've also assisted a number of SMEs with internships. In particular, I'm proud of my contribution to Tec.Fit, an SME focused on fashion manufacturing, where we have placed three Interns in nine months and are currently looking for a fourth. Tec. Fit's parent Company, won an AFR award "for Innovation Culture" in September 2017 coming 3/50 organisations.

Currently, I've got interns at MLA, Tec.Fit, Taggle, Lamson, Canon CISRA, Nod, Staybil and SynFlyt and Cisco. I'm also working on finding more interns for CSR, Dolby and Tec.Fit.

HOW DO YOU GENERATE NEW INTERNSHIP OPPORTUNITIES?

I have regular discussions with academics at NSW universities, calling up contacts in government and industry, attending expos, network events, talking to SMEs, referrals and some cold calling. Most internships are industry led, but we need to have a greater awareness and involvement from academics to share their industry partners and use the Intern program. Mathematics, data science, IT, engineering are "hot" through short supply—industry appetite is mainly technology driven, and these companies are constantly trying to stay ahead of their competition. Sometimes, though, it can be hard to get other disciplines to understand what innovation means to them.

OUR PROGRAM PREPARES POSTGRAD STUDENTS FOR INDUSTRY USING A COST-EFFECTIVE MODEL OF INTERNSHIP

WHY SHOULD POTENTIAL INDUSTRY AND ACADEMIC PARTNERS JUMP ON BOARD? WHAT ARE THE BENEFITS?

Firstly, they both need to trust each other, have discussions and see the PhD students as both a critical source of talent and a new pathway to innovation by undertaking research projects that are leading to success. Secondly, universities need to be seeking industry partners as the Government changes their funding – interns are one way. Universities get the opportunity to share their laboratories and bring in-house potential collaborations. Our program prepares postgraduate students for industry whilst using a cost-effective model of internship and it builds into the future of collaboration and an innovative culture.

WHAT ADVICE WOULD YOU GIVE TO POTENTIAL PhD INTERNS? WHY CHOOSE APR.INTERN OVER OTHER PATHWAYS?

Undertake a program before you leave University to increase soft skills, gain experience and demonstrate your employability. Choose AMSI as it's a tried and tested program with over 200 interns placed to date. It's a great experience that often leads to employment.

WHAT DO YOU THINK MAKES AMSI'S APR. INTERN PROGRAM SO SUCCESSFUL IN COMPARISON TO OTHER PROGRAMS?

AMSI has a solid track record in delivering national intern programs and outcomes for students, academics and industry partners over the last 10 years. Everyone wins in the AMSI model, it is trusted and reliable.

PHOTOGRAPHY: MICHAEL SHAW

THE PROGRAM IS A LOW-RISK, COST-EFFECTIVE & RAPID SOLUTION TO TACKLE INNOVATION CHALLENGES

FIONA DRUITT

Former data scientist and researcher Fiona Druitt brings a unique perspective to the Intern business development team.

TELL ME ABOUT YOUR ROLE AND HOW YOU GENERATE NEW OPPORTUNITIES?

At present, I'm managing internships for City West Water, GELI Australia, Cycling Victoria, and Zen Within. I am working on offering internship opportunities within the health and energy sectors. I usually find projects from industry through networking and engagement with channel partners and peak bodies. Often, it's just by word of mouth, but as APR.Intern grows to national scale and more people hear about the program, I foresee things could get quite busy! I also talk to academics and PhD researchers at various meetings and forums at the universities. The APR.Intern program is integrated at the various universities, embedded into the Graduate Research Schools. This makes the process seamless for students, academics and industry because we take care of the administrative details. They don't have to apply to the government for a grant, and we work directly with the universities so that industry partners don't have to.

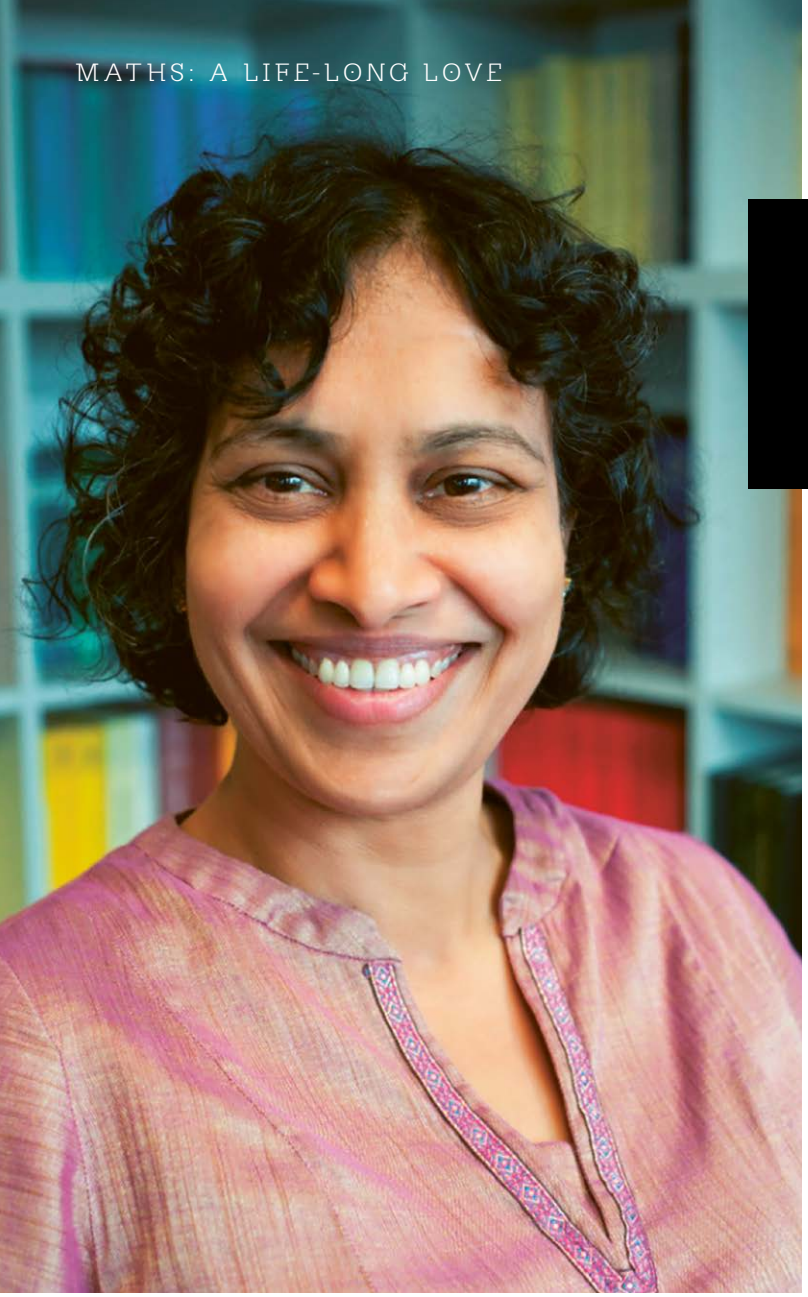
WHAT ROLE CAN APR.INTERN PLAY IN ADDRESSING RESEARCH-INDUSTRY INNOVATION AND STRENGTHENING INNOVATION CAPABILITY?

There's an unmet demand for data science and mathematical optimisation in the market at the moment. Industry partners often tell me that they have trouble finding STEM-trained employees and that they need to recruit from overseas. APR.Intern addresses this supply and demand problem in a couple of ways. We help industry see the value of PhD graduates who are often overlooked by employers unsure whether research training is really what they want or need. Secondly, we better equip researchers to effectively engage with industry and tell them what they need to know. PhD students have determination and skills that are transferable in many other ways, and should be interested in applying their knowledge and skills to real-world problems. The trick is getting industry partners to recognise this on the demand side, while helping PhD researchers to realise that there are interesting, novel and worthwhile research problems to solve in industry too.

WHY CHOOSE APR.INTERN OVER OTHER PATHWAYS?

APR.Intern is unique because it offers the chance to do a genuine research collaboration with industry, instead of just a work placement or work integrated learning. There are no other schemes with national scale that link university researchers to Australian industry partners in a way that respects each of their needs, and in a way that benefits both parties without compromising what's important to each of them. It offers PhD students more than just the chance to find employment quickly (which is no small feat) but to perhaps use their expertise as researchers to create a more innovative, research-orientated job that may not have otherwise existed. This is a unique opportunity. Even if they are planning to pursue academic pathways, having experience of doing linkage or applied research is invaluable. The program's academic impact extends beyond the interns, with mentors reaping significant benefits from new industry collaborations. For industry the program is a low-risk, cost effective and rapid solution to tackle innovation challenges. Our access to specialised research talent and cost structure makes it possible to do research collaborations on small, tightly-focused projects that wouldn't be possible under normal academic consulting arrangements. Industry partners are therefore encouraged to invest in research and development or to just try out whatever it is that they do in new and innovative ways. □

To contact the APR.Intern team, email us at contact@aprintern.org.au or call us on (03)8344-1785. APRintern.org.au.



MATHS: A LIFE-LONG LOVE

Gender Equity & Industry Engagement

RMIT's Associate Dean of Mathematical Sciences, Professor Asha Rao talks about her career, industry collaboration and fostering a new generation of female mathematicians.

HAVE YOU ALWAYS BEEN INTERESTED IN MATHS?

Maths was always easy. As my mum tells me, I had to give an entrance exam for grade 1 (this is common in India), in which I scored 98/100 in maths (and 2/100 for spelling). My parents encouraged me to study, with my mum being the main force – she always insisted that I did the best I could, and that usually meant I had to be near the top in class. Because it was easy, maths was not really a challenge. I did learn early that I needed to put effort into it, else I could not ace it. However, this was never a problem – I preferred doing maths to anything else, except drawing.

WHO WERE YOUR ROLE MODELS AND MENTORS AS A WOMAN ENTERING THE MATHEMATICAL SCIENCES?

I did my master's degree at Bombay University (now Mumbai University). The faculty in the Department of Mathematics at Bombay University had a big gender imbalance – there were almost twice as many female lecturers as male! This meant that I did not find it strange to be female entering mathematical sciences. I just thought it was natural to be female and doing maths.

HOW IS ACCESS TO FEMALE MATHEMATICS ROLE MODELS FOR GIRLS AND WOMEN ENTERING THE DISCIPLINE?

It is very important for female mathematicians to mentor and be role models for not only girls and women entering the discipline, but also males. By being role models for all genders, we will help girls and women to progress better. Strong female role models help boys and men to recognise that their sisters and daughters, and female colleagues and students can be the same. Throughout my career, I have endeavoured to show all students what a strong female role model looks like.

WHAT CHANGES HAVE YOU SEEN SINCE YOU BEGAN YOUR ACADEMIC CAREER?

I have been in academia for almost 25 years and I have seen sporadic changes over that period. Often there are positive bias steps taken, but then there is lassitude within the discipline, and things are allowed to slide. It is almost as if, every generation of women has to

WE SHOULDN'T LOSE SIGHT OF THE VALUE OF INVESTING IN OUR YOUNGEST AUSTRALIANS WHEN IT COMES TO STEM INTEREST

PHOTOGRAPHY : COURTESY OF ASHA RAO

reinvent the wheel. Currently the SAGE initiative is causing universities to advertise and employ women – however this may not be achieving its stated aim of improving the actual number of women, with each university trying to attract females, especially those at higher levels, from other universities.

HOW DOES INDUSTRY BENEFIT FROM ENGAGEMENT WITH THE MATHEMATICAL SCIENCES?

One of the recurring themes is that people do not realise the need for mathematics. They believe it is an esoteric field people pursue to become teachers, a myth that is reinforced by the fact there are no jobs advertised specifically for mathematicians. The only way this myth can be debunked is by industry engagement with the mathematical sciences. There is immense wealth of knowledge within the discipline and to be able to cash in on the new economy, industry will need more mathematicians. Without these skills, the solutions achieved will not be anything more than nibbling at the edges of the problems. I have been involved in projects with a range of industries from SMEs to large companies, working on problems such as biometric applications and insider threats, from countering money laundering to risk management. Every day I find a new venue that needs more mathematicians – indeed I believe that if an industry feels that it does not need mathematicians, it means that industry has not really looked for deep solutions to its problems.

HOW IMPORTANT ARE PROGRAMS LIKE APR.INTERN IN GIVING YOUNG MATHEMATICIANS EXPOSURE TO INDUSTRY?

A program such as APR.Intern allows young mathematicians to experience a real-world setting, as well as demonstrating the need for these mathematicians within industry and the gains that can be made therein. The AMSI program is a very important step toward bridging the gap that seems to exist between the mathematical research that is being in maths disciplines across Australia and industry's perception of the usefulness of this research. As an academic mentor, I have seen young mathematicians explore and become enthused by their time in industry, and come back with fresh ideas and renewed vigour – that they can make a difference. With the existing gender imbalance within industry and academia, involvement by female academic mentors as well as female students is very important, as this will lead to the creation of new role models for industry and for society. □

Professor Asha Rao is the Associate Dean of Mathematical Sciences at RMIT University, a frequent collaborator with industry and a past mentor with AMSI's Intern program.

AMSI OPTIMISE

A FIVE-DAY SYMPOSIUM INSPIRING INDUSTRY & RESEARCH COLLABORATION

OPTIMISING AUSTRALIA

The Next Industrial Revolution

AMSI's newest flagship research training program aims to unite industry and academia in the name of optimisation.

Industry's response to rapid technology advancement and the resulting data deluge is opening new opportunities for cross-disciplinary university research-industry collaboration. Optimisation and the inclusion of AMSI Optimise in the Institute's flagship event calendar make for an exciting time for mathematics.

Launched in June 2017, the event has provided a much-needed platform for industry-research engagement. Run over five days, the three-day conference and two-day workshop aims to foster discussion and stimulate new ideas and opportunities for collaboration. An expansion of the Institute's Securing Australia's Mathematical Workforce project, the event represents an exciting new chapter in the Institute's long-time funding collaboration with the Commonwealth Department of Education and Training.

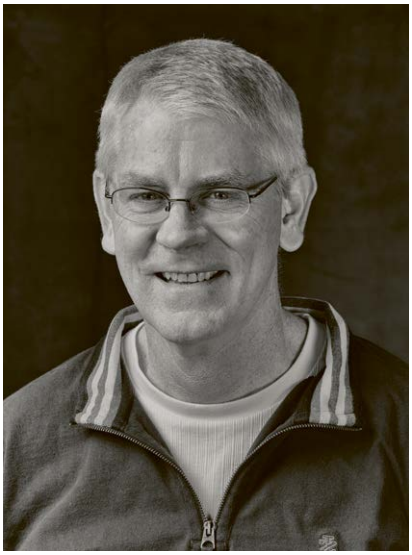
With a strong presence from the Australian and international research communities and industry leaders such as IBM, AGL and Biarri, the launch event explored the application of optimisation to data mining and analytics, strategic planning and operational decision making within the fast-growing energy and transport sectors.

The event has already caught the attention of optimisation stakeholders for its ambitious approach and span of the innovation pipeline, offering a unique chance to explore current applications, future research opportunities and pathways to equip the emerging mathematical workforce for the challenges ahead.

Essential to Australia's future economic competitiveness and security, Optimisation is a critical area for mathematical innovation and AMSI is excited to be helping drive new innovation and secure future capability.

As we prepare for AMSI Optimise 2018, we chat to Professor Stephen Wright and Biarri's Dan Sutherland about optimisation and why Australia needs to be ready for the 4th industrial revolution.

Jointly sponsored by AMSI, the Department of Education and Training, Monash University, Maxima and Optym, AMSI Optimise 2017 was part of the Institute's Securing Australia's Mathematical Workforce project. Other events funded by this project include AMSI Summer School, AMSI BioInfoSummer, AMSI Winter School and the Vacation Research Scholarship Program. For information on AMSI Optimise, visit the website optimise.amsi.org.au.



PHOTOGRAPHY: COURTESY OF THE UNIVERSITY OF WISCONSIN

Optimise keynote speaker Professor Stephen Wright explains how optimisation methods can be applied to the energy sector.

CAN YOU TELL ME A LITTLE ABOUT YOURSELF AND YOUR RESEARCH BACKGROUND?

My research is in algorithms for computational optimisation, and their applications to many areas, including engineering, control, data science, and computational biology.

Optimisation problems arise wherever there is some mathematical model of a situation, and something to be minimised or maximised. In science, the model is often dictated by physical principles, such as the energy associated with the conformation of molecules in a cell; a prediction of the diffraction pattern observed when an x-ray beam is trained on a crystal, or the differential equations that model the dynamics of the atmosphere. Physical principles are the basis of models in engineering applications too, but here we must also model the effects of possible human decisions. An example here is the power flow in an electrical power grid, and how this is affected by changes in demand or by the construction of new capacity in various parts of the grid. In data science, the model is often based on statistical principles, such as when we seek the "most likely" state of an observed system, given the observations that have been made about that system.

I have worked on many applications of this kind. But I also work on more fundamental questions, such as the mathematical properties of the methods that are used to solve these problems – how rapidly they find a solution, how much computation and data movement they require, and so on. I have also worked on software for solving certain key classes of optimisation problems, including linear programming and quadratic programming.

CAN YOU TELL ME A LITTLE ABOUT YOUR RESEARCH AND IN PARTICULAR ITS IMPORTANCE TO ENERGY APPLICATIONS?

Applications of optimisation abound in the energy industry. Take just the electrical power grid, optimisation arises in modelling the flow of power in a grid; in deciding how to design the grid to meet projected demand and make it robust to attacks; in scheduling generators to meet anticipated demands (and possibly respond in a reasonable way to unanticipated demands); in determining the locations of failures in the grid from indirect sensor readings; and in designing well-functioning markets for electrical power. I have worked on several of these problems, which are quite challenging from the point of view of optimisation, in part because they must be solved rapidly in order to be of use to grid operators.

CAN YOU EXPLAIN THE ROLE OF MATHS IN OPTIMISATION, AND THE VALUE FOR INDUSTRY WITH REFERENCE TO ENERGY APPLICATIONS?

Optimisation is a mathematical discipline. It builds on the successes of applied mathematics and statistics, in that these disciplines produce useful mathematical models of physical and information systems that can be used as the basis of optimisation models. Optimisation provides a toolbox of techniques to add features to these mathematical models, which allow the models to be used to make decisions or extract information. Optimisation also provides algorithmic techniques for "solving" the resulting models, obtaining answers that are useful to practitioners.

Energy applications typically involve models with physical and economic components, with many moving parts that interact in complex ways, and many points at which human decisions play a potential role.

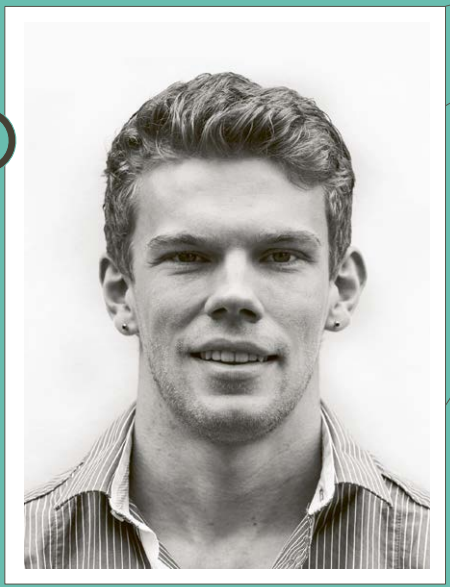
HOW IS THE ENERGY SECTOR LIKELY TO CHANGE IN TERMS OF THE IMPACT OF OPTIMISATION?

Optimisation methods have become highly influential in the research side of the energy sector during the past two decades. In this sector (as in others), engineers and practitioners have become convinced of the usefulness of optimisation as a prism through which to view many of the important problems that arise, and as a source of computational tools for solving these problems. I'm less equipped to say how this influence has propagated into everyday practice, where human factors and other logistical issues arise. For example, in electrical power grids, there are human grid operators that make key decisions regarding shedding load, or regarding bids to supply power to the grid at a certain schedule of prices. In such situations, optimisation tools can play a powerful advisory role, showing the operator the effects of the various decisions they may take and providing them with a "what if" capability.

WHAT RISK DOES AUSTRALIA'S RELATIVELY LOW RATE OF RESEARCH-INDUSTRY COLLABORATION POSE IN TERMS OF HOW WE INNOVATE AND RESPOND TO THE FUTURE?

The optimisation and applied mathematics community in Australia has a great track record in engaging with industry. Several of my colleagues, for example in Newcastle and Brisbane, have been involved in joint projects with the mining and electricity industries, in some cases spanning many years. Such interactions should be encouraged – they help point optimisation researchers toward problem types of practical interest, and thus to guide their fundamental research activities. They can also potentially provide researchers with funding that is sorely lacking the Australian system – funding to support and incentivise students, to support travel to conferences, and to allow them to spend time away from their other academic responsibilities, to engage in the intense, focused intellectual effort that is needed to make significant advances in research. ⇨

Professor Stephen Wright, from the University of Wisconsin, Madison (USA) was one of the keynote speakers at AMSI Optimise in June, delivering two plenary presentations during the week-long event.



Biarri's Energy, Mining and Infrastructure Lead, Dan Sutherland, shares his thoughts on optimisation in the energy, mining and infrastructure sectors.

HOW DOES BIARRI APPLY OPTIMISATION INNOVATION WITHIN ENERGY, MINING & INFRASTRUCTURE (EMI)?

The most frequent way in which we apply our optimisation capability in the EMI sectors is to solve logistics problems. Common examples are FIFO scheduling, maintenance scheduling, transport load consolidation. In addition to the logistics problems common across the three industries, optimisation is also crucial in industry specific problems such as operational mine throughput optimisation, long term mine design and planning and utilities (e.g. water) flow optimisation. The overarching benefits of these optimisations are an increase in safety, productivity and revenue and a decrease in cost and waste.

Recently we have been involved in a number of projects to reduce unnecessary driving and increase efficiency in onshore LNG projects. These focus around the scheduling and prioritisation of work to create an overall reduction in the travel required to do this work while considering constraints such as worker skills and work interactions. In addition to optimisation a key aspect of this work centres around identifying the opportunities for optimisation and where a business process change can unlock further optimisation capability. This has demonstrated an overall decrease of as much as 30 per cent in driving time and distance. The flow on effects of decreasing driving time and distance are increased productivity and increased safety which is a particularly large consideration in these industries.

Biarri has also been involved in underground mining throughput optimisation by optimising the scheduling of loaders and trucks to work in synergy. This has demonstrated an increase in productivity and ultimately revenue through the mine. A long-term customer of Biarri's continually use our water flow model to optimise their capital and operational spend in maintaining and upgrading their water supply network. We're currently undertaking new projects with clients to globally reduce travel and increase efficiency

THE FUTURE IS COMING, THE ONLY THING WE CAN CONTROL IS HOW WE RESPOND TO IT

WHAT WILL WE SEE NEXT? WHAT ARE THE EMERGING CHALLENGES IN EMI OPTIMISATION?

The future is coming, the only thing we can control is how we respond to it. As we move into the 4th Industrial Revolution the Energy, Mining and Infrastructure sectors will need to keep up with the changing environment and new workforce used to this new environment. Being industries with large capital expenditure and costly assets, EMI companies typically make decisions based on long term forecasts and decisions. As the world continues to change at an accelerated rate (it is frequently said that we will see more change in the next 5 years than the previous 30), this will pose a particularly big challenge for the Energy, Mining and Infrastructure sectors.

As we negotiate the changing tides of our world, optimisation and mathematical modelling can provide a framework for data driven decision making for responding to the changing world. Using optimisation for decision making can help change the operating dynamic from "the way it's always been done" to "it's the most efficient way to operate". Having the capability to run scenarios and mathematically model the impact a major shift in environment will make to operations (e.g. a large increase in power demand, or modelling the benefit of drone usage on power line inspection) and establish the most effective response.

I think we'll see a large up take in the use of drone / automated / remote technology. Mines have already started using automated trains, trucks and loaders. The energy sector has already started using drones to inspect assets throughout distributed networks. In the next five years I believe these technologies will become 'table steaks'; they'll be used ubiquitously.

There's also likely to be fundamental shifts in the operating models of some businesses, but what I can't yet tell. All of this will create a confusing environment in which mathematical modelling and optimisation can play a key role in understanding.

WHERE DOES AUSTRALIA'S ENERGY SECTOR LAG IN TERMS OF ITS ENGAGEMENT WITH OPTIMISATION?

The Energy, Mining and Infrastructure sectors are engaging with optimisation as a part of software products or developments. While this is a step in the right direction there is a still a gap in explorative use of optimisation. Collaboration between industry, research and optimisation providers such as Biarri will help to close this gap. However, I see the most important step as the incorporation of mathematics graduates and professionals into these companies to identify and model early opportunities for optimisation (as is done in the financial and meteorological industries).

With the setup of the Australian government growth centres, the industries are well poised to take advantage of research and development opportunities. The Collaborative Project Funds offered by both NERA and METS Ignited (the growth centres for Energy and Mining Equipment, Technology and Services (METS) industries), are already encouraging and providing great opportunity for collaboration between industry, technology providers and research institutions. □

PHOTOGRAPHY: COURTESY OF BIARRI

Biarri is an Australian commercial mathematics company working across a range of industry sectors to assist companies with optimisation and other maths-based problems.

SECURING AUSTRALIA'S MATHEMATICAL WORKFORCE

By Senator the Hon. Simon Birmingham

One of the biggest challenges Australia faces and a key focus of mine as Federal Education and Training Minister is ensuring Australians are getting the knowledge and skills to meet our present and future workforce needs.

With technology progressing at rapid knots, the changing nature of our industries and the fact that three in four of the fastest-growing occupations need skills in STEM it is more important than ever that we are building an agile and flexible workforce.

This is a key driver behind the Turnbull Government's National Innovation and Science Agenda (NISA). NISA has a key focus on skilling our workforce for the future as well as playing a vital role in promoting co-investment and collaboration in research so that promising ideas come to fruition and deliver social and economic benefits to all Australians.

A demonstration of this is the Turnbull Government's ongoing collaboration with the Australian Mathematical Sciences Institute (AMSI).

For example, the Turnbull Government is supporting the Securing Australia's Mathematical Workforce (SAMW) project which aims to secure a pipeline between universities and jobs in mathematical sciences. It seeks to inspire students in preparation for research careers and specialist roles in the industry, as well as contributing to their current studies and research projects.

The AMSI Summer and Winter Schools, funded under SAMW are also incredibly valuable in increasing the mathematics skills of participants through courses and lectures provided in collaboration with industry.

The Turnbull Government is also providing $28.2 million to AMSI over four years to support 1400 new industry internships through a nationally expanded PhD industry internships program, with a particular focus on increasing female students' participation in STEM.

We know female participation in science and mathematics has declined and initiatives such as this are giving students more choice and opening up new career paths. These industry-based internships for PhD students provide work experience in commercial research environments and will enhance students' entrepreneurial skills and work-readiness.

We are also fully focused on boosting the number of Indigenous, regional, remote students undertaking STEM subjects. I recently launched 1200 new scholarships for regional and rural students to attract them to STEM university subjects to ultimately improve educational attainment, skills development, and employment opportunities for students from these areas.

We shouldn't lose sight of the value of investing in our youngest Australians when it comes to STEM interest. There is no doubt that the more engaged our youngest learners are in STEM, the better chance we have of leading them down pathways in these fields. That's why the Turnbull Government is also investing $64 million in early childhood and school-level STEM programs to boost opportunities and participation in STEM subjects in our schools.

There is no doubt that our future workforce will look very different to what it does today, but together with organisations like AMSI we are working hard to ensure this generation and the next have the skills they need to succeed in the future. □

PHOTOGRAPHY: COURTESY OF THE DEPARTMENT EDUCATION AND TRAINING

WE SHOULDN'T LOSE SIGHT OF THE VALUE OF INVESTING IN OUR YOUNGEST AUSTRALIANS WHEN IT COMES TO STEM INTEREST

Senator the Hon. Simon Birmingham, Minister for Education and Training.

THE CHANGING HISTORY OF MATHS

Ancient Tablet Reveals Babylonian Trigonometry Beginnings

By Laura Watson

You'd be forgiven for thinking that it was an airport thriller, perhaps the latest Dan Brown: an ancient civilisation, a broken tablet, mysterious numbers, and a long-forgotten form of trigonometry.

However, you won't find this story on the shelves but in *Historica Mathematica*. Two University of New South Wales mathematicians have challenged the origins of trigonometry in an explosive paper, *Plimpton 322 is Babylonian exact sexagesimal trigonometry*.

With 15 rows of complicated Pythagorean triples written in the Babylonian sexagesimal (base 60) arithmetical system, missing columns and rows, and curious errors, Plimpton 322 has been the subject of decades of intense scholarship. Lecturer Dr Daniel Mansfield and Professor Norman Wildberger are among the many drawn to its mysteries. Their theory was born from a routine discussion following Daniel's explanation of the tablet to his first year Linear Algebra class.

"Daniel and I started talking about Plimpton 322 and it occurred to us that it might have something to do with the Rational Trigonometry theory that I had written a book about earlier. It turns out that we were much more correct than I could have wished," says Professor Wildberger.

To understand the enormity of the pair's theory and its potential impact, you need to first understand the geometrical thinking behind Plimpton 322. The world's first trigonometry bears little resemblance to the more familiar application of angles to triangles.

"It is unlike anything we have today. There are no angles and no approximations. The Babylonians thought of a right triangle as half a rectangle, and used the ratio of sides to measure steepness. Concepts such as sin, cos and tan of an angle are out," explains Dr Daniel Mansfield.

"They measured fields, built temples, palaces and canals– so why should we presume that this advanced society did not have a trigonometry of some kind?" he says.

Wildberger agrees, citing the Old Babylonian notion of *ukullu*.

"This measure is similar to *seked*, a ratio based on the Egyptian length measure of the royal cubit. Run over rise, the reciprocal to our slope, it was used to describe the steepness of pyramids," Wildberger explains.

But this is not the first time that Plimpton 322 has made headlines. In 1945 the tablet showed us something new about the origins of another ancient discovery.

FIGURE 1

"Plimpton 322 showed that the Babylonians understood Pythagoras' theorem more than 1000 years before Pythagoras. This suggests that a lot of other Greek innovations may have had their origins in earlier Mesopotamian understandings," says Wildberger.

The impact of these findings on our understanding of mathematics is significant. Trigonometry as we know it began with Hipparchus in the 2nd century BC. But Plimpton 322 shows us that there is a much older, more precise way of thinking about trigonometry.

"The traditional way to study triangles uses angles. In his book, Norman showed that triangles can also be studied using ratios alone. Then we discovered that this is what the Babylonians were doing in this tablet," says Mansfield.

The ordering of the Plimpton table is also significant, however, Mansfield urges caution in using this to draw conclusions the table is trigonometric. An argument must give careful thought to the historical context.

"Plimpton 322 enumerates shapes of right triangles which are decreasing at roughly uniform intervals, so it is easy to conclude the table is trigonometric. But saying it is about sin, cos and tan is fatal because the concept of angle did not exist at the time it, Plimpton 322, was written," Mansfield explains.

One of the challenges for many mathematicians, according to Wildberger, is that the table brings into question so much that is assumed not only about geometry but arithmetic and computation.

"Plimpton 322 is not only the world's first trig table, but remarkably the only complete exact table! We are so used to thinking of trigonometry as an approximate science that it is hard for us to fathom an exact approach," he says.

With less than 200 years of discovery to draw from, there is still a great deal we don't know about this mysterious ancient culture and its contribution to mathematical and scientific understanding. Like many of our favourite fiction series, what's in the sequel may prove even more exciting.

"We have some good ideas about other directions for Old Babylonian research,

THE BABYLONIANS UNDERSTOOD PYTHAGORAS' THEOREM MORE THAN 1000 YEARS BEFORE PYTHAGORAS

particularly into the question of how they managed to perform such advanced arithmetic," says Wildberger.

With the application of mathematics to history a rich and under-developed research area, Mansfield confirms the pair have their sights on how Babylonian computation might have something to teach us.

"I've always been attracted to logic in both history and mathematics. However, logic alone is not sufficient. You also need to understand the spirit of the subject to guide your reasoning – then the subject comes to life," says Mansfield.

It is clear that in this quest to solve the mysteries of the Plimpton 322, the spirt of this ancient culture is as vital to understand as the mathematical legacy they left behind. □

You can read the full paper published in Historia Mathematica. Daniel F. Mansfield, N. J. Wildberger. Plimpton 322 is Babylonian exact sexagesimal trigonometry. Historia Mathematica, 44(4), November 2017, Pages 395-419.

THE UNSW MATHEMATICIANS

DR DANIEL MANSFIELD

Daniel Mansfield is a Lecturer in the School of Mathematics and Statistics at UNSW Sydney. He is an award-winning educator who was voted as UNSW's most inspiring first year lecturer in 2017. He has a passion for improving mathematics education, especially in schools.

PROFESSOR NORMAN WILDBERGER

Professor Norman Wildberger of the School of Mathematics and Statistics at UNSW Sydney has done research in harmonic analysis, combinatorics and hyperbolic geometry. He has written a book on Rational Trigonometry, and is also a keen YouTube educator, with his own channel Insights into Mathematics.

FIGURE 1: WHAT IS PLIMPTON 322?

The clay tablet Plimpton 322 is named after George Arthur Plimpton, who bought it from Edgar Banks in about 1922 and later bequeathed it to Columbia University. It measures 12.7 cm by 8.8 cm, and based on a comparison of writing styles with other Babylonian tablets, has been dated to between 1822 and 1762 BC, which is the time of the Babylonian king Hammurabi.

It has four columns and 15 rows of numbers. Vertical column lines are also drawn on the back of the tablet, which is otherwise empty.

In 1945, the Austrian mathematician Otto Neugebauer and his associate Abraham Sachs noted that Plimpton 322 has 15 pairs of numbers forming parts of Pythagorean triples, meaning three whole numbers a, b and c such that $a^2 + b^2 = c^2$. The integers 3, 4 and 5 are a well-known example of a Pythagorean triple, but the values on Plimpton 322 are often considerably larger with, for example, the first row referencing the triple 119, 120 and 169.

FIGURE 2: TRANSLATING PLIMPTON 322 INTO MODERN MATHEMATICAL TERMS

Mansfield and Wildberger have built on previous research to present new mathematical evidence suggesting there were originally 6 columns, and that the tablet was meant to be completed to 38 rows. They also present the most likely method of construction of the tablet.

The table below lists the numbers in the first 11 rows of this completed form of Plimpton 322, written in our decimal number system, approximated to eight decimal points. (For more rows see the published paper).

The completed tablet contains the three ratios of sides of right-angle triangles – but written exactly using the Babylonian base 60 place value system. A known ratio of sides of a right-angle triangle could be compared to these lists to work out the unknown ratios.

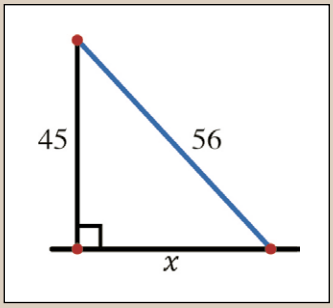
The table describes the shapes of right-angle triangles with base b, long side l, and diagonal d, where in all cases l is a regular number in their system, with only factors 2, 3 and 5.

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
ß = b/l	δ = d/l	δ^2	base b	diagonal d	Row number
0.99166666	1.40833333	1.98340277	119	169	1
0.97424768	1.39612268	1.94915855	3367	4825	2
0.95854166	1.38520833	1.91880212	4601	6649	3
0.94140740	1.37340740	1.88624790	12709	18541	4
0.90277777	1.34722222	1.81500771	65	97	5
0.88611111	1.33611111	1.78519290	319	481	6
0.84851851	1.31148148	1.71998367	2291	3541	7
0.83229166	1.30104166	1.69270941	799	1249	8
0.80166666	1.28166666	1.64266944	481	769	9
0.76558641	1.25941358	1.58612256	4961	8161	10
0.75	1.25	1.5625	45	75	11

COLUMN 1 - contains the exact ratio b/l. | COLUMN 2 - contains the exact ratio d/l. | A modern trigonometric table would also contain the ratio b/d or d/b. But this ratio could not be written exactly by the Babylonians in base 60. So, to maintain the exact nature of the table, they split this ratio into three parts. | COLUMN 3 - contains the exact ratio $(d/l)^2$ and was used as an index into the table when b/d or d/b was already known. | COLUMNS 4 & 5 - contain the numbers b and d with common factors removed and was used so the scribe could construct their own approximation to b/d or d/b. | COLUMN 6 is just the row number

FIGURE 3: USING THE PLIMPTON 322 TABLE

Suppose that a ramp leading to the top of a ziggurat, or stepped pyramid, is 56 cubits long, and the vertical height of the ziggurat is 45 cubits. What is the distance x from the outside base of the ramp to the point directly below the top?



Solution using Plimpton 322:

For this right-angle triangle, l = 45 and d = 56.

This means δ = d/l = 56/45 = about 1.2444.

On the tablet, the closest value of δ in column 2 is found in row 11, where δ = 1.25.

From columns 4 and 5 in row 11 you can work out that the corresponding ratio for this triangle is b/d = 45/75 = 3/5 = 0.6.

Thus x approximately equals 56 x 0.6 = 33.6

Using a calculator today, we can determine that x approximately equals the square root of (562 – 452) which is approximately 33.3317.

The UNSW mathematicians show the Babylonian approach, which avoids calculating square roots, was more accurate than a trigonometric sine table approach devised by the Indian mathematician Madhava more than 3000 years later.

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IN THE MATHEMATICAL SCIENCES

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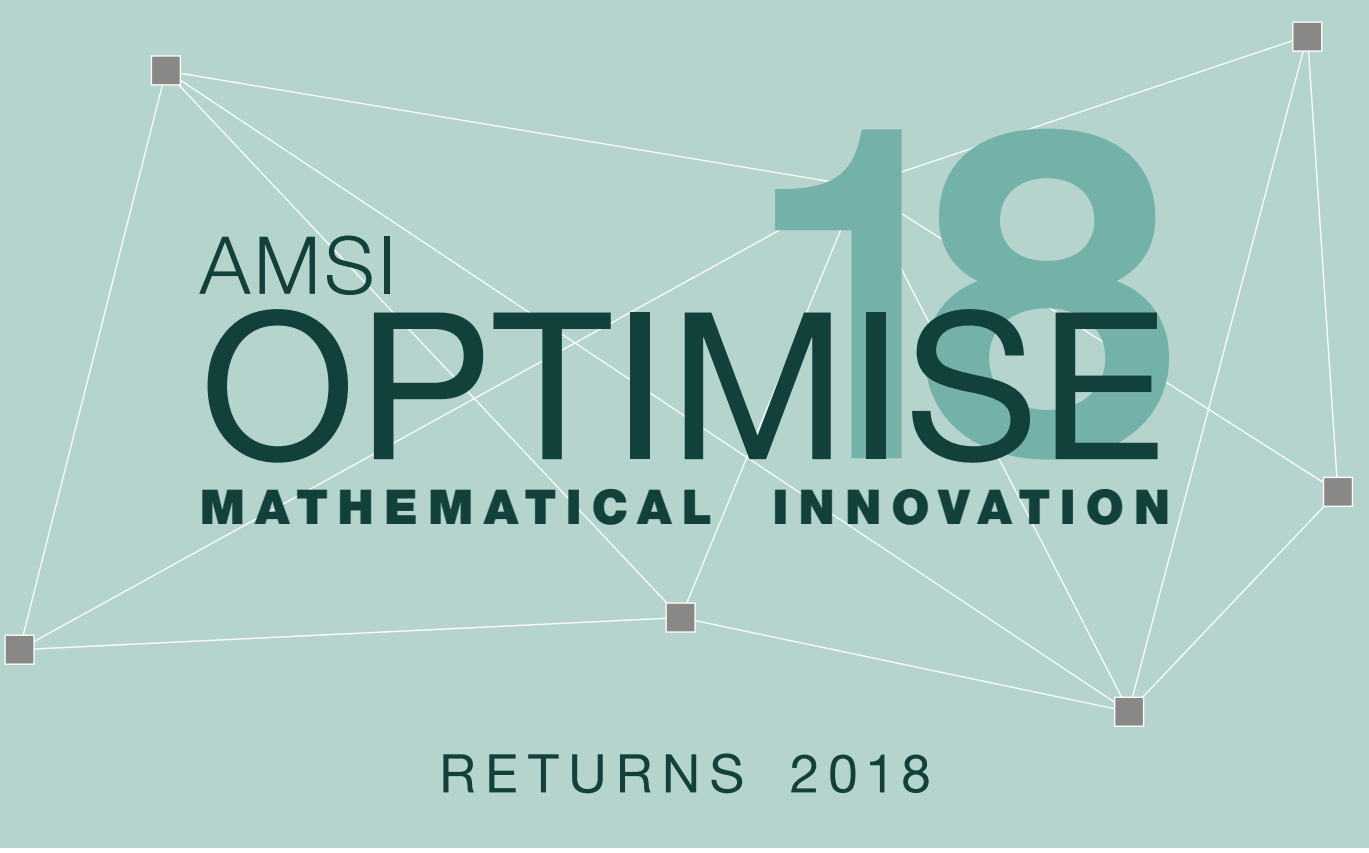

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