

ANNUAL REPORT

2016

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Australian Government
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COLLABORATORS



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To create world-class research at the **FRONTIERS**
of the **MATHEMATICAL SCIENCES** dealing with

PROBABILITY AND RANDOMNESS

and to translate this research into **NEW INSIGHTS**
that **BENEFIT SOCIETY**



CONTENTS

4	ABOUT ACEMS	75	ACEMS RESEARCH PROGRAM 2015–2017
5	CHAIRMAN'S REPORT	78	CROSS-NODE COLLABORATION
6	DIRECTOR'S REPORT	80	MENTORING ACTIVITIES
10	2016 HIGHLIGHTS	86	EDUCATION AND TRAINING
12	STRUCTURE, GOVERNANCE AND MANAGEMENT	87	SPONSORSHIPS
19	STRATEGIC PLAN 2016–2020	90	COMMUNICATIONS AND MEDIA REPORT
22	2017 PLANS: THE YEAR AHEAD	92	NATIONAL AND INTERNATIONAL ENGAGEMENT
26	PERSONNEL	97	NATIONAL AND INTERNATIONAL VISITORS
31	PERSONNEL CHANGES	100	NATIONAL AND INTERNATIONAL RESEARCH WORKSHOPS AND CONFERENCES
34	STAFF AND STUDENT RECOGNITION: PRIZES AWARDS AND OTHER PRESTIGE MEASURES	110	STAKEHOLDER ENGAGEMENT REPORT
36	STUDENT AND EARLY CAREER RESEARCHER RECRUITMENT AND COMPLETION	124	COMMERCIALISATION AND TECHNOLOGY TRANSFER
40	CHIEF INVESTIGATORS	126	OUTREACH REPORT
48	RESEARCH THEMES OVERVIEW	136	INFRASTRUCTURE
50	THEME 1: CHALLENGING DATA	138	MEDIA RELEASES AND MEMBERS IN THE MEDIA
57	THEME 2: MULTISCALE MODELS	144	2016 KEY PERFORMANCE INDICATORS
64	THEME 3: ENABLING ALGORITHMS	152	PUBLICATIONS
70	THEME 4: INFORMED DECISIONS	160	GRANTS AND OTHER RESEARCH INCOME
		163	FINANCES



14 HELPING SAVE JAGUARS WITH A VIRTUAL PERUVIAN JUNGLE



24 UNDERSTANDING RARE EVENTS: SIMULATING RARE DISEASE OUTBREAKS AND POWER BLACKOUTS



38 STAYING TRUE TO THE DETAIL IN BIG DATA



54 PLUGGING THE GAPS IN MISSING DATA



62 NEW STATISTICS HELP PREDICT WHEN CORALS ARE MOST VULNERABLE



68 FROM FUTURE STOCK PRICES TO CORAL BLEACHING: MODELLING RANDOMNESS AND INTERDEPENDENCE



76 SAFER DRUG SCREENING AND BETTER SIMULATIONS: MATHS GETTING TO THE HEART OF THE MATTER



82 THE FUNCTION WITH A \$1 MILLION BOUNTY ON ITS HEAD

CASE STUDIES

- 14** HELPING SAVE JAGUARS WITH A VIRTUAL PERUVIAN JUNGLE
- 24** UNDERSTANDING RARE EVENTS: SIMULATING RARE DISEASE OUTBREAKS AND POWER BLACKOUTS
- 38** STAYING TRUE TO THE DETAIL IN BIG DATA
- 54** PLUGGING THE GAPS IN MISSING DATA
- 62** NEW STATISTICS HELP PREDICT WHEN CORALS ARE MOST VULNERABLE
- 68** FROM FUTURE STOCK PRICES TO CORAL BLEACHING: MODELLING RANDOMNESS AND INTERDEPENDENCE
- 76** SAFER DRUG SCREENING AND BETTER SIMULATIONS: MATHS GETTING TO THE HEART OF THE MATTER
- 82** THE FUNCTION WITH A \$1 MILLION BOUNTY ON ITS HEAD

MEMBER STORIES

- 9** TWO BIG AWARDS FOR ACEMS ASSOCIATE INVESTIGATOR JOSHUA ROSS
- 18** TWO MAJOR AWARDS AND A NEW TITLE FOR ACEMS DEPUTY DIRECTOR KERRIE MENSERSEN
- 23** FROM UTS, TO GOOGLE, TO HARVARD – AN ACEMS STUDENT'S AMAZING JOURNEY
- 37** ACEMS RESEARCHER RECEIVES PRESTIGIOUS AWARD FROM THE UNIVERSITY OF MELBOURNE
- 47** ACEMS STUDENT ALREADY BUILDING CROSS-NODE COLLABORATION
- 101** MIXING MATHS AND ECONOMICS TURNS OUT TO BE THE RIGHT FORMULA FOR MELBOURNE ACEMS STUDENT
- 123** ACEMS STATISTICIAN GETTING THE BEST OF BOTH WORLDS AS SHE TEAMS WITH ACEMS PARTNER ORGANISATION

OTHER FEATURES

- 56** RELEASE OF 10-YEAR MATHEMATICS PLAN FOR AUSTRALIA
- 84** BIG DATA ANALYTICS MOOC
- 88** GENDER IMBALANCE
- 99** MIT PROFESSOR HIGHLIGHTS ACEMS WORKSHOP
- 102** MATRIX
- 104** ACEMS MEMORIAL CONFERENCE TO HONOUR PROFESSOR PETER HALL
- 106** MATHSCRAFT: DOING MATHS LIKE A RESEARCH MATHEMATICIAN
- 108** THE NATIONAL SCIENCE QUIZ
- 117** 'DRY DIVE' THE GREAT BARRIER REEF
- 118** ENGAGEMENT TASK FORCE
- 120** PATHWAYS TO IMPACT
- 132** ACEMS ANNUAL RETREAT
- 134** ACEMS STUDENT RETREAT

ABOUT ACEMS

THE AUSTRALIAN RESEARCH COUNCIL (ARC) CENTRE OF EXCELLENCE FOR MATHEMATICAL AND STATISTICAL FRONTIERS (ACEMS) BRINGS TOGETHER LEADING AUSTRALIAN APPLIED AND THEORETICAL RESEARCHERS IN THE FIELDS OF MATHEMATICS, STATISTICS, MATHEMATICAL PHYSICS AND MACHINE LEARNING.

Today's world collects a massive amount of data via a multitude of sources daily. Much of this data may be in 'non-traditional' forms such as images, fragments of mathematical functions or more complex mathematical objects, histograms, text or social network interconnections. Many of the resulting data sets have the potential to make vital contributions to society, business and government, as well as impact on international developments, but are so large or complex that they are difficult to process and analyse using traditional tools.

ACEMS brings together for the first time a critical mass of Australia's best researchers in applied mathematics, statistics, mathematical physics and machine learning, with partner researchers to engage in research programs that combine innovative methods for the analysis of data with theoretical, methodological and computational foundations provided by advanced mathematical and statistical modelling. ACEMS will focus on the impact of new insights for end users working in the Collaborative Domains of Healthy People, Sustainable Environments and Prosperous Societies.

Originally ACEMS organised its research into three research programs:

- Big Data—which uses mathematical, statistical and machine learning tools to analyse data characterised by volume, variety, velocity and complexity

- Big Models—which develops new theories, methodologies and implementations that underpin predictive models required to interpret and utilise big data
- New Insights—which bridge the gap between theory and practice by providing solutions to problems driven by cross-organisational and cross-disciplinary collaboration, using big data and big models

An initial objective of ACEMS was to unify the programs by emphasising:

- Globally innovative research and research leadership across the discipline spectrum;
- Integration and translation, bridging theory and practice so that the research programs are motivated by and inform the Collaborative Domains for real world impact; and
- Training the next generation of quantitative researchers integrating technical expertise, industry exposure and high-level cross-disciplinary and scientific communication skills.

During 2016, ACEMS decided that the optimal way to achieve this was by reorganising its 'Big Data' and 'Big Models' research programs into four themes:

- Challenging Data
- Multiscale Models
- Enabling Algorithms
- Informed Decisions

The 'New Insights' program has remained to focus applications comprising the three Collaborative Domains.

The synergy of the Centre's compelling research programs, together with its strong collaborations, both domestically and internationally; its composition, management and governance arrangements; and research, training and translation strategy; mean that ACEMS will deliver real value for money as well as make a transformative contribution to Australian research in mathematics, statistics, mathematical physics and machine learning.

CHAIRMAN'S REPORT

ACEMS IS A VITAL PART OF THE FABRIC OF AUSTRALIA'S RESEARCH CAPABILITY, ADDRESSING AS IT DOES SOME OF THE CHALLENGING AND AS YET UNANSWERED QUESTIONS THAT SURROUND "BIG DATA".



One of the design features of ACEMS is the blend of theory development coupled with genuinely challenging applications. In part this design feature was a by-product of the Centre's genesis as the fusion of two proposals put to the ARC. I believe that these convergent themes will continue to bring depth and strength to the Centre's programs, fostering both research excellence and genuine impact.

As Chair of the Centre's Governance Advisory Board one of the perks of the position has undoubtedly been the opportunity to engage with researchers from the Chief Investigators through to the postgraduate students.

The Chief Investigators represent the cream of the crop of Australian researchers engaged in both the theoretical and applied components of the Centre's work. In a series of discussions at the ACEMS Retreat held at UTS in November 2016 I was impressed with their understanding that, for the Centre to be successful, the whole must be greater than the sum of the parts. Indeed, the demonstration of this in practice is near the top of the ARC's requirements of the Centre. Embracing the essence of this challenge is of course a big ask for researchers who have already reached the pinnacle of their careers.

In similar discussions with the postgraduate students I was struck by a number of things. The first was the gender balance and ethnic diversity of the group. The second was the respectful way they listened to their colleagues as they spoke; the responses came from virtually everyone in the room. But the best thing of all was the clarity with which they saw the mission of ACEMS and understood the benefits of working in such an environment (as opposed to working as an individual cloistered in a single department). It will be wonderful to follow these students as they move through into careers in academia, research institutions and industry. They will wear the badge of ACEMS training that will serve them and Australia well in the future.

Dr Ron Sandland

Chair, ACEMS Governance Advisory Board



DIRECTOR'S REPORT

THE YEAR 2016 TURNED OUT TO BE A YEAR OF LOSS AND RENEWAL FOR ACEMS. ITS FOUNDING DIRECTOR PETER HALL WAS ALIVE AT THE BEGINNING OF 2016 AND HE IS NOT NOW. IN ADDITION, OTHER KEY ACEMS STAFF, NOTABLY CHIEF OPERATING OFFICER (COO) TANIA SMITH AND CHIEF INVESTIGATOR (CI) JOHN GEWEKE, DEPARTED.

It is appropriate here for me to acknowledge the contributions of all who played a part in the initial development of ACEMS, especially those who have moved on. In particular, I wish Tania and John all the best in their future endeavours.

On the other hand, ACEMS acquired many new members in 2016, including a new COO Emily Duane and two new CIs, Scott

Sisson from the University of New South Wales and Kate Smith-Miles of Monash University, as well as confirming Tim Garoni as a permanent CI. As it happens, Scott and Kate have been recently appointed as, respectively, President of the Statistical Society of Australia and President of the Australian Mathematical Society. Put together with their many other achievements, this underlines the leadership quality that ACEMS has managed to add. Indeed, Scott is already on the ACEMS Executive Committee in the capacity of Deputy Director (Communications and Media).

A consequence of Kate and Tim joining is that Monash University has become ACEMS' seventh node. ACEMS now has five two-CI nodes (the Universities of Adelaide (UoA), Queensland (UQ) and New South Wales (UNSW), together with the University of Technology Sydney (UTS) and Monash University (MU)) in addition to the Central nodes, The University of Melbourne (UoM, with four CIs) and Queensland University of Technology (QUT, with five CIs).

In December 2016, ACEMS, along with UoM and the ARC, sponsored a conference in Peter Hall's honour. Arguably this conference attracted the most distinguished list of invited speakers in statistics that has ever been assembled in Australia. The conference also coincided with the renaming of the building that houses UoM's School of Mathematics and Statistics as the Peter Hall Building. This is an honour that was entirely appropriate for someone who made such a massive contribution to the discipline of statistics, both in Australia and worldwide.

The conference demonstrated something that is very important - that we can move forward to great things even when celebrating departed

friends and past achievements. Speaker after speaker stood up and explained the background to an open problem that they had started to discuss with Peter, or were intending to discuss with him. People in the audience contributed their ideas and groups assembled to take the discussions forward. By the time the final day of the conference came around, I was confident that new collaborations would form and much new and significant research would occur as a result of the interactions that took place.

This reflects a reality that applies to ACEMS more generally. Despite the losses that I mentioned above, ACEMS is moving forward very well: members are getting to know each other, instigating new research collaborations, and making connections via outreach, stakeholder engagement, publicity and mentoring activities. All this augurs well for the future. We can anticipate with confidence that ACEMS is going to deliver all the things that a Centre of Excellence should deliver.

The original ACEMS proposal was based on the premise that one of the obstacles to making use of the massive amount and variety of data that is available in today's society is the lack of adequate communication between the various disciplines working in this field. The way in which applied mathematicians, statisticians, mathematical physicists and machine learners tackle problems can be discipline-specific, with each area evolving its own body of theory, methods and computational algorithms. The vision for ACEMS was that

“We can anticipate with confidence that ACEMS is going to deliver all the things that a Centre of Excellence should deliver.”

PROFESSOR PETER TAYLOR

it should change this paradigm: to create a forum for collaboration and knowledge transfer across the disciplines, and to foster a generation of researchers for whom the traditional discipline barriers are much more permeable.

The first two years of the Centre has seen marked progress towards achieving this goal. ACEMS' original list of research projects tended to be disparate and focused on the interests of individual researchers. However, they have since been opened up to the general ACEMS community, providing new avenues for communication and collaboration that would not have occurred without the Centre. This has overflowed into the research projects being undertaken by ACEMS postgraduate students and postdoctoral fellows, who are increasingly utilising cross-disciplinary ideas and techniques to form novel, blended approaches to theory, methods, computation and application.

We believe that this is a seminal achievement in the Australian mathematical sciences community. It points the way to the development of the research program over the next stage of the Centre. Recognising this change, the ACEMS Executive Committee decided in 2016 to refocus the original research projects and programs of the Centre into four 'Research Themes'. These Themes are consistent with the Centre's original pillars of 'Big Data', 'Big Models' and 'New Insights', but they more accurately reflect the current collaborative efforts of ACEMS researchers and the sustained and emerging global challenges in this field.

Specifically:

- the 'Big Data' and 'Big Models' pillars have been collected into the Research Themes; 'Challenging Data', 'Multiscale Models', 'Enabling Algorithms' and 'Informed Decisions';
- the 'New Insights' pillar has remained to focus applications within its three Collaborative Domains 'Healthy People', 'Sustainable Environments' and 'Prosperous Societies'.

This refocus is explained in detail on [pages 48-49](#).

Research is, of course, the core activity of ACEMS. However ACEMS also takes its Stakeholder Engagement, Outreach, Media and Capacity Building activities very seriously. To this end, it employs a Stakeholder Engagement Officer, an Outreach Officer and a Communications and Media Officer to help the general ACEMS membership participate in these activities.

During 2016, the part-time Stakeholder Engagement position at the QUT node was upgraded to a full-time position, now occupied by Jessie Roberts. The part-time Outreach Officer position at the QUT node was transferred to the UoM node, where it is currently held by Anita Ponsaing. Tim Macuga's Communications and Media Officer position at the QUT node has remained in place, but it has been supplemented by an extension of QUT node administrator Claudia Deasy's role, specifically to support an upgrade of ACEMS' website.

A report on all of ACEMS' Stakeholder Engagement Activities can be found on [pages 110-116](#). In brief, Jessie Roberts was specifically tasked with coordinating liaison with ACEMS Partner Organisations; the Australian Bureau of Statistics, CSIRO, the Australian Institute of Marine Science, the SAX Institute, Mitacs, VicRoads and AT&T. Despite having to deal with some difficulties, most notably changes in personnel in the Partner Organisations, Jessie has been assiduous in this role. She has also put considerable effort into developing an Industry Affiliate Program with organisations that might want to engage with ACEMS on a medium term basis, as well as pointing ACEMS researchers to successful short term projects. During 2016, the Australian Institute of Sport, the Australian Red Cross Blood Service, the Australian Agricultural Company, the Australian Tax Office and the Cancer Council Queensland all participated in the Industry Affiliate Program.

In its first two years, ACEMS has involved itself in a number of outreach activities

- to the mathematics and statistics community,
- to schools, and
- to the general community.

Examples of outreach to the mathematics and statistics community include ACEMS' support for the MATRIX research institute at Creswick ([described on pages 102-103](#)), support for conferences and workshops across the mathematical science community ([see page 87 and page 100](#))

and provision of training courses on specific topics (page 86). One such is the FutureLearn 'Big Data Analytics' courses created by ACEMS members at the QUT node (pages 84-85).

Outreach to schools included visits to regional schools, engagement with CSIRO's 'Mathematicians in Schools' program and support for the 'Doing Maths like a Mathematician' program, coordinated by ACEMS Affiliate Member Anthony Harradine, together with Outreach Officer Anita Ponsaing. During 2016, ACEMS commenced a strong investment in this program, which has now been renamed as 'Mathscraft: Doing Maths like a Research Mathematician'. The rationale for making this an ACEMS priority is that, at a level appropriate to high school students, the program focuses on fostering the type of thinking that ACEMS members (and other mathematical scientists) use in their research—initially 'playing with' a problem to gain insight, noticing patterns and formulating general hypotheses, which almost always leads to yet more questions. We believe that it is essential to present such an approach to school students who, all too often, are taught mathematics as a static body of knowledge that has little scope for open problems and novel thinking. You can read more about 'Mathscraft' on pages 106-107 of this report.

A highlight of ACEMS 2016 outreach activities to the general community was the National Science Quiz which was sponsored by a consortium of Centres of Excellence led by ACEMS. This quiz, modelled on the Dutch television program *Nationale Wetenschapsquiz*, was a great success that, we think, can be taken further. I know that those present enjoyed the witty interplay between host Charlie Pickering and a panel consisting of Red Symons, Leonie Walsh, Terry Speed, Tanya Ha and Alan Duffy in discussing such questions as 'Why do cornflakes clump together when milk is poured on them?' or (posed by the Nobel Prize Winning Vice-Chancellor of the Australian National University, Brian Schmidt) 'What does general relativity have to do with GPS positioning devices?'

Tim Macuga has led ACEMS in encouraging its members to engage with all forms of the media. ACEMS members have given public lectures, taken part in debates in 'The Conversation' and on television and radio, as well as engaging with social media via ACEMS' Facebook, Twitter and YouTube channels. I'd recommend, in particular, that readers have a look at the YouTube channel, where PhD student 'Three-Minute Thesis' talks, stories of ACEMS research, and stories of PhD student experience can all be found. Accessible articles on ACEMS Research also appeared in the 2016 issue of 'Stories of Australian Science' published by Science in Public.

ACEMS defines mentoring as a process that involves a more experienced person helping to guide a less experienced or less knowledgeable person in their learning and development to formulate and achieve their goals. In 2016 ACEMS established a committee to oversee its mentoring programs. It recognised six types of mentoring programs.

- Research Group Mentoring
- Higher Degree Research Student Personal Mentoring
- Early Career Researcher Personal Mentoring
- Next Level Mentoring
- Vacation Researcher Mentoring
- External Mentoring

These are discussed in detail on pages 80-81.

The 2016 ACEMS Annual Retreat was held at the UTS node in the first week of November. It was attended by 112 people. Among them were eighteen Chief Investigators, twenty-one Postdoctoral Fellows, eighteen Associate Investigators, eight Professional Staff, forty-two PhD Students and five guests.

In contrast to the 2015 ACEMS Retreat, which focused on ACEMS members learning about each other's research interests, the 2016 Retreat had the theme 'Preparing for the Mid-Term Review'. The Retreat started with an address from the Acting Chief Executive Officer of the Australian Research Council (ARC), Leanne Harvey, that described how the ARC views the Centre of Excellence scheme in general and the Mid-Term Review process in particular. This was followed up with a talk in which one of our new Chief Investigators, Kate Smith-Miles, introduced herself and her research.

Two highlights of the second day were the presentations by the finalists of the PhD students' 'Three Minute Talk' competition and the joint tutorial on simulation by CI Dirk Kroese, AI Joyce Zhang and CI Scott Sisson. The morning of the third day was taken up with 'mock mid-term interviews' of separate groups of professional staff, postdoctoral fellows, PhD students and chief investigators, as well as presentations of the prizes in the 'Three Minute Talk', poster and Matlab competitions. I'd like to thank the Chair of ACEMS Governance Advisory Board Dr Ron Sandland for the extremely diligent way in which he judged the former two competitions.

Highlights of ACEMS' 2016 are briefly listed in the following two pages, before being discussed elsewhere in the Annual Report. Here I'd like to finish off by drawing attention to prestigious national and international awards won by ACEMS members:

- The Statistical Society of Australia's Pitman Medal was awarded to Deputy Director Kerrie Mengersen.
- The JH Michell Medal of the Australian and New Zealand Division of Industrial and Applied Mathematics (ANZIAM) was awarded to Associate Investigator Joshua Ross.
- The Australian Academy of Science's Moran Medal was awarded also to Associate Investigator Joshua Ross.
- An Honorary Doctorate at the University of Ghent was awarded to Chief Investigator Louise Ryan.

A full list of all prizes and awards earned by ACEMS members appears on pages 34-35.

The year 2017 promises to be a big one for ACEMS, with the mid-term review scheduled for August 31. To prepare for that, and ACEMS' future operation more generally, the Executive Committee has carried out a significant planning process for 2017, the results of which are discussed on pages 19-22.

In conclusion, I'd observe that while the changes ACEMS experienced in 2016 were sometimes challenging, they have led to a more robust Centre that is better prepared for the mid-term review and beyond.



Professor Peter Taylor
Director

TWO BIG AWARDS FOR ACEMS ASSOCIATE INVESTIGATOR JOSHUA ROSS

During 2016, ACEMS Associate Investigator Dr Joshua Ross received two top honours for his research work at The University of Adelaide. Josh focuses predominantly on problems arising in infectious disease epidemiology and conservation biology, though the methodological developments that he has provided to solve such problems are more widely applicable.

In February, Josh won the 2016 JH Michell Medal at the annual Australian and New Zealand Industrial and Applied Mathematics (ANZIAM) Conference.

The JH Michell Medal is awarded annually to an outstanding early career researcher, and is named in honour of the early twentieth century mathematician, John Henry Michell.

"There's a lot of maths now being applied to interesting biological problems, like epidemics, cancer and cell biology," Josh said.

"Josh is a highly committed and exciting researcher," commented ACEMS University of Adelaide Node Leader and Deputy Director, Professor Nigel Bean.

"He has been very productive in his early career and has published consistently high quality research. He also conducts research that has potentially significant impact for the community."

In November, the Australian Academy of Science awarded Josh the 2017 Moran Medal for his contributions to applied probability and statistics.

The Moran Medal is normally awarded every two years, and its purpose is to recognise outstanding research by scientists up to 10 years post-PhD in one or more of the fields of applied probability, biometrics, mathematical genetics, psychometrics and statistics.

The Academy recognised Josh's work on addressing problems arising in infectious disease epidemiology and conservation biology, calling his contributions to these fields significant.

The Academy also said the methodological developments he has provided could be applied more widely.

"This award means a great deal to me," Josh said.

"Particularly since it is awarded by the peak scientific body in Australia, and given the list of previous winners, which includes some of my mentors."

Josh is an associate professor in applied mathematics at The University of Adelaide, as well as being an Australian Research Council Future Fellow.



Joshua Ross receiving the JH Michell Medal at ANZIAM 2016 from Yvonne Stokes (Michell Medal Committee member). Photo courtesy: Mark J McGuinness



Joshua Ross. Photo courtesy: Ben Osborne

2016 HIGHLIGHTS

RESEARCH

- Restructured the original research programs and projects of the Centre into four new research themes: Challenging Data, Multiscale Models, Enabling Algorithms and Informed Decisions (pages 48-49)
- Made advances in various areas: see the detailed list of research highlights within each research theme report (pages 50, 57, 64 and 70)
- Significantly increased cross-node collaborations (pages 78-79)

ENGAGEMENT

- Developed an Industry Affiliates Program with five new organisations (pages 114-115)
- Entrusted the Stakeholder Engagement Officer with the responsibility of liaising with Partner Organisations
- Increased full-time equivalent allocation for the Stakeholder Engagement Officer from 0.5 to 0.8
- Significantly contributed to the AMSI Industry/Mathematical Sciences Engagement Taskforce (pages 118-119)

COMMUNICATION

- Enhanced ACEMS' social media presence (pages 90-91)
- Highlighted postgraduate students in the ACEMS YouTube channel
- Produced media releases on ACEMS-related research (page 138)
- Contributed articles to major news outlets
- Contributed articles to 'The Conversation'
- Initiated the redevelopment of the ACEMS website
- Focused the Student Retreat on better science communication, including presentations by Antony Green and Robyn Williams, as well as a short talk competition and a poster competition (pages 134-135)
- Delivered a half-day media and communications training session at the Student Retreat (page 86)

OUTREACH TO SCHOOLS

- Scaled up 'Mathscraft: Doing Maths Like a Research Mathematician' so that it is a national program (pages 126-127)
- Expanded Mathscraft to train teachers to run the sessions (pages 106-107)
- Delivered mathematical outreach programs to school students, especially in regional and remote Australia (pages 127-128)
- Participated in the Mathematicians in Schools program

OUTREACH TO THE GENERAL PUBLIC

- Took the lead, with other Centres of Excellence, in developing and presenting 'The National Science Quiz' to a sold-out audience of over 400 people (pages 108-109)
- Presented talks open to the public (page 131)
- Delivered a 'Big Data Analytics' MOOC (pages 84-85)
- Participated in five National Science Week events across three cities (page 129)
- Participated in three World Science Festival Brisbane events (pages 129-130)

OUTREACH WITHIN THE MATHEMATICAL SCIENCES RESEARCH COMMUNITY

- Organised ACEMS research workshops (page 100)
- Supported the mathematical research institute MATRIX (pages 102-103)
- Supported relevant workshops/conferences proposed in Australia (pages 87)
- Supported the Australian Mathematical Society's Women in Mathematics Special Interest Group
- Co-organised the 'ACEMS/AMSI Workshop on Measuring Research Engagement and Impact in the Mathematical Sciences'
- Contributed to the new decadal plan for mathematical sciences in Australia launched in early 2016 (page 56)

MENTORING

- Supported and facilitated ACEMS student and early career researcher achievements including new publications, grants, awards, international and national travel, collaborations and professional development
- Included mentoring and professional development sessions on communication skills and career development at the Student Retreat (page 86)
- Consolidated and planned for expansion of the mentoring program (pages 80-81)
- Provided vacation scholarships and interacted with existing vacation scholarship schemes
- Identified opportunities for ACEMS postgraduate students and early career researchers to engage with the international research community
- Nominated people for prestigious awards

SUCCESSION PLANNING

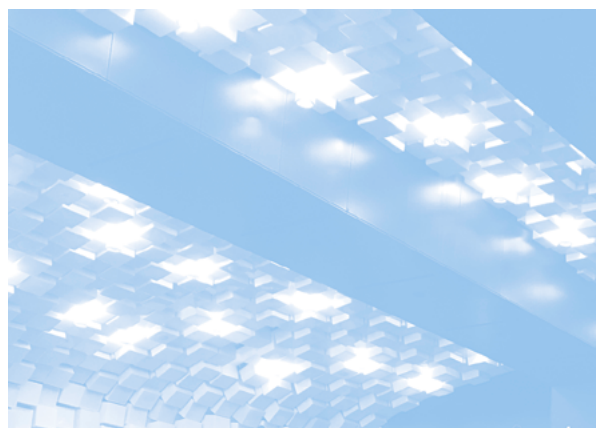
- Strategically refreshed the cohort of Chief Investigators (page 32)
- Strategically refreshed the membership nodes
- Strategically refreshed membership of the Executive Committee

GOVERNANCE

- Developed a Strategic Plan for the Centre with sub-plans for Outreach, Communication and Stakeholder Engagement (pages 19-21)
- Reviewed the effectiveness of the Governance Advisory Board
- Reviewed the effectiveness of the Scientific Advisory Committee
- Engaged closely with the Australian Research Council
- Conducted mock review sessions at the Annual Retreat (page 132)

OTHER HIGHLIGHTS

- Organised and sponsored a scientific memorial conference in honour of ACEMS Founding Director Peter Hall (pages 104-105)
- Over 100 national and international visitors to the Centre from 26 countries (pages 97-98)
- Staff and students recognised for excellence via prizes, awards and other honours (pages 34-35)
- Over 100 Centre members attended the Centre's Annual Retreat (pages 132-133)



The 2016 National Science Quiz



Robyn Williams, host of Radio National's The Science Show, talks to students at the 2016 ACEMS Student Retreat

STRUCTURE, GOVERNANCE AND MANAGEMENT

ACEMS is a collaborative research centre that links The University of Melbourne (UoM), Queensland University of Technology (QUT), The University of Queensland (UQ), The University of Adelaide (UoA), The University of New South Wales (UNSW) and the University of Technology Sydney (UTS), funded by the Australian Research Council (ARC) Centre of Excellence program. In 2016, steps were taken to add Monash University as a seventh node. ACEMS' Partner Organisations are: AT&T Labs, Australian Bureau of Statistics (ABS), CSIRO, Mathematics of Information Technology and Complex Systems (Mitacs), VicRoads, Sax Institute, and the Australian Institute of Marine Science (AIMS).

As the lead administering node, The University of Melbourne manages the grant and node contributions, and distributes funds in accordance with the signed agreements. These agreements cover ACEMS management, collaboration and policy arrangements.

ACEMS day to day management is overseen by the Executive Committee (EC), which meets fortnightly. The ACEMS Governance Advisory Board (GAB) and Scientific Advisory Committee (SAC) meet twice annually.

Centre Management

The ACEMS Executive Committee is responsible for administration as it pertains to Centre policy, performance, financial matters, research output, research training and professional education of members, partnerships, national and international liaison, commercialisation and outreach.

The members of the EC are:

Professor Peter Taylor, Director

Professor Jan de Gier, Deputy Director, Operations

Professor Nigel Bean, Deputy Director, Outreach

Professor Kerrie Mengersen, Deputy Director, Stakeholder Engagement

Governance Advisory Board

The ACEMS Governance Advisory Board met in June and December 2016. The meetings focused on personnel changes, strategic planning, recommendations made by the ACEMS Scientific Advisory Committee, engagement with the ARC and the upcoming mid-term review.

The GAB members are:

Dr Ron Sandland (Chair), Former Deputy Chief Executive of the CSIRO

Professor David Abramson, Director, Research Computing Centre, UQ

Professor Mike Brooks, Deputy Vice-Chancellor (Research), UoA

Professor Robert Calderbank, Director, Information Futures Initiative, Duke University

Dr Julian Caley, Leader, AIMS and QUT Collaboration, AIMS (outgoing Partner Organisation Representative)

Professor Peter Donnelly, Director, Wellcome Trust Centre for Human Genetics, Oxford University

Professor Tony Dooley, Head of the School of Mathematical and Physical Sciences, UTS

Dr Emily Duane (ex officio), Chief Operating Officer, ACEMS, UoM

Professor Martin Grötschel, President, Berlin-Brandenburgische Akademie der Wissenschaften (BBAW)

Professor Tony Guttmann, Director, MASCOs, UoM

Ms Sybille McKeown, Reconciliation Champion and Program Manager, ABS (incoming Partner Organisation representative)

Mr Daniel Owens, Grants Management Office, UNSW

Professor Arun Sharma, Deputy Vice-Chancellor (Research and Commercialisation), QUT

Professor Liz Sonenberg, Pro Vice-Chancellor (Research Collaboration & Infrastructure), UoM

Professor Peter Taylor (ex officio), Director, ACEMS, UoM

Scientific Advisory Committee

The ACEMS Scientific Advisory Committee met in June 2016. Recommendations included suggestions for improving future annual reports, the ACEMS website and the annual retreat. A second meeting was postponed until March 2017 due to changes to the committee's membership.

The SAC members are:

Professor Peter Taylor (Chair), Director, ACEMS, UoM

Dr Ken Anthony[^], Principal Research Scientist, AIMS (Partner Organisation representative)

Professor Louis Chen, Distinguished Professor, National University of Singapore

Professor Montserrat Fuentes^{*}, Head of Statistics, North Carolina State University

Professor Bronwyn Harch^{*}, Assistant Dean, Science and Engineering Faculty, QUT

Professor Iain Johnstone, Professor of Statistics and Health Research and Policy (Biostatistics), Stanford University

Professor Michael Jordan^{*}, Pehong Chen Distinguished Professor, University of California, Berkeley

Professor Xihong Lin, Professor of Biostatistics, Harvard University

Professor Michel Mandjes[^], Faculty of Science Professor, University of Amsterdam

Professor Herbert Spohn[^], Emeritus Professor, TU München

Professor Terence Tao, Professor of Mathematics, University of California, Los Angeles

Professor Ruth Williams[^], Distinguished Professor, University of California, San Diego

^{*} Outgoing members [^] Incoming members

GOVERNANCE ADVISORY BOARD

SCIENTIFIC ADVISORY COMMITTEE

ORGANISATION CHART

AS AT 31 DECEMBER 2016

EXECUTIVE COMMITTEE

Director, Peter Taylor

Deputy Director (Operations), Jan de Gier

Deputy Director (Outreach), Nigel Bean

Deputy Director (Stakeholder Engagement), Kerrie Mengersen*

PROFESSIONAL STAFF

Chief Operating Officer, Emily Duane[°]

Communications and Media Officer, Tim Macuga

Outreach Officers, Andrew Stephenson and Anita Ponsaing

Stakeholder Engagement Officer, Jessie Roberts

Finance Officer, Kate Hall

Central Administration Officer, Ben Hess

CHIEF INVESTIGATORS

QUT

Peter Bartlett
Kevin Burrage[°]
Kerrie Mengersen*
Anthony Pettitt
Ian Turner[†]

UoM

Aurore Delaigle^{†°}
Peter Forrester*
Jan de Gier
Peter Taylor

UQ

Dirk Kroese[†]
Phil Pollett^{**†}

UoA

Nigel Bean*
Matthew Roughan[†]

UNSW

Robert Kohn*
Scott Sisson[°]

Monash

Tim Garoni[†]
Kate Smith-Miles[°]

UTS

Louise Ryan^{**†}
Matt Wand[†]

NODE ADMINISTRATION OFFICERS

Ben Hess (UoM)
Claudia Deasy (QUT)
Lucia Kralova (UTS)
Claire Nitsch (UQ)
Snezana Ilic (UoA)

PARTNERS AND COLLABORATORS

Partner Organisations and Investigators
Industry Affiliate Organisations
Affiliate Members
Other National and International Partners and Collaborators

POSTDOCTORAL RESEARCH FELLOWS
STUDENTS
ASSOCIATE INVESTIGATORS

* Node Leaders † Research Theme Leaders ° Mentoring Program Leaders ° new CIs from late 2016

HELPING SAVE JAGUARS WITH A VIRTUAL PERUVIAN JUNGLE

“The project is proof that the study of statistics and mathematics can make a difference in the real world... like trying to save jaguars in Peru.”



Photo courtesy: Vanessa Hunter



HOW DO YOU TRY TO SAVE AN ANIMAL THAT DOESN'T WANT TO BE SEEN, LET ALONE BE COUNTED?

Professor Kerrie Mengersen
Queensland University of Technology

How do you try to save an animal that doesn't want to be seen, let alone be counted?

This was the problem facing Distinguished Professor Kerrie Mengersen, Deputy Director and Chief Investigator at the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS). Her job as a statistician is all about data, giving meaning to it, and then making sure it's being used to make better and smarter decisions about real-world problems.

However, when it comes to the jaguar population in South America, there is very little data, other than the fact the numbers are going down. In fact, it's believed the population has been cut in half over the last century, thanks to factors such as the loss of habitat, interactions with humans, declines in the number of prey, and even extreme weather events like flooding and drought.

For Kerrie, this was an application-driven problem that was going to need some statistical and mathematical theory to help solve it. That's where ACEMS fits in.

"If we look across maths, stats and machine learning, this project has all those things," Kerrie says.

"So we need mathematical models, we need statistical models and we need the machine learning to be able to integrate the information and create the computational tools to do that modelling."

Less than two years into the project, the first and main goal—to establish a jaguar corridor in Peru—seems very much achievable. That's nothing short of amazing, when you consider how this project started.

"We started with just a little spark, a vision, two women in a boat sort of thing," Kerrie says.

The other 'woman in the boat,' was the Lupunaluz Foundation, a conservation group that was already working on efforts to protect the jaguar population in Peru.

The foundation knew about previous conservation efforts Kerrie had taken part in, most notably working to protect critically endangered cheetahs in Southern Africa and orangutans in Indonesia. With those projects, she tapped into local knowledge to build statistical models to guide the conservation efforts.

This project, though, would really build upon those citizen science efforts by adding some new and very cool technology—such as 360-degree cameras and 3D immersive environments.

"This was a first in using virtual reality for a really serious purpose, and not just for the 'ooh-ah' of the virtual environments," Kerrie says.

"We're using it for scientific purposes to extract information about how to help with decision-making in conservation."

However, to take that cool technology and make it work in the harsh elements of the Amazon jungle would require a real team effort involving researchers from across multiple disciplines. Kerrie put together such a team from ACEMS and the Queensland



Photo courtesy:
Vanessa Hunter



ACEMS Principal Research Fellow Associate Professor Tomasz Bednarz, along with other colleagues at QUT, helped organise all the camera technology for the team that travelled to Peru.

Even Tomasz was amazed by the immersive environments the team could create from the images and video.

“We’ve created presentations from different parts of the forest so you can imagine being in the forest, or jumping to different locations where jaguars possibly lived,” Tomasz says.

“We can display it in a 360-degree view so you can look around and immerse yourself with those unique landscapes. You can also read or listen to the information about the place, see Amazonian animals, or see snapshots of our team travelling through the wild jungle.”



University of Technology (QUT), where Kerrie is based, and led a four-week expedition deep into the Amazon jungle in Peru.

“The project has brought together people from computer science, statistics, mathematics, spatial ecology, conservation and so on. We had ACEMS members at all levels—chief investigators, postdoctoral fellows, PhD students and associate investigators—all come on board for this project. We also had to reach out to people outside this community,” Kerrie says.

The team took countless photos and videos using 360-degree and 3D cameras, which gave them plenty of material to create the virtual environments.

ACEMS Principal Research Fellow Dr Erin Peterson (pictured to the left) was part of that expedition, and talked about the urgency of the group’s work and how this technology could help.

“We can’t wait to make decisions about the jaguar’s conservation because their habitat is being destroyed as we speak,” Erin says.

“We can use these sexy new technologies to get information to biologists who aren’t in Peru. We can essentially take the forest to the biologist and get their expert opinion and put that into our models.”

The team also worked to establish ties with the local indigenous communities, so they could tap into the knowledge of jaguars and the jungle.

After the first trip, the team developed several main models, including a spatial model for jaguar presence. Another was a population dynamics model, which showed just how sensitive jaguar numbers were to impacts such as deforestation, hunting and climate change.

The project continued to grow, with Kerrie taking a second trip to Peru in August 2016. Even more technology was rolled out during this second phase, including planes and drones, camera traps (used to capture the image below), and bioacoustics. Kerrie also stepped up her efforts to work with the people who live there and show them how they could help.

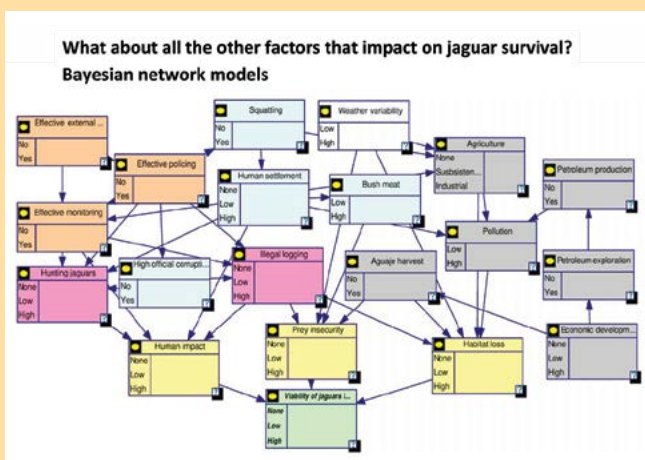


"A major part of the trip was to 'skill up' the local indigenous people to start monitoring their own environment, including the jungle and animals that live in it," Kerrie says.

"This is essential if we are to have any hope of conserving jaguars."

The trip also helped her continue to get the international support she needed to keep things moving forward. Kerrie says local and regional governments are now supporting the project, and it has even caught the eye of the United Nations.

All this support will be needed to not only establish a jaguar corridor, but to monitor and maintain it as well, which means Kerrie is continuing her work on the project in 2017.



For Kerrie, it's a project unlike anything she's ever done before, both personally, and statistically.

"This has been hugely challenging as a stats project, both in core stuff that I do and in the broader statistical methods," Kerrie says.

"We're opening the way to using all these different types of data sources. These are things that we talk about, but when you're faced with actually doing it, you have to work out the methods. There is no other way."

More importantly, though, the project is proof that the study of statistics and mathematics can make a difference in the real world, as well as offer someone a chance to do some amazing things—like trying to save jaguars in Peru.

"The stats and new technology, the things ACEMS is into, have really got a profile in this and could be the thing that drives us to succeed in this—to actually create a corridor for the protection of the jaguars and all of the jungle. That would be really cool."



Photo courtesy: Vanessa Hunter

For ACEMS Chief Investigator Professor Kevin Burrage (pictured above), it has been a life-long dream to be able to travel to the Amazon. He was able to do that by being part of the team's first expedition to Peru.

"This is without doubt the most exciting trip, scientific or otherwise, I have been on," Kevin says.

Kevin worked to develop a jaguar population dynamics model.

"Jaguars are notoriously secretive and the rainforest is very dense," Kevin says. "Thus animal abundance data is very difficult to collect, so mathematical and statistical models can help fill in any missing or messy data."

He says their statistical and mathematical models show that climate change is really starting to play a major role in the jaguars' survival.



CREDITS

Tomasz Bednarz, Ross Brown, Kevin Burrage, Sam Clifford, Gerard Davis, Jacqueline Davis, Claudia Deasy, Fiona Harden, Vanessa Hunter, Allan James, June Kim, Efreim Lloyd, Kerrie Mengersen (Project Leader), Erin Peterson, Steven Psaltis, Julie Vercelloni, Gavin Winter, Nan Ye

VR Production: Tomasz Bednarz & June Kim

ACKNOWLEDGEMENTS

OUT IFE, ACEMS, Lupunaluz Foundation, SERNANP

TWO MAJOR AWARDS AND A NEW TITLE FOR ACEMS DEPUTY DIRECTOR KERRIE MENGENSEN

The Statistical Society of Australia presented ACEMS Deputy Director Kerrie Mengensen with its highest honour, the Pitman Medal. Kerrie is a leader in Bayesian statistics which she has applied to advise on improving cancer services and on managing the Great Barrier Reef.

The Pitman Medal is just one of several major honours earned by Professor Mengensen in late 2016. In addition, the Cooperative Research Centre for Spatial Information (CRCSI) awarded her its 2016 Research Excellence Award. Finally, Kerrie's home institution, Queensland University of Technology (QUT), awarded her the title of Distinguished Professor.

Kerrie is only the 22nd person to receive the Pitman Medal since it was first presented in 1978, and is the first woman to receive it.

"When I look at the group of people who've received the honour before, I think of them as the heroes of the profession," Kerrie said.

"Many of them have been very strong supporters of women, but it's great to have a woman's name on there now. I'm delighted that it's me."

The Society awards the Pitman Medal in recognition of "outstanding achievement in, and contribution to, the discipline of statistics." For Kerrie, it's for her work with Bayesian statistics.



"Being in Bayesian statistics over the years, it's great to have seen it come from something that was a small component of stats to now being a fundamental component of modern statistics," Kerrie said.

"As spatial statisticians, we can poke our noses into so many problems, from saving the Great Barrier Reef to improving the lives of cancer patients, so we get to work with our heads, on a professional level, and with our hearts, on a very personal level."

She is only the sixth person at QUT to be awarded the title of distinguished professor.

"Distinguished Professor Mengensen is a national and international leader in her discipline, recognised extensively for her applied research work, which has had a significant impact on science in different domains," QUT Vice-Chancellor Professor Peter Coaldrake said.

"She is held in the highest esteem by her peers for her leadership of large research teams and her work has inspired others and influenced colleagues across the world."

The CRCSI awarded Kerrie its research excellence award for her research project with Cancer Council Queensland, the outcomes of which led the Queensland Government to increase travel assistance to people in remote areas to access cancer screening and treatment services. CRCSI also recognised her work to improve environmental monitoring and management of the Great Barrier Reef.

"I am proud to be a statistician, and proud to be part of the CRCSI, since spatial information is so important in almost every field," Kerrie said.

Kerrie is a part of QUT's Institute for Future Environments. She is an Australian Research Council Laureate Fellow, and served as president of the Statistical Society of Australia from 2011-2012. She is also a chief investigator with ACEMS.

Award winner: ACEMS Deputy Director Kerrie Mengensen

STRATEGIC PLAN 2016–2020

DURING 2016, THE EXECUTIVE COMMITTEE DRAFTED THE CENTRE'S STRATEGIC PLAN AND REFINED IT WITH ADVICE FROM THE GOVERNANCE ADVISORY BOARD. WHILE THIS PLAN IS STILL A WORK IN PROGRESS, IT ENCAPSULATES THE INTENT, OBJECTIVES, HIGH-LEVEL GOALS, STRATEGIES AND MEASURES THAT WILL BE USED TO GUIDE THE CENTRE FOR THE REMAINING PERIOD OF FUNDING.

INTENT

To create *world-class* research at the *frontiers of the mathematical sciences* dealing with *probability* and *randomness*, and to translate this research into *new insights* that *benefit society*.

OBJECTIVES

1. To pursue this Intent through leading-edge research and research training across the areas of the mathematical sciences that deal with big and complex data, big probabilistic models and their application to real world problems.
2. To link the streams of research in mathematics, statistics and machine learning, from theory to applied.
3. To align and capitalise on this value chain to deliver impact in the collaborative domains of Healthy People, Sustainable Environments and Prosperous Societies.

These objectives will be achieved by focusing on four strategies:

Capability — Capacity — Impact — Governance

Capability:

- To become an internationally respected and renowned focus for world-class frontier research and research translation
- To encourage a collaborative research culture for the mathematical and statistical sciences in Australia

Capacity:

- To train postgraduates, researchers and practitioners within the ACEMS research culture
- To engage with partner organisations and external collaborators

Impact:

- To add value to society by using ACEMS research to help solve real world problems
- To leave a legacy for the mathematical and statistical sciences

Governance:

- To operate as a well-managed and financially-stable organisation

CAPABILITY

HIGH LEVEL GOALS	STRATEGIES	MEASURES
To become an internationally respected and renowned focus for world-class research and research translation	<p>Ensure that ACEMS membership is of high quality and in line with the vision of the Centre</p> <p>Produce high quality research and researchers</p> <p>Promote ACEMS research and research translation</p> <p>Receive recognition and awards</p>	<p>Active ACEMS membership</p> <p>Papers in high ranking journals</p> <p>Presentations at international conferences</p> <p>Public discourse on matters related to ACEMS expertise</p> <p>Awards and recognition</p>
To encourage a collaborative research culture	<p>Undertake world-class research projects that would not have been attempted without the Centre</p> <p>Conduct individual and joint research for which 'the whole is more than the sum of the parts'</p> <p>Form strong links with the national and international research community and like-minded research groups</p> <p>Collaborate across nodes, between the different disciplines represented in ACEMS, between researchers working in theory and applications and on topics ranging across the big data/big models/new insights dimension</p>	<p>International visits</p> <p>International visitors</p> <p>Demonstrated activities with other national and international research groups</p> <p>Collaborative workshops</p> <p>Inter-node interaction</p> <p>Big picture research topics that clearly reflect a merger of the separate disciplines within the Centre</p> <p>Projects that cross theory, methods, computation and application</p> <p>Projects that cross data, modelling and insights</p>

CAPACITY

HIGH LEVEL GOALS	STRATEGIES	MEASURES
To train world class postgraduates, researchers and practitioners within the ACEMS research culture	<p>Establish a culture of high quality collaborative learning and training</p> <p>Expose the students to translation opportunities</p> <p>Assist members to create long-lasting professional networks</p> <p>Assist members to create national and international collaborative research networks</p> <p>Develop an ACEMS mentoring program</p>	<p>Engagement with ECR resources in professional societies</p> <p>Involvement of postgrads and ECRs in research translation meetings and projects with external groups</p> <p>Cross-nodal collaboration</p> <p>Visitors to the Centre</p> <p>Overseas research visits</p> <p>ACEMS mentoring program</p> <p>Sponsorship of mentoring and training activities</p>
To engage with partner organisations and external collaborators	<p>Bring mutual value to researchers and partners through engagement and collaborations through partner organisations</p> <p>Increase national and international research networks</p> <p>Grow the partnership base</p> <p>Establish agreements with cognate national and international research centres</p>	<p>High quality activities with partner organisations</p> <p>Short courses</p> <p>Joint postgrad supervision with partner organisations and collaborators</p> <p>Strategy for inclusion of relevant research and researchers who are not in ACEMS</p> <p>Signed agreements and substantive activity with relevant national and international research centres</p>

IMPACT

HIGH LEVEL GOALS	STRATEGIES	MEASURES
To add value to society by using ACEMS research to help solve real world problems	<p>Identify and engage with significant high value problems of significance to the Australian and international community</p> <p>Communicate the implications of ACEMS research to the wider community</p> <p>Communicate the value chain from theory to application of mathematical sciences, and different timescales for impact</p> <p>Be a 'first thought of call' for mathematical and statistical problems in Australia</p> <p>Define measures of impact relevant to ACEMS</p>	<p>Evidence of impact of ACEMS research in practice</p> <p>Effective Communication Plan</p> <p>Effective website and social media strategy</p> <p>Effective Stakeholder Engagement Plan</p> <p>Contribution to discussion on impact in mathematical sciences</p> <p>Database of ACEMS impact measures</p>
To leave a legacy for the mathematical and statistical sciences	<p>Develop an overarching plan for the long lasting legacy of ACEMS</p> <p>Produce high quality and influential research</p> <p>Produce examples where ACEMS research has an impact on the wider community</p> <p>Produce highly-trained graduates and ECRs who can operate in the collaborative culture and communicate to external stakeholders</p> <p>Raise awareness of the influence and impact of the mathematical and statistical sciences in the wider community</p>	<p>Legacy plan</p> <p>Developed examples of ACEMS impact</p> <p>Successful ACEMS graduates and ECRs</p> <p>Outreach Plan</p>

GOVERNANCE

HIGH LEVEL GOALS	STRATEGIES	MEASURES
To operate as a well-managed and financially stable organisation	<p>Stable leadership</p> <p>Deliver efficient administration across the Centre</p> <p>Operate a financially responsible and viable Centre</p> <p>Promote transparency and accountability</p> <p>Collect and provide timely and accurate information to all stakeholders</p> <p>Encourage professional development of Professional staff</p> <p>Develop a positive relationship across all levels of the Centre</p>	<p>Effective Director, EC and COO, evidenced by feedback from ACEMS members and ARC</p> <p>Effective, efficient administrative and professional team, evidenced by positive feedback from ACEMS members and ARC</p> <p>Operational and strategic focus on finance</p> <p>Clear visibility of Centre operations and finances for EC, CIs and GAB</p> <p>Efficient data collection procedures</p> <p>Uptake of career development opportunities by the Professional and Administrative Staff</p> <p>Positive feedback based on review of Centre members</p>

2017 PLANS: THE YEAR AHEAD

RESEARCH

- Host research workshops aligned with the four new themes: Challenging Data, Multiscale Models, Enabling Algorithms and Informed Decisions
- Create world-class research at the frontiers of the mathematical sciences: see the six-point plan and CI cameos within each research theme report (pages 52-53, 61, 66 and 74)
- Hire additional postdoctoral researchers
- Further increase cross-node collaborations

MENTORING

- Formalise a cross-node mentoring program
- Increase mentoring for postdoctoral researchers and professional staff
- Organise a postdoctoral workshop as well as the first annual postdoctoral retreat
- Consider a mentoring seminar series broadcast across the nodes
- Investigate options to facilitate greater cross-node interaction
- Provide vacation scholarships and interact with existing vacation scholarship schemes
- Identify opportunities for ACEMS HDR students and ECRs to engage with the international research community

STAKEHOLDER ENGAGEMENT

- Set up two secondments with the Australian Taxation Office
- Participate in the Woodside “Work Integrated Learning” Project
- Further expand the Industry Affiliate Program
- Further engage with the Australian Mathematical Sciences Institute (AMSI) Industry/Mathematical Sciences Engagement Task Force
- Engage with new Partner Investigators and Industry Affiliate Organisations as they come on board
- Host engagement-focused workshops
- Host annual research planning meetings with Partner Organisations

NATIONAL AND INTERNATIONAL LINKS

- Organise MOUs with major international centres and institutes
- Organise at least one cross-node visiting fellowship for a prestigious international visitor
- Host esteemed national and international visitors
- Engage with existing national and international collaborators
- Strengthen links with other ARC Centres of Excellence

COMMUNICATION

- Redevelop the ACEMS website
- Identify and mentor members looking to improve their career path through use of communications
- Produce more personal stories about Centre members and their research
- Continue to expand the ACEMS brand through a presence in media stories
- Continue to grow the Centre’s audience on social media

OUTREACH TO SCHOOLS

- Facilitate Mathscraft’s continued expansion into teacher training
- Maintain the Centre’s involvement in the Mathematicians in Schools program and consider options for expansion
- Lead and co-support the re-boot of the Adelaide “Saturday Morning Maths” program that assists interested and motivated secondary school students
- Engage with the proposal to include “Introductory Data Science” in secondary schools
- Consider opportunities to partner with existing outreach programs such as The University of Melbourne’s Maths Fair and School Mathematics Competition

OUTREACH TO THE GENERAL PUBLIC

- Expand the National Science Quiz to be held in multiple states
- Present talks open to the public
- Organise and participate in National Science Week events

OUTREACH WITHIN THE MATHEMATICAL SCIENCES RESEARCH COMMUNITY

- Support and co-organise workshops with the mathematical research institute MATRIX
- Organise another workshop on engagement and impact in the mathematical sciences with AMSI
- Support the Australian Mathematical Society’s Women in Mathematics Special Interest Group
- Support relevant workshops, conferences and events

SUCCESSION PLANNING

- Review the medium-term career aspirations of all ACEMS Chief Investigators, with a view to maintaining energy and expertise in ACEMS senior leadership
- Identify candidates amongst ACEMS Associate Investigators who might move into Chief Investigator positions in the medium term
- Consider the career prospects of all ACEMS postdoctoral staff and provide appropriate mentoring

GOVERNANCE AND OPERATIONS

- Refine the Centre’s Strategic Plan
- Prepare for the mid-term review
- Closely engage with the Scientific Advisory Committee about the four new research themes
- Closely engage with the Governance Advisory Board in the lead up to the Centre’s review
- Continue to improve the Centre’s reporting systems

OTHER ACTIVITIES

- Nominate people for prestigious awards
- Organise the Centre’s Student Retreat
- Organise the Centre’s Postdoctoral Fellow Retreat
- Organise the Centre’s Annual Retreat for all members
- Expand the Advanced Sampling and Exploration competition

FROM UTS, TO GOOGLE, TO HARVARD — AN ACEMS STUDENT'S AMAZING JOURNEY

"I actually didn't like statistics at all!"

That's how Cathy Yuen Yi Lee described her first experience with statistics in a class at the University of Wollongong. Cathy has come a long way since then. She left ACEMS and UTS in July 2016 with a PhD in Statistics, and headed to Harvard to begin her postdoctoral fellowship. That's not all. Just before she left ACEMS Cathy completed a four-month internship with Google Zurich.

Cathy said her stats professor at Wollongong saw something in her, and told her to give statistics a chance. So she did. She agreed to take two more subjects that first year of university.

"The second subject was about inference," says Cathy, "and I started to see why people like statistics. I could see why we learn about normal distributions and bell curves, it all started to make sense. Things just kind of came together and I started enjoying the subjects."

Before learning statistics, though, Cathy had to learn English. Her mother sent her from Hong Kong to Australia when she was 16.

"The first day I arrived, I didn't understand anyone," said Cathy. "The Australian accent is so hard to understand!"

Now, 12 years later, she's finished her PhD in statistics at UTS. Her PhD research focused on developing fast and memory-efficient machine learning algorithms for analysing large-scale databases, which typically have a complex correlation structure. As Cathy was finishing up her PhD at UTS, she also landed a four-month internship with Google, where she was based in Zurich, Switzerland, and worked on analysing large-scale online experiments.

"It was totally overwhelming at first," says Cathy.

Cathy says she was really nervous going into the Google experience, but walked away from it with a lot of confidence.

"Because everyone was so self-motivated and so positive about everything, I had this kind of fire inside of me every day."

"One thing I found really powerful was that if I had any questions, I knew there must be someone, somewhere around the globe that was an expert in that area. I just pinged them and said, 'look, I have this question. I have no idea how to solve this,' and within a minute there would be someone saying, 'don't worry, I know this person who is really good at this, so get a hold of him or her.'"

She also spent two weeks at Google's massive headquarters in California.

"It was insane. They have twenty-something cafes."

Cathy was there to make a presentation on her work in front of what she thought would be a small group of people at a team meeting. She was jetlagged from her trip from Switzerland.

"When I got there, there was a room full of statisticians, analysts, software engineers, some people from New York and other parts of the country, and it was just very overwhelming. So I just took a deep breath a few times and went for it." She survived.

"I had two of the most fantastic supervisors. They knew my strengths and weaknesses, so they were able to push me and challenge me to my limits, so that I could do really high quality work."

Now, Cathy is moving on to a postdoc position at Harvard University, with Professor Brent Coull. There, she hopes to do something more with using machine learning algorithms to analyse health and environmental data.

Leaving UTS, though, is bittersweet for Cathy. She described the whole stats group there as family, with that family being led by ACEMS Chief Investigators Matt Wand and Louise Ryan.

"I had two of the most fantastic supervisors," says Cathy. "They knew my strengths and weaknesses, so they were able to push me and challenge me to my limits, so that I could do really high quality work."

"I've known Cathy since 2009," says Professor Matt Wand, "when I supervised her honours project. She's very sharp, and also well-rounded. She can solve difficult mathematical problems one day, give a fantastic presentation the next day and then collaborate with health researchers the day after that."

Cathy described Louise Ryan as her emotional support.

"She really taught me how to be more confident, and suggested I should do more exercise, or some yoga, to help my work-life balance. She knows I work very hard."

"I really enjoyed my time at UTS and will miss them all."

ACEMS and UTS will miss you too, Cathy. Best wishes at Harvard.



UNDERSTANDING RARE EVENTS: SIMULATING RARE DISEASE OUTBREAKS AND POWER BLACKOUTS

“Finding the optimal solution **randomly** is a rare event, and our techniques are exactly tailored to simulating such an event efficiently.”



Preferential attachment models can describe interconnections in social networks.

RARE EVENTS SUCH AS THE STATE-WIDE POWER BLACKOUT IN SOUTH AUSTRALIA IN SEPTEMBER 2016, NATURAL DISASTERS SUCH AS FLOODS AND BUSHFIRES, OR THE ENSUING CHAOS WHEN PARTS OF COMPLEX INTERCONNECTED SYSTEMS SUCH AS THE INTERNET FAIL, ARE DIFFICULT FOR RESEARCHERS TO SIMULATE OR MODEL. THEY'RE THE PRIMARY INTEREST OF PROFESSOR DIRK KROESE.



Professor Dirk Kroese
The University of Queensland

"If you simulate a complex system such as a power grid, you don't normally experience a rare event, even if you run it for a long time," says Dirk, who is a chief investigator at the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) and Professor of Mathematics and Statistics at the University of Queensland.

"But you need to be able to understand rare events to gauge reliability, and identify bottlenecks or sensitive points that might trigger a series of component failures, and have a big impact."

The answer is to speed up the simulation somehow to make rare events occur more frequently, to explore their consequences and then map back to the original system. And that's exactly what Dirk does. He essentially loads the dice in his simulations to increase the probability of rare events occurring, and make them more likely.

"You can also use rare event simulation to optimise things. If you design a power grid for example, you want to make links between its components that minimise cost, minimise the chances of outages, and ensure the grid can distribute enough electricity for all," Dirk says.

"You could try all the possibilities to see which is best—but there are far too many to evaluate. Or you could randomly select options, but there are so many that you would almost never hit an optimal solution. In fact, finding the optimal solution randomly is a rare event, and our techniques are exactly tailored to simulating such an event efficiently."

Another type of rare event increasingly in the news is when someone contracts a rare but scary infectious disease—such as the Ebola virus, or the 2016 outbreak of measles in Sydney. What is the best public health strategy to implement? The answer depends on how quickly the virus spreads—it depends on how often the infected person encounters other people, who contact other people—in other words, on the dynamics of the local social network.

But how can you measure that? What statistics might provide a useful indicator of the activity of a social network? That's what Dirk and his PhD student Morgan Grant have been working on, and Morgan has developed a new and efficient means of doing so. His research was presented at the Winter Simulation Conference in Washington DC in December 2016 and published in its proceedings.

It's based on estimating a property called typical distance, a measure of the time it takes something to pass through a network. In a social network where the typical distance is small, for instance, a few people are connected to many and disease can spread widely in just a few steps. But where the typical distance is large, there are not many connections between people, and a virus takes longer to spread through the network.

"If you can describe such networks, you can describe the spread of disease," Dirk says.

But in the real world, social networks are often large, change frequently and are usually difficult to measure accurately, which is why the work on estimating the typical distance is so useful.

PERSONNEL

THE FOLLOWING PEOPLE WERE CENTRE MEMBERS DURING 2016. MEMBERS APPEAR IN MULTIPLE CATEGORIES IF THEIR ROLE IN THE CENTRE CHANGED DURING THE YEAR.



ACEMS Professional Staff at the Main Retreat: Snezana Ilic, Andrew Stephenson, Claire Nitsch, Lucia Kralova, Emily Duane, Tim Macuga and Kate Hall

Director

Peter Taylor, UoM

Deputy Directors

Nigel Bean, Outreach, UoA

Jan de Gier, Operations, UoM

Kerrie Mengersen, Stakeholder Engagement, QUT

Chief Operating Officer

Emily Duane, UoM (in-coming)

Tania Smith, UoM (out-going)

Professional Staff

Claudia Deasy, Administration Officer, QUT

Emily Duane, Administration Officer and Central Administrator, UoM (out-going)

Kate Hall, Finance Officer, UoM

Ben Hess, Administration Officer and Central Administrator, UoM (in-coming)

Snezana Ilic, Administration Officer, UoA

Lucia Kralova, Administration Officer, UTS

Greg Lee, Stakeholder Engagement Officer, QUT (out-going)

Tim Macuga, Communications and Media Officer, QUT

Claire Nitsch, Administration Officer, UQ

Anita Ponsaing, Outreach Officer, UoM (in-coming)

Jessie Roberts, Stakeholder Engagement Officer, QUT (in-coming)

Andrew Stephenson, Outreach Officer, QUT (out-going)

Chief Investigators

A Chief Investigator is a member named in Schedule A of the ARC Centre of Excellence Funding Agreement as Chief Investigator. This person has direct responsibility to the ARC for delivering on ACEMS objectives. Usually, he or she will have overall intellectual responsibility for an ACEMS research project, leading research, providing effective supervision to students and mentoring as required.

Peter Bartlett, QUT

Nigel Bean, UoA

Kevin Burrage, QUT

Jan de Gier, UoM

Aurore Delaigle, UoM

Peter Forrester, UoM

Tim Garoni, MU

John Geweke, UTS (out-going)

Robert Kohn, UNSW

Dirk Kroese, UQ

Kerrie Mengersen, QUT

Anthony (Tony) Pettitt, QUT

Philip (Phil) Pollett, UQ

Matthew Roughan, UoA

Louise Ryan, UTS

Scott Sisson, UNSW (in-coming)

Kate Smith-Miles, MU (in-coming)

Peter Taylor, UoM

Ian Turner, QUT

Matt Wand, UTS

ABBREVIATIONS

ANU	Australian National University
MU	Monash University
QUT	Queensland University of Technology
UoA	The University of Adelaide
UoM	The University of Melbourne
UNSW	The University of New South Wales
UQ	The University of Queensland
USyd	The University of Sydney
UTas	The University of Tasmania
UTS	University of Technology Sydney

Chief Investigator Aurore Delaigle, Scientific Advisory Committee members Iain Johnstone and Xihong Lin, Director Peter Taylor, Chief Operating Officer Emily Duane, Associate Investigator Davide Ferrari and Melbourne Node Administration Officer Ben Hess



Associate Investigators

An Associate Investigator is a member nominated by a Chief Investigator and approved by the Executive Committee, who is employed at an Australian or overseas research institution. An Associate Investigator is not a Chief Investigator but does have significant engagement with ACEMS in some way. For example, this could be by engaging in a significant and ongoing research project in conjunction with an ACEMS Chief Investigator or by being a joint supervisor of an ACEMS student. Associate Investigators are appointed for renewable two-year terms.

Yasin Abbasi-Yadkori, QUT

George Athanasopoulos, MU

Andrew Barbour, UoM

Adrian Barnett, QUT

Andrew Black, UoA

Konstantin (Kostya) Borovkov, UoM

Rhys Bowden, UoM

James Brown, UTS

Pamela Burrage, QUT

Julian Caley, QUT

Chris Carter, UNSW

Jinyuan Chang, UoM

Ian Charles, UTS

Nathan Clisby, UoM

Mary Coupland, UTS

Susanna Cramb, QUT

Aaron Darling, UTS

Giuseppe de Martino, QUT

Pierre Del Moral, UNSW

Alexander Dokumentov, MU

Chris Drovandi, QUT

Mark Fackrell, UoM

Yanan Fan, UNSW

Troy Farrell, QUT

Davide Ferrari, UoM

Caley Finn, Laboratoire d'Annecy-le-Vieux de Physique Théorique

Jing Fu, UoM

Victor Gabillon, QUT

Peter Grace, QUT

Nick Graves, QUT

Peter Green, UTS

Anthony (Tony) Guttman, UoM

Sophie Hautphenne, UoM

Markus Hegland, ANU

Rob Hyndman, MU

Iwan Jensen, UoM

Paul Keeler, The Weierstrass Institute

Bonsoo Koo, MU

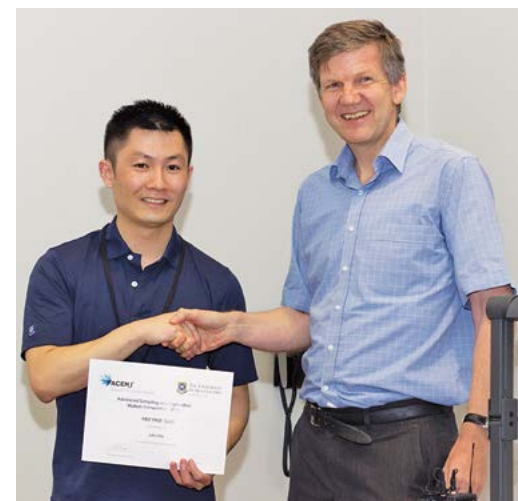
Benoit Liquet, QUT

Gael Martin, MU

Anthony Mays, UoM

James McGree, QUT

Matthew McLean, UTS



Chief Investigator Dirk Kroese awarding PhD student Jun Chen the First Prize in the ACEMS Advanced Sampling and Exploration Matlab Student Competition (page 67)



ACEMS QUT node members



Associate Investigator Anthony Mays demonstrating the mathematics of juggling during National Science Week



ACEMS UTS postdocs and students celebrating with graduating PhD student Cathy Lee

Lewis Mitchell, UoA
 Paula Moraga Serrano, QUT
 Tim Moroney, QUT
 Yoni Nazarathy, UQ
 Giang Nguyen, UoA
 Malgorzata O'Rielly, UTas
 John Ormerod, USyd
 Anastasios Panagiotellis, MU
 Tristan Perez, QUT
 Juan Perez Bernal, UoM
 Graeme Pettet, QUT
 Tung Pham, UoM
 Michael Pitt, UNSW
 Anita Ponsaing, UoM
 Charl Ras, UoM
 Christian Robert, QUT
 Leonardo Rojas-Nandayapa, UQ
 Joshua Ross, UoA
 Nathan Ross, UoM
 Benjamin Rubinstein, UoM
 Scott Sisson, UNSW
 Kate Smith-Miles, MU
 Steven Stern, QUT
 Laleh Tafakori, UoM
 Thomas Taimre, UQ
 Peter Timms, QUT
 Ali Tirdad, UoM
 Ming-Ngoc Tran, USyd
 Jonathan Tuke, UoA
 Julie Vercelloni, QUT
 You-Gan Wang, QUT
 Ole Warnaar, UQ
 Alan Welsh, ANU
 Michael Wheeler, UoM
 Gentry White, QUT
 Nicole White, QUT
 Sally Wood, USyd
 Paul Wu, QUT
 Hongbo Xie, QUT
 Huaxin Xu, UTS
 Qianqian Yang, QUT
 Nan Ye, QUT
 Joseph Young, QUT

Joyce Zhang, UoM
 Wenxin Zhou, UoM

Partner Investigators

A Partner Investigator is a member employed at a Partner Organisation, who is the main contact for that organisation. The person may collaborate with an ACEMS Chief Investigator, act as the main contact for access to in-kind contributions, and contribute to strategic decisions as required.

Siu-Ming Tam, ABS
 Daniel Elazar, ABS
 Ken Anthony, AIMS (in-coming)
 Julian Caley, AIMS (out-going)
 Jennifer Yates, AT&T Labs Research (in-coming)
 Walter Willinger, AT&T Labs Research (out-going)
 Andrew George, CSIRO (in-coming)
 John Taylor, CSIRO (out-going)
 Arvind Gupta, Mitacs (out-going) (replacement not identified)
 Mark Bartlett, Sax Institute (in-coming)
 Timothy Churches, Sax Institute (out-going)
 Jeremy Burdan, VicRoads (in-coming)
 Keith Weegberg, VicRoads (out-going)

Research Fellows

A Research Fellow is employed by ACEMS to work directly on an ACEMS research project. The person is responsible for contributing to research, helping with mentoring students and with other activities as directed by their supervisor.

Craig Anderson, UTS
 Andrea Bedini, UoM
 Tomasz Bednarz, QUT
 Wilson Chen, UTS
 Praveen Choppala, UNSW
 Yuguang Fan, UoM
 David Gunawan, UNSW
 Alexandr (Sasha) Garbali, UoM
 Jesper Ipsen, UoM
 Brodie Lawson, QUT
 Benoit Liquet, QUT
 Inna Lukyanenko, UoM

Ross McVinish, UQ
 Chris Oates, UTS
 Bin Peng, UTS
 Juan Perez Bernal, UoM
 Erin Peterson, QUT
 Steven Psaltis, QUT
 Silvio Tarca, UoA
 Paul Tune, UoA
 Radislav (Slava) Vaisman, UQ
 Brendan van Rooyen, QUT
 Joanna Wang, UTS
 Stephen Wright, UTS
 Huaxin Xu, UTS
 Simon Yin, UTS
 Zongzheng (Eric) Zhou, MU

Students

A Student is a member who belongs in at least one of the following categories:

1. Is supervised by an ACEMS Chief Investigator;
2. Is a recipient of an ACEMS top-up scholarship;
3. Is supervised by an ACEMS Associate Investigator or Research Fellow in a project that forms part of ACEMS activities.

Ibrahim Al Khairy, QUT
 Fadhah Alanazi, QUT
 Ziwen An, QUT
 Jiyuan An, QUT
 Hugh Andersen, QUT
 Ganathipan Vidura Aruneswaran, UNSW
 Azam Asanjarani, UQ
 Aswi Aswi, QUT
 Jannah Baker, QUT
 Eka Baker, UoA
 Peter Ballard, UoA
 Denise Beaudequin, QUT
 Joel Craig Bennett, QUT
 Abhishek Bhardwaj, ANU
 Imke Botha, QUT
 Peter Braunsteins, UoM
 Lachlan Bridges, UoA
 Amelia Briggs, UoA

Lachlan Bubb, UoA
 James Bubear, QUT
 Jonathan Budd, UoM
 Louise Campbell, UoA
 David Campbell, UQ
 Marcela Cespedes, QUT
 Zeying Chen, UoM
 Jun Chen, UNSW
 Vincent Chin, UNSW
 Aaron Chong, UoM
 Timothy Churches, UTS
 Stephanie Clark, UNSW
 Brigitte Colin, QUT
 Eamon Conway, QUT
 Amy Cook, QUT
 Stephen Crotty, UoA
 Doan Khue Dung Dang, UNSW
 Kale Davies, UoA
 Matthew DeMaere, UTS
 Nicholas Dendle, QUT
 Ashley Dennis-Henderson, UoA
 Qibin Duan, UQ
 Earl William Duncan, QUT
 Debajit Dutta, UoM
 Anthony Ebert, QUT
 Michelle Edwards, UoA
 Andrew Elvey-Price, UoM
 Megan Farquhar, QUT
 Charisse Farr, QUT
 John Feenstra, UoA
 Libo Feng, QUT
 Benjamin Fitzpatrick, QUT
 John Foxcroft, UoM
 Lawrence Garufi, QUT
 Yani Geng, UoM
 John Gilbertson, UoM
 Luke Ginn, QUT
 Vanessa Glenny, UoA
 Max Glonek, UoA
 Morgan Grant, UQ
 Caitlin Gray, UoA
 Jens Grimm, MU
 Leah Gustafson, QUT

Adam Hamilton, UoA
 Shovanaur Haque, QUT
 Cartriona Hargrave, QUT
 Patrick Hassard, QUT
 Robert Hickingbotham, MU
 Liam Hodgkinson, UQ
 Jeff Ching-Fu Hsieh, QUT
 Wei Huang, UoM
 Derek Hung, UoA
 Hamidul Huque, UTS
 Hon Hwang, UTS
 Tim Hyndman, UoM
 Sarah James, UoA
 Zhou (Joyce) Jiang, UQ
 Scott Jones, QUT
 Lachlan Kang, UoA
 Daniel Kennedy, QUT
 Sang Il Kim, UTS
 Julia Kuhn, UQ
 Ashwani Kumar, UoM
 Helen Lan, UoM
 Patrick Laub, UQ
 Huong Le, QUT
 Xing Lee, QUT
 Jarod Lee, UTS
 Cathy Yuen Yi Lee, UTS
 Shaoke Lei, UoM
 Angus Lewis, UoA
 Cong Li, UoM
 Andrew Liang, UQ
 Jaslene Lin, UNSW
 Kieran Maguire, UoM
 Alan Malecki, UTS
 Jiadong Mao, UoM
 Scott Mason, UoM
 Peter Mathews, UoA
 Ignatius McBride, UTS
 James McBroom, QUT
 Michelle McGrath, QUT
 Rachel McLean, UoA
 Ellen Muir, UoM
 Mitchell Neill, QUT
 Tan Nguyen, QUT

Tui Nolan, UTS
 Vincent Pang, UoM
 Jonathon Pantelis, UoA
 Eric Parsonage, UoA
 Brendan Patch, UQ
 Alan Pearce, QUT
 Martin Brice Peron, QUT
 Bethany Pickles, UoA
 Ramethaa Pirathiban, QUT
 Aiden Price, QUT
 Leah Price, QUT
 Shanlin Qin, QUT
 Timothy Quelch, QUT
 Anas Rahman, UoM
 Samithree Rajapaksha, MU
 Dinesha Ranathunga, UoA
 Nicholas Read, UoM
 Nicolas Rebuli, UoA
 Tristan Reddan, QUT
 Adam Redman, QUT
 Jessie Roberts, QUT
 Thais Rodrigues, UNSW

Guilherme Rodrigues, UNSW
 Adam (Ben) Rohrlach, UoA
 Adam Rosenow, UoM
 Matthew Rushworth, UNSW
 Marcus Ruttkay, UoM
 Jacob Ryan, QUT
 Robert Salomone, UQ
 Aviva Samuelson, UTas
 Sarini Sarini, QUT
 Kate Saunders, UoM
 Shrupa Shah, UoM
 Rohan Shah, UQ
 Aminath Shausan, UQ
 Xiangnan Shi, UoM
 Somayeh Shiri, MU
 Noon (Michael) Silk, UoM
 Alex Simmons, QUT
 Rachael Smith, QUT
 Simon Smith, UoA
 Yueyue Song, UNSW
 Tobin South, UoA
 Dimity Stephen, QUT
 Nicholas Sterkenburg, QUT
 Amy Stringfellow, QUT
 Thyraphol Sutanujinda, QUT
 Matthew Sutton, QUT
 Ria Szeredi, UoM
 Mingmei Teo, UoA
 Johnny Thew, QUT
 Pubudu Thilan, QUT
 Aleysha Thomas, QUT
 Nicholas Tierney, QUT
 Erin Trainer, UTas
 Dang Quang Michael Tran, MU
 Jason Tran, UoM
 Allan Trinh, UoM
 Phoebe Truswell, QUT
 Paco Tseng, UoM
 Michael Ucci, UoA
 Tea Uggen, UTS
 Zoe van Havre, QUT
 Nho Vo, QUT
 James Walker, UoA

Erli Wang, UQ
 Tom Whitaker, UNSW
 Beau White, UQ
 Jason Whyte, UoM
 Jianyun Wu, QUT
 Wangyue Xie, UQ
 Hui (Alice) Yao, UQ
 Yawei Zhang, UoM
 Jinyuan Zhang, UoM
 Xin Zhang, UNSW
 Zongzheng (Eric) Zhou, MU
 Wanchuang Zhu, UNSW

Affiliate Members

An Affiliate Member is a person engaged in ACEMS outreach or stakeholder activities, or who contributes to ACEMS via other non-research activities.

Mary Coupland, UTS
 Robyn Grote, QUT
 Anthony Harradine, Prince Alfred College
 Mark Lawrence, Mark Lawrence Group
 Miles McBain, QUT



PhD student Nick Tierney at Science Meets Parliament

PERSONNEL CHANGES

ACEMS EXPERIENCED SIGNIFICANT CHANGES DURING 2016: THIS WAS MOST VISIBLE IN CHANGES TO KEY PERSONNEL.

In December 2015, Professor Peter Taylor officially replaced Professor Peter Hall as the Centre's Director, after acting in this position for more than half of 2015. Peter Taylor has brought extensive leadership experience, including as a Head of School, an Associate Dean and President of the Australian Mathematical Society, to the role. Following the challenges presented by Peter Hall's long illness and the devastation that followed his death in January 2016, Peter Taylor's hands-on approach to ACEMS operations has brought stability and facilitated other important changes. This has contributed to 2016 being the Centre's best year yet with growth in the number, depth and breadth of its activities; these activities will be further strengthened in 2017. With new systems, procedures, personnel and activities in place, Peter looks forward to taking a more hands-off approach in 2017.

PROFESSIONAL STAFF CHANGES

In June 2016, Dr Emily Duane was promoted to Chief Operating Officer following Tania Smith's resignation.

Emily has a PhD in Operations Research, via which she gained an excellent understanding of the research culture in the mathematical sciences, as well as a good appreciation of what it takes to make systems work. Emily has already taken a significant role in driving the update of ACEMS' reporting systems, and a major reorganisation of ACEMS' website. Furthermore, she has established good relations with ACEMS staff, both professional and academic, across all the nodes, which puts her in an excellent position to make sure that there is further progress in 2017.



Ben Hess

Following Emily's promotion, Ben Hess joined the Melbourne node as both a central and node administrator in September. With a background in mathematics and physics, in addition to several years of experience working in university administration, Ben has been a fantastic addition to the ACEMS professional staff team. Along with Emily, Ben led the successful organisation of the Peter Hall memorial conference in December ([pages 104-105](#)).



Jessie Roberts

Following Greg Lee's resignation, Jessie Roberts joined ACEMS in February 2016 as its new Stakeholder Engagement Officer based at the QUT node. Jessie has brought considerable energy and insight to a very challenging role. She has visited all the nodes, putting considerable effort in getting to know the research strengths and interests of ACEMS members, with a view to taking advantage of opportunities presented by external partners. She has been tasked with liaising with ACEMS' formal Partner Organisations and has also overseen the successful introduction of the ACEMS Industry Affiliate Program, designed for organisations interested in working with ACEMS on a medium-term basis ([pages 114-115](#)).



Anita Ponsaing



Tim Garoni



Scott Sisson



Kate Smith-Miles

Dr Anita Ponsaing joined the Centre's professional staff team in April 2016 as a lead organiser of the first ever National Science Quiz ([pages 108-109](#)) having already been an Associate Investigator with the Centre since early 2015. In September, Anita began organising the Centre's hugely successful Maths Craft professional development workshop for teachers which was held at the MATRIX Institute in November ([pages 106-107](#)). In December, Anita was officially appointed ACEMS Outreach Officer following Andrew Stephenson's resignation.

The ACEMS community thanks Tania, Greg and Andrew for their contributions to the Centre and wish them all the very best in their future endeavours.

There were other short term opportunities for ACEMS professional staff that expanded their skills and experience. From July to November, Finance Officer Kate Hall performed additional administrative duties including extra support for the Centre's executive while Emily and Ben transitioned to their new roles. From August, UQ node administrator Claire Nitsch led the successful introduction of a new Centre-wide Reportal system that has greatly improved efficiency and effectiveness in reporting. In 2017, further improvements to this system will be led by Ben Hess. From November, QUT node administrator Claudia Deasy has been tasked with leading the Centre's website upgrade. The Centre will continue to encourage and support the development and mentoring of its professional staff in 2017 ([pages 80-81](#)).

VARIATIONS TO CIS AND NODES

Two CI departures during 2016—Peter Hall and John Geweke—provided an opportunity to review the remaining CI cohort with a view to addressing succession planning, the next generation of Centre leaders and the future direction of the Centre's research. Following long and extensive discussions as part of the Centre's strategic planning process, Tim Garoni from Monash was confirmed as a continuing CI, and Scott Sisson from UNSW and Kate Smith-Miles from Monash were appointed as new CIs; short biographies for Tim, Scott and Kate can be found on [page 42](#).

A consequence of Kate and Tim joining the Centre as continuing CIs is that Monash University will become ACEMS' seventh node in 2017.

VARIATIONS TO THE SCIENTIFIC ADVISORY COMMITTEE (SAC) AND GOVERNANCE ADVISORY BOARD (GAB)

The year 2016 also saw a strategic refresh of the SAC membership. The Centre welcomed four new SAC members to the committee:

- Professor Michel Mandjes from the University of Amsterdam
- Professor Herbert Spohn from TU München
- Professor Ruth Williams from the University of California in San Diego, and
- Dr Ken Anthony from the Australian Institute of Marine Science (Partner Organisations representative).

To facilitate this update, three SAC members retired from the committee: Professors Bronwyn Harch, Michael Jordan and Montserrat Fuentes.

The Centre also welcomed Ms Sybille McKeown from the ABS to the GAB as the new Partner Organisations representative. Sybille replaced Dr Julian Caley on the GAB when Julian left the Australian Institute of Marine Science (AIMS) in mid-2016. Since Julian's departure from the board and as a Partner Investigator for AIMS, ACEMS has appreciated his continued active engagement as an Associate Investigator.

ACEMS thanks the retiring SAC and GAB members—Bronwyn, Mike, Montserrat and Julian—for their contributions and wishes them all the best. The Centre welcomes Michel, Herbert, Ruth, Ken and Sybille, and looks forward to working with them in 2017.

VARIATIONS TO PARTNER INVESTIGATORS

There have been a number of substantial changes to the Partner Investigators that represent ACEMS' Partner Organisations. A full update of these changes is discussed in the Stakeholder Engagement Report ([pages 110-116](#)).



Jan de Gier

“Jan was the major driver behind the University of Melbourne-led Expression of Interest (Eol) that was merged with the Queensland University of Technology-led Eol to form the application that led to ACEMS. In addition he was the driving force behind, and Founding Director of, the MATRIX Research Institute. It is not overstating things to say that, without Jan, neither organisation would exist.”

UPCOMING CHANGES TO THE EXECUTIVE COMMITTEE

In December 2016, it was announced that Jan de Gier would become the Head of the School of Mathematics and Statistics at The University of Melbourne. As a consequence, Jan has decided to step down as a member of ACEMS Executive Committee (EC).

Jan was the major driver behind the University of Melbourne-led Expression of Interest (Eol) that was merged with the Queensland University of Technology-led Eol to form the application that led to ACEMS. In addition he was the driving force behind, and Founding Director of, the MATRIX Research Institute. It is not overstating things to say that, without Jan, neither organisation would exist. Jan has been on the ACEMS Executive Committee with the portfolio of Deputy Director (Operations) since it started. His contribution to ACEMS has been enormous. ACEMS thanks Jan for his outstanding contribution and looks forward to his continued engagement as a Chief Investigator.

Following Jan's announcement to step down, new Chief Investigator Scott Sisson was appointed to the EC with the role of Deputy Director (Communications and Media). Starting in January 2017, this position will complement Kerrie Mengersen and Nigel Bean's portfolios of Stakeholder Engagement and Outreach respectively. Initially, the primary task of the Communications and Media portfolio will be to liaise with the working group that is updating the website. However, Scott will also have oversight of ACEMS' other outward-facing communications and media.



DR EMILY DUANE
Chief Operating Officer

Emily holds a Bachelor of Commerce, Bachelor of Science (Honours) and a PhD in Operations Research, all from The University of Melbourne. During her PhD she developed novel mathematical solution algorithms for automatic scheduling of cranes at seaport container terminals. Her work provided new insights into the creation of cost effective schedules for this operationally complex problem and will guide future algorithm development in this area.

Since 2003 Emily has worked in various university administrative roles, and was ACEMS Founding Director Peter Hall's assistant from 2009. She has been with ACEMS since its inception, and has thoroughly enjoyed her transition to the Chief Operating Officer role during 2016.

Emily's administrative skills, along with her academic background, are an asset to ACEMS; she appreciates and understands the fundamental importance of the mathematical sciences, and is passionate about supporting and promoting the mathematical sciences in Australia.

STAFF AND STUDENT RECOGNITION: PRIZES, AWARDS AND OTHER PRESTIGE MEASURES

DURING 2016 A NUMBER OF CENTRE MEMBERS WERE RECOGNISED FOR EXCELLENCE OF RESEARCH QUALITY, OUTREACH AND SCIENTIFIC CONTRIBUTION VIA PRIZES, AWARDS AND OTHER PRESTIGE MEASURES.



Kerrie Mengersen with her Pitman Medal (L) awarded by the Statistical Society of Australia and her Research Excellence Award (R) from the Cooperative Research Centre for Spatial Information



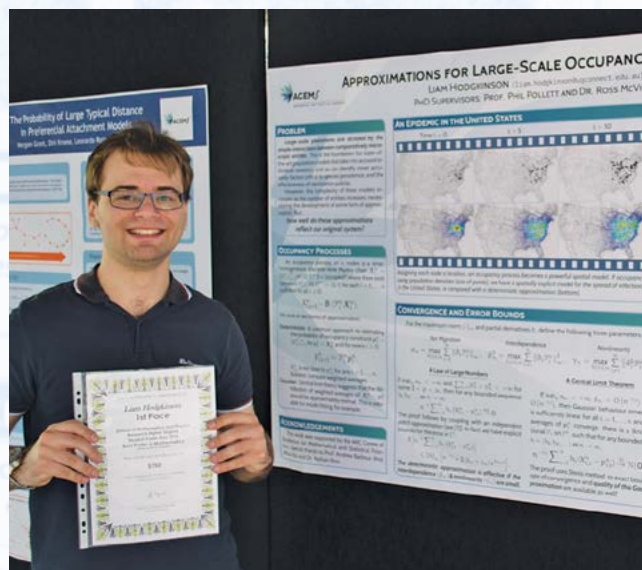
Professor Louise Ryan was awarded an Honorary Doctorate by The University of Ghent

- Professor Kerrie Mengersen was awarded the Pitman Medal by the Statistical Society of Australia ([page 18](#))
- The CSIRO awarded Associate Professor Tomasz Bednarz the CSIRO Corporate Citizen Award
- The University of Ghent awarded Professor Louise Ryan an Honorary Doctorate
- Dr Joshua Ross was awarded the Moran Medal by the Australian Academy of Science ([page 9](#))
- Professor Kerrie Mengersen was awarded the title of Distinguished Professor by Queensland University of Technology ([page 18](#))
- Professor Ian Turner was awarded the Queensland University of Technology's Vice-Chancellor's Excellence Award for Leadership
- Queensland University of Technology awarded Dr Erin Peterson the Vice-Chancellor's Performance Award for Research Impact
- The Faculty of Science at The University of Melbourne awarded Dr Michael Wheeler the Dean's Award for Excellence in Research ([page 37](#))
- The Association for Computing Machinery (ACM) awarded Associate Professor Tomasz Bednarz the Recognition of Service Award
- Dr Hongbo Xie received a Vice-Chancellor's Research Fellow Travel Award at the Queensland University of Technology
- Professor Kerrie Mengersen was awarded the Research Excellence Award by the Cooperative Research Centre for Spatial Information ([page 18](#))
- Associate Professor Tomasz Bednarz received a Pioneer Member Award from ACM Special Interest Group on Computer Graphics and Interactive Techniques

Dr Michael Wheeler receives the Dean's Award for Excellence in Research from The Faculty of Science at The University of Melbourne (page 37)



- PhD student Thais Rodrigues was the winner of the EJG Pitman Prize at the Australian Statistical Conference, awarded for the most outstanding talk presented by a 'young statistician'. Thais also won the JB Douglas Award for best presentation at the Statistical Society of Australia's 17th annual JB Douglas Postgraduate Awards Day
- The JS Hunter Award was awarded to Professor Kerrie Mengersen at the annual J Stuart Hunter Lecture at The International Environmetrics Society 2016 meeting
- Dr Joshua Ross was awarded the JH Michell Medal by ANZIAM (page 9)
- PhD Student Liam Hodgkinson was awarded both the University Medal and the Ethel Raybould Prize from the University of Queensland, and also received the Best Poster in Mathematics at their Student Poster Day (page 47)
- Dr Erin Peterson was awarded the US Forest Service's Rise to the Future Award
- PhD Student Ellen Muir was awarded a Journal of Industrial Economics Graduate Student Travel Fellowship
- PhD Student Somayeh Shiri won the Best Poster in the Mathematical and General Topic at the Statphys26 conference held in France, awarded by the International Union of Pure and Applied Physics
- PhD Student Benjamin Fitzpatrick was part of the winning team on the Cooperative Research Centre for Spatial Information's Student Day Blockchain Challenge
- Professor Ian Turner and Professor Peter Hall both appeared on Thomson Reuters' 2016 list of "Highly Cited Researchers"
- PhD Student Leah Price won 2nd prize in the student poster/talk competition at the Asia Pacific Consortium of Mathematics for Industry Forum "Math-for-Industry" 2016. The prize was a fully funded work trip to Japan for 2 weeks
- At the ACEMS Retreat, PhD Students Peter Braunsteins, Shrupa Shah and Robert Salomone won the three-minute thesis competition; Abhishek Bhardwaj and Wangyue Xie were finalists. PhD student Anthony Ebert won the Best Poster Prize (pages 134-135)
- Jun Chen was awarded First Prize in the ACEMS Advanced Sampling and Exploration Matlab Student Competition (page 67). Robert Salomone and Patrick Laub were joint second place
- PhD student Matthew Sutton received a certificate of outstanding achievement for the Big Data Analytics MOOC Project from ACEMS



Liam Hodgkinson with his award winning poster

STUDENT AND EARLY CAREER RESEARCHER RECRUITMENT AND COMPLETION

ACEMS WELCOMED FOUR NEW POSTDOCTORAL RESEARCHERS TO THE CENTRE DURING 2016: BRODIE LAWSON (QUT), INNA LUKYANENKO (UOM), WILSON CHEN (UTS) AND ERIC ZHOU (MU).

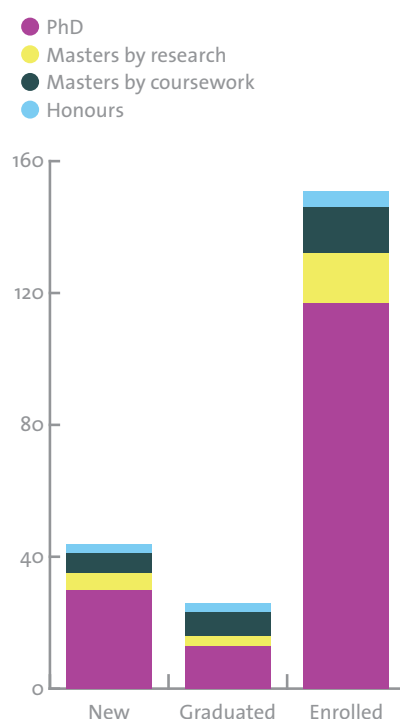
In total, the Centre had 36 early career researchers – members who are within 5 years of PhD completion – across both the Research Fellow and Associate Investigator membership categories.

ACEMS members recruited a total of 42 students to the Centre, including 30 PhD students, five Masters by research students, six Masters by coursework students and three Honours students. This brought total student enrolments to 151 for 2016: 117 PhD students, 15 Masters by research students, 14 Masters by coursework students and five Honours students. Centre researchers also supervised 31 vacation research students, bringing the total number of students involved in the Centre to 181. This includes one student who graduated from their Masters by research and subsequently enrolled in a PhD.

ACEMS celebrated the successful completion of 25 student members, including 12 PhD students, three Masters by research students, seven Masters by coursework students and three Honours students. The Centre wishes these students all the very best with their future endeavours.

ACEMS STUDENT SCHOLARSHIP RECIPIENTS IN 2016 WERE:

- Jiyuan An (QUT)
- Abhishek Bhardwaj (ANU)
- Peter Braunsteins (UoM)
- Zeying Chen (UoM)
- Aaron Chong (UoM)
- Qibin Duan (UQ)
- Puwasala Gamakumara (MU)
- Liam Hodgkinson (UQ)
- Timothy Hyndman (UoM)
- Daniel Kennedy (QUT)
- Patrick Laub (UQ)
- Huan Lin (UNSW)
- Alan Malecki (UTS)
- Brendan Patch (UQ)
- Leah Price (QUT)
- Adam (Ben) Rohrlach (UoA)
- Matthew Sutton (QUT)
- Erli Wang (UQ)



ACEMS RESEARCHER RECEIVES PRESTIGIOUS AWARD FROM THE UNIVERSITY OF MELBOURNE

Congratulations to ACEMS Associate Investigator Dr Michael Wheeler for winning the *Dean's Award for Research Excellence* at The University of Melbourne.

The award recognises one early career researcher across the entire Faculty of Science at the university. This year, Michael won the award for his research in mathematical physics.

Michael's research interests centre on integrable probability, which deals with stochastic, or random, processes with a rich underlying mathematical structure.

"It is a very exciting area of contemporary mathematics, which is allowing us to make exact predictions for the behaviour of certain randomly evolving systems," Michael said.

"It combines several ingredients from pure mathematics, such as algebra and representation theory, to study the behaviour of real physical phenomena."

His research touches on an active field of research, the Kardar-Parisi-Zhang, or KPZ universality class.

One example would be the growth of an ice crystal.

"What we're interested in is looking at the surface of the growing crystal. It grows step by step, in a seemingly random way. Since the surface is jagged, it looks like it would be really hard to study. It turns out, though, models of this type live in the KPZ universality class. Because of this, you can actually learn a lot about how this ice crystal is growing."

Michael returned to The University of Melbourne two years ago, after a two year postdoctoral position in Paris.

"Paris is one of the main centres of mathematics in the world. It has a huge concentration of leading mathematicians in one place doing cutting-edge research. I met a lot of people while I was there. It was a fantastic experience," he said.

The Australian Research Council awarded Michael a Discovery Early Career Researcher Award (DECRA) in 2015, so that he could continue his research in Melbourne.

Among those he's collaborating with are ACEMS Deputy Director Jan de Gier.

"Michael's results on polynomials with many variables provide new advanced mathematical tools to describe collective behaviour in stochastic processes with many constituents, and



ACEMS Associate Investigator Dr Michael Wheeler with Professor Karen Day, Dean of Science at The University of Melbourne

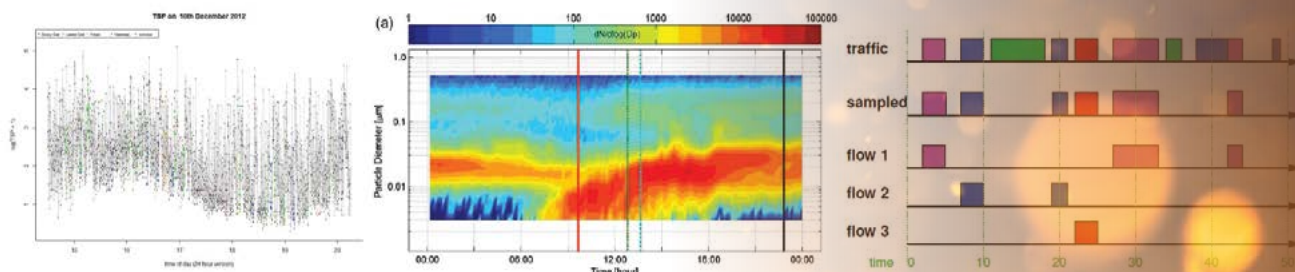
"In a relatively brief period of time Michael has made outstanding contributions to the Big Models research program of ACEMS," Jan said.

already have significant impact internationally. We are thrilled that his results have been recognised by the prestigious and well deserved Dean's Award for Research Excellence."

Michael said he wants to develop his research into a core strength within ACEMS, as well as The University of Melbourne's School of Mathematics and Statistics.

STAYING TRUE TO THE DETAIL IN BIG DATA

“What people do at present is build models using the symbols—but such models can only predict more symbols, which are already at arm’s length from the data.”



Challenging and motivating research. (Left) Snippet of large coal train dust exposure dataset, varying by train type and environmental variables, from the Hunter Valley region. (Centre) Time series of aerosol particle size histograms, directly measured in histogram format, with clear particulate formation event. (Right) Computer network traffic flow datasets, typically measured in petabytes/month, contain critical information on cyber security and network performance.

EVERY SIX SECONDS OVER MANY DAYS, DETECTORS HAVE BEEN RECORDING THE LEVELS OF DIFFERENT SIZES OF AIRBORNE PARTICLES NEAR THE MAIN COAL TRANSPORT RAILWAY CORRIDOR THROUGH THE HUNTER VALLEY.



Professor Scott Sisson
The University of New South Wales

It's part of a New South Wales Environment Protection Authority (EPA) study to gauge the impact of pollution from rail traffic on the health of residents—and a perfect application for a new way of creating models from enormous data sets, without losing the detail contained in the underlying data.

The EPA has already gathered more than 600,000 observations under different wind and weather conditions near lines over which passenger, coal and other goods trains—some loaded, some empty—run past at different time intervals.

As described in last year's annual report, one investigation suggested that the pollution was largely due to dust thrown up by the vibrations of passing trains, no matter whether the trains were empty or full of cargo. Now the data is being explored further.

Collecting big data sets like this is the 'easy' part. Extracting useful information from it—how particulate pollution depends on the type and schedule of the trains, and what role the weather plays—is another story.

That's where Professor Scott Sisson, a chief investigator at the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) comes in. With his colleagues and a team of five ACEMS PhD students, he has been developing new techniques for analysing large or non-standard datasets. The team has come up with novel approaches that can generate a firmer understanding of the underlying story Big Data tells. The work is available at [arXiv.org](https://arxiv.org).

"The theoretical paper mathematically validates what people have been doing in the past, but it also shows these methods have serious shortcomings. They don't give results you're actually interested in most of the time. In fact, people should be doing what we're doing," says Scott, who is from the School of Mathematics and Statistics at the University of New South Wales, and current President of the Statistical Society of Australia.

Scott's group works in a field known as symbolic data analysis. The classic way of dealing with problems of too much data is through summarising the measurements with symbols—mathematical representations that collapse the data and make it easier to handle. This approach is also used to deal with measurements presented in a non-standard form, such as blood pressure which, because it changes constantly, is recorded not as a single figure, but in terms of maxima and minima over a short period of time.

Symbols ideally capture the essence of data in a simpler form and can be used to weed out meaningless and unnecessary data. They can then be processed using classical statistical techniques. At least that has been the theory.

"What people do at present is build models using the symbols—but such models can only predict more symbols, which are already at arm's length from the data. What we do is the other way around. We're using symbols to build models of the underlying data, which we don't even see."

In short, Scott's group has developed ways of estimating how components of the underlying data mix and interact to produce the values of the symbols they observe. So the models they build relate more closely to what's really happening.

The potential applications are enormous. In addition to the Hunter Valley data on which they are working in partnership with Chief Investigator Professor Louise Ryan from the University of Technology Sydney, Professor Matthew Roughan from the University of Adelaide (another ACEMS chief investigator) has provided Scott with the challenge of analysing data on computer network traffic to determine points of congestion and external attack. The group is also working with the Australian Institute of Marine Science—one of ACEMS' partner organisations—on how best to estimate species abundances from diverse published data sources.

CHIEF INVESTIGATORS

ALL OF THE CENTRE'S CHIEF INVESTIGATORS HAVE BEEN SELECTED FOR THEIR RESEARCH EXCELLENCE: THEIR CAPABILITY AND CAPACITY TO CREATE WORLD-CLASS RESEARCH AT THE FRONTIERS OF THE MATHEMATICAL SCIENCES DEALING WITH PROBABILITY AND RANDOMNESS, AND TO TRANSLATE THIS RESEARCH INTO NEW INSIGHTS THAT BENEFIT SOCIETY.

The following brief biographies highlight the depth and breadth of expertise and leadership at the Centre's highest level. These biographies are not comprehensive, rather a glimpse at the Chief Investigators' research interests and backgrounds that illustrate the calibre of this team: there are four Australian Research Council Laureate Fellows; Fellows of numerous prestigious national and international academies, societies and other organisations; members of various boards, committees and advisory groups; former Heads of Schools and other senior university leadership positions; leaders of the Australian mathematical sciences community including current and former society presidents; recipients of prestigious national and international awards and honours; high-citation authors; leaders of industry/mathematical sciences engagement; and mentors and supervisors of the next generation of Australian mathematical scientists.

This leadership team is enriched by its diversity—it contains a mix of junior and senior leaders; applied mathematicians, statisticians, mathematical physicists, and experts in machine learning and optimisation; very applied to more theoretical researchers; and genders that is better than in many Schools of Mathematical Sciences in Australia.

DIRECTOR



PROFESSOR PETER TAYLOR

The University of Melbourne

Peter Taylor holds the Chair of Operations Research and an Australian Research Council Laureate Fellowship at the University of Melbourne. From 2005 until 2010, he was Head of the Department of Mathematics and Statistics.

Peter's research interests lie in the fields of stochastic modelling and applied probability, with particular emphasis on applications in telecommunications, biological modelling, economics, healthcare and disaster management. He is regularly invited to present plenary papers at international conferences.

Peter is the Editor-in-Chief of 'Stochastic Models', and is a member of several other editorial boards. He has served on international awards panels and has held a number of leadership positions in the mathematical science community, including the Chair of the Australia and New Zealand Division of Industrial and Applied Mathematics (ANZIAM) and the Presidency of the Australian Mathematical Society.

DEPUTY DIRECTORS



PROFESSOR NIGEL BEAN

The University of Adelaide

Nigel Bean completed his PhD at the University of Cambridge in 1993. Since then he has been at the University of Adelaide in various roles. Nigel was appointed to the Chair of Applied Mathematics in 2004. He has also been Director of Research (2011-2016) and Deputy Head of School (2004-06, 2012--).

Nigel is known internationally for his research in stochastic modelling. The quality of his research has been recognised through the award of the 2001 JH Michell Medal by the Australia and New Zealand Division of Industrial and Applied Mathematics (ANZIAM) and the 2003 Moran Medal by the Australian Academy of Science. He has successfully supervised 23 PhD students and 6 MPhil students.

Nigel has been very active in national leadership roles. From 2008-2010, he was on the Board of Science and Technology Australia (then FASTS). He was Co-Chair of the sub-committee for mathematics and statistics research in universities and related institutions of the Mathematical Sciences Decadal Plan (2012-2015). He was recently on the Australian Mathematical Sciences Institute (AMSI) Board and is now Deputy Chair of the AMSI Industry/Mathematical Sciences Engagement Task Force.



PROFESSOR JAN DE GIER

The University of Melbourne

Jan de Gier is incoming Head of the School of Mathematics and Statistics at The University of Melbourne, and Founding Director of Australia's first international mathematical sciences research institute, MATRIX.

Jan is interested in the theory and applications of solvable lattice models, an area of mathematics that offers exciting research possibilities in pure as well as applied mathematics. The study of solvable lattice models uses a wide variety of techniques and often produces unexpected links between different areas of research. Currently, Jan studies stochastic models of interacting particle systems employing a variety of advanced methods from mathematical physics. These provide useful frameworks for modelling real world transport phenomena such as in biology and road traffic. Jan is involved in the development and study of a cellular automaton simulator for arterial roads (CEASAR), a model for road networks with realistic traffic lights.

Jan has proved to be an extremely energetic leader in the wider mathematical sciences community, where he played crucial roles in the establishment of both ACEMS and MATRIX.



PROFESSOR KERRIE MENGERSEN

Queensland University of Technology

Kerrie Mengersen is a Research Professor of Statistics in the School of Mathematical Sciences at QUT, where she leads a Bayesian Research and Applications Group (BRAG). She is also an Australian Research Council Laureate Fellow.

Kerrie's methodological research interests include Bayesian statistics, modelling and analysis of big data, statistical computation and complex systems. A strong parallel focus is the application of this research in areas of health, environment and industry.

Kerrie is a fellow of numerous international statistical societies and is currently the President of the International Society for Bayesian Analysis. In 2016 she was awarded the Pitman Medal by the Statistical Society of Australia and made a Distinguished Professor at QUT.

During 2016, Tim Garoni from Monash University was confirmed as a continuing CI, and Scott Sisson from UNSW and Kate Smith-Miles from Monash were appointed as new CIs. A consequence of Kate and Tim joining the Centre as continuing CIs is that Monash University will become ACEMS' seventh node in 2017.

NEW CHIEF INVESTIGATORS IN 2016



PROFESSOR SCOTT SISSON

The University of New South Wales

Scott Sisson is Professor in Statistics in the School of Mathematics and Statistics at UNSW. He is a new Chief Investigator of ACEMS and is a previous Queen Elizabeth II Research Fellow.

Scott is internationally recognised for his work in computational and Bayesian statistics, and in particular for developing inferential techniques for computationally intractable models. He is a previous winner of the Moran Medal (Australian Academy of Science), the 2015 G. N. Alexander Medal (Engineers Australia) and a 2010 J. G. Russell Award (Australian Academy of Science). Scott currently supervises 10 PhD students and one postdoc.

Scott is the current President of the Statistical Society of Australia (SSA) and Chair of the Australasian Chapter of the International Society of Bayesian Analysis (ISBA). He is a member of the Australian Mathematical Sciences Institute's Research and Higher Education Committee, was previously a member of the Research Section Committee of the Royal Statistical Society, and is Associate Editor for the Australian and New Zealand Journal of Statistics.



PROFESSOR KATE SMITH-MILES

Monash University

Kate Smith-Miles holds a Professorial position in the School of Mathematical Sciences at Monash University, and a Laureate Fellowship from the Australian Research Council (ARC). She is also the inaugural Director of the Monash Academy for Cross and Interdisciplinary Mathematical Applications (MAXIMA).

Kate has published two books on neural networks and data mining, and over 230 refereed journal and international conference papers in the areas of neural networks, optimisation, data mining, and various applied mathematics topics. She has supervised to completion 22 PhD students, and has been awarded over AUD\$12 million in competitive grants. In 2010 she was awarded the Australian Mathematical Society Medal for distinguished research. She also regularly acts as a consultant to industry in the areas of optimisation, data mining and intelligent systems.

Kate is a Fellow of the Institute of Engineers Australia and a Fellow of the Australian Mathematical Society (AustMS). She is the current President of AustMS and a member of the ARC College of Experts from 2017-2019.



ASSOCIATE PROFESSOR TIM GARONI

Monash University

Tim Garoni is an Associate Professor in the School of Mathematical Sciences at Monash University. Since he received his PhD from The University of Melbourne in 2003, he has held positions at the University of Minnesota, New York University, The University of Melbourne and as a Research Fellow at the ARC Centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS).

Tim's research areas of interest include mathematical physics, statistical mechanics, combinatorics, Markov-chain Monte Carlo (MCMC) methods and stochastic cellular automata. During his time at MASCOS, Tim began collaborating with VicRoads to develop a computational tool for simulating traffic on arterial road networks. This partnership has continued to develop as part of ACEMS.

FOUNDATION CHIEF INVESTIGATORS



PROFESSOR PETER BARTLETT

Queensland University of Technology

Peter Bartlett is a Professor in the School of Mathematical Sciences at QUT and a Professor in the Computer Science Division and Department of Statistics at the University of California at Berkeley. He has also been an Honorary Professor at the University of Queensland and a Visiting Professor at the University of Paris.

Peter is the co-author, with Martin Anthony, of the book *Learning in Neural Networks: Theoretical Foundations*, has edited four other books, and has co-authored many papers in the areas of machine learning and statistical learning theory.

Peter was awarded the Malcolm McIntosh Prize for Physical Scientist of the Year in Australia in 2001, and was chosen as an Institute of Mathematical Statistics (IMS) Medallion Lecturer in 2008, and an IMS Fellow and Australian Research Council Laureate Fellow in 2011. He was elected to the Australian Academy of Science in 2015.



PROFESSOR KEVIN BURRAGE

Queensland University of Technology

Kevin Burrage is a Professor of Computational Mathematics at QUT, and a Visiting Professor to the Department of Computer Science at the University of Oxford.

Kevin is interested in the development of modelling and computational techniques for solving fundamental problems that involve some form of variability either in time or in time and space. Within this context he has worked recently on a number of problems in biology and physiology including genetic regulatory processes, protein dynamics on the membranes of cells, chemical kinetics, and cardiac electrophysiology. He also has a record in developing modelling and computational pipelines for complex scientific problems.

Previously, Kevin has been an Australian Research Council Federation Fellow and Professor of Computational Systems Biology at the University of Oxford as well as founding CEO of the Queensland Parallel Supercomputing Foundation (now QCIF). Kevin has supervised 42 PhD students and 12 Postdoctoral Fellows, and written more than 250 journal publications with over 10,000 citations.



PROFESSOR AURORE DELAIGLE

The University of Melbourne

Aurore Delaigle is a Professor and Australian Research Council Future Fellow at The University of Melbourne. She received her PhD in statistics from the Université catholique de Louvain in Belgium in 2003. Before moving to Melbourne in 2007, she held positions at the University of California at Davis and at San Diego, and at the University of Bristol.

Aurore's main research interests include nonparametric estimation, measurement errors, deconvolution problems and functional data analysis. She is particularly interested in developing new methods for indirectly and imperfectly observed data, especially if they have some seemingly unappealing form (for example incomplete, irregular, non stationary, too big to handle with usual methods).

In 2013, Aurore was elected a Fellow of the Institute of Mathematical Statistics (IMS) and was awarded the Moran Medal from the Australian Academy of Science. She is an associate editor for some of the most prestigious international statistics journals. She is the Executive Secretary of the IMS. In 2017, she is an Associate Program Chair of the Joint Statistical Meetings, the largest international meetings in statistics.

FOUNDATION CHIEF INVESTIGATORS



PROFESSOR PETER FORRESTER

The University of Melbourne

Peter Forrester received his Doctorate from the Australian National University in 1985, and held a postdoctoral position at Stony Brook before joining La Trobe University as a lecturer in 1987. In 1994 Peter was awarded a senior research fellowship by the Australian Research Council, which he took up at The University of Melbourne where he is a Professor in the School of Mathematics and Statistics.

Peter's research interests are broadly in the area of mathematical physics, and more particularly in random matrix theory and related topics in statistical mechanics. This research and its applications motivated the writing of a large monograph *Log-gases and Random Matrices* (PUP, Princeton) which took place over a fifteen-year period.

Peter's research has been recognised by the award of the Medal of the Australian Mathematical Society (AustMS) in 1993, and election to the Australian Academy of Science in 2004, in addition to several ARC personal fellowships. He was AustMS President from 2012 to 2014, and is the present Chair of the National Committee for the Mathematical Sciences.



PROFESSOR ROBERT KOHN

The University of New South Wales

Robert Kohn is a Scientia Professor in the School of Economics at UNSW School of Business. He is a former Head of the Statistics and Operations Group at UNSW Australian Graduate School of Management, and previously held an Australian Research Council Discovery Outstanding Researcher Award (DORA).

Robert has pioneered Bayesian methodology in time series, nonparametric regression, graphical models, variable selection, covariance selection and copula models. His primary current research interests are in Bayesian inference and Bayesian computation, in particular for models with intractable likelihoods, and the application of the methodology to a number of model classes. His areas of application are health and financial econometrics.

Robert is a Fellow of the Academy of the Social Sciences in Australia, Fellow of the American Statistical Association, Fellow of the Institute of Mathematical Statistics, and Fellow of the Journal of Econometrics. He has over 8,000 Google scholar citations and an h-index of 42. He has had various editorial roles and is currently Associate Editor of *Bayesian Analysis* and the *Journal of Econometrics*.



PROFESSOR DIRK KROESE

The University of Queensland

Dirk Kroese is a Professor of Mathematics and Statistics at UQ. Educated at the University of Twente, he has since had positions at the University of Texas at Austin, Princeton University, the University of Melbourne, and the University of Adelaide.

Dirk is the co-author of several influential monographs on simulation and Monte Carlo methods, including the *Handbook of Monte Carlo Methods* and *Simulation and the Monte Carlo Method* (3rd Edition). He is a pioneer of the well-known Cross-Entropy method—an adaptive Monte Carlo technique which is used around the world to help solve difficult estimation and optimisation problems in science, engineering, and finance. He has supervised 12 PhDs to completion as principal supervisor. His research impact is demonstrated by 12,000 citations on Google Scholar.

Dirk has had various editorial roles. He is a current member of the panel of experts for the Austrian Special Research Programme. He has been invited to give advanced courses on Monte Carlo methods at Summer Schools in Germany, the USA and Australia. He shares his passion for mathematics and statistics through CSIRO's Mathematicians in Schools program.



PROFESSOR ANTHONY PETTITT

Queensland University of Technology

Tony Pettitt is a Professor in the School of Mathematical Sciences at QUT. From 2011 to 2015 he was an Australian Research Council (ARC) Professorial Fellow and, prior to that, Head of the School of Mathematics at QUT for over 19 years. He has also had positions with the universities of Nottingham, Loughborough and Lancaster in the UK and with CSIRO.

Tony is a statistician who has made important contributions in applied, computational and theoretical areas. He is well known for his work in Bayesian computational statistics and applied work in infectious diseases in hospitals and neurology, in particular motor neuron disease, working with clinicians in Brisbane hospitals. Other recent applications include statistical methods applied to investigating cancer cell mobility and model uncertainty quantification.

Tony has published over 130 papers in refereed journals, with an h-index of 33 and over 5200 citations (his change-point paper has over 1500 citations). He has supervised over 25 PhDs to completion, served on various committees and panels of the ARC and the National Health and Medical Research Council (NHMRC), and had editorial roles.



PROFESSOR PHILIP POLLETT

The University of Queensland

Phil Pollett is a Professor of Mathematics at the University of Queensland. Since he received his PhD in Applied Probability from the University of Cambridge he has held positions at the University College of Cardiff, Murdoch University, and the University of Adelaide.

Phil's research is recognised internationally for significant contributions to Markov process theory, having settled several open problems and conjectures, and mathematical modelling in population biology, ecology, epidemiology, chemical kinetics, and telecommunications. He devised the Probability Web, recognised as the main web resource for probabilists throughout the world.

Phil served on the Australian Research Council (ARC) 2010 Excellence in Research for Australia (ERA) Research Evaluation Committee, and the ARC College of Experts 2013-15. He is a Fellow of the Australian Mathematical Society, and was a Chief Investigator within the ARC Centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS). Phil has served on numerous editorial boards, and the organising committees of several major international conferences.



PROFESSOR MATTHEW ROUGHAN

The University of Adelaide

Matt Roughan is a Professor in the School of Mathematical Sciences at the University of Adelaide. Since he obtained his PhD in Applied Mathematics in 1994, Matt has worked for the Cooperative Research Centre for Sensor Signal and Information Processing (CSSIP), in conjunction with DSTO (now DST Group); at the Software Engineering Research Centre at RMIT and The University of Melbourne, in conjunction with Ericsson; and at AT&T Shannon Research Labs in the United States.

Matt's research interests range from stochastic modelling to measurement and management of networks like the Internet. He has written over 100 refereed publications, some very highly cited; presented keynote talks at conferences around the world; and his work has been talked about on radio, in the press and on TV.

FOUNDATION CHIEF INVESTIGATORS



PROFESSOR LOUISE RYAN

University of Technology Sydney

Louise Ryan is a Distinguished Professor of Statistics in the School of Mathematical Sciences at UTS. Louise left Australia in 1979 to pursue her PhD in statistics at Harvard University in the United States, where she was eventually appointed the Chair of the Department of Biostatistics. Louise returned to Australia in early 2009 to take up the role as Chief of CSIRO's Division of Mathematics, Informatics and Statistics. She joined UTS in 2012.

Louise is well known for her contributions to the development of statistical methods for cancer and environmental health research. She loves the challenge and satisfaction of multi-disciplinary collaboration and is passionate about training the next generation of statistical scientists.

Louise is a Fellow of the Australian Academy of Science and has received many prestigious awards over her career.



PROFESSOR IAN TURNER

Queensland University of Technology

Ian Turner is a Professor of Computational Mathematics at QUT. He held the positions of acting Head and then Head of School of Mathematical Sciences from 2009-2015, and was awarded the Vice Chancellor's award for excellence in Leadership in 2016.

Ian's main research interests are in the fields of computational mathematics and numerical analysis, where he has over thirty years experience in solving systems of coupled, nonlinear partial differential equations that govern multiphase flow in heterogeneous porous media. His latest contributions to this field focus on the use of multiscale modelling approaches. Over his career he has published over two hundred research articles in a wide cross section of journals spanning science and engineering. His multidisciplinary research demonstrates a strong interaction with industry and highlights the applicability of computational and applied mathematics to some important environmental problems.

Ian was named in the 2015 and 2016 Thomson Reuters list of Highly Cited Researchers. Most recently he joined the AMSI Industry/Mathematical Sciences Engagement Task Force.



PROFESSOR MATT WAND

University of Technology Sydney

Matt Wand is a Distinguished Professor of Statistics at UTS. He has held faculty appointments at Harvard University, Rice University, Texas A&M University, UNSW and the University of Wollongong.

Matt is chiefly interested in the development of statistical methodology for finding useful structure in large multivariate data sets. He has co-authored two books and more than 110 papers in statistics journals. He has six packages in the R language on the Comprehensive R Archive Network.

In 2008 Matt became an elected Fellow of the Australian Academy of Science. He also has been awarded two Australian Academy of Science honorific awards for statistical research: the Moran Medal in 1997 and the Hannan Medal in 2013. He received the 2013 Pitman Medal from the Statistical Society of Australia in recognition of outstanding achievement in, and contribution to, the discipline of Statistics. He is an elected fellow of the American Statistical Association and the Institute of Mathematical Statistics.

ACEMS STUDENT ALREADY BUILDING CROSS-NODE COLLABORATION

You've probably heard the saying, "jack of all trades, master of none."

Even though Liam Hodgkinson describes himself as a jack of all trades when it comes to mathematics, don't look for that saying to apply to him.

If Liam's young history shows anything, it is that he will certainly master whatever area of mathematics and probability he decides to work on.

Liam is in the first year of his PhD with ACEMS at UQ. His supervisor is ACEMS Chief Investigator Professor Phil Pollett.

"Liam is the most gifted mathematician I have supervised: honours or PhD," Phil said. "What distinguishes Liam is his passion for inquiry, his imagination and depth of insight, and his breadth of mathematical knowledge."

Liam's current work for his PhD looks at the accuracy of approximations to large-scale occupancy models. These models arise in ecology or epidemiology, for example, and are becoming more prominent as powerful spatial models; detailed enough to investigate important phenomena that were largely ignored for decades.

Already, Phil has helped Liam by arranging a two-week collaboration trip to the ACEMS node at The University of Melbourne. Liam says the things he was starting to get interested in were overlapping with the work of some of the people in Melbourne, namely ACEMS Deputy Director and Chief Investigator Jan de Gier, and ACEMS Associate Investigator Andrew Barbour.

"Liam is a prime example of an ACEMS PhD student who crosses borders to make significant advances in mathematics," Jan said.

"In our discussions we explored an exciting collaborative project where Liam will use his mathematical background to significantly upscale precise results we obtained for a specific model to a very large class of stochastic models used for realistic population modelling, transport phenomena and droplet growth."

The trip was equally beneficial to Liam.

"By going to Melbourne, it expanded my horizons," Liam said.

"They were able to help me with some of the problems that I had. It also opened quite a few doors."

Liam recently finished his honours year at UQ, where he received a University Medal placing him in the top five per cent of all First Class Honours graduates, and the university's Ethel Raybould Prize, for having the best overall honours work in mathematics.

"The honours year is really tough here," Liam said.

"I had a pretty good idea that I had done a very good job of it, but to be told I did the best among everyone, I was pretty chuffed by that."

Liam started his studies in pure mathematics, but says Phil made him very interested in doing probability.

"With my background, I've been a bit of a jack of all trades in all kinds of different maths," Liam said.

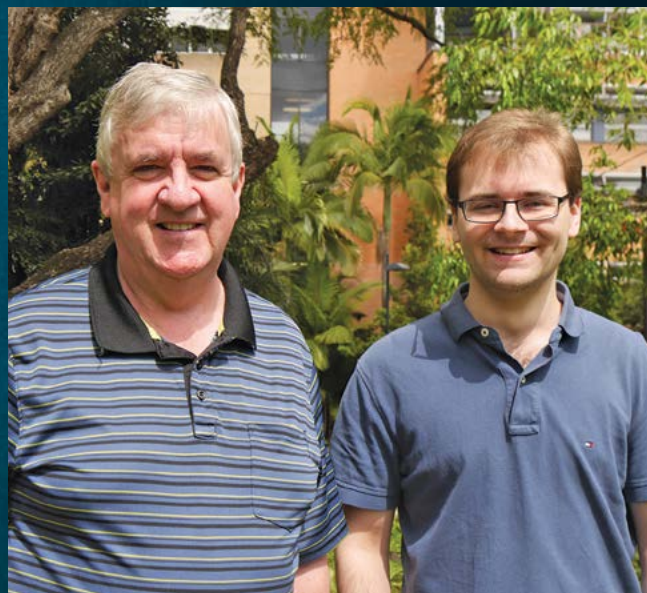
"Phil has allowed me to look into the things that interest me, and he's certainly been very helpful with my writing."

At this point, Liam isn't entirely clear where his PhD and his research will take him. It's clear, though, that he's made quite a start for himself with ACEMS and we look forward to watching him these next few years.

To see highlights of Liam's interview, visit the ACEMS YouTube channel or this story on the ACEMS website:

www.youtube.com/channel/UCf1mumslcl4VFVik1NMClA
www.acems.org.au/liam-hodgkinson/

ACEMS Chief Investigator Phil Pollett with Liam Hodgkinson



RESEARCH THEMES OVERVIEW

THE ACEMS RESEARCH PROGRAM HAS MATURED AND CONSOLIDATED OVER THE PAST YEAR.

One of the obstacles to research in mathematical and statistical modelling and analysis of big data, that was recognised in the original ACEMS proposal and was a primary motivation for the creation of the Centre, is the lack of adequate communication between the various disciplines working in this field. It is a commonly acknowledged challenge that although researchers in the discipline may face similar problems, the way in which they tackle problems is primarily discipline-specific: applied mathematicians, statisticians and machine learners have evolved their own bodies of theory, methods and computational algorithms, and there is often little communication between them. ACEMS aimed to change this paradigm: to create a forum for collaboration and knowledge transfer across the disciplines, and to foster a generation of researchers for whom the traditional discipline barriers are much more permeable.

The first two years of the Centre has seen a marked shift towards achieving this goal. The disparate and single researcher focused project topics that were proposed at the commencement of the Centre have been opened to the general ACEMS research community and have provided new avenue for communication and collaboration that would not have occurred without the Centre. This has permeated into many of the research projects being undertaken by ACEMS postgraduate students, and some of the postdoctoral fellows, who are increasingly accessing cross-disciplinary ideas and techniques to form novel, blended approaches to new mathematical and statistical theory, methods, computation and application for modelling and analysis of big data.

This is a seminal achievement in Australian mathematical sciences community and paves the way for the research program over the next stage of the Centre. It has also resulted in a refocus of the original research programs and projects of the Centre.

The new ACEMS Research Themes, discussed below, adhere to the pillars of 'Big Data, Big Models and New Insights' of the Centre, but more accurately reflect the collaborative efforts of ACEMS researchers and the sustained and emerging global challenges in this field. Specifically:

- the 'Big Data' and 'Big Models' pillars have emerged as four Research Themes, 'Challenging Data', 'Multiscale Models', 'Enabling Algorithms' and 'Informed Decisions';
- the 'New Insights' pillar has remained to focus applications comprising three Programs 'Healthy People', 'Sustainable Environments' and 'Prosperous Societies'.

Chief Investigators Peter Taylor, Aurore Delaigle and Kerrie Mengersen discussing ACEMS research during a break at the Peter Hall memorial conference (see pages 104-105)



The four Research Themes are strongly intertwined with each other and with the three Programs in New Insights. Moreover, each of the Themes hosts a gradient of research from theory to methodology and translation, and an acknowledgement of both long-term and short-term outputs, outcomes and impact.

CHALLENGING DATA

Modern data comes in all sorts of different forms that do not necessarily fit well with traditional data analysis methods. Under this theme we explore these data sources and develop new methods to understand such data.

MULTISCALE MODELS

Multiscale models reflect the fundamental structures required to make sense of data and systems. Under this theme we develop the new models, both stochastic and statistical in nature, required by new problems and to support the Challenging Data theme.

INFORMED DECISIONS

The purpose of data collection and modelling is to learn more about systems and make the best possible decisions about their operation. Under this theme we develop new decision-making methodologies, and exploit Challenging Data, Multiscale Models, and Enabling Algorithms to make decisions.

ENABLING ALGORITHMS

Developments in computing technology have provided the opportunity for the creation of new algorithms to enable improved analysis of data and models. Under this theme we develop the new enabling algorithms required for Challenging Data, the new Multiscale Models and other advances.

NEW INSIGHTS

HEALTHY PEOPLE

SUSTAINABLE ENVIRONMENTS

PROSPEROUS SOCIETIES

A mapping of the original research projects to these Research Themes is provided on page 75. In the following pages, the research objectives, activity, and outcomes from these projects are described in the context of these themes.

THEME 1: CHALLENGING DATA

OVERVIEW

Modern data comes in all sorts of different forms that do not necessarily fit well with traditional data analysis methods. For example, it can occur in the form of images, text, visual displays or mathematical functions. The size of datasets can be much larger than those traditionally analysed and the speed at which decisions have to be made about such data can be much faster than previously required. Under this theme we explore these data sources different types of challenging data and develop new methods to explore such data for its analysis.

HIGHLIGHTS

- New methods to describe and cluster fragments of curves and fit surfaces for irregularly spaced data, using functional data analysis
- New approaches to the problem of large data, both in terms of the number of cases and the number of variables, contaminated with high dimensional noise, using random matrix theory
- New ways to make better use of citizen science data, using Bayesian methods
- New models for analysing big data presented in the form of summaries, using symbolic data analysis
- Collection and analysis of “browserprints”—notional fingerprints of Internet browsers.

RELATED CASE STUDIES

Helping save jaguars with a virtual Peruvian jungle ([pages 14-17](#))

Staying true to the detail in big data ([pages 38-39](#))

Plugging the gaps in missing data ([pages 54-55](#))

The function with a \$1 million bounty on its head ([pages 82-83](#))

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“One of the ways in which data can arrive is as fragments of curves, and the objective is to reconstruct the full curves, estimate their properties and cluster them into similar patterns. This is a pervasive challenge.”

SUMMARY

One of the ways in which data can arrive is as fragments of curves, and the objective is to reconstruct the full curves, estimate their properties and cluster them into similar patterns. This is a pervasive challenge. Consider, for example, observations of the growth of children over time: the children may be measured at irregular time periods and the aim may be to identify different growth profiles. A second example is in estimation of crop yield based on satellite data. The remote sensing data provide irregular time series of the earth, where the irregularity arises because of cloud or measurement error. The challenge is to identify crops based on their growth patterns over the growing season.

ACEMS researchers, led by CI Aurore Delaigle, have been developing a method for clustering in two groups functional data that are only observed in the form of fragments. That is, there is an underlying curve but we observe only a fragment of the curve. Since the curves are only observed partially, the fragments alone often do not contain enough information to discriminate between two groups. For example, suppose that two curves differ significantly on the interval $[0, 0.75]$, but are very close on the interval $[0.75, 1]$. Then if we only observe fragments of the two curves located on the interval $[0.75, 1]$, we could have the impression that the two curves come from the same group. However, suppose now that the first curve increases on $[0.75, 1]$, whereas the second curve decreases. Suppose also that all the curves from group 1 increase on $[0, 0.75]$ and all those from group 2 decrease on $[0, 0.75]$. In this case, the two fragments actually come from two different groups, but this can only be picked up if we take the derivatives into account. Motivated by this, the research team proposes to cluster the fragments using a criterion that combines the information contained in both the fragments and their derivatives.

In 2016, the research team developed an adaptive criterion which is a weighted version of distances to the means based on fragments, and those based on the fragments derivatives. They have developed two versions of the criterion: one for continuously observed data and one for discretely observed data. In some cases, the data are

so sparse that there are some intervals without any observed fragments, so that the data are observed with a gap. If not taken into account, such gaps can cause the method to break down and a way has been proposed to overcome this issue. The team has also defined new descriptive tools for fragments. The method has been applied to data and found to work very well in practice.

This research has direct application to a New Insights project on using remote sensing for official statistics; see the section on Sustainable Environments in the Informed Decisions Research Theme.

An extension of this research is to fit surfaces for irregularly spaced data. In this project the research team, again led by CI Aurore Delaigle, is developing a bivariate smoother in the case where the data are observed on an irregular domain, that is, a domain that is far from being rectangular. This sort of data corresponds to cases such as data observed within the boundary/ frontier of a town, city or country (the frontiers between countries are rarely regular, and the geographical boundary of a country is rarely rectangular). It is easy to define a smoother (a spline regression estimator) on an irregular domain, but the difficulty is: how do we compute it in practice? For example, when the domain of the data is not rectangular, we cannot simply obtain a spline fit by multiplying matrices and vectors. During 2016, the research team has found a way to compute such a solution in practice and they are now investigating the various properties of the solution.

In classical statistics, a big data set is considered to be 'big' when the population size and/or the number of observations are large. The corresponding data matrix has one column for each member of the population. Each member of the population can be thought of as a variable and thus as an extra dimension. A celebrated example is the situation of 95 genes at 400 locations across Europe. This data set was analysed to support the hypothesis that the transfer of farm technology across Europe thousands of years ago was the result of a migration of people rather a transfer of technology. The question is to quantify the number of different populations, as inferred from the data. The classical solution is to perform a principal component analysis of the corresponding covariance matrix. The eigenvector corresponding to the largest eigenvalue

2017 RESEARCH PLANS: CI CAMEOS

CI Robert Kohn and Scott Sisson:

“We aim to develop a new collaboration that will merge symbolic data analysis and pseudo-marginal methods for big data with intractable likelihoods.”

CI Nigel Bean:

“We aim to use social media data (specifically Twitter) for prediction. This will cross over with Multiscale Models and Informed Decisions.”

CI Peter Forrester:

“From exact data, numerical extrapolation can be used to isolate finite size effects. In noisy data, only big data sets have small enough variances that such extrapolation is feasible. The Riemann zeros provide such a big data set. The fact that the leading correction term is well predicted by random matrix theory leads to two further topics for investigation: how to systematically compute large N expansions in random matrix theory; and to investigate further the mechanism behind the correction term for the Riemann zero statistics.”

tells what linear combination of the variables is responsible for the largest variation in the data and, furthermore, the relative size of the eigenvalues measures the relative importance of other linear combinations. What now if the data matrix is contaminated by high dimensional noise? Such a situation is typical in the time series of value of various international currencies against the US dollar, for example. Correlation between the variables is then thought of as a signal, and the objective is to devise inference methods to detect the signal. The study of such questions is the domain of random matrix theory.

This challenge has been taken by ACEMS researchers, led by CI Peter Forrester. It is an excellent example of international collaboration, bringing globally renowned researchers from Germany (Folkmar Bornemann, Technische Universität München), India (Santosh Kumar, Shiv Nadar University), the United Kingdom (Henning Schomerus, Lancaster University), the USA (Parsi Diaconis, Stanford University) and China (D.-Z. Liu, Chinese Academy of Science, Hefei). Two research topics were proposed for this project: Odlyzko's data set for the Riemann zeros, and random matrix theory relating to multivariate statistics and numerical linear algebra.

Odlyzko's data set for the Riemann zeros gives over 109 consecutive Riemann zeros beginning beyond zero number 1023. This data set offers such high quality statistics (having very small errors due to fluctuations), providing the opportunity to test predictions for corrections to leading asymptotic forms like the celebrated Montgomery Odlyzko law predicting coinciding statistics with the eigenvalues of large Hermitian random matrices in the limit. Earlier studies have predicted that the leading correction is also of a form known from random matrix theory: it can be identified with the leading correction to the large N forms of statistics for random unitary matrices with Haar measure. The research team tested this prediction on a novel statistic, motivated by the theory of point processes, in which each Riemann zero is deleted with probability $(1 - z)$. In random matrix theory it is known that the corresponding spacing distributions for the finite N random unitary matrices have expressions in terms of Painleve transcendents, with

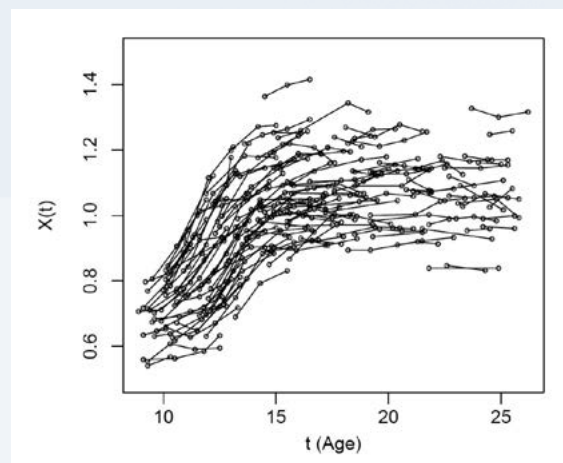
the dependence on z appearing only in the boundary condition. The differential equation can be expanded for large N to give a characterisation of the leading correction in terms of a second order linear differential equation with the leading Painleve transcendents as coefficients. The subtraction of the leading order random matrix prediction from histograms of the spacing distribution obtained from the diluted data set gave some definite functional forms (mostly free of noise). The agreement obtained from the theoretical prediction obtained by solving the differential equation was excellent, providing further evidence for a determinantal origin of the Riemann zero correlations through to second order.

In addition to a characterisation in terms of a Painleve transcendent, the spacing distribution is also given in terms of a Fredholm determinant. Bornemann (Munich) is an expert on the topic of the numerical evaluation of Fredholm determinants in random matrix theory. The relevance of correction terms gives a new focus of attention not part of earlier studies, and provided the beginning of a follow up to the study outlined above. The follow up study also introduced a new statistic into the study of the Riemann zeros: its superposition with a Poisson process and the closest spacing distribution to a Riemann zero.

With great international attention on random matrix products at present, ACEMS CI Peter Forrester noted that the most promising model for the high dimensional noise is a product of standard complex Gaussians. With other colleagues in ACEMS, he has been studying this latter model and also researching the topic of invariant measures, which is foundational to many high dimensional models involving randomness. With Jesper Ipsen and D.-Z. Liu (Chinese Academy of Science, Hefei), the matrix product structure GAG, with A Hermitian and G a complex Gaussian, is presently under investigation, and is showing itself to be very rich, with a relationship to the pseudo-unitary group $U(n|m)$ uncovered. This model is also closely related to the Gaussian version of the so-called Muttalib-Borodin model. The bigger picture topic here is multiplicative processes, which Peter Forrester plans to pursue further under the theme 'Multiscale Models'.

CI Aurore Delaigle:

“We aim to develop new and simple nonparametric fitting procedures for data located on an irregular domain, where standard computational techniques cannot be implemented.”



Fragments of growth curves of children. The horizontal axis is age t , and the vertical axis is growth $X(t)$. See the 'Plugging the gaps in missing data' case study on pages 54-55

Data collected as a result of citizen science can also be considered as 'challenging data'. An ACEMS research team led by CIs at QUT have been investigating the elicitation of information from international experts and local residents, and the integration of this information into mathematical and statistical models. This research has also involved the development of virtual reality (VR) and augmented reality (AR), with the aim of improving the elicitation process.

Another form of 'challenging data' that is increasingly being encountered in the big data world is data that have been summarised into various forms of distributions. An ACEMS research project, led by Associate Investigator Scott Sisson, is interpreting these summaries as 'symbols' and investigating ways of analysing them through symbolic data analysis (SDA). The approach is completely different compared to the current state of the art, and progress in 2016 has focused on theoretical and computational issues. A cross-node collaboration between researchers at UTS and UNSW on time series aspects of SDA, facilitated through the appointment of a joint student, is an example of new research links that have been fostered by the Centre.

A final form of data comes in the form of "browserprints"—notional fingerprints of Internet browsers. CI Roughan and his student Lachlan Kang have collected over 20,000 such prints, and are analysing them to understand their uniqueness, and see whether they can be used to classify browsers using machine learning techniques.

SIX STEP RESEARCH PLAN FOR 2017

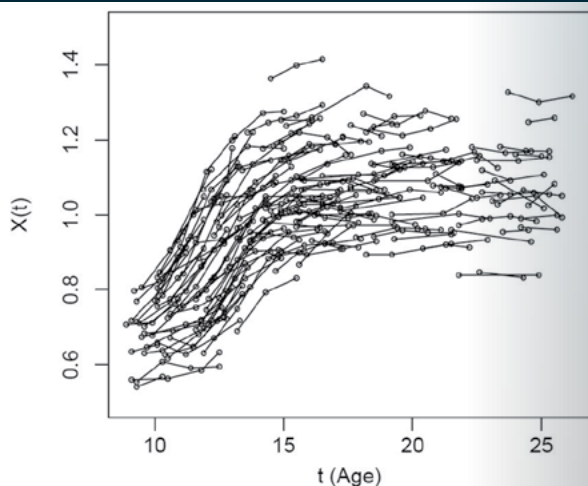
1. Progress research developed in 2016
2. Disseminate research findings through presentations at international and national conferences
3. Initiate new cross-node and cross-disciplinary collaborative research
4. Promote international research networks through collaborative visits by CIs and ECRs
5. Continue to produce high quality research outputs and provide world class research training
6. Develop opportunities for research translation and impact



ACEMS Research Fellow Tomasz Bednarz leading a big data visualisation workshop

PLUGGING THE GAPS IN MISSING DATA

“We needed to develop a method, called clustering, that uses only mathematics to compare everyone with everyone else and creates groups of the fragments of growth curves that are most similar to each other, without previously knowing anything about them.”



Fragments of growth curves of children. The horizontal axis is age t , and the vertical axis is growth $X(t)$.

RESEARCHERS AT THE ARC CENTRE OF EXCELLENCE FOR MATHEMATICAL AND STATISTICAL FRONTIERS (ACEMS) ARE DEVELOPING TECHNIQUES TO 'FILL IN' AND USE DATA THAT HASN'T BEEN RECORDED, TO ADDRESS A RANGE OF CHALLENGES SUCH AS MODELLING GROWTH PATTERNS OF CHILDREN TO THE AUTOMATED INTERPRETATION OF SPEECH.



Professor Aurore Delaigle
The University of Melbourne

Imagine you're a medical officer in an industrial area charged with determining if pollution is having an impact on the growth of children. You would need to track their development over time, comparing the growth curves to those of similar children elsewhere.

But height typically is recorded only when children visit the doctor—some frequently, some infrequently. At best, there will only be data for segments of individuals' growth. So how can you compensate for the missing information, particularly when growth patterns vary widely depending on genetic inheritance?

Professor Aurore Delaigle, Chief Investigator at ACEMS and an Australian Research Council Future Fellow, has set out to solve this type of problem.

"We're trying to fill in data that hasn't been observed," she says.

Aurore and her team at The University of Melbourne have devised practical methods that seem to be working well. Now they need to generate a theoretical basis for their technique so it can be generalised for use in a wide range of problems—from assisting automated answering machines to interpret a caller's speech patterns, to making the most of satellite data that can only be collected intermittently.

It's really a two-part problem. To compensate for the missing data, the researchers compare a whole series of curves with fragments of data that overlap, eventually coming up with a 'typical' complete growth curve. But how do they know they are comparing like with like? The growth patterns of Somali children, for instance, are not the same as those of Anglo-Saxons. And even within those two broad categories there are subgroups that can be very different in their growth.

"We needed to develop a method, called clustering, that uses only mathematics to compare everyone with everyone else and creates groups of the fragments of growth curves that are most similar to each other, without previously knowing anything about them. Then we can try to uncover the reasons behind why those groups exist," Aurore says.

ACEMS has financed a postdoctoral fellow to work with Aurore on the problem, allowing her to use the research to motivate her students by using a realistic example of modern statistics.

"We have meetings and brainstorming sessions," Aurore says.

Now, Aurore needs data and further problems to extend the work. The original fragmentary growth curves on which she and her team have been working, while taken from a real-life situation, were published online as part of a statistics text. Aurore and her team are currently trying to find medical colleagues with access to other datasets that could be used to fine-tune and test her methods.

ACEMS PLAYS A PROMINENT ROLE IN RELEASE OF 10-YEAR MATHEMATICS PLAN FOR AUSTRALIA

Australia needs to do more to promote and teach mathematics, in a world where STEM skills are becoming more important than ever.

That's the message from the new Decadal Plan for Mathematical Sciences in Australia, released by Education Minister Simon Birmingham in Canberra in early 2016.

The plan, developed by the National Committee for Mathematical Sciences, makes a dozen key recommendations to improve mathematics in Australia. They include requiring at least Year 12 intermediate mathematics subjects as prerequisites for all university bachelors programs in science, engineering and commerce. Currently only 14 per cent of Australian universities require science students to have studied intermediate mathematics in Year 12.

Several ACEMS chief investigators were in Canberra for the March 2016 event, including Professor Nigel Bean (Adelaide), Professor Peter Forrester (Melbourne), and Professor Kerrie Mengersen (QUT).

Nigel and Peter were both subcommittee chairs, and members of the Decadal Plan Steering Committee that came up with recommendations for the report.

Kerrie took part in the expert panel discussion following the release of the report.

While not listed as one of the top three recommendations, Nigel said he felt a very important proposal was that everyone involved in mathematics "should embark upon a coordinated program of promotion to ensure that parents, school students and teachers understand that studying mathematics subjects at the highest level possible increases career options."

"We really have to change the public's minds about mathematics," Nigel said. "When your kid comes home and says, 'I'm finding maths hard,' it's not OK to say, 'Don't worry, I couldn't do it either. You won't need it.' We need a hearts and minds campaign that maths is just as important as learning to read and write."

"We really have to change the public's minds about mathematics."

Peter said there are a lot of issues vying for the attention of government, and that more needs to be done to promote mathematical research to a wider community.

"Individual researchers, coordinated by their Departments, and Centres of Excellence such as ACEMS need to be more aware of the need to promote their research, and to be able to argue the value of research in the Mathematical Sciences for Australia's future," Peter said.

Finally, the plan pays tribute to the late Professor Peter Hall, ACEMS Founding Director, for his massive contribution to the project.

"The development work for this decadal plan was led with characteristic energy, acumen and sensitivity by Professor Peter Gavin Hall AO FAA FRS FASSA FAustMS. His untimely death following a prolonged illness has deprived the Australian mathematical sciences community of one of its brightest stars," said members of the plan's executive committee, who dedicated it to Professor Hall's memory.

ACEMS Deputy Director Kerrie Mengersen (second from left) took part in the panel discussion following the release of the Decadal Plan. Photo courtesy: Australian Academy of Science

L-R: Cheryl Praeger, Kerrie Mengersen, Ian Chubb, Geoff Prince, Clio Creswell, Steve Thornton, Karen Andrews, Chennupati Jagadish



THEME 2: MULTISCALE MODELS

OVERVIEW

Models are the fundamental structures required to make sense of data and systems. Under this theme we develop the new models, both stochastic and statistical in nature, required by new problems and to support Challenging Data.

HIGHLIGHTS

- New theory, models and applications for interacting particle systems
- New ways of describing emerging collective behaviour on a global scale of systems consisting of many microscopic degrees of freedom
- New formulations for stochastic fluid models, using matrix analytic methods
- New advanced computational models for describing flows in porous media, as found in groundwater modelling, electro-chemical systems and biological media
- New methods for creating populations of models for simulating coal seam gas in the Surat Basin in Queensland, Australia
- New mathematical models for population dynamics in biological systems, such as metapopulations and epidemics, that account for local population behaviour, individual variation, spatial structure and differing migration patterns
- New models for extremes in space and time, with a focus on using ‘big climate’ data to better understand and predict anomalies such as extreme heat waves

RELATED CASE STUDIES

Helping save jaguars with a virtual Peruvian jungle ([pages 14-17](#))

Understanding rare events: simulating rare disease outbreaks and power blackouts ([pages 24-25](#))

Staying true to the detail in big data ([pages 38-39](#))

New statistics help predict when corals are most vulnerable ([pages 62-63](#))

From future stock prices to coral bleaching: modelling randomness and interdependence ([pages 68-69](#))

Safer drug screening and better simulations: maths getting to the heart of the matter ([pages 76-77](#))

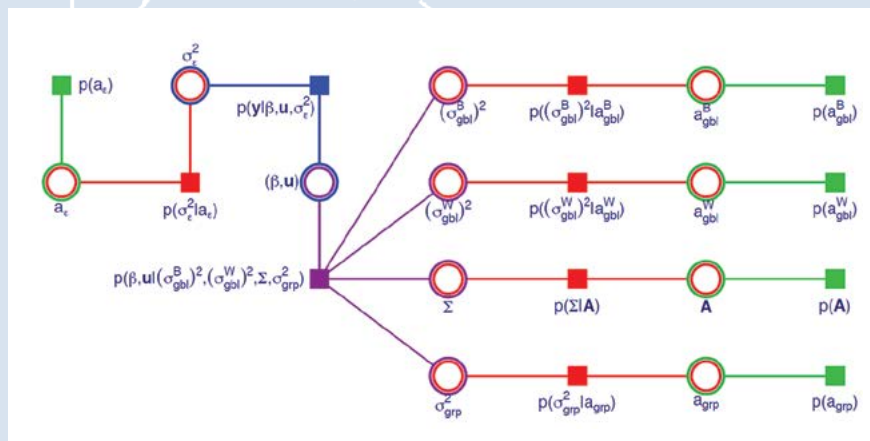
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Kevin Burrage (QUT)
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Tim Garoni (MU)
Dirk Kroese (UQ)
Kerrie Mengersen (QUT)
Tony Pettitt (QUT)
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Paul Tune (UoA)
Slava Vaisman (UQ)
Eric Zhou (MU)



A factor graph for a group-specific curve semiparametric regression model.

See the 'New statistics help predict when corals are most vulnerable' case study on pages 62-63

SUMMARY

A multi-node team of ACEMS researchers, led by CIs Jan de Gier and Peter Forrester from The University of Melbourne and CI Tim Garoni from Monash, has been pushing the frontiers of theory and applications of interacting particle systems. This work has also involved Associate Investigator Michael Wheeler and a large team of early career researchers, including Andrea Bedini, Caley Finn, Sasha Garbali, Inna Lukyanenko, Anita Ponsaing and Joyce Zhang, and PhD students Zeying Chen, Alex Lee, Samithree Rajapaksha and Somayeh Shiri.

Fundamental models of interacting particles, such as those occurring in mathematical physics and queueing theory, are widely studied to understand non-equilibrium behaviour in physical systems consisting of large numbers of particles, to study large classes of transport phenomena, scheduling mechanisms and interface growth. This project combines theoretical approaches with computational and statistical analysis.

The theoretical part of the project aims to derive exact analytical expressions for properties encoding emerging and collective behaviour from microscopic principles. Such properties include important stationary and dynamical properties of model systems such as exclusion processes and queueing systems. Tools to be used and further developed lie in the realm of stochastic calculus, queueing theory, integrable probability, and include matrix product states and random matrix theory.

Strong progress has been made on this project in 2016. Important relations have been established between the stationary distribution of multi-species asymmetric exclusion processes (mASEP) and the theory of many-variable polynomials. The research team has established that the notoriously difficult stationary distribution of mASEP with open particle reservoirs at the boundaries is described by Koornwinder polynomials corresponding to a particular root system. Their approach has led to important new advances in the theory of multi-variable polynomials. Using techniques from stochastic processes, such as matrix product formulas, they have obtained completely new and

explicit formulas for Macdonald polynomials. An exciting and well received result using this methodology is the explicit formulation of a new class of polynomials based on bosonic solutions to the quantum Knizhnik-Zamolodchikov equation, unifying Macdonald with Borodin-Petrov polynomials. This result is expected to lead to a new class of integrable stochastic processes. A recent result of Chen, de Gier and Wheeler, in preparation, is the development of a general theory for constructing stochastic dualities based on the connection with integrability. These dualities relate systems with many degrees of freedom to those with just a few, and hence provide a very significant reduction in computational complexity for natural observables.

The application of this research to a New Insights project on modelling urban traffic on networks is described in the section on Prosperous Societies in the Informed Decisions Research Theme.

Emerging collective behaviour on a global scale of systems consisting of many microscopic degrees of freedom is often very non-trivial and interesting. ACEMS researchers Collevocchio and Garoni have worked on systems of reinforced random walkers in urn models leading to novel attraction properties. Similar systems are investigated in the quantum setting where the emerging behaviour in atomic systems can lead to supersymmetry with applications in condensed matter, as well as percolation systems where universal entropic measures have been identified and computed.

Stochastic fluid models are one of the most versatile, but challenging, classes of models considered by ACEMS researchers. CIs Nigel Bean and Peter Taylor with Associate Investigators Giang Nguyen, Malgorzata O'Reilly, PhD student Aviva Samuelson and international colleagues are developing new ways of formulating these models using matrix analytic methods. Under this topic there is a variety of projects, including single and multi-dimensional models and Markov-modulated diffusions.

A project led by CIs Ian Turner and Kevin Burrage, with Associate Investigators Troy Farrell and Tim Moroney, is also focused on physical modelling of flows in porous media, including groundwater modelling, electro-chemical systems, biological

“ Important relations have been established between the stationary distribution of multi-species asymmetric exclusion processes (mASEP) and the theory of many-variable polynomials. ”

media and coal seam gas, and the development of advanced computational models to describe these systems. This has involved further research into accelerated computational simulation science, including High-Performance Computing, General Purpose Graphics Processing Units, Cloud Computing and High Performance Graphics. It has also involved multiscale modelling with Lattice-Boltzmann and Smoothed Particle Hydrodynamics, and derivation of complex models based on generalised partial differential equations that involve fractional operators to study anomalous transport processes (spatial variability, heterogeneity, and memory effects).

During 2016, the team continued work on the use of Population of Models for estimating parameters in a coal seam gas simulator for the Surat Basin. Three approaches for Population of Models were compared: Random Sampling; Latin Hypercube Sampling (LHS) and Sequential Monte Carlo Approximate Bayesian Computation (SMC ABC). This was accomplished within a framework for exploring variability in complex mathematical models used to simulate cardiac electrophysiology. The team has also progressed work on numerical simulation methods for complex electrochemical models in nanoporous regimes. Cross-institution collaboration and co-supervision of research students has commenced with Associate Investigator Markus Hegland at ANU, focusing on model reduction methods and multiscale approaches, in particular on matrix polynomial approximation methods for the various matrix functions used for Bayesian analysis.

CI Kevin Burrage and Ian Turner also have a strong research focus on developing computational models that are based on generalised partial differential equations containing derivatives of fractional order in space, or time, or both space and time for simulating anomalous transport phenomena. These phenomena are strongly connected to the interactions within the complex and non-homogeneous microstructures evident at the pore scale in porous media. Fractional-order derivatives provide useful alternatives to their integer order counterparts due to their ability to model memory and other hereditary properties of different media, such as spatial heterogeneity. Anomalous transport processes have been observed in many areas of the natural,

biological, and geological sciences. Typically, the macro-models take the form of single or multi-term time-, space-, or time-space-fractional differential equations. We are analysing these models to study their effectiveness for a range of applications where anomalous diffusion is evident. At the core of this work is the convergence and stability analysis of the underlying numerical schemes, and the development of efficient computational algorithms. Ian Turner and Kevin Burrage are also collaborating with CI Peter Taylor on the matrix analysis related to Markov-modulated Erlang loss queues.

It can be seen that a key problem in this Research Theme is modelling and calibration of data intensive systems. A cross-node project led by CI Philip Pollett aims to develop mathematical models for population dynamics that account for local population behaviour, individual variation, spatial structure, and differing migration patterns, and to calibrate these models to real data. The team has been developing mathematical models for biological systems, particularly metapopulations (populations that occupy geographically separated patches of habitat), and epidemic models that incorporate spatial structure and individual variation.

Five of the research topics that have progressed in 2016 are as follows. The first topic is focused on connecting deterministic and stochastic metapopulation models. Using Vapnik-Chervonenkis theory the research team has shown that certain stochastic versions of existing models can be well approximated by the deterministic version when the number of patches is large, provided that the presence or absence of individuals in a given patch is influenced by a large number of other patches. Explicit bounds have been obtained that assess the quality of the approximation. The second topic is overdispersion in parasite counts, with a focus on parasite burden in fish populations. The aim is to explain the degree of overdispersion observed in parasite counts and how this is affected by trophic level (position in the food chain). The third topic, modelling cell proliferation in tissue growth, is in its early stages. The fourth topic involves the study of population models that account for the evolution over time of landscape characteristics which affect the persistence of local populations. Threshold conditions for persistence of

the population have been obtained using an approximating deterministic model that is realized in the limit as the number of patches becomes large. The fifth topic focuses on limiting the spread of disease through altered migration patterns. The research team has examined how individuals susceptible to a disease can act collectively to limit its spread during the initial phase of an epidemic. More specifically, they have considered how susceptible individuals can distribute themselves in a metapopulation in order to minimize the growth rate of the epidemic when the infectives migrate so as to maximise the growth rate (minimax optimisation).

This large project team is cross-nodal and international, involving researchers at the University of Queensland, The University of Melbourne, Zurich, Liverpool and Aarhus, and including four PhD students, four Research Fellows, three Associate Investigators and two Chief Investigators.

Research on multiscale models is being pursued from a Bayesian perspective by a multi-node research team led by CI Kerrie Mengersen. The primary focus on this work in 2016 has been on Bayesian spatial and spatio-temporal models that can accommodate different sources of information. A new model has been developed with associated model selection criterion for identification of anomalous outcomes in space and time. The application under consideration is spatial mapping of cancer incidence and survival. Models have also been developed for imperfectly observed data. These data are endemic in ecology (observation of 'presence only' data) and health (observation of disease cases only). The applications under consideration are improved monitoring of the Great Barrier Reef and modelling reported jaguar sightings in the Peruvian Amazon. Methods have also been explored for spatio-temporal modelling of remotely sensed images. This work is being written as a chapter in a Methodology Report requested by the United Nations Global Working Group on the topic, and will also be translated through a series of workshops for National Statistics Organisations in 2017.

The modelling and analysis of extremes of space/time data is a challenging and topical issue in many fields, as illustrated by "big" climate data and the temperature extremes experienced in Australia during 2016. Associate Investigator Scott Sisson is leading a team of ACEMS researchers in developing new models and techniques to improve predictions and understanding of these extreme events. This involves derivation of new extremal distributions, kernel smoothing techniques, and applied data analysis. With his PhD student Kate Saunders and her co-supervisor David Karoly, CI Peter Taylor is working on the spatial modelling of extreme rainfall events, with a particular focus on south-east Queensland, which suffered from major floods in 2011.

This project is an excellent example of the merger of the ACEMS Research Themes, with cross-over into symbolic data analysis (see 'Challenging Data') and intractable likelihoods (see 'Multiscale Models'). It has also generated new collaborations with researchers in the ARC Centre of Excellence for Climate System Science (and soon to be the new ARC Centre of Excellence for Climate Extremes).

CI Roughan and postdoc Paul Tune have been working on multi-scale models for efficient synthesis of Internet traffic matrices, which are used for many network planning tasks, such as risk mitigation. The project, in conjunction with DST group, has developed new modelling approaches that naturally take into account the hierarchical nature of Internet engineering approaches.

CIs Nigel Bean, Matt Roughan and Peter Taylor have been leading a project on distributed networks of resource allocation facilities, working with ACEMS postdoctoral fellows Silvio Tarca and Juan Perez. As might be expected from investigators based in South Australia, Nigel and Silvio have been concentrating on models of electricity distribution. Juan arrived from the United Kingdom, having worked on the management of distributed systems in his previous position and has concentrated on a number of projects involving replication and subsequent discard of service tasks and allocation of capacity. Associate Investigators Sophie Hautphenne and Yoni Nazarathy, PhD student Peter Braunsteins and international colleagues Guy Latouche and Sarah Dendievel have also worked on capacity allocation. Recently, newly-arrived Associate Investigator Jing Fu has started collaborating in this area.

CI Peter Taylor, together with visitors Paul Keeler and Tony Krzesinski, and Tony's colleague Johannes Gobel have collaborated on modelling of the Bitcoin blockchain. Their initial paper on this subject 'Bitcoin blockchain dynamics: The selfish-mine strategy in the presence of propagation delay' has been the most-downloaded paper published by the journal Performance Evaluation over the last six months or so.

SIX STEP RESEARCH PLAN FOR 2017

1. Progress research developed in 2016
2. Disseminate research findings through presentations at international and national conferences
3. Initiate new cross-node and cross-disciplinary collaborative research
4. Promote international research networks through collaborative visits by CIs and ECRs
5. Continue to produce high quality research outputs and provide world class research training
6. Develop opportunities for research translation and impact

2017 RESEARCH PLANS: CI CAMEOS

CIs Kevin Burrage, Ian Turner and Peter Taylor:

“We aim to develop a new collaboration on the matrix analysis related to Markov-modulated Erlang loss queues.”

CI Nigel Bean:

“We aim to commence new research on model selection in phylogenetics that will cross over with Challenging Data and Informed Decisions. Our work on Markov Modulated diffusion processes will also be applied to modelling electricity spot prices and animal foraging.”

CI Jan de Gier:

“Research directions in 2017 include the development of multi-variable polynomials, leading to a new class of integrable stochastic models in two-dimensional spatial dimensions. Such a model would provide novel insights into variability and uncertainty in applications such as traffic networks, but also in a variety of other applications such as membranes and growth processes. It is particularly interesting to understand what KPZ scaling, a non-Gaussian law of large numbers ubiquitous in stochastic models, looks like in two dimensions.”

CI Robert Kohn:

“In 2017 we plan to extend our copula framework to flexible copula methods based on a Dirichlet process mixture as well as to use copulas for flexible regression density estimation. We also plan to estimate high dimensional copulas via ABC methods.”

CI Tim Garoni:

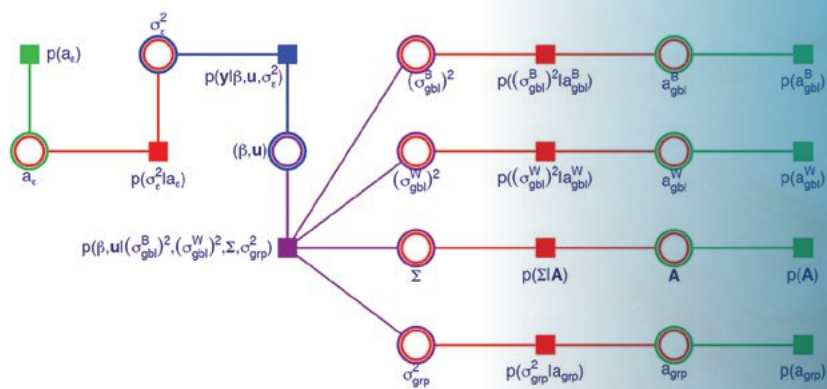
“My new project in 2017 will focus on Monte Carlo methods for studying phase transitions. Phase transitions are one of the most ubiquitous and dramatic phenomena observed in large networks; a small change in a system’s parameters can lead to qualitatively different behaviour. An everyday example is the phase transition from water to steam. Understanding phase transitions mathematically is both of fundamental scientific interest, and of significant practical importance. The mathematical models that have been developed to understand phase transitions are prime examples of the Big Models that are the remit of ACEMS. Given their complexity, understanding such models typically requires sophisticated computational techniques. This project will contribute to the development of such techniques. Equally, it will contribute to the rigorous mathematical study of the efficiency of known techniques; with the aim of determining which methods currently being employed in practice actually work well, which do not, and how such methods could be improved. In addition to studying such computational techniques in their own right, these techniques will also be employed to study fundamental questions related to phase transitions in particular, and collective behaviour in general.”

CI Peter Taylor:

“We will be extending our work on the BitCoin blockchain to a statistical analysis of the point process of block mining instants. The Bitcoin controls are designed so that, to a first approximation this is a Poisson process with rate six per hour. However, the actual process is not quite like this. Its rate is higher than six per hour and there are local dependencies that affect behaviour. It’s on our agenda for 2017 to produce a model that describes the fine detail of this process.”

NEW STATISTICS HELP PREDICT WHEN CORALS ARE MOST VULNERABLE

“We need to develop methodologies ready to confront bigger and bigger data sets and models that have more and more parameters.”



A factor graph for a group-specific curve semiparametric regression model.

FROM NEARLY 17,000 MEASUREMENTS OF CORAL POSITION AND GROWTH ON A REEF IN FRENCH POLYNESIA, AN INTERNATIONAL RESEARCH TEAM TEASED OUT WHICH REEF-BUILDING SPECIES WERE MOST SENSITIVE TO ATTACK BY CROWN-OF-THORNS STARFISH AND DESTRUCTION DURING TROPICAL CYCLONES, AND AT WHAT TIMES OF THEIR LIFE HISTORY.



Professor Matt Wand
University of Technology Sydney

The scientists, including researchers from the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) and the Australian Institute of Marine Science (AIMS), with international colleagues, were able to suggest management techniques most likely to help bolster the resilience of the reef.

The information is of significance to Australia since, according to AIMS (a partner organisation of ACEMS), cyclones and crown-of-thorns starfish are also the biggest threats to the Great Barrier Reef. But it wouldn't have been possible without using statistical methods for handling large amounts of data devised by Professor Matt Wand, one of the paper's authors and a chief investigator at ACEMS.

In an era of credit cards, Facebook, the internet, geographical positioning systems, and growing numbers of electronic sensors in medicine, biology and the physical sciences, data keeps flooding in, Matt says.

"We need to develop methodologies ready to confront bigger and bigger data sets and models that have more and more parameters."

And that's just what Matt, who is Distinguished Professor of Statistics at the University of Technology Sydney, has been doing. The results of his efforts have been so significant that they will be published in the March 2017 issue of the *Journal of the American Statistical Association* as one of the few selected discussion papers, a rare honour for someone from outside the USA. In the journal, the work is discussed by six experts in the field.

"The paper lays down a framework that makes it easier to implement models to extract useful information from large data sets, but which also allows you to extend these models to more complicated versions in future."

The work is built around a technique known as message passing, borrowed from computer engineering, where it's used to optimise computer systems and electronic devices.

"It's an iterative process. Each time a message is passed you get closer and closer to the optimal solution," Matt says.

And for more complex models, he says, you can build on formulae that have already been derived for simpler models. To move from fitting a straight line to the data to a more sophisticated curve, for instance, you don't need to go back to square one and revisit the maths that gave you the straight line—you can just add to it. In other words, the technique is future-ready. You can elaborate on what you have today to efficiently produce a more complicated model to accommodate tomorrow.

"It's like drilling a series of different-sized holes. You don't have to go back to the hardware store to buy a different drill each time. All you need is a new drill bit," Matt says.

"There are two advantages of the work. It provides a faster way to usefully analyse what the data means. Often we can get it down to less than a second on ordinary laptop computers. And it gives you a way of going beyond today's models. You don't have to go back and do all the algebra and coding from scratch. You only have to figure out a few new message types and program them."

ACEMS supported this development and helped facilitate Matt's collaborations, to discuss ideas and elements of his methodologies with his colleagues. Other colleagues have contributed data on which to work, such as the information on the coral in French Polynesia, and 80,000 measurements of the growth of babies in Africa for an ongoing project on the impact of the environment on their development.

THEME 3: ENABLING ALGORITHMS

OVERVIEW

Developments in computing technology have provided the opportunity for the creation of new algorithms to enable improved analysis of data and models. Under this theme we develop the new enabling algorithms required for Challenging Data, the new Multiscale Models and other advances.

HIGHLIGHTS

- New theory underpinning advanced machine learning methods
- New theory for expectation propagation and variational message passing on factor graphs, which scale well to large models and sample sizes, as well as high velocity data
- New efficient learning and sampling algorithms, for example for autonomous systems
- New techniques for subsampling estimation for big data or complex models, based on pseudo-marginal computations
- New methods for fitting flexible copula models
- New algorithms for big data and intractable likelihoods
- New fast, generaliseable and parallelisable versions of popular approximation algorithms such as Approximate Bayesian Computation and Variational Bayes

RELATED CASE STUDIES

Helping save jaguars with a virtual Peruvian jungle ([pages 14-17](#))

Understanding rare events: simulating rare disease outbreaks and power blackouts ([pages 24-25](#))

Staying true to the detail in big data ([pages 38-39](#))

New statistics help predict when corals are most vulnerable ([pages 62-63](#))

From future stock prices to coral bleaching: modelling randomness and interdependence ([pages 68-69](#))

TEAM

Chief Investigators

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Ian Turner (QUT) – Theme Leader

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Kevin Burrage (QUT)

Peter Forrester (UoM)

Tim Garoni (MU)

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Huaxin Xu (UTS)

Simon Yin (UTS)

Eric Zhou (MU)

```
); % iteration counter
```

```
le sigma > eps
```

```
t = t+1;
```

```
x = mu + sigma*randn(N,1);
```

```
SX = S(x); % Compute the performance.
```

```
sortSX = sortrows([x SX],2);
```

“The initial aim of this project was focused on developing efficient learning for autonomous systems, but this has widened to efficient learning and sampling algorithms in general”

SUMMARY

The development of trustworthy, efficient and useful algorithms involves both computational and theoretical challenges, both of which are addressed in this ACEMS Theme.

A research project, led by CI Peter Bartlett, has focused on developing and understanding the theory underpinning advanced machine learning methods. This research has primarily focused on three canonical problems: developing sampling methods for nonconvex but smooth sets, regularized estimation, and large scale convex optimisation. For example, methodology for regularized estimation has been developed based on Laplacian solvers that are suitable for large scale graph data, and algorithms have been developed for large scale optimisation that generalize Nesterov's acceleration approach using a Lyapunov analysis of second order differential equations. This research has been acclaimed internationally as providing major advances in the way that we can analyse high-dimensional data.

CI Matt Wand has progressed a theoretical research project focusing on statistical theory for expectation propagation (EP) and variational message passing (VMP) on factor graphs. EP and VMP are two protocols for performing approximate inference in Bayesian hierarchical models. They have the advantage of scaling up well to large models and sample sizes, as well as high velocity data. These two so-called inference engines are the basis on which the software framework Infer.NET (<http://research.microsoft.com/infernet>).

The factor graph representation of EP and VMP is not well known, especially in Statistics. However, it provides an attractive means by which a large array of models, particularly those involving exponential family distributions, can be accommodated. The statistical accuracy of VMP and, especially, EP has received very little attention. The statistical theory in the proposal concerning the accuracy of VMP and EP was put on hold due to the illness of CI Peter Hall, but discussions have been initiated with Ian Johnstone of the Department of Statistics, Stanford University U.S.A. to progress this work. A foundational paper on VMP for

statistical analyses will be published as a Journal of the American Statistical Association discussion paper in early 2017 with author CI Matt Wand and four sets of discussants. This is one of three new papers that have been written on this topic in 2016.

A project that encompasses both theory and computation is on Efficient Learning Algorithms, led by CI Dirk Kroese. The initial aim of this project was focused on developing efficient learning for autonomous systems, but this has widened to efficient learning and sampling algorithms in general. During 2016, new theory has been developed for efficient search of combinatorial structures such as polytopes and trees, with applications to network reliability and random networks. New sampling methods have been developed for Partially Observable Markov Decision Processes (POMDP). The success of this work and the interest that it has generated across the ACEMS community is illustrated by the creation of an annual ACEMS Sampling and Exploration Matlab Competition. Inter-node collaboration has also been instigated, for instance between CI Matthew Roughan (University of South Australia) and CI Dirk Kroese and Slava Vaisman at UQ.

Another computational research project, led by CI Robert Kohn, has focused on four topics of intense international interest in modelling and analysis of big data. The first topic is subsampling estimation for big data or complex models. The idea is that for large data sets or for very complex models where likelihood computation for the entire model is expensive, it is useful to use subsampling methods based on pseudo marginal computations. The second topic is development of flexible copula models, which have become an underpinning modelling approach in random effects modelling, finance and time series. These models are of interest because they can cater for both discrete and continuous marginals and because they are based on mixtures. The third topic is on the development of pseudo-marginal methods which can be employed in situations in which the likelihood is intractable. The fourth topic is the development of fast, generalizable and parallelizable versions of the popular approximation algorithms known as Variational Bayes.

There has been substantial progress on this project in 2016.

2017 RESEARCH PLANS: CI CAMEOS

CIs Kerrie Mengersen and Aurore Delaigle:

“We aim to develop a new collaboration on algorithms for Bayesian high dimensional data analysis with Professor Judith Rousseau of the University of Oxford and Universite Paris Dauphine.”

CI Scott Sisson:

“We aim to develop a collaboration with researchers in the ARC Centre of Excellence for Climate System Science (and soon to be the new ARC Centre of Excellence for Climate Extremes, at UNSW), with the aim of extending and translating our research on algorithms for big data when only summaries are available.”

CI Robert Kohn:

“Our work in 2017 will involve improving the new methodology for Variational Bayes (VB) with intractable likelihood developed in 2016 by incorporating derivative information, and then applying the ideas to time series and panel data problems. We are also aiming to develop modern VB methods for spatial temporal problems and for multivariate mixture of expert models.”

CI Matt Wand:

“We will develop factor graph fragment updates, based on both variational message passing and expectation propagation principles, for semiparametric regression model components corresponding to data that are subject to measurement error or are partially missing.”

CI Dirk Kroese:

“One focus in 2017 will be to develop efficient algorithms for searching combinatorial structures, such as polytopes and trees, with applications to network reliability and random networks. Another focus is to advance the knowledge of Monte Carlo methods for autonomous decision making, in collaboration with Professor Shie Mannor of the Israel Institute of Technology (Technion). We will continue and expand the yearly ACEMS Sampling and Exploration Matlab Competition.”

For the first topic, the researchers have devised a subsampling scheme for a perturbed likelihood and shown that the perturbation is very small. They have also carried out subsampling for the exact likelihood but at a higher cost. Both approaches are based on pseudo marginal methods and the aim is to improve these methods by incorporating information about derivatives, and to apply the methods to more complex random effects models, to copula models with discrete margins and to time series models.

For the second topic, a range of flexible copula models and computationally efficient algorithms have been devised, which provide for the first time a way of modelling discrete and mixed margins. The aim is to extend these methods to copulas of a Dirichlet process mixture and to use copulas for flexible regression density estimation.

For the third topic, a new correlated block-wise method to make pseudo-marginal methods more efficient has been developed and is currently being extended to time series models. Mixed strategy algorithms, such as Particle Markov chain Monte Carlo, have also been devised and their theoretical and computational properties investigated.

For the fourth topic, a new approach that employs Variational Bayesian with intractable likelihoods has been developed. The aim is

to apply these ideas to time series and panel data problems, spatio-temporal problems and multivariate mixture of expert models.

This work is another excellent example of inter-node, cross-node and international collaboration facilitated by ACEMS. In this case, the collaborators include Mattias Villani and Matias Quiroz, both of the University of Linköping, David Nott of the National University of Singapore, Mohamad Khaled of UQ, and Minh Ngoc Tran of University of Sydney. The new intra-node collaboration between CIs Scott Sisson and Robert Kohn at UNSW on the topic of intractable likelihoods is a direct result of ACEMS.

The collective interest across ACEMS nodes in computational algorithms is further illustrated by the project on Bayesian methods for big datasets and intractable likelihoods, led by CI Tony Pettitt. As discussed above, there are many situations where analytically or computationally intractable likelihoods are encountered in a wide range of applications from stochastic models in genetics and biology through to spatial and temporal models in image analysis. Some of the current approaches are analytic based on pseudo likelihoods or quasi likelihoods or numerically based on optimisation such as expectation-maximisation (EM) algorithm-like methods or variational Bayes. Other methods are computer intensive based on Monte Carlo such as Markov chain Monte Carlo, Sequential Monte Carlo, Approximate Bayesian Computation

ADVANCED SAMPLING AND EXPLORATION MATLAB COMPETITION

Every year ACEMS organises a *Student Competition* on the design and implementation of fast and efficient algorithms. The purpose of this competition is to (1) stimulate student engagement in the Enabling Algorithms research theme, and (2) to initiate new directions of research by solving interesting problems. Most of all, being involved in a challenging competition is an enjoyable activity for many students that strengthens the collective.

This year's competition was about designing learning algorithms where, for various scenarios, the objective was to classify whether the output of a binary input vector should be classified as 0 or 1. For example, in Figure 1 the output is determined by matching the input to the closest vector in a dictionary, and in Figure 2 it is decided by the internals of a neural net. However, the content of the dictionary or the neural net are unknown and have to be learnt via test samples.

The challenge was to find learning algorithms that give the highest number of correct binary responses for several problems. The solution techniques involved a combination of focus areas of ACEMS: optimisation, Monte Carlo sampling algorithms, and machine learning.

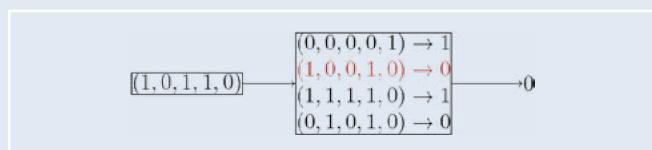


Figure 1. A binary dictionary

The competition was targeted at all students associated with ACEMS, but any interested student outside the Centre could submit as well. The solutions found by the participating students were extremely innovative and showed a high degree of diversity and creativity. The three top-ranking entries students were given modest prizes (\$600, \$300, \$100). The winning solutions were made available to everyone.

ACEMS plans to continue the competition in 2017, and even expand it to include a larger international audience, by increasing the prize money and involving sponsors from industry.

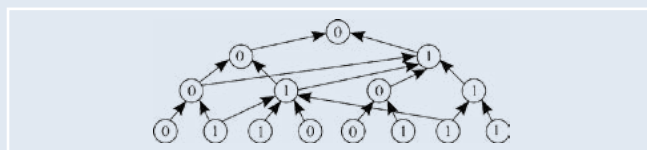


Figure 2. A neural net

(ABC) or indirect inference. For the computer intensive approaches, parallel computing approaches are providing platforms to make computationally intensive Monte Carlo approaches feasible for large data sets. Sequential Monte Carlo (SMC) provides an embarrassingly parallel approach. Network or graphical data provides an example where there are computationally tractable models to simulate from but exact likelihood methods are intractable. Here, there is a need for approximate likelihood approximations based on summary statistics whose computation is scalable and the application of these approximations in Bayesian methods.

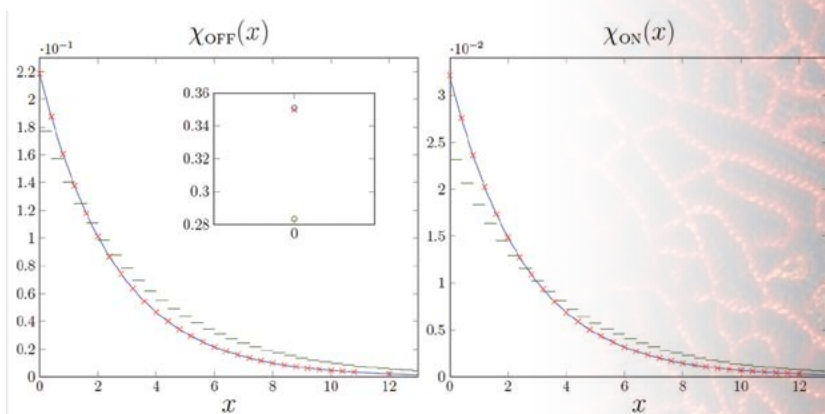
Progress on this project in 2016 has focused on making ABC, SMC and approaches based on sampling and approximate likelihood proposals more efficient; developing scalable Matrix algebra methods using Gaussian process approximations; using indirect inference or approximating models and estimation of functions relating parameters to mean values of statistics; and implementing algorithms in parallel computational environments. Some of the specific applications and motivating examples include stochastic models of population dynamics from disease modelling and systems biology; spatial analysis and image analysis; network or graphical data; neurology with investigations involving upper and lower motor neurons, neuropathies and disease. Like most of the ACEMS research projects, this research has ignited international interest and attracted international visitors, in this case Professor Nial Friel (UK) and Professor Fabrizio Ruggeri (Italy).

SIX STEP RESEARCH PLAN FOR 2017

1. Progress research developed in 2016
2. Disseminate research findings through presentations at international and national conferences
3. Initiate new cross-node and cross-disciplinary collaborative research
4. Promote international research networks through collaborative visits by CIs and ECRs
5. Continue to produce high quality research outputs and provide world class research training
6. Develop opportunities for research translation and impact

FROM FUTURE STOCK PRICES TO CORAL BLEACHING: MODELLING RANDOMNESS AND INTERDEPENDENCE

“The real difficulty is that the futures of all three dimensions are partly **random** and partly dependent on each other.”



Comparisons between exact densities (red crosses) and their approximations (blue and green curves) for various scenarios of a stochastic fluid-fluid process. The piecewise-linear approximation (blue curve) fit through all exact values, indicating that the approximation is highly accurate. The subplot inside the left plot shows the corresponding probability masses at value 0, where once again the piecewise-linear approximation (blue circle) takes the same value as the exact probability mass (red cross).



Dr Giang Nguyen
The University of Adelaide

STOCK MARKETS ARE DIFFICULT TO MODEL. TAKE FOR EXAMPLE MODELLING THE EVOLUTION OF A STOCK OPTION, A PROMISE TO BUY OR SELL A STOCK AT AN AGREED PRICE SOMETIME IN THE FUTURE.

ALL YOU KNOW ARE THREE THINGS: THE TREND OF THE ASSOCIATED STOCK, WHERE THE MARKET IS IN THE ECONOMIC CYCLE, AND HOW THE OPTION PRICE VARIES AS A FUNCTION OF THE ECONOMIC CYCLE AND THE STOCK. THE REAL DIFFICULTY IS THAT THE FUTURES OF ALL THREE DIMENSIONS ARE PARTLY RANDOM AND PARTLY DEPENDENT ON EACH OTHER.

It's one of a general set of problems that mix randomness and interdependence (known as stochastic fluid-fluid processes), with which Dr Giang Nguyen and colleagues including Chief Investigator Professor Nigel Bean from the University of Adelaide, are wrestling. Another example is the impact of bleaching on coral growth.

"These kinds of processes, because of the dependence between the dimensions, are difficult to analyse. It wasn't until 2014 that Nigel and a colleague, Associate Investigator Dr Malgorzata O'Reilly from the University of Tasmania, devised a formula to describe the long-term behaviour of

such systems, where they converged to an equilibrium," says Giang, who is an Associate Investigator at the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS). Unfortunately, their formula incorporated mathematical elements that were not easily computed.

So Giang and her team have been working on practical ways to do so. They have been making significant headway, coming up with a numerical method for approximating the solution.

"We are turning the mathematical operators into matrices that computers can handle, and the approximations we're producing look quite good. Right now, we can numerically evaluate the long-term behaviour of all three dimensions in such processes."

What the ACEMS researchers need to do next is develop mathematical theory behind their methods, to prove analytically how their approximations are correct, so that their technique can be generalised across many problems.

The research has benefited from feedback from other researchers after Giang has presented it at conferences, which ACEMS gave her financial support to attend. For instance, after talking about her work at the Australian Mathematical Science Conference in Canberra in December 2016, she has recently received a relevant paper and suggestions on how she might proceed on the theoretical front from Professor Gary Froyland of the University of New South Wales. Giang also presented the research at the International Conference on Matrix Analytic Methods in Stochastic Models in Budapest in June 2016.

THEME 4: INFORMED DECISIONS

OVERVIEW

The purpose of data collection and modelling is to learn more about the system and make the best possible decisions about it. Under this theme we develop new decision-making methodologies, and exploit Challenging Data, Multiscale Models, and Enabling Algorithms to make decisions.

RELATED CASE STUDIES

Helping save jaguars with a virtual Peruvian jungle ([pages 14-17](#))

Understanding rare events: simulating rare disease outbreaks and power blackouts ([pages 24-25](#))

Staying true to the detail in big data ([pages 38-39](#))

Plugging the gaps in missing data ([pages 54-55](#))

New statistics help predict when corals are most vulnerable ([pages 62-63](#))

From future stock prices to coral bleaching: modelling randomness and interdependence ([pages 68-69](#))

Safer drug screening and better simulations: maths getting to the heart of the matter ([pages 76-77](#))

The function with a \$1 million bounty on its head ([pages 82-83](#))

HIGHLIGHTS

- New insights into modelling and control of stochastic networks of resource allocation facilities
- Improved ability to make earlier, more effective health management decisions for epidemics
- Investigation of ancient DNA through improved phylogenetic methods that can detect degraded signals
- New techniques for assisting with studying and formalising the practice of clinical judgement in medical decision making
- New mathematical models to address challenges related to health systems monitoring
- Supervision of postgraduate students working as professionals in hospitals, government agencies and businesses
- Creation of virtual logs to investigate the properties of sawn timber, aimed at improving the returns from pine plantations, in collaboration with Southern Pine Plantation
- Creation of a virtual reef to upload and annotate images from underwater vehicles and scuba divers, aimed at improving monitoring of the Great Barrier Reef, in collaboration with ACEMS Partner Organisation the Australian Institute for Marine Science
- New traffic simulation models to improve road traffic networks, in partnership with ACEMS Partner Organisation Vic Roads
- Better understanding of electricity networks, in collaboration with South Australian electricity organisation and wind farmers
- Development and implementation of methods for using remotely sensed data for official statistics, in collaboration with ACEMS Partner Organisation the Australian Bureau of Statistics
- New, more appropriate ways of analysing social media data
- Development of new ways of visualising data
- Creation of a massive open online course (MOOC) with ACEMS and FutureLearn, focused on mathematical and statistical methods for modelling and analysis of big data

Professor Kerrie
Mengersen in
Peru. *Read the case
study on pages
14-17.*

Photo courtesy:
Vanessa Hunter



TEAM

Chief Investigators

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Tim Garoni (MU) – Theme Leader
Peter Bartlett (QUT)
Nigel Bean (UoA)
Kevin Burrage (QUT)
Dirk Kroese (UQ)
Kerrie Mengersen (QUT)
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Slava Vaisman (UQ)
Brendan van Rooyen (QUT)
Joanna Wang (UTS)
Stephen Wright (UTS)

SUMMARY

There is a dynamic interplay between the development of mathematical and statistical theory, methods that pertain to decision-making, and the translation of this research to high profile challenges in Australia and internationally. The ‘Informed Decisions’ Theme is where this interplay comes into focus. More than the other themes, this theme feeds directly into the three collaborative domains, ‘Healthy People’, ‘Sustainable Environments’ and ‘Prosperous Societies’.

ACEMS researchers have been engaged in research from both the theoretical direction: producing frontier research related to decision-making, and from interaction with problems arising in the collaborative domains.

Monitoring and control

Modelling and control of stochastic networks of resource allocation facilities is a challenging, pervasive problem in many fields. A multi-node ACEMS research project on ‘networks of resource allocation facilities’, that lies across the Multiscale Models and Informed Decisions Themes has been led by CIs Peter Taylor, Nigel Bean and Matthew Roughan. The project aims to answer the following problems: How do we define suitable transient and stationary measures of system performance? How do we characterise ‘optimal performance’ and the policies that achieve it? How do we decide on optimal placement of sensors and observation regimes? What are cost-effective methods for analysing sensor data in real-time? What type of undesirable user behaviour does the system need to protect itself against? How do we control selfish users? Do price-signalling mechanisms have a role in controlling a decentralised system?

A simple example lies in configuring security in complex networks: firewalls form a bulwark of such security, but the architectural design, organisation and deployment of these crucial devices is often haphazard. CI Roughan and his team have made significant progress in automating this, based on underlying mathematical abstractions of the security problem to be solved.

Healthy People

CIs Nigel Bean and Associate Investigator Joshua Ross, together with PhD students Mingmei Teo, Peter Ballard and Nic Rebuli at the University of Adelaide have developed mathematical models of epidemics. They are aiming to develop methods to estimate the parameters of the models early in the epidemic, in order to facilitate earlier, more effective health management decisions. True to the aims of dynamic decision-making, this research team is also aiming to use their models to optimise interventions. At The

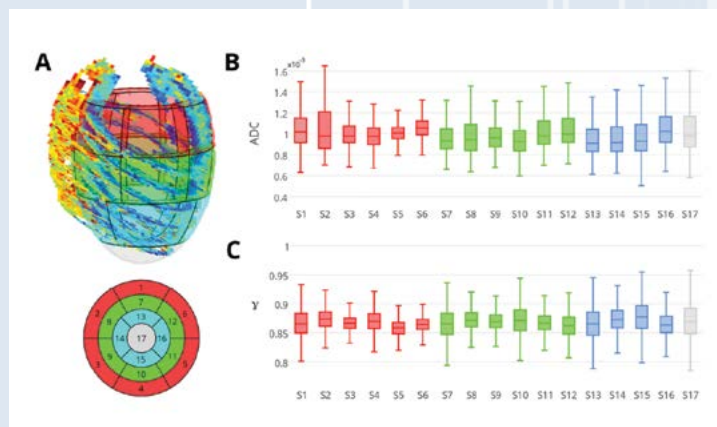


Figure A shows the standardised American Heart Association segmentation of the cardiac ventricle V2 (bottom) into 17 segments with the apex of the heart in the centre. The fibres and their orientation in the myocardial tissue are shown in the top figure of A. Figures B and C show computed results from Diffusion Magnetic Resonance Imaging (DMRI) experiments from four female rat hearts for each of the 17 segments given in Figure A. DMRI is a noninvasive imaging technique that is sensitive to the magnetisation of molecules undergoing diffusion and so can map structural features and can characterise tissue heterogeneity. Figures B and C show how certain key spatial metrics vary both within a single heart and between different hearts. [See the case study on pages 76-77](#)

University of Melbourne CI Peter Taylor, PhD student Shruba Shah and Shruba's other supervisors from the School of Population and Global Health, Nic Geard, James McCaw and Jodie McVernon have been studying the effect of spatially-dependent contact patterns among individuals on the way that epidemics spread.

CI Nigel Bean has teamed up with Dr Stephen Fitzgerald FRACP and is using mathematical modelling to explore the effect of comorbidities on the value of medical treatments. The aim of this work is to assist with studying and formalising the practice of "clinical judgment" in medical decision making, and to challenge the prevailing theory around set points in thyroid physiology and other physiological examples of homeostasis.

Interest in developing mathematical models to address challenges related to health systems monitoring has led to cross-node collaboration between ACEMS researchers, led by CIs Nigel Bean and Peter Taylor, and Associate Investigators Mark Fackrell and Malgorzata O'Reilly, among many other collaborators. This project is also an excellent example of cross-funded leveraging of ACEMS resources: the project has attracted substantial funding under a Premier's Science Research Fund grant, and the research team is currently preparing a significant proposal to put to South Australian Health that already has the support of the Minister and an ARC Linkage Grant with Monash Medical Centre held by Mark, Malgorzata and Peter.

CI Ian Turner and collaborator Joe Young are supervising ACEMS Masters student Michelle McGrath who is a Senior Medical Engineer in the Queensland Motion Analysis Centre at the Royal Brisbane and Women's Hospital. Michelle is working on a project that seeks to develop a technical protocol to collect newborn movement data using three-dimensional motion analysis (3DMA) technology. Prechtl's assessment classifications - Writhing (up to 1 month) and Fidgeting (3 months) - in normative population will be used to validate the 3DMA infant movement technical protocol. The validated technical protocol will be used to identify movement differences in typically developing infants and at-risk infants. CI Mengersen also supervises a group of postgraduate students who are allied health professionals working in hospitals in Brisbane. These students are using mathematical and statistical models to push the frontiers of medical imaging, making decisions for radiotherapy and physiotherapy.

Sustainable Environments

ACEMS researchers Ian Turner, Steve Psaltis, Tomasz Bednarz and AI Troy Farrell have commenced work on a new industry project in collaboration with Forest and Wood Products Australia (FWPA), Department of Agriculture and Fisheries (DAF), and the University of the Sunshine Coast on novel resource characterisation aimed at improving the returns from Queensland's Southern Pine plantations. This part of the project is focused around the development of virtual log models, reconstructed from physical timber billets, which will act as a repository for measured data such as density, stiffness and shrinkage. These virtual logs will be used to investigate properties of timber boards sawn from the logs, and facilitate the prediction of whole log properties from core samples taken in the field. The team is also developing visualisation tools to allow inspection of and interaction with the reconstructed timber billets.

With co-funding from the Cooperative Research Centre for Spatial Information and the Queensland Department of Natural Resources and Mines, and in collaboration with ACEMS Partner Organisation the Australian Institute for Marine Science (AIMS), an ACEMS team at QUT has been developing methods for using imagery provided by underwater vehicles and scuba divers to improve models for monitoring the health of the Great Barrier Reef. The challenge that they have addressed is how to augment the long-term but location-specific monitoring programs by AIMS with other information to provide better estimates of coral cover, biodiversity, water quality and the impact of threats such as coral bleaching, cyclones and crown of thorns. The team has created an online virtual reef and employed virtual reality to allow upload and annotation of images by experts and the general community.

CI Nigel Bean, Associate Investigator Jono Tuke and HDR students Stephen Crotty, Ben Rohrlach and Sarah James have been working on bringing improved statistical methods to the field of phylogenetics, with a particular focus on ancient DNA. This work has focused on developing new mathematical models and model selection methods, as well as contributing to identifying pre-historic events using such data.

“The resultant interplay between the development of new methods generating new applications, and the application to new problems generating new insights and new methods, is clearly evident in this project, and is an example of the strength of ACEMS.”

Prosperous Societies

How do developments in the theory of interacting particle systems, described above in the Research Theme of Multiscale Models, translate to practice? The ACEMS researchers who are working in this area have been engaged in a range of real world problems that can potentially benefit from their research. For example, consider traffic modelling. In a successful and ongoing collaboration with partner VicRoads, researchers Zhang, Garoni and de Gier have translated insights from theoretical studies into a simulation model called CEASAR, with practical application to road traffic modelling. They studied underlying mechanism for traffic disruption and protocols for resolving resulting network congestion. They produced a number of technical reports analysing impact of new scenarios on a traffic network, including traffic speed limits, arterial road management, tram priority and scheduling, continuous flow intersection, and tram stop relocation. Several results from these studies provided new insights into traffic management, in particular those concerning interplay between tram scheduling and parking policies. In a collaboration with engineers, Zhang and Garoni contributed to a new method for optimizing the performance of existing urban traffic lights and the use of perimeter control in managing congestion. Other examples of work by this research team is a formulation of a priority scheduling protocol for queues with blockage (de Gier and Finn) and batch scheduling of a single machine with family setups (Zhang and Wirth).

This project has also generated new inter-node collaborations that exploit expertise across the Research Themes. For example, Associate Investigators Scott Sisson and Tim Garoni are collaborating on using Approximate Bayesian Computation for road traffic modelling. This offers great ABC challenges due to high dimensionality of the problem, where current ABC methods are weak. The resultant interplay between the development of new methods generating new applications, and the application to new problems generating new insights and new methods, is clearly evident in this project, and is an example of the strength of ACEMS.

One of the most high profile challenges facing Australia is energy. ACEMS researchers have engaged in this challenge by developing

models of networks of stochastic resource allocation facilities.

Led by a multi-node consortium of CIs, Nigel Bean and Matthew Roughan from the University of Adelaide and Peter Taylor from The University of Melbourne, ACEMS researchers have engaged in this challenge focusing on electricity networks, and in particular the South Australian electricity network. It is particularly interesting given that it has over 40% production by renewable sources (wind 34% and solar 7%). This introduces many challenges, as exhibited by the well-publicised network failures over the past year. ACEMS researchers have developed mathematical networks of stochastic resource allocation facilities, and have permission from some wind energy farm owners to access commercial data that will be used to translate and calibrate their models. This will be one of the first attempts to model these networks at a commercial level in Australia.

Social media data has much potential, but the challenge is to develop appropriate ways of analysing these data in order to make reliable, informative predictions. ACEMS researchers, including CI Nigel Bean, Associate Investigators Lewis Mitchell, Giang Nguyen and Jono Tuke, and HDR students Peter Mathews, Max Glonek and Vanessa Glennly, have been investigating the use of open data (currently in the form of social media data, and predominantly Twitter data) to predict a range of issues such as election results, candidate/celebrity popularity, and topic modelling. One of the underlying issues they are addressing is to study the structure of the Twitter population so that such biases can be managed. This work is an example of cross-program collaboration, since it relates to two projects that are funded by the Data to Decisions Cooperative Research Centre.

In a completely different direction, CI Peter Taylor has been working with his PhD student Jonathan Budd on modelling credit card accounts using the purchase data of the individuals that hold those accounts, instead of regarding individuals as representative of a particular demographic. The banks can use this data to decide on the optimal credit limit to offer the customer. Jonathan submitted his PhD thesis in October 2016 and it has subsequently been passed. Another PhD student Ellen Muir has been working with CI Peter Taylor and her second supervisor, economist Simon Loertscher, on a dynamic version of the classical theory of

2017 RESEARCH PLANS: CI CAMEOS

CI Ian Turner and AI Markus Hegland:

“The MATRIX committee approved our application on “Computational Inverse Problems” and proposed that we hold the workshop June 11-23, 2017. The organisers of the workshop are Tiangang Cui (Monash University), Hans De Sterck (Monash University), Markus Hegland (Australian National University), Youssef Marzouk (Massachusetts Institute of Technology), Ian Turner (Queensland University of Technology), and Karen Willcox (Massachusetts Institute of Technology).”

CI Jan de Gier:

“In 2017 we will study traffic scenarios, in particular focusing on multi-modal traffic by including buses, trams, pedestrians and cyclists into CEASAR.”

CI Kerrie Mengersen:

“Our project with ACEMS PO Australian Bureau of Statistics, involving the development of methods for spatio-temporal modelling of remotely sensed images, is being written as a chapter in a Methodology Report requested by the United Nations Global Working Group on the topic, and will also be translated through a new series of workshops for National Statistics Organisations in 2017.”

CI Ian Turner:

“In 2017 we will work with Southern Pine plantations to develop virtual logs that will be used to investigate properties of timber boards sawn from the logs, and facilitate the prediction of whole log properties from core samples taken in the field. We also plan to develop visualisation tools to allow inspection of and interaction with the reconstructed timber billets.”

mechanism design, which is used by economists to understand how markets should be designed when participants, either buyers or sellers, have private valuations of a good or service.

Visualisation

A multi-disciplinary research team at QUT, comprised of mathematicians, statisticians, machine learners, computer scientists, information scientists and ecologists, have been engaged in two projects that push the frontiers of visualisation. The first is the development of methods and applications for improved visualisation of mathematical and statistical models, that is, visual analytics and big data analytics. The second is the development and use of virtual reality (VR) and augmented reality (AR) as a visualisation platform for elicitation and integration of expert information in these models. This work has been applied to a range of challenging real-world problems, including monitoring of the Great Barrier Reef and creating of a jaguar corridor in the Peruvian Amazon.

Engagement with CSIRO Data61

Recognising the strong connections between research in ACEMS and CSIRO, new collaborations have been established between the two entities. During 2016, a joint Senior Research Associate position was established for Tomasz Bednarz. ACEMS CI Ian Turner and Research Associate Steven Psaltis were also appointed as visiting scientists to CSIRO Data61.

Translation via a MOOC

The commitment of ACEMS to translating research outcomes and expertise is evidenced in a major undertaking by the ACEMS research team at QUT, to develop a massive open online course (MOOC) on modelling and analysis of big data. This MOOC was developed with FutureLearn and attracted around 115,000 enrolments over two runs, with 30,000 of these translating to learners and 4,000 fully participating to completion; see [pages 84-85](#) for more details.

SIX STEP RESEARCH PLAN FOR 2017

1. Progress research developed in 2016
2. Disseminate research findings through presentations at international and national conferences
3. Initiate new cross-node and cross-disciplinary collaborative research
4. Promote international research networks through collaborative visits by CIs and ECRs
5. Continue to produce high quality research outputs and provide world class research training
6. Develop opportunities for research translation and impact

ACEMS RESEARCH PROGRAM 2015–2017

As detailed earlier in the Research Themes Overview (pages 48-49), the ACEMS Research Program has matured over the past year from 13 Research Topics into four collaborative Research Themes.

The Research Topics that formed the Centre's Research Program at the commencement of 2016 were as follows.

1. Random Matrices and Big Data Sets
2. Bayesian Methods for Big Data Sets and Intractable Likelihood: Scalable Methods and Approaches
3. Bayesian Approaches to Modelling and Analysis of Big Data
4. Large-Scale Decision Problems and Data Analysis on Graphs
5. Statistical Theory for Expectation Propagation and Variational Message Passing on Factor Graphs
6. Analysis of functional data
7. Modelling and Control of Stochastic Networks of Resource Allocation Facilities
8. Modelling and calibration of Data Intensive Systems
9. Data Assimilation using Large-scale Bayesian Computation and Multiphase Transport
10. Theory and Applications of Interacting Particle Systems
11. Efficient Learning Algorithms (ELA)
12. Modelling Spatial Heterogeneity, Stochastic Simulations and Computational Biology
13. Emerging Projects (e.g. bitcoin, social media)

The four Research Themes that have emerged as underpinning the ACEMS Research Plan going forward are:

1. Challenging Data (CD)
2. Multiscale Models (MM)
3. Enabling Algorithms (EA)
4. Informed Decisions (ID)

Below is a mapping from the 13 early Research Topics to the four Research Themes:

RESEARCH TOPIC	CD	MM	EA	ID
1	X			
2			X	
3	X	X	X	
4			X	X
5	X	X	X	
6	X			
7	X	X		X
8	X	X		X
9	X	X	X	
10		X		
11			X	X
12		X	X	
13	X	X	X	X

The table below indicates each Chief Investigator's main strengths in the new research themes (X means strong; XX means very strong). The highlighted cells indicate the inaugural theme leaders.

CI	CD	MM	EA	ID
Peter Bartlett			XX	X
Nigel Bean	X	X		X
Kevin Burrage		XX	X	X
Jan de Gier		XX		
Aurore Delaigle	XX	X		
Peter Forrester	X	X	X	
Tim Garoni		X	X	X
Robert Kohn			XX	
Dirk Kroese		X	XX	X
Kerrie Mengersen	X	X	X	X
Tony Pettitt	X	X	XX	X
Phil Pollett		XX		X
Matt Roughan	X	X		X
Louise Ryan	X	X		XX
Scott Sisson	XX		X	
Kate Smith-Miles			XX	X
Peter Taylor		XX		X
Ian Turner	X	X	XX	X
Matt Wand	X	X	XX	

SAFER DRUG SCREENING AND BETTER SIMULATIONS: MATHS GETTING TO THE HEART OF THE MATTER

“It’s not about modelling, so much as the insights that models can bring to understanding the different types of human heart diseases.”

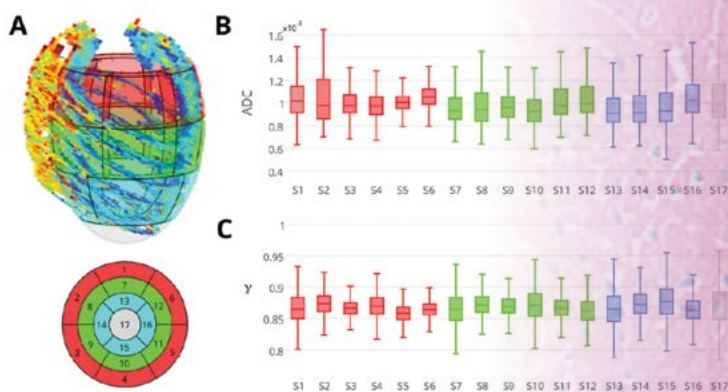


Figure A shows the standardised American Heart Association segmentation of the cardiac ventricle V2 (bottom) into 17 segments with the apex of the heart in the centre. The fibres and their orientation in the myocardial tissue are shown in the top figure of A.

Figures B and C show computed results from Diffusion Magnetic Resonance Imaging (DMRI) experiments from four female rat hearts for each of the 17 segments given in Figure A. DMRI is a noninvasive imaging technique that is sensitive to the magnetisation of molecules undergoing diffusion and so can map structural features and can characterise tissue heterogeneity. Figures B and C show how certain key spatial metrics vary both within a single heart and between different hearts.

MORE ACCURATELY SIMULATING HOW THE HEART FUNCTIONS AND SCREENING FOR SIDE-EFFECTS OF NEW DRUGS ARE JUST TWO RESULTS THAT HAVE SPRUNG FROM A COLLABORATION BETWEEN AUSTRALIAN AND BRITISH SCIENTISTS.



Professor Kevin Burrage
Queensland University of Technology

Their simulations account for the many natural differences not only between individual hearts, but between different heart cells.

Mathematical modellers and statisticians from the Queensland University of Technology (QUT) and the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) are collaborating with a British research group that generates some of the world's most sophisticated computer models of the operation of the heart.

The ACEMS contribution has helped the Computational Cardiovascular Science Group at Oxford University employ new modelling approaches to simulate how the heart functions. Among other outcomes, the group's work has led to software that can be used to test for potential side effects of new drugs, potentially saving hundreds of millions of dollars by ruling out unsafe compounds. Known as Virtual Assay, the package is currently being assessed by major pharmaceutical companies and the US Food and Drug Administration.

The link with ACEMS is through Chief Investigator Kevin Burrage, Professor of Computational Mathematics at QUT and a Visiting Professor at Oxford. He has worked with the Oxford group led by Professor Blanca Rodriguez since 2008.

"The group has a unique focus. It's not about modelling, so much as the insights that models can bring to understanding the different types of human heart diseases. The group really cares about calibrating and, where possible, validating its models against experimental and clinical data," Kevin says.

One of the significant issues the researchers have struck, and of major interest to Kevin, is the problem of variability. At the cellular level, no two cells are alike. And at the tissue level, there's huge variation in the structure of how hearts are constructed from different cells, fibre, fat, blood vessels, pores and connective tissue. Yet all these different hearts still function.

"You could build a model to fit average values of the data from sources such as electrocardiograms (ECGs) and magnetic resonance imaging (MRI). That was what was done historically. But then you would ignore all the variability."

With help from Kevin and his colleagues at QUT, such as Research Fellow Dr Brodie Lawson, Associate Investigators Dr Pamela Burrage and Dr Chris Drovandi, and Chief Investigator Professor Anthony Pettitt, the Oxford group has constructed models that incorporate the variability at different scales. At the cellular scale, they have borrowed from climate science to come up with a technique of populations of models, all of which are calibrated to the data and can be run to provide a distribution of outcomes.

At the tissue level, Kevin has developed new techniques using ideas from statistical physics that capture the structural diversity via a concept known as fractional diffusion. In work that's been published, the group has already calibrated their models against mouse data. Studies linking to human data are in press.

"This collaboration fits beautifully with what ACEMS is about in the important area of complex modelling using simulation and statistical techniques to address fundamental problems in science."

CROSS-NODE COLLABORATION

A KEY CHALLENGE FOR ANY CENTRE IS TO BE MORE THAN THE SUM OF ITS PARTS. IN MATHEMATICAL RESEARCH, THIS IS BEST DEMONSTRATED BY NEW CROSS-NODE COLLABORATIONS THAT ARE HIGHLY UNLIKELY TO HAVE HAPPENED WITHOUT THE EXISTENCE OF THE CENTRE.

In 2016 the cross-node collaborations within ACEMS really took off, and will impact the Centre's research for years to come. There were interactions across the full range of the Centre's activities, from big data to big models, from theory to application, and across the collaborative domains. The interactions involved various CIs, AIs and HDR students. It is the interactions involving the more junior members of ACEMS that are particularly exciting and likely to lead to significant outcomes, as well as growth and development. This will become part of ACEMS' legacy.

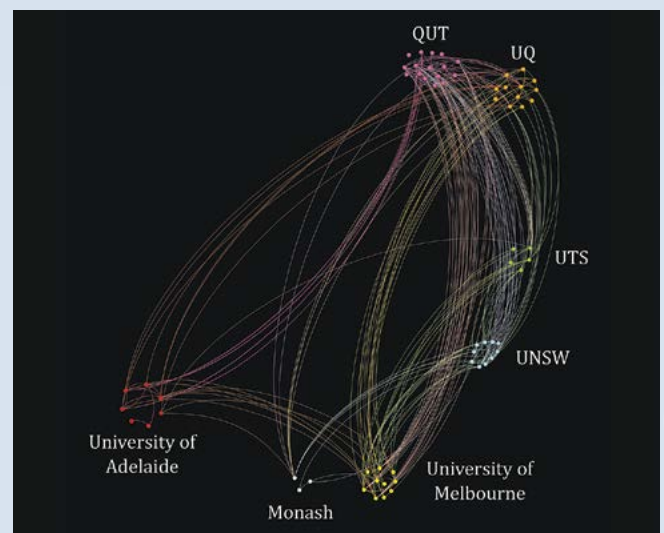
The Centre's plans for 2017 are more expansive, with an extra up-kick in this activity to further escalate ACEMS' research. The Centre is also arranging more workshops, with one focused on ACEMS' postdoctoral researchers and at least one on each of the four new research themes. With these in place, the Centre will see yet a further surge in cross-node collaboration in 2017.



*ACEMS members
at the 2016
Annual Retreat*

enerate $\gamma_1, v_1, \gamma_2, v_2,$

ACEMS students are actively encouraged to visit and work with members located at other ACEMS nodes. To facilitate this collaboration, the Centre asked the students to provide a list of keywords describing their research interests. These keywords were processed and cross-referenced, resulting in a database that was used to match students with similar interests across nodes. The graph illustrates the connections between the students' research interests, showing a rich collaborative structure. Using the data, students were better able to identify students outside their own node with whom they could exchange ideas.



2016 HIGHLIGHTS

- CIs Aurore Delaigle and Matt Wand collaborated to write and publish a paper about ACEMS Founding Director Peter Hall:
Delaigle, A. and Wand, M.P. (2016). A conversation with Peter Hall. Statistical Science, 31:275-304. (UoM and UTS nodes)
- CIs Kerrie Mengersen and Aurore Delaigle are working on analysis of remotely sensed data for crop identification, with ACEMS Partner Organisation the Australian Bureau of Statistics (ABS). This will lead to a contribution to a United Nations Global Working Group report and international workshop. (QUT, UoM nodes and Partner ABS)
- CI Ian Turner is working with AI Markus Hegland at ANU on model reduction methods and multiscale approaches (with ANU PhD student Abhishek Bhardwaj) as well as matrix polynomial approximation methods for the various matrix functions used for Bayesian analysis. (QUT node and ANU)
- CIs Jan de Gier and Tim Garoni are working with AI Joyce Zhang to continue their collaboration with ACEMS Partner Organisation VicRoads on road traffic modelling. (UoM, new Monash nodes and Partner VicRoads)
- CIs Peter Taylor and Phil Pollett are working with UoM AI Laleh Tafakori with the broad aim to improve our understanding of the role of cell proliferation in tissue growth. (UoM and UQ nodes)
- CI Tony Pettitt is working with Chris Oates on Bayesian computations for model selection. (QUT and UTS nodes)
- CI Peter Taylor is working with AIs Yoni Nazarathy and Sophie Hautphenne, as well as international colleague Erjen Lefeber, on a book. This book discusses two topics that have hitherto received separate consideration in the literature, but are related mathematically. It will teach readers elements of linear control theory as well as how to analyse structured Markov chains. (UoM and UQ nodes)
- CI Phil Pollett is working with Research Fellow Ross McVinish and AI Andrew Barbour to connect deterministic and stochastic metapopulation models. (UQ and UoM nodes)
- CIs Phil Pollett and Jan de Gier are working with PhD student Liam Hodgkinson on The KPZ Universality Conjecture. (UQ and UoM nodes)
- CIs Scott Sisson and Louise Ryan are working with PhD student Alan Malecki on environmental time series modelling using symbolic data analysis. (UNSW and UTS nodes)
- CIs Scott Sisson and Tim Garoni are working with AI Joyce Zhang and PhD student Samithree Rajapaksha on calibrating their traffic modelling simulator using approximate Bayesian computational methods. (UNSW, UoM and new Monash nodes)
- CI Nigel Bean is working with AI Malgorzata O'Reilly and PhD student Aviva Samuelson on analysis of Stochastic Fluid Models. (UoA node and UTas)
- CIs Matt Roughan and Louise Ryan are discussing potential data linkage research with ACEMS Partner Organisation Sax Institute. (UoA, UTS nodes and Partner Sax Institute)
- CIs Matt Roughan and Dirk Kroese have worked with Research Fellow Slava Vaisman on using an evolutionary optimisation algorithm to address a counting problem in statistical physics. (UoA and UQ nodes)
- CIs Peter Taylor, Ian Turner and Kevin Burrage are working on a matrix-invertibility proof related to Markov-modulated Erlang loss queues. (UoM and QUT nodes)
- CIs Nigel Bean, Peter Taylor, Ian Turner and Kate Smith-Miles (new) are collaborating with others on the Australian Mathematical Sciences Institute's (AMSI) Industry/Mathematical Sciences Engagement Taskforce, which has been driven by Industry to improve the mathematical sciences skills of the Australian workforce. (UoA, UoM, QUT and new Monash nodes)
- ACEMS members at UTS have a collaboration that involves QUT and several non-ACEMS universities to develop capacity for statistical analysis on distributed data systems using the DeltaRho package in R. (UTS and QUT nodes)
- CI Louise Ryan, AI Tung Pham and Research Fellow Stephen Wright are working on a method to handle the analysis of very large datasets via clever subsampling. The motivating application is drawn from the collaboration with the Australian Red Cross Blood Service and involves predicting the rates of adverse outcomes among blood donors. (UTS and UoM nodes)

MENTORING ACTIVITIES

ACEMS DEFINES MENTORING AS A PROCESS THAT INVOLVES A MORE EXPERIENCED OR MORE KNOWLEDGEABLE PERSON HELPING TO GUIDE A LESS EXPERIENCED OR LESS KNOWLEDGEABLE PERSON IN THEIR LEARNING AND DEVELOPMENT TO FORMULATE AND ACHIEVE THEIR GOALS. OUR MENTORING PROGRAMS OCCUR ON AN ONGOING BASIS AND MAY HAVE EITHER A FORMAL OR INFORMAL STRUCTURE.

ACEMS recognises that various forms of mentoring already exist for its members. Three principal sources are the institutions to which the members belong, relevant professional societies, and institutions such as the Australian Mathematical Sciences Institute (AMSI). For example, universities have: a formal, usually annual, departmental peer review; formal mentoring programs for junior, senior and professional staff; and more informal and

personal mentoring schemes by supervisors and research groups. Professional societies such as the Statistical Society of Australia and the Australian Mathematical Society offer informal mentoring activities, typically linked to their workshop and conference programs. AMSI offers mentoring through its intern program. ACEMS members are encouraged to access these and other existing mentoring programs.

In recognition of the important role of mentoring, ACEMS has established a range of bespoke programs for its members. These are designed to complement rather than replace the existing activities indicated above.

ACEMS has established a committee to oversee its mentoring programs. It consists of Chief Investigator Professor Aurore Delaigle (Chair), Chief Operating Officer Dr Emily Duane and Chief Investigator Professor Kevin Burrage.

The ACEMS programs have four main aims:

- to engender a community of academic and non-academic support amongst its members
- to facilitate discussion and advice about broad professional issues
- to develop skills in areas such as leadership, public speaking and communication
- to encourage a life-long awareness of, and participation in, mentoring.

In 2016, ACEMS formalised six mentoring programs:

- 1. Research Group Mentoring:** Depending on the nodes, several or most CIs and AIs from the node gather once every one-to-two weeks with their students and early career researchers (ECRs) to discuss ongoing research, and listen to an informal presentation or a more formal talk by a visitor.
- 2. Higher Degree Researcher (HDR) Personal Mentoring:** All students—whether PhD, masters, honours or vacation students—have supervisors whose responsibilities include mentoring. An advantage of working in a Centre is that senior members have regular contact with students who they are not directly supervising and so Centre students interact with additional senior mentors.



An ACEMS planning day at QUT



Peter Taylor's research group during one of their meetings



3. **ECR Personal Mentoring:** As with students, all ECRs have supervisors whose responsibilities include mentoring, as well as regular opportunities to interact with non-supervisory mentors.
4. **Next Level Mentoring:** In this program, mentors are one level above the mentee. Examples include: postdoctoral researchers supervising PhD students; PhD students supervising vacation research students; and CIs mentoring AIs. Common topics addressed during this type of mentoring include the challenges and opportunities of the mentees at their current level, as well as pathways to progress to the next level (that is, the mentor's level).
5. **Vacation Researcher Mentoring:** This program involves mentoring of undergraduate vacation research students by any Centre member. This type of mentoring includes personal interactions, but also often includes integrating the undergraduate student into research groups, the School and broader Centre, as well as facilitating personal interaction with HDRs and ECRs (formally or informally).
6. **External Mentoring:** The key feature of this program is that the mentoring is predominantly offered to people external to ACEMS, including students, postdoctoral researchers, professional staff, and researchers not in academia or at other institutions. Mentors are predominately CIs and AIs, but not exclusively. This type of mentoring is often delivered via one-on-one interactions, but can also be delivered via organised sessions to groups of people. Examples of group sessions may include topics such as: how to apply for particular grants; how to translate research into a variety of publications for different audiences; important things to think about when supervising HDRs and ECRs; tips to start your own reading group; how to apply for a promotion; publication strategies; and ethics. Examples of individual mentoring could include: reviewing grant and job applications prior to submission; providing advice about issues at the mentee's university; and helping professional staff to better understand academics and academia.

MENTORING ACTIVITIES FOR 2017

One of the strengths of ACEMS is the diversity between the nodes. To date, ACEMS has had an informal cross-node mentoring program and this will be formalised in 2017:

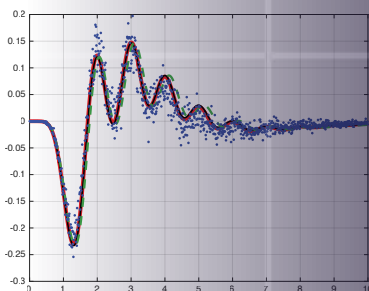
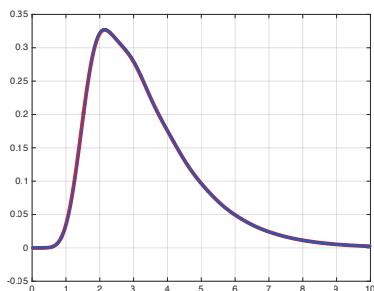
Cross-node Mentoring: ACEMS members interact with members from different nodes to discuss research talks, research posters and mentoring talks at the three ACEMS annual retreats (student, postdoc and main), at ACEMS workshops and conferences, and through cross-node visits.

Based on feedback received from ECRs and HDRs after the 2016 ACEMS annual retreat, ACEMS plans to enrich the existing mentoring programs by introducing several new activities in 2017. In particular, the following new initiatives have been proposed:

1. A mentoring seminar series broadcast across the nodes. Topics could include: building a positive working relationship with your supervisor, and what to do when things are not working well; building an academic career and profile, including aspects on collaboration, professional societies and networks; writing grant applications; applying for jobs, including the difference between academic and non-academic CVs; preparing for life outside academia (featuring past ACEMS members); and writing for an academic audience, including thesis and academic papers and reports for industry.
2. A forum on the ACEMS website allowing the posting of questions, mechanisms for developing collaborations, facilitation of mentoring, and so on.
3. Targeted mentoring programs for sectors of the ACEMS community. Two such groups are postdoctoral researchers and professional staff. Postdocs are particularly keen on interacting with CIs and researchers from other nodes. ACEMS will try to implement more frequent cross-node group meetings (in part by videoconference), an annual postdoc retreat, and assign, when possible, mentors from other nodes. This will complement the cross-node mentoring program described above. Professional staff are also keen to interact across nodes to increase learning and skills, expand networks, improve their workplaces and develop career pathways.

THE FUNCTION WITH A \$1 MILLION BOUNTY ON ITS HEAD

“Quantifying the **randomness** of the primes as initiated by Riemann is perhaps the most famous unsolved problem in mathematics.”



The first graph compares data to random matrix predictions. The statistical accuracy of the data set is so great that a structured difference can be extracted in the second graph. This difference also agrees with random matrix predictions.

IN 1859, THE GERMAN MATHEMATICIAN
BERNHARD RIEMANN WROTE A PAPER
GENERATING CONSEQUENCES THAT ARE
STILL ECHOING ALMOST 160 YEARS LATER.



Professor Peter Forrester
The University of Melbourne

In it, he proposed an analysis of the prime numbers using a special function with seemingly mystical properties and now named after him: the Riemann zeta function. A famous hypothesis Riemann formulated about his function is considered so significant, for instance, that the Clay Mathematics Institute in the US has put up a bounty of US \$1 million for anyone who can give a proof of it.

Now, Professor Peter Forrester, a Chief Investigator at the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) together with collaborators Dr Anthony Mays and Professor Folkmar Bornemann are adding to the legend by employing the Riemann zeta function in their quest to develop tools to analyse big data sets using analogies with physical systems.

The prime numbers are the building blocks of the integers—a sequence with perfect order—although they themselves occur seemingly at random. Quantifying the randomness of the primes as initiated by Riemann is perhaps the most famous unsolved problem in mathematics.

Riemann analysed the primes using the zeros of the zeta function. In recent years it has emerged that the zeros behave like the energy levels of a quantum billiard system with chaotic dynamics. If this physical analogy could be proved true, the optimal randomness of the primes would follow, but at present there is only partial validation.

Peter, a professor in the School of Mathematics and Statistics at The University of Melbourne, is using an enormous database of more than one billion Riemann zeros generated by US mathematician and computer scientist Andrew Odlyzko to probe the quantum analogy. He has found unequivocal evidence for the hypothesis that the zeros and quantum energy levels have the same statistics, as the zeros get bigger. But the statistical accuracy provided by the dataset reveals more.

“It doesn’t only provide a measure of the limiting distribution, it even shows the approach—how you reach it,” Peter says.

More broadly, Peter and his collaborators are seeking analogies with physical systems as a method to analyse big and complex datasets, such as would be found in problems to do with logistics, transport and government decisions relating to health care and welfare systems.

BIG DATA ANALYTICS MOOC



Sam Rathmanner and Miles McBain



Steven Psaltis and Guiseppe de Martino

Tens of thousands of people from around the world were exposed to the world of big data analytics, thanks to a MOOC created by ACEMS members at the Queensland University of Technology (QUT).

The MOOC acronym stands for “massive open online course.”

The team from ACEMS and QUT worked with the online platform, “FutureLearn,” to offer the following four-course series as part of the program:

- From data to decisions
- Statistical inference and machine learning
- Mathematical modelling
- Data visualisation

ACEMS Deputy Director Kerrie Mengersen was the leader of the QUT MOOC team. She was surprised by the variety of ‘learners’ who took part in the course.

“There was a 94-year-old woman who wrote that she was doing the course so that she could talk to her grandchildren,” Kerrie said. “There was also a cardiac surgeon who wanted to learn how to use data to improve treatment of her patients, and a nine-year-old boy who was bored playing computer games and wanted to do something more ‘real.’”

The four-course series was run twice in 2016, from April through July, and then again in August through November. According to QUT’s eLearning Services, more than 115-thousand people signed up for the courses.

ACEMS Chief Investigator Ian Turner worked with ACEMS Research Fellow Steven Psaltis to design and teach the third course on mathematical modelling.

“This was fun, but was much different from teaching one of our standard units,” Ian said. “A lot of careful design was required, including refining some of the mathematical content so that a broader audience could access it.”

Once the courses went online, ACEMS members had to make sure there were people there to answer questions.

“We really worked to be engaged with the learners,” Steven said. “They saw our faces and heard our voices on the video, so they appreciated us taking the time to respond to their comments and questions.”

ACEMS Affiliate Member Miles McBain helped develop content for the second course on statistical inference and machine learning.

“It included topics like clustering and principle component analysis,” Miles said. “We also created some practicals for the students to do, and when the course went live, we made sure we were available to help them get through those exercises.”

ACEMS PhD student Matthew Sutton also helped answer questions and respond to learner comments. He thought the courses really worked well in introducing a lot of people to the world of big data.

“It’s really important to put forward a course that provides something new that a lot of other online courses don’t have. I think that’s something that our course did,” Matthew said. “It was a good introduction to a lot of big data technologies.”

The ACEMS team that took part in the courses was made up of Chief Investigators Kerrie Mengersen and Ian Turner, Research Fellows Tomasz Bednarz and Steven Psaltis, Affiliate Member Miles McBain, PhD students Anthony Ebert, Phil Gough, Samuel Rathmanner and Matthew Sutton, and MOOC organiser Jenna Thompson.

The online courses helped spread the ACEMS and QUT brands to people all over the world.

“There was a large contingent from Europe because the platform was UK-based,” Steven said. “But there were a lot of people from Australia, as well as people from South America and parts of Asia. We were able to reach out to a lot of people who normally would never know about us.”

“It was great to see QUT and ACEMS promoted in this way, as well as seeing our work translate to a wider community,” Kerrie said. “The QUT eLearning team and the FutureLearn group were wonderful collaborators.”

Team members also got a lot out of the courses, saying the process was also a learning experience for them.

BIG DATA COURSES (SOURCE: QUT E-LEARNING SERVICES)

RUN 1 SUMMARY

BIG DATA COURSE	START DATE	ENROLMENTS (END WEEK 2)	LEARNERS* (END WEEK 2)	FULLY PARTICIPATING LEARNERS**
1: From data to decisions	04-April-2016	13,949	5,645	999
2: Statistical inference and machine learning	02-May-2016	8,513	3,059	391
3: Mathematical modelling	30-May-2016	10,764	3,669	355
4: Data visualisation	27-June-2016	12,799	3,652	564
TOTAL		46,025	16,025	2,309

RUN 2 SUMMARY

BIG DATA COURSE	START DATE	ENROLMENTS (END WEEK 2)	LEARNERS (END WEEK 2)	FULLY PARTICIPATING LEARNERS
1: From data to decisions	08-August-2016	16,025	5,223	857
2: Statistical inference and machine learning	05-Sept-2016	15,661	3,135	479
3: Mathematical modelling	03-Oct-2016	17,335	3,474	255
4: Data visualisation	31-Oct-2016	20,078	2,955	441
TOTAL		69,099	14,787	2,032

ALL COURSES	TOTAL	115,124	30,812	4,341
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*Learners are users (of any role) who have viewed at least one step at any time in any course week (and includes those who go on to leave the course). For comparison, the average number of learners on a course is 50% of joiners (people who enrol).

**Fully Participating Learners are those who have completed at least 50% of the available steps on a course. On courses containing tests, they must also complete them. For comparison, the average number of fully participating learners on a course is 21% of learners.

EDUCATION AND TRAINING

The commitment of ACEMS to translating research outcomes and expertise is evidenced in a major undertaking by the ACEMS research team at QUT, to develop a massive open online course (MOOC) on modelling and analysis of big data. This MOOC was developed with FutureLearn and attracted around 115,000 enrolments over two runs during 2016, with 30,000 of these translating to learners and 4,000 fully participating to completion; see [pages 84-85](#) for more details.

ACEMS also offered three professional training/development courses with a total of 104 attendees:

- **Media and Communications Training**

ACEMS Communications and Media Officer, Tim Macuga, and his counterpart from the ARC Centre of Excellence for Climate System Science, Alvin Stone, ran a half-day workshop at the start of the 2016 ACEMS Student Retreat. It focused on the importance of communication skills, the benefits for researchers in being active science communicators, and practical exercises to start building their communications toolkit. To complement the course, the following day featured guest speakers Robyn Williams and Antony Green.

- **Life after PhD and Career Planning**

ACEMS Outreach Officer Andrew Stephenson moderated a half-day professional development workshop focused on career planning for research students. Also held at the student retreat, the workshop featured seminars by Melanie Roberts from IBM Research, ACEMS Research Fellow Craig Anderson and ACEMS Director Peter Taylor. Melanie spoke to the students about pursuing a career in industry, while Craig talked about transitioning from being a PhD student to becoming a postdoc, and Peter spoke about a career in academia. The interactive presentations were followed by a Q&A panel discussion.

- **Bridging the Gap from Research Student to Research Professional**

ACEMS Stakeholder Engagement Officer Jessie Roberts organised a series of four workshops on the intangible skills required to transition from a research student to a research professional. The series involved invited speakers trained in quantitative methods that had gone on to a range of professional paths.

ACEMS members were also involved in 12 research training activities, the majority of which were short courses.

MEMBER	RESEARCH TRAINING	LOCATION
Kerrie Mengersen	Intermediate Bayesian Statistics	Melbourne
Kerrie Mengersen	Intermediate Bayesian Statistics	Adelaide
Kerrie Mengersen	Introduction to Bayesian Modelling and Analysis	Edinburgh
Kerrie Mengersen	Introduction to Bayesian Modelling and Analysis	Canberra
Kerrie Mengersen	Big Data Analytics	Kuala Lumpur
Kerrie Mengersen	Big Data Analytics	Canberra
Erin Peterson	Spatial Statistical Modelling on Stream Networks using GIS and R Statistical Software	Boise, USA
Erin Peterson	Spatial Statistical Modelling on Stream Networks using GIS and R Statistical Software	Seattle, USA
Louise Ryan	Smooth Modelling in R	Sydney
Louise Ryan	Statistical Computing	online via Lynda LinkedIn
Peter Taylor	AMSI Summer School Women in Maths Seminar	Melbourne
Peter Taylor	ANZIAM Early Career Workshop	Canberra

Further to this, the Centre and its members organised or co-organised a further 16 national and international research workshops and conferences during 2016; these are listed on [page 100](#).

SPONSORSHIPS

Launched in May 2016, MATRIX is Australia's first international research institute for the mathematical sciences. By providing initial seed funding, ACEMS played a key role in getting MATRIX off the ground, along with The University of Melbourne. Subsequently, Monash came on board, and MATRIX is now a joint partnership between Monash University and The University of Melbourne. ACEMS continues to be a supporting associate providing \$100,000 per year. For details about the institute's activities in 2016, see [pages 102-103](#).

The following is a list of 16 events that ACEMS sponsored in 2016; an additional investment of \$29,593.

EVENT	SPONSORSHIP AMOUNT
The University of Melbourne Maths Fair 2016, Melbourne, May	\$2,000
aMATHing day, Adelaide, May	\$353
STEMS Conference, Sydney, June	\$5,000
Computational and Mathematical Foundations Workshop, Brisbane, July	\$3,000
AMSI 2016 Winter School, Brisbane, July	\$1,000
Designing Health Conference, Adelaide, October	\$1,000
Spot the Bull Science Sydney Powerhouse Museum, Sydney, October	\$500
Statistical Mechanics of Soft Matter Meeting, Melbourne, November	\$1,000
International Symposium on Big Data Visual Analytics, Sydney, November	\$2,000
Statistical Society of Australia JB Douglas Postgraduate Awards Dinner, Sydney, November	\$250
2nd UQ Control Theory Workshop, Brisbane, November	\$250
Jeffrey Rosenthal's 'From Lotteries to Polls to Monte Carlo' Public Lecture, Brisbane, November	\$350
AustMS Women in Mathematics Dinner, Canberra, December	\$4,000
ANZIAM 2017, Handorf (to be held in February 2017)	\$2,000
5th Annual Meeting of ANZAMP, Kiama (to be held in February 2017)	\$2,000
37th International Symposium on Forecasting, Cairns (to be held in June 2017)	\$5,000

ACEMS also received sponsorships for the National Science Quiz, held in Melbourne on 1 May 2016, to a total value of \$14,000. The co-sponsors of the event were: the School of Mathematics and Statistics at The University of Melbourne, the Centre of Excellence for Biosecurity Risk Analysis (CEBRA), the ARC Centre of Excellence for Particle Physics at the Terascale (CoEPP), and the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO).

ACEMS AND THE GENDER IMBALANCE IN THE MATHEMATICAL SCIENCES

IT IS WELL-KNOWN THAT THERE IS A MARKED GENDER IMBALANCE IN FAVOUR OF MALES AMONGST PEOPLE WORKING IN THE MATHEMATICAL SCIENCES IN AUSTRALIA (SEE FOR EXAMPLE MARGINSON, S., TYTLER, R., FREEMAN, B. AND ROBERTS, K. (2013) *STEM: COUNTRY COMPARISONS, INTERNATIONAL COMPARISONS OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION*, CHAPTER 12). IT CAN BE ARGUED THAT THIS IMBALANCE IS EVEN MORE PRONOUNCED AT SENIOR LEVELS.

Unfortunately, this gender imbalance is also present in ACEMS' membership. Table 1 contains details of the gender make-up of ACEMS academic staff and students at all levels and at all nodes. The table shows that only just over a quarter of all ACEMS academic staff and students are female.

The reasons for this imbalance are, of course, complex, and it will almost certainly take a range of measures to address the situation within ACEMS and within the wider mathematical sciences community. During 2016, ACEMS members played a significant role in some of these measures.

Perhaps most notably, three ACEMS Chief Investigators (CIs), Peter Forrester, Aurore Delaigle and Peter Taylor, along with their colleague Kerry Landman, formed a departmental committee that initially pushed the idea that the School of Mathematics and Statistics at The University of Melbourne should advertise female-only continuing positions. Under the leadership of the Head of School Aleks Owczarek, this led to the School using a clause in the Victorian Equal Opportunity Act to advertise three positions, one each in pure mathematics, applied mathematics and statistics, during 2016. The advertisements attracted a great deal of interest from the national media, with Aleks being interviewed on a number of radio programs.

In the end, the process attracted over 120 applicants, many of whom were of a very high quality. The School has currently appointed four women to the positions, one of whom is ACEMS Associate Investigator Sophie Hautphenne, and there is a significant possibility that further appointments will follow.

Not surprisingly, opinions vary as to whether advertising such positions was the right thing to do, but those involved, including the ACEMS CIs, are proud of the role that they played. Certainly, the leadership displayed by The University of Melbourne has put the issue squarely on everyone's agenda.

ACEMS also co-sponsored the joint 'Women in Mathematics and Statistics' dinner, which was held in Canberra on December 4 when the Australian Mathematical Society and Statistical Society of Australia conferences coincidentally were hosted in the same city at the same time.

ACEMS members also participated in 'Ada Lovelace Day' on 11 October 2016. This is an annual international celebration of Women in STEM held on the second Tuesday in October. ACEMS Research Fellow Dr Erin Peterson—an ecologist, geographic information systems expert and environmental statistician—presented and participated in a panel discussion at an event held at QUT.



ACEMS Research Fellow Dr Erin Peterson
at an Ada Lovelace Day event held at QUT
in October 2016



With the addition of Kate Smith-Miles, ACEMS now has four female CIs (Kate, Kerrie Mengersen, Aurore Delaigle and Louise Ryan). All four act as excellent role models for younger female academics. In addition, a number of ACEMS male CIs act as 'champions of change' by mentoring female early-career academic staff and students.

Looking forward to 2017, two activities that ACEMS has already planned are support for mentoring activities, including a

women's lunch, to be hosted by our distinguished visitor and ACEMS Scientific Advisory Committee member Professor Ruth Williams of the University of California, San Diego, and support for the inaugural 'Women in Mathematics Special Interest Group Conference: A Celebration of Women in Australian Mathematical Sciences', which will be held in Adelaide from 24-26 September.

TABLE 1: 2016 ACEMS GENDER BREAKDOWN BY MEMBER CATEGORY AND NODE

	UOM		QUT		UTS		UA		UQ		UNSW		MONASH		OTHER		TOTAL		TOTAL PERSONNEL IN THIS CATEGORY	PERCENTAGE OF FEMALE PERSONNEL BY CATEGORY
MEMBER CATEGORY	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F		
Chief Investigators	3	1	4	1	1	1	2	0	2	0	2	0	1	1	0	0	15	4	19	21%
Research Fellows	4	2	5	1	7	1	2	0	2	0	2	0	1	0	0	0	23	4	27	15%
Associate Investigators	18	5	22	7	5	1	4	1	4	0	3	1	4	1	6	2	66	18	84	21%
Affiliate members	0	0	1	1	0	1	0	0	0	0	0	0	0	0	2	0	3	2	5	40%
PhD Students	13	5	26	19	8	2	12	1	8	5	6	5	2	2	1	2	76	41	117	35%
Masters by Research Students	0	0	2	4	0	0	6	3	0	0	0	0	0	0	0	0	8	7	15	47%
Masters by Coursework Students	9	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10	4	14	29%
Honours Students	0	0	0	0	1	0	0	1	3	0	0	0	0	0	0	0	4	1	5	20%
Vacation Students	4	0	10	3	0	0	6	4	0	1	1	0	2	0	0	0	23	8	31	26%
	51	17	70	36	22	6	32	10	19	6	15	6	10	4	9	4	228	89	317	28%
TOTAL PERSONNEL AT NODE		68		106		28		42		25		21		14		13		317	TOTAL CENTRE MEMBERS IN 2016	
PERCENTAGE OF FEMALE PERSONNEL BY NODE		25%		34%		21%		24%		24%		29%		29%		31%		28%	PERCENTAGE OF FEMALE PERSONNEL, CENTRE-WIDE	

COMMUNICATIONS AND MEDIA REPORT

ACEMS STRONGLY BELIEVES IN THE IMPORTANCE OF COMMUNICATING THE RESEARCH ITS MEMBERS ARE DOING IN MATHEMATICS AND STATISTICS. THE STORIES OF THAT RESEARCH ARE NOW REACHING AROUND THE WORLD.

This annual report features the story of the ACEMS research team who travelled deep into the Amazon jungle in Peru to begin a project involving statistics and virtual reality, to help save the jaguar population in South America.

The story of that project first appeared in *The Australian*, and quickly spread. News organisations including The Conversation, The Huffington Post, and Mashable picked up the story, and soon news outlets from around the world were posting it. The project and team members were also featured on Australian TV and radio news reports.

Other ACEMS projects also attracted news attention. They include stories about how mathematics and statistics are being used to look at things such as tram lanes in Melbourne, cancer survival rates in Queensland, monitoring the Great Barrier Reef, and even protecting your online identity.

The stories about ACEMS and its research and people really picked up momentum on social media in 2016. The Centre has a very active presence on Facebook, Twitter and YouTube.

ACEMS first appeared on Twitter in late 2015, but enjoyed a dramatic jump in followers at the end of 2016. The Centre also made a big push to provide quality content on its Facebook page, and saw the number of page likes nearly double in 2016. The Centre sees both platforms as a way to interact with the mathematics and statistics community both inside and outside of ACEMS. In addition, they provide a way for others outside of ACEMS to find the Centre, and see what's being done by those in it.

The Centre also continues to provide video content on its YouTube channel, ranging from interviews with students, to workshop presentations, to some of its major outreach events. There were 25 new videos added to the channel in 2016. The ACEMS YouTube channel now has 88 subscribers, more than double the number it had at the end of 2015.

Finally, the stories about ACEMS and its research continue to attract more people to the Centre's website. More than seventeen thousand people used the website in 2016, leading to more than sixty-five thousand page views. A major redevelopment of the website currently underway to further enhance the communication of ACEMS' research, achievements and activities, will be a key point of emphasis in 2017, along with:

“In my opinion, communication is not something you add onto science like icing on a cake. It’s the cake itself, it’s of the essence of science.”

Alan Alda, Actor & Visiting Professor at the Alan Alda Center for Communicating Science
(from an interview in The Conversation, March 2016)

- identifying and mentoring members looking to improve their career path through use of communications;
- producing more personal stories about the people in the Centre and the research they’re doing;
- continuing to expand the ACEMS brand through a presence in more media stories; and
- continuing to grow our audience on social media.

2017 will continue to see more emphasis placed on ACEMS communications, because the stories of this Centre, its people, and its research are stories worth telling—and worth knowing about.

TOTAL FOLLOWERS	2015	2016	HIGHLIGHT
Twitter	123	673	550 new followers
Facebook	144	277	Nearly doubled followers
YouTube	37	88	25 new videos

ACEMS WEBSITE	2015	2016
Web Sessions	15,453	27,750
Users	9,942	17,616
Page Views	41,772	67,774



FROM TOP: ACEMS Facebook page, ACEMS Twitter feed, ACEMS website

NATIONAL AND INTERNATIONAL ENGAGEMENT

ACEMS members have continued to maintain, strengthen and forge new national and international links during 2016. These links are demonstrated in a variety of ways:

LEADERSHIP ROLES IN THE MATHEMATICAL SCIENCES COMMUNITY, BOTH IN AUSTRALIA AND ABROAD

The brief biographies on [pages 40-46](#) highlight the depth and breadth of expertise and leadership at the Centre's highest level. Many Chief Investigators are: Fellows of prestigious national and international academies, societies and other organisations; members of various boards, committees and advisory groups; leaders of the Australian mathematical sciences community including current and former society presidents; recipients of prestigious national and international awards and honours; and leaders of industry/mathematical sciences engagement. Through all of the abovementioned roles, the Centre's leadership team are gaining recognition for Australian research both in Australia and abroad. During 2016 alone, Scott Sisson commenced as President of the Statistical Society of Australia, Kate Smith-Miles was appointed President of the Australian Mathematical Society, and Louise Ryan was elected as incoming President of the International Biometric Society.

COLLABORATIONS WITH NON-ACEMS RESEARCHERS AND INSTITUTIONS, BOTH NATIONALLY AND INTERNATIONALLY

ACEMS members are constantly developing relationships and building new networks with researchers outside of the Centre. While all Centre members do this to some extent, the capability and capacity of the Chief Investigators to create world-class research puts them at the forefront of this endeavour. Some of their highlights from 2016 as well as plans for 2017 are summarised on [pages 94-95](#). Moreover, maintaining and developing these collaborations often involve: hosting visitors; visiting other institutions; attending and presenting at conferences and workshops; and organising conferences and workshops.

VISITORS TO ACEMS

ACEMS nodes hosted 101 visitors from 26 countries during 2016, including 30 from around Australia and 71 from overseas. The complete list of these visitors and their home institutions, as well as a map summarising the number of visitors from each country, can be found on [pages 97-98](#).

VISITS TO OTHER COUNTRIES

A total of 169 visits to 35 countries by 62 Centre members were made during 2016. These visits include research collaborations as well as conferences, seminars and courses. The number of these visits to each country is summarised and illustrated on [page 98](#).

VISITS TO OVERSEAS INSTITUTIONS

A subset of the visits to other countries, a total of 57 visits by 27 members were made to 47 different overseas research institutions in 18 different countries during 2016. A selection of these institutions is given on [page 96](#).

ACEMS-ORGANISED NATIONAL AND INTERNATIONAL WORKSHOPS AND CONFERENCES

ACEMS and its members organised or co-organised 16 national and international research workshops and conferences during 2016; these are listed on [page 100](#). One of the most significant conferences was the memorial conference held in honour of ACEMS Founding Director Peter Hall.

Arguably, this ACEMS conference put together the most distinguished list of statistical speakers ever assembled in Australia. It helped strengthen mathematical statistics across Australia, while honouring the incredible scientific life of Professor Peter Hall. The relatively intimate size of the conference allowed for rich discussions after each talk. Several participants reported that the conference re-ignited their spark for scholarship and confirmed their commitment to research in statistics. Conference participants soaked up the latest ideas from conference presenters, shared their perspective with colleagues, made new contacts, honed their own ideas, and discussed the most recent discoveries in statistics. see [pages 104-105](#) to read more about this conference.



The packed-out theatre during the National Science Quiz organised by ACEMS (pages 108-109)

Professor Karen Willcox from MIT presenting at an ACEMS workshop (page 99)



NATIONAL AND INTERNATIONAL WORKSHOPS AND CONFERENCES ATTENDED BY ACEMS MEMBERS

Centre members, including research students, attended over 260 conferences during 2016; the majority of members also presented, including 51 invited talks/papers/keynote lectures given at major international meetings. Attending these events is important for a researcher: they often present their latest research, learn about other academics' latest research, share ideas and expertise, start new collaborations, and build their academic network both nationally and internationally.

EDUCATION AND TRAINING PROGRAMS DELIVERED

ACEMS developed a massive open online course (MOOC) on modelling and analysis of big data. This MOOC was developed with FutureLearn and attracted around 115,000 enrolments over two runs during 2016, with 30,000 of these translating to learners and 4,000 fully participating to completion; see pages 84-85 for more details.

ACEMS members also ran ten short research training courses, of which four were held at international locations; see page 86 for details.

PUBLIC TALKS

Centre members delivered 40 presentations that were open to the public to attend, including some talks that were repeated in multiple locations. Of these 40 talks, summarised on page 131, 15 were presented overseas.

MATRIX INSTITUTE

Launched in May 2016, MATRIX is Australia's first international research institute for the mathematical sciences. MATRIX provides intensive residential mathematical programs at MATRIX House in Creswick, Victoria. The Institute's five 2016 research programs have already attracted notable and world leading mathematical scientists from respected tertiary organisations, and a Fields

Medallist (Nobel Prize equivalent in mathematics) will be among the organisers and participants of a 2017 program.

By providing initial seed funding, ACEMS played a key role in getting MATRIX off the ground, along with The University of Melbourne. Subsequently, Monash came on board, and MATRIX is now a joint partnership between Monash University and The University of Melbourne. ACEMS continues to be a supporting associate providing \$100,000 per year; see pages 102-103 for more information about MATRIX.

STAKEHOLDER ENGAGEMENT WITH NATIONAL AND INTERNATIONAL ORGANISATIONS

ACEMS engaged with its seven Partner Organisations, five Industry Affiliate Organisations and a wide variety of other stakeholders during 2016. The nature of this engagement is described in the Stakeholder Engagement Report (pages 110-116).

Senior ACEMS members are also playing a key role in the AMSI Industry/Mathematical Sciences Engagement Task Force; see pages 118-119.

OUTREACH

The Centre and its members organised and participated in numerous national outreach programs and events; these are summarised in the Outreach Report (pages 126-130).

ACEMS most notable flagship outreach program to schools and their students is Mathscraft (pages 106-107), and for the general public, it is the National Science Quiz (pages 108-109). Both of these activities will be up scaled in 2017, reaching an even larger audience.

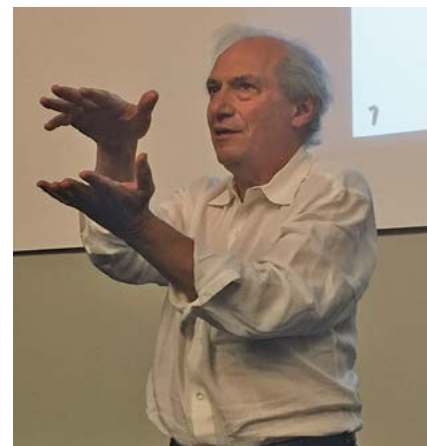


A subset of invited speakers and the organising committee at the Peter Hall Memorial Conference held in December 2016 (pages 104-105)

2016 HIGHLIGHTS IN NATIONAL AND INTERNATIONAL ENGAGEMENT

- Kerrie Mengersen is developing substantial research networks with universities in Peru as part of ACEMS' research project on creating a jaguar corridor in the Peruvian Amazon; read the related case study on [pages 14-17](#). This has led to co-supervision of a Masters student who is working on the project.
- Scott Sisson was elected onto the 'Research and Higher Education' Committee of Australian Mathematical Sciences Institute (AMSI). A particular component of interest here is AMSI's pursuit of a National Research Centre in mathematics and statistics, where Scott's role of President of the SSA will be very useful.
- Jan de Gier spent a week at the Simons Center in Stony Brook (USA) where he was invited to participate in a program on statistical mechanics and solvable lattice models.
- Louise Ryan continued her collaborations with the Bill and Melinda Gates Foundation on the analysis of multiple studies involving child growth and development. She presented her work at an International Workshop in Spain.
- Kevin Burrage is continuing the research with the Computational Cardiovascular Science Group at the University of Oxford on modelling the electrical activity of the human heart; read the related case study on [pages 76-77](#).
- Ian Turner continued collaboration with Professor Fawang Liu (at QUT) with a number of researchers from various universities in China on fractional calculus.
- Peter Bartlett participated in the semester-long program on 'Algorithms and Uncertainty' at the Simons Institute for Theory of Computing at UC Berkeley, and also had a long visit at the Institute working with research collaborators. In the 2017 spring semester, Peter will co-organise a program on Machine Learning at the Institute. This program is an opportunity to collaborate with the many visitors involved in the program (it will bring around 40 senior and 25 junior researchers in this area to Berkeley during that 4 month period), as well as Berkeley faculty, postdocs, and students in the area of machine learning.
- Phil Pollett co-supervised ACEMS PhD student Patrick Laub with Professors Soren Asmussen and Jens Jensen, both of Aarhus University, under a joint PhD arrangement.
- Tony Pettitt collaborated with Professor Nial Friel (University College Dublin) on the development of Bayesian methods for model choice in complex situations. Professor Friel is a principal researcher in Insight, an Irish national research centre for data analytics that brings together more than 400 researchers and over 40 industry partners.
- Aurore Delaigle was the Executive Secretary of two international societies of statistics: the Institute of Mathematical Statistics and the International Society for Nonparametric Statistics. Aurore is also Vice Program Chair of the 2017 Joint Statistical Meetings (JSM), the largest gathering of statisticians held in North America. JSM is held jointly with ten statistical institutes, societies and associations, with over 6,500 attendees from 52 countries.
- Peter Forrester was an invited lecturer at the summer school 'Randomness in Physics and Mathematics' held at the research institute ZIF, Bielefeld University, Germany. This University is where Peter's ACEMS Research Fellow Jesper Ipsen did his PhD, and his supervisor Gernot Akemann is now on the Board of Directors at ZIF. In 2017, Peter will also present at the 'Random matrices' summer school at College Park, Utah (USA).
- Nigel Bean and Peter Taylor are involved in the project to send a cohort of Work-Integrated Learning students to Woodside Energy in Perth during January and February 2017; read the related feature on [pages 118-119](#).
- Louise Ryan was an invited speaker at a symposium in Stockholm in September 2016 where she presented the work involving ACEMS Research Fellow Stephen Wright and Associate Investigator Tung Pham. She met several people who are also interested in the statistical issues in the analysis of blood service data. She is hoping to continue the collaboration and run a workshop in Sydney during 2017, as well as planning an invited session at the 2018 meetings of the International Biometric Society.
- Jan de Gier was invited to the Kavli Institute in Santa Barbara (USA) and spent four weeks there during a research program on non-equilibrium stochastic processes.

Professor Xihong Lin from Harvard University (L) and Professor Persi Diaconis from Stanford University (R) presenting at the Peter Hall Memorial Conference (pages 104-105)



- Kerrie Mengersen has established research links with universities in Malaysia and Indonesia, evidenced by invited presentations, co-supervision of a PhD student in Malaysia and primary supervision of a student from Indonesia who has come to QUT as part of ACEMS.
- Tony Pettitt collaborated with Professor Fabrizio Ruggeri on simulation modelling for disease transmission control. Professor Ruggeri is Research Director at Consiglio Nazionale delle Ricerche Istituto di Matematica Applicata e Tecnologie Informatiche (CNR-IMATI) in Milan.
- Peter Forrester was an invited lecturer at the Australia and New Zealand Industrial and Applied Mathematics (ANZIAM) and the Japan Society for Industrial and Applied Mathematics (JSIAM) joint session of the JSIAM meeting in Kokura, Japan. The purpose of this joint session, the first of its kind, was to strengthen ties between applied mathematics Australia and Japan.
- Louise Ryan was elected as President of the International Biometric Society. This Society brings together statisticians from all around the world who have a common interest in the analysis of health, biology and the environment.
- Phil Pollett is presently serving on the International Advisory Committee of the Workshop Stochastic Models and Applications to Natural, Social and Technical Systems, which will be held within the 16th International Conference on Computer Aided Systems Theory (Eurocast 2017), Canary Islands, Spain, 19–24 February 2017.
- Dirk Kroese developed new networks with the Lefschetz Center for Dynamical Systems (USA) and the National Science Foundation (USA) research training group on integrated dynamics and stochastics. In 2017, Dirk will work on artificial intelligence research in Tokyo, via Professors Masanori Fushimi and Hirotaka Sakasegawa (Tokyo University).
- Jan de Gier gave two invited lectures in Osaka (Japan), and an invited lecture at the 28th International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC) in Vancouver (Canada).
- Tim Garoni began collaborating with members of the Applied Mathematics Research Centre at the University of Coventry (UK).
- Scott Sisson commenced his role as the new President of the Statistical Society of Australia (SSA); this has the potential for many positive national linkages.
- Kevin Burrage developed links with the Cooperative Research Centre for Optimising Resource Extraction in the modelling and data analysis of the ore extraction process.
- Tony Pettitt collaborated with Professor Glenn Marrion on statistical and mathematical modelling for infectious diseases and their control; Professor Marrion is the Director of Research at Biomathematics and Statistics Scotland (BioSS) in Edinburgh.
- Peter Taylor was, with Maria Mayorga (USA), the co-Chair of the INFORMS Nicholson Prize Committee which is responsible for selecting the best student paper in Operations Research worldwide.
- ACEMS members, led by Nigel Bean and Peter Taylor, built a new relationship with the Cumberland Initiative (UK) in health system modelling, including Professor Terry Young (Brunel University), Professor Paul Harper (Cardiff University) and Professor Adele Marshall (Queens University, Belfast). Nigel and Peter plan to significantly develop this link during 2017.
- Louise Ryan and other ACEMS members were instrumental in bringing a high profile visitor to Australia, Professor Bill Cleveland, from Purdue University. In addition to participating in the annual conference of the Statistical Society of Australia, Professor Cleveland ran a one-day workshop at UTS related to the DeltaRho project. In 2017, this ACEMS team will continue to work on several projects involving Bill Cleveland and his team; this includes ACEMS PhD student Hon Hwang.
- Scott Sisson continued to be an Associate Investigator (AI) on the ARC Centre of Excellence for Climate System Science; this Centre finishes in 2017. From 2017, Scott is also an AI on the Centre's successful rebid as the ARC Centre of Excellence for Climate Extremes.
- As Director of the international research institute MATRIX, Jan de Gier, continued to build international linkages, in particular with the Mathematical Sciences Research Institute (MSRI) in Berkeley (USA), which he visited in early 2016.

INTERNATIONAL LINKS: INSTITUTIONS

In 2016, a total of 57 visits by 27 Centre members were made to 47 different overseas institutions in 18 countries.

INSTITUTION NAME	COUNTRY	VISITS
Australian Embassy (Peru)	Peru	1
Cambridge University	United Kingdom	2
Columbia University	United States	2
École polytechnique fédérale de Lausanne	Switzerland	1
Filmakademie Baden-Württemberg	Germany	1
Gates Foundation	United States	1
Harvard University	United States	1
Huazhong (Central China) Normal University	China	1
Humboldt University	Germany	1
Imperial College	United Kingdom	1
Karolinska University	Sweden	2
Kyushu University	Japan	1
LAAS-CNRS Toulouse	France	1
Lupunaluz Foundation	Peru	1
Massey University	New Zealand	1
Mathematical Sciences Research Institute, Berkeley	United States	1
Ministry of Environment (Peru)	Peru	1
National Centre For Atmospheric Research	United States	1
National University of Singapore	Singapore	1
Norwegian University of Science and Technology	Norway	1
Oxford University	United Kingdom	3
Plant and Food Research	New Zealand	1
Princeton University	United States	1
RIKEN Brain Science Institute	Japan	1
Siemens Research and Technology Centre	Germany	1
Simons Center for Geometry and Physics	United States	1
Texas A&M University	United States	1
The Japan Society for Industrial and Applied Mathematics	Japan	1
The Kavli Institute	United States	1
Universidad de los Andes	Columbia	1
Université Paris-Dauphine	France	3
University of Amsterdam	Netherlands	3
University of Auckland	New Zealand	1
University of Bamberg	Germany	1
University of Calcutta	India	1
University of California, Davis	United States	1
University of Copenhagen	Denmark	1
University of Ghent	Belgium	1
University of Liverpool	United Kingdom	1
University of Lugano	Switzerland	1
University of Macau	China	1
University of Manchester	United Kingdom	1
University of Twente	Netherlands	1
University of Warwick	United Kingdom	2
University of Wuppertal	Germany	1
Zhongnan University of Economics and Law	China	1
ZIF Center for Interdisciplinary Research, Bielefeld University	Germany	1

NATIONAL AND INTERNATIONAL VISITORS

DURING 2016, ACEMS NODES HOSTED
101 VISITORS FROM 26 COUNTRIES;
30 FROM AROUND AUSTRALIA,
AND 71 FROM OVERSEAS.

National visitors

- Mr Matt Adcock, CSIRO
- Mr Jon Baginski, Euclidean
- Mr Abhishek Bhardwaj, Australian National University
- Professor Noel Cressie, University of Wollongong
- Professor Hans De Sterck, Monash University
- Professor Diane Donovan, University of Queensland
- Professor Jerzy Filar, Flinders University
- Dr Andrew George, CSIRO
- Dr Mark Harris, NVIDIA
- Dr Julian Heinrich, CSIRO
- Mr Xavier Ho, CSIRO
- Ms Jacinta Holloway, Australian Bureau of Statistics
- Ms Kim-Anh Lê Cao, University of Queensland
- Professor Ross Maller, Australian National University
- Dr Vladimir Mangazeev, Australian National University
- Professor Michael Martin, Australian National University
- Dr Melanie Massaro, Charles Sturt University
- Dr Annette McGrath, CSIRO
- Mr Aidan O'Brien, CSIRO
- Dr Sean O'Donoghue, CSIRO
- Mr John Pearson, QIMR Berghofer Medical Research Institute

- Mr Zhihao Qiao, Australian National University
- Dr Ana Sequeira, University of Western Australia / Australian Institute of Marine Science
- Mr Carson Sievert, Monash University
- Mr Piotr Szul, CSIRO
- Dr John Taylor, CSIRO
- Mr Charles Thompson, University of Queensland
- Dr Martin Tomitsch, University of Sydney
- Professor Berwin Turlach, University of Western Australia
- Mr Lu Yaojie, University of Western Sydney

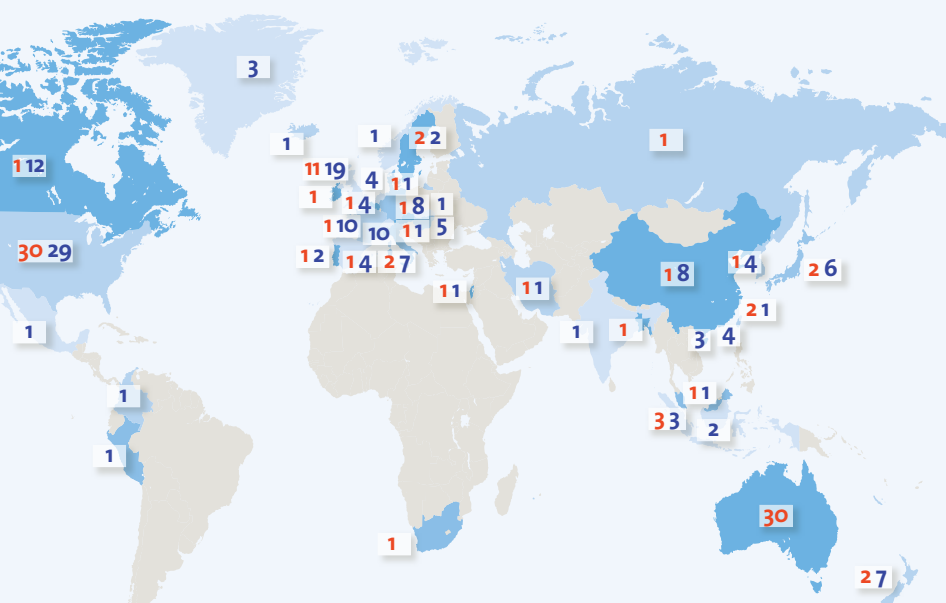
International visitors

- Professor Takayuki Aoki, Tokyo Institute of Technology, Japan
- Dr Robert Aykroyd, University of Leeds, United Kingdom
- Dr Oscar Beijbom, University of California Berkeley, United States
- Professor Rudy Beran, University of California Davis, United States
- Professor Lynne Billard, University of Georgia, United States
- Professor Richard Boys, Newcastle University, United Kingdom
- Associate Professor Paula Brito, Universidade de Porto, Portugal
- Professor Louis Chen, National University of Singapore, Singapore
- Professor Song Xi Chen, Iowa State University, United States
- Professor Ming-Yen Cheng, National Taiwan University, Taiwan
- Dr Alain Chesnais, ACM and ACM SIGGRAPH, Canada
- Dr HyeJin (Jinny) Choo, Korea National University of Arts, South Korea
- Professor William Cleveland, Purdue University, United States
- Dr Tiangang Cui, ExxonMobil, United States
- Dr Andrew Dann, University of Oxford, United Kingdom
- Dr Geoffrey Decrouez, National Research University – Higher School of Economics, Russian Federation
- Professor Persi Diaconis, Stanford University, United States
- Dr Philip Ernst, Rice University, United States
- Associate Professor Nial Friel, University College Dublin, Ireland
- Professor Eleanor Gates-Stuart, National Cheng Kung University, Taiwan
- Professor Malay Ghosh, University of Florida, United States
- Dr Ryan Hafen, Purdue University Indiana, United States
- Professor Moshe Haviv, Hebrew University of Jerusalem, Israel
- Professor Heike Hofmann, Iowa State University, United States
- Professor Herbert Huppert, University of Cambridge, United Kingdom
- Dr Shereen Hussein, King's College, United Kingdom
- Mr Mohamed Isamil, National Institute for Health Research, United Kingdom
- Professor Masahiko Ito, Tokyo Denki University, Japan

- Ms Farzana Jahan, East West University Bangladesh, Bangladesh
- Professor Jiming Jiang, University of California Davis, United States
- Professor Iain Johnstone, Stanford University, United States
- Professor Tony Krzesinski, University of Stellenbosch, South Africa
- Professor Soumendra Lahiri, North Carolina State University, United States
- Professor Xihong Lin, Harvard University, United States
- Professor Oliver Linton, Cambridge University, United Kingdom
- Professor Grant Lythe, University of Leeds, United Kingdom
- Professor Alexander Meister, University of Rostock, Germany
- Professor Xiao-Li Meng, Harvard University, United States
- Professor Hans Mueller, University of California Davis, United States
- Professor Ursula Müller, Texas A&M University, United States
- Dr Alicia Nieto-Reyes, Universidad de Cantabria, Spain
- Associate Professor David Nott, National University of Singapore, Singapore
- Dr Chris Omerod, California Institute of Technology, United States
- Professor Wolfgang Polonik, University of California Davis, United States
- Dr Matias Quiroz, Linkoping University, Sweden
- Professor Kavita Ramanan, Brown University, United States
- Professor Eric Renault, Brown University, United States
- Professor Sidney Resnick, Cornell University, United States
- Mr Sandy Ressler, National Institute of Standards and Technology, United States
- Associate Professor Adrian Roellin, National University of Singapore, Singapore
- Professor Fabrizio Ruggeri, CNR Imati Milano, Italy
- Mr Mohsen Salehi, Tehran Polytechnic, Iran
- Professor Francisco Samaniego, University of California Davis, United States
- Associate Professor Bruno Scarpa, Università di Padova, Italy
- Professor Michael Schimek, Medizinische Universität Graz, Austria
- Professor Siti Mariyam Shamsuddin, UTM Big Data Centre, Malaysia
- Dr Nokuthaba Sibanda, Victoria University of Wellington, New Zealand
- Mr Matthieu Simon, Université libre de Bruxelles, Belgium
- Miss Maria Simonsen, Aarhus University, Denmark
- Associate Professor Sumeet Singh, Cambridge University, United Kingdom
- Dr Jay Ver Hoef, National Marine Mammal Lab of the National Oceanic and Atmospheric Association, United States
- Professor Mattias Villani, Linkoping University, Sweden
- Professor Jane-Ling Wang, University of California Davis, United States
- Professor Karen Willcox, Massachusetts Institute of Technology, United States
- Professor Ruth Williams, University of California San Diego, United States
- Dr Nicholas Witte, Massey University, New Zealand
- Professor Stephen Wright, University of Wisconsin, United States
- Ms Hui Xia, Chongqing University, China
- Professor Jinghao Xue, University College London, United Kingdom
- Professor Qiwei Yao, London School of Economics and Political Science, United Kingdom
- Professor Paul Zinn-Justin, Université Pierre et Marie Curie LAPH, France

NUMBER OF VISITORS AND MEMBER VISITS BY COUNTRY

30	–	Australia	2	7	New Zealand
1	1	Austria	–	1	Norway
1	–	Bangladesh	–	1	Peru
1	4	Belgium	1	2	Portugal
1	12	Canada	1	–	Russia
1	8	China	3	3	Singapore
–	1	Colombia	–	1	Slovakia
1	1	Denmark	1	–	South Africa
1	10	France	1	4	Spain
1	8	Germany	2	2	Sweden
–	3	Greenland	–	10	Switzerland
–	4	Hong Kong	2	1	Taiwan, Province of China
–	5	Hungary	11	19	United Kingdom
–	1	Iceland	30	29	United States
–	1	India	30	–	National
–	2	Indonesia	71	169	International
1	1	Iran, Islamic Republic of	101	169	Total
1	–	Ireland			
1	1	Israel			
2	7	Italy			
2	6	Japan			
1	4	Korea, Republic of			
–	3	Macao			
1	1	Malaysia			
–	1	Mexico			
–	4	Netherlands			



In 2016, a total of 169 visits to 35 countries by 62 centre members were made. These visits include research collaborations as well as conferences, seminars and courses.

MIT AERONAUTICS AND ASTRONAUTICS PROFESSOR HIGHLIGHTS ACEMS WORKSHOP

A long time ago, in a galaxy far, far away...

OK, it wasn't that long ago—it was the 1970s. And it wasn't another galaxy, it was just 'across the ditch' from Australia—in New Zealand.

That's when and where Professor Karen Willcox first realised she was interested in the stars, in space travel, and in flying. That's because she had just seen *Star Wars*.

"I was and still am a huge *Star Wars* fan," Karen said.

"So I often joke that *Star Wars* inspired me to think about aerospace and aerospace engineering and that's what got me into taking maths and science in school. Then ultimately engineering, and it's what led to me being a professor, which is something I certainly never imagined."

Karen is actually a professor of aeronautics and astronautics at one of the world's most prestigious universities—the Massachusetts Institute of Technology (MIT) in Boston. She worked for Boeing before that, and still collaborates extensively with the airline manufacturer.

Karen was on sabbatical during 2016, allowing her to spend a good deal of time in her hometown of Auckland, New Zealand, as a visiting professor at The University of Auckland.

In 2016, Karen was a distinguished plenary speaker at two separate Australian conferences. The first was the annual ANZIAM meeting, held in Canberra in February. The second was the *ACEMS Workshop on Computational and Mathematical Foundations for Big Data Analytics*. While she was in Australia, Karen took time to visit the ACEMS node at QUT in Brisbane in Brisbane.

"It's great to be focusing on this topic of big data and, particularly, the computational and mathematical foundations of big data which is such an exciting area," Karen said.

"It has a lot of applications in my own area of aerospace engineering, as well as many other applications. Thinking about what the fundamental, mathematical and computational challenges are that span all those fields and talking with people who work with those different problems is really interesting. Hopefully it will lead to some productive research ideas and collaborations."

In our galaxy, in the not-so distant future, we could be seeing ideas that Karen is working on right now. One such idea involves Boeing. She's collaborating with the aircraft giant on a blended-wing body aircraft. It's a concept for future airline aircraft where, instead of a fuselage with wings and a tail, there would be an integrated design where the fuselage and the wings would be blended together. Plus, the aircraft wouldn't have a tail.

"We're working with Boeing to try to take some of the methods we've been working on over the years and incorporate them into a

"We're really thinking about the next generation of aerospace systems—starting to exploit some of the opportunities with data that could be available is exciting."

design tool that will let Boeing explore the design space early on. Particularly, to understand the effects of uncertainties and how those propagate through the decisions they make."

Karen said the use of data to change the way things are designed and operate could have applications not just for airliners, but everything from drones to space systems.

"We're really thinking about the next generation of aerospace systems—starting to exploit some of the opportunities with data that could be available is exciting. It means we have the opportunity to make our systems high-performance, more reliable, safer, cheaper, lighter, and to have less environmental impact."

While on sabbatical, Karen volunteered at a primary school in Auckland where she taught a science extension class on designing and building water rockets.

"There's nothing more fun than getting out in New Zealand, sometimes in the driving rain and mud, and having the children launch the water rockets that they've been designing for a few weeks. That's something that shows just how exciting maths and science can be."

To watch Karen's workshop presentation and see highlights of her interview, visit the ACEMS YouTube channel or this story on the ACEMS website:

www.youtube.com/channel/UCflmums1cl4VFVik1NMClA
www.acems.org.au/karen-willcox-mit/



Professor Karen Willcox

NATIONAL AND INTERNATIONAL RESEARCH WORKSHOPS AND CONFERENCES

The following 16 national and international research workshops and conferences were organised or co-organised by the Centre and its members during 2016:

WORKSHOP/CONFERENCE NAME	LOCATION	MONTH
Visualisation, Big Data, Art + Science Festival	Brisbane	February
Workshop on Symbolic Data Analysis (featuring Paula Britto)	Sydney	March
ROpenSci Unconference Australia	Brisbane	April
ACEMS/SAX Institute Workshop	Sydney	April
STEMS2016: Putting Statistics into STEM in the Age of Data	Sydney	June
Joint Australia-Japan Workshop on Dynamical Systems with Applications in Life Sciences	Brisbane	July
Computational and Mathematical Foundations for Big Data Analytics workshop (featuring Karen Willcox)	Brisbane	July
ACEMS/Red Cross Blood Service Workshop - Exploring Future Partnerships	Sydney	August
Random Product Matrices: New Developments and Applications	Germany	August
ACEMS/AMSI Workshop on Measuring Research Engagement and Impact in the Mathematical Sciences	Melbourne	September
Introduction to Inverse Problems in Applied Statistics (featuring Robert Aykroyd)	Sydney	October
ACEMS/Sydney Plant Ecophysiology Workshop	Sydney	November
2016 Forum Mathematics-for-Industry (FMfI)	Brisbane	November
Big Data Visual Analytics 2016	Sydney	November
Memorial Conference in Honour of Peter Hall	Melbourne	December
Analysing Data Using Tessera Workshop (featuring William Cleveland)	Sydney	December

The following five research workshops were organised and hosted by the international mathematical research institute MATRIX ([see pages 102-103](#)) with ongoing support from ACEMS and its members:

WORKSHOP NAME	LOCATION	MONTH
Higher Structures in Geometry and Physics	Creswick	June
Winter of Disconnectedness	Creswick	June
Approximation and Optimisation	Creswick	July
C*-algebraic invariants for dynamics using KK-Theory	Creswick	July
Interactions between Topological Recursion, Modularity, Quantum Invariants and Low-dimensional Topology	Creswick	November

MIXING MATHS AND ECONOMICS TURNS OUT TO BE THE RIGHT FORMULA FOR MELBOURNE ACEMS STUDENT

You've heard the song before. Frank Sinatra singing, "New York, New York," and hearing him sing the phrase "if I can make it there, I'll make it anywhere..."

For Ellen Muir, she's made it there... and back!

That's just one part of Ellen's continuing journey towards her PhD. That journey included leaving her home on Queensland's Sunshine Coast and moving to The University of Melbourne. Her academic journey began in mathematics, but picked up economics along the way. Then late last year, that journey included a stay at Columbia University in New York City.

"Ellen is one of those rare students who educates her supervisor," said Professor Peter Taylor, Director of ACEMS.

Peter is now one of Ellen's PhD supervisors. He has known her since 2010, when she was an undergraduate at The University of Melbourne.

"It was immediately apparent that she had enormous mathematical talent," said Peter.

"But she was also very interested in the role that mathematical reasoning can have in understanding everyday problems."

Ellen started out as a mathematics student at Melbourne, but was encouraged to take some economics courses along the way.

"The more subjects I took, the more I started to like it, and the more I started to see that studying maths and doing research in economics at the same time could be two really complementary fields," Ellen said.

Ellen started to tutor in economics, spending more time in that field of study, but also still working very hard on her mathematics. When it was time to choose her PhD, she decided she wanted to use her mathematical skills in the emerging economic field of 'mechanism design,' which attempts to devise practical schemes for allocating scarce resources. Ellen says mechanism design is also concerned with optimally designing markets in environments with incomplete information.

"With her second supervisor, Simon Loertscher, she has introduced me to this field and the three of us have made some contributions that we are proud of," Peter said.

"As might be expected, Ellen has been the driving force behind this effort."

During the first year of her PhD at Melbourne, Columbia Economics Professor Michael Riordan visited Simon Loertscher. Ellen did some work as a Research Assistant for Michael while

he was in Melbourne, and the two stayed in touch. Michael later invited Ellen to visit Columbia University, and they were able to figure out a way to make that happen at the end of 2015.

For Ellen, it was the opportunity of a lifetime to visit Columbia University, and New York City. Combined, the city, the university, and the school of economics attract some top visitors.

"If you physically go to the place where a lot of research in your area is being done, then you really get an idea of what problems are of interest to people, and what they're working on right now," Ellen said.

Ellen also got a sneak peek of what's to come. Many of those prominent visitors presented working papers that hadn't been published yet. Ellen also presented some seminars.

"I was able to give three talks while I was there, and all of those were quite well attended," Ellen said.

"Each time I would get really great feedback from the academics and the other PhD students and so I was made to feel very welcome and I really enjoyed my time in the department."

Ellen is back in Melbourne now with ACEMS, working towards completing her PhD by the start of 2017.

She's come a long way since she first arrived at The University of Melbourne.

"I remember being impressed that she had built her own computer at home and was using it to study betting systems," Peter said.

Now it's clear, with her education and experience, that Peter—or anyone else for that matter—isn't betting against her as she moves forward in life.

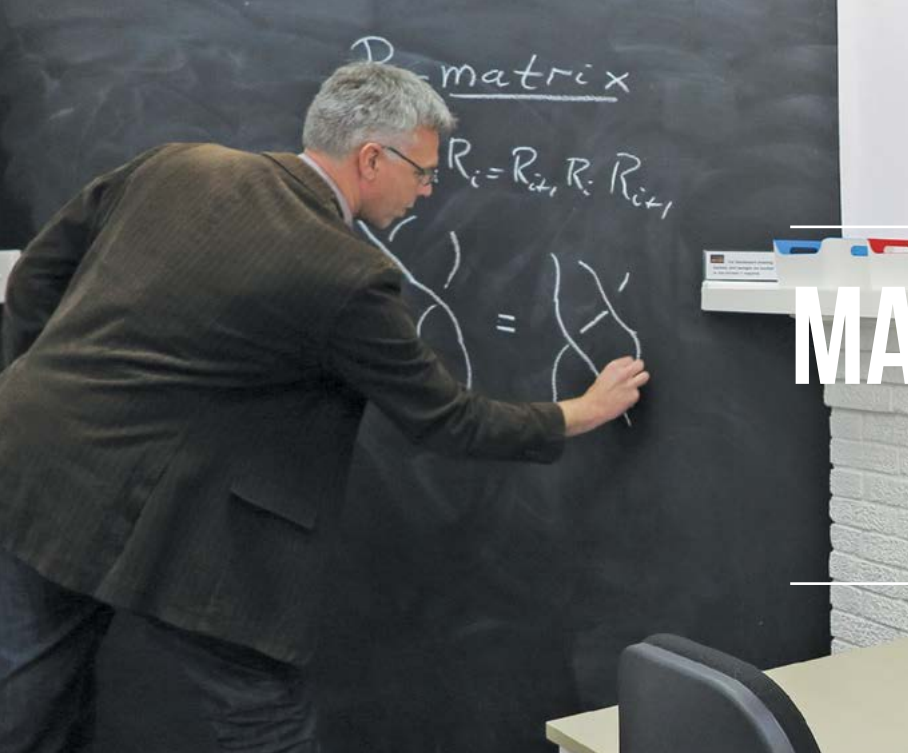
To see highlights of Ellen's interview, visit the ACEMS YouTube channel or this story on the ACEMS website:

www.youtube.com/channel/UCfImumsIck4VFVik1NMCIA
<http://acems.org.au/ellen-muir-columbia-univ/>



Ellen Muir in New York





MATRIX

LAUNCHED IN MAY 2016, MATRIX IS AUSTRALIA'S
FIRST INTERNATIONAL RESEARCH INSTITUTE FOR
THE MATHEMATICAL SCIENCES.

By providing initial seed funding, ACEMS played a key role in getting MATRIX off the ground, along with The University of Melbourne. Subsequently, Monash came on board, and MATRIX is now a joint partnership between Monash University and The University of Melbourne. ACEMS continues to be a supporting associate providing \$100,000 per year.

MATRIX provides intensive residential mathematical programs at MATRIX House, Creswick, Victoria. During 2016, MATRIX coordinated and presented five successful research programs:

- Higher Structures in Geometry and Physics
- Winter of Disconnectedness
- Approximation and Optimisation
- C^* -algebraic invariants for dynamics using KK-Theory
- Interactions between Topological Recursion, Modularity, Quantum Invariants and Low-dimensional Topology.

These programs have attracted notable and world leading mathematical scientists from respected tertiary organisations such as: Massachusetts Institute of Technology; Imperial College London; Chelyabinsk State University and Russian Science Academy; Centre for Quantum Geometry of Moduli Spaces; Aarhus University; Australian National University and the University of Geneva.

MATRIX also co-hosted an outreach program with ACEMS targeted at secondary school teachers:

- Mathscraft: Doing Maths like a Research Mathematician ([see pages 106-107](#))

MATRIX looks forward to a very busy 2017. Upcoming programs include:

- Hypergeometric Motives and Calabi-Yau Differential Equations
- Computational Inverse Problems
- Integrability in Low-Dimensional Quantum Systems
- Elliptic Partial Differential Equations of Second Order: Celebrating 40 years of Gilbarg and Trudinger's book

“MATRIX has received consistent positive feedback across all programs with many participants already returning to attend programs in 2017 or in the process of preparing their own MATRIX programs.”

- Combinatorics, statistical mechanics, and conformal field theory
- Mathematics of Risk
- Tutte Centenary Retreat
- Geometric R-matrices: From Geometry to Probability.

A Fields Medallist (Nobel Prize equivalent in mathematics) will be among the organisers and participants of the MATRIX research program Geometric R-matrices.

MATRIX has received consistent positive feedback across all programs with many participants already returning to attend programs in 2017 or in the process of preparing their own MATRIX programs as a result of their collaborations with fellow colleagues at the Institute.

The Institute continues to attract and secure travel grants for program participants from ACEMS, the Australian Mathematical Sciences Institute, the Australian Mathematical Society, the Priority Research Centre for Computer-Assisted Research Mathematics and its Applications, and funding from overseas organisations such as Compositio Mathematica, the European Mathematical Society, The Number Theory Group and The National Science Foundation.

During 2016—its first eight months of operation—MATRIX hosted 67 days of intensive international research collaboration with 78 international and 84 domestic participants and looks forward to launching Volume 1 of the MATRIX Book Series in September 2017.



MATRIX House, Creswick, Victoria

MATRI

ACEMS MEMORIAL CONFERENCE TO HONOUR PROFESSOR PETER HALL

ON 9 JANUARY 2016, IN MELBOURNE, ACEMS
LOST ITS FOUNDING DIRECTOR, PROFESSOR
PETER HALL. IT IS NOT OVERSTATING THINGS
TO SAY THAT PETER WAS ONE OF THE
GREATEST STATISTICIANS IN THE WORLD.

Peter spent the last 10 years of his career at The University of Melbourne, most recently as an Australian Research Council Laureate Fellow. To acknowledge the massive contribution that Peter made to both ACEMS and the university, as well as to celebrate his standing in the worldwide statistical community, a memorial conference in Peter's honour was held at the university from 10-12 December 2016.

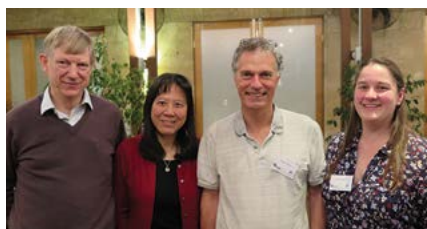


Peter's friends and colleagues from around the world were invited to talk about their latest research as well as say something about how they were influenced by Peter, to help celebrate this exceptional man and his unique contributions to statistics.

The conference was sponsored by ACEMS, The University of Melbourne and the Australian Research Council, and was fully organised by ACEMS. In particular, the organising committee comprised ACEMS Director Peter Taylor, Chief Investigator Aurore Delaigle, Associate Investigator Davide Ferrari, Melbourne Node Administration Officer Ben Hess and Chief Operating Officer Emily Duane.



The conference was attended by a well-balanced mix of established scholars, early career researchers, and postgraduate students. It had a strong showing with more than 100 participants from local and international universities providing a considerable impact on the local statistical community due to the depth and level of invited speakers. Across the three-day conference participants heard 23 invited talks contributed by leading scholars in fields of mathematical statistics and statistical methodology closely related to Peter's research. Invited speakers who knew Peter as a colleague, co-author, or former supervisor were often able to share anecdotal glimpses arising from the intersection of their lives with that of Peter's. The conference also featured 12 contributed poster presentations where young statisticians affiliated with Victorian research institutions showcased their work. Scientific discussions among participants were fostered by lunch and coffee breaks held in the conference venue and the conference dinner held nearby on the second night.



ACEMS Director Peter Taylor opened the scientific proceedings by giving a welcome message encouraging scholarly exchanges among participants, which set the tone for the rest of the conference. In her opening address, Professor Aurore Delaigle presented an overview of selected research topics from Peter Hall's impressive contributions. She also shared some connections between his personal interests and research; for example, she highlighted the link between his passion for photography and the development of new de-convolution methods related to image de-noising.

Professor Persi Diaconis (of Stanford University) gave the first scientific talk. In his thought-provoking address, he discussed new statistical tests for randomness in the context of card



In Memory of Peter Hall (Nov 20, 1951 – Jan 9, 2016)

- Brilliant & inspiring statistician
- Leader
- Supportive & caring colleague
- Modest
- Generous
- A great role model



shuffling. He then posed deep open research questions wishing that “Peter Hall was around to help out.”

Professor Iain Johnstone (also of Stanford University) opened the second day by reviving participants’ interest in a remarkable unfinished project of Peter Hall’s related to expectation propagation, and discussed recent efforts in progress to complete such a work.

Across the proceedings, multiple talks were related to Peter’s revolutionary work in the area of bootstrap re-sampling. For example, Professor Soumendra Lahiri (of North Carolina State) gave a detailed discussion on bootstrap re-sampling for high-dimensional regression, while Professor Michael Martin (of the Australian National University) discussed new bootstrap diagnostic tools to detect influential data points in modelling.

Professors Jane-Ling Wang (of University of California, Davis) and Ming-Yen Cheng (of National Taiwan University) discussed work on functional data analysis, another central area in Peter’s research. Professors Rudy Beran (of University of California, Davis), Oliver Linton (of Cambridge University) and ACEMS Deputy Director Kerrie Mengersen (of Queensland University of Technology) discussed methods in different domains of non-parametric statistics.

Arguably, this ACEMS conference put together the most distinguished list of statistical speakers ever assembled in Australia. It helped strengthen mathematical statistics across Australia, while honouring the incredible scientific life of Professor Peter Hall. The relatively intimate size of the conference allowed for rich discussions after each talk. Several participants reported that the conference re-ignited their spark for scholarship and confirmed their commitment to research in statistics. Conference participants soaked up the latest ideas from conference presenters, shared their perspective with colleagues, made new contacts, honed their own ideas, and discussed the most recent discoveries in statistics.

LIST OF INVITED SPEAKERS:

- Rudy Beran (University of California, Davis)
- Lynne Billard (University of Georgia)
- Song Xi Chen (Iowa State University)
- Ming-Yen Cheng (National Taiwan University)
- Geoffrey Decrouez (Higher School of Economics, Moscow)
- Persi Diaconis (Stanford University)
- Jiming Jiang (University of California, Davis)
- Iain Johnstone (Stanford University)
- Soumendra Lahiri (North Carolina State University)
- Xihong Lin (Harvard University)
- Oliver Linton (Cambridge University)
- Ross Maller (Australian National University)
- Michael Martin (Australian National University)
- Kerrie Mengersen (Queensland University of Technology)
- Hans Mueller (University of California, Davis)
- Wolfgang Polonik (University of California, Davis)
- Francisco Samaniego (University of California, Davis)
- Michael G. Schimek (Medical University of Graz, Austria)
- Berwin Turlach (The University of Western Australia)
- Jane-Ling Wang (University of California, Davis)
- Alan Welsh (Australian National University)
- Jinghao Xue (University College London)
- Qiwei Yao (London School of Economics)

PHOTOS – Top Left: Professor Persi Diaconis. Top Right: ACEMS Scientific Advisory Committee (SAC) member Professor Xihong Lin. Previous Page – Top: Organising committee: Peter Taylor, Aureore Delaigle, Ben Hess, Emily Duane, and Davide Ferrari. Middle: A subset of invited speakers and the organising committee. Bottom: ACEMS SAC members Iain Johnstone and Xihong Lin with Peter Taylor and Emily Duane

MATHSCRAFT—DOING MATHS LIKE A RESEARCH MATHEMATICIAN

WHAT IF MORE STUDENTS USED WORDS LIKE “JOY” AND “PASSION” WHEN TALKING ABOUT MATHEMATICS?

- Exploring
- Noticing patterns
- Making conjectures and
- Proving or disproving them
- Figuring out “why”, and
- Thinking of ways to extend the problem.

That’s the goal of the ACEMS Mathscraft program led by ACEMS Affiliate Anthony Harradine (Prince Alfred College, Adelaide), ACEMS Associate Investigator and Outreach Officer Anita Ponsaing and ACEMS Deputy Director Nigel Bean.

We want to show that mathematics isn’t just about getting a right answer. It’s a process, and often one problem or question will lead to other problems, and those can lead to others. It’s that process that a research mathematician goes through when he or she starts to tackle a problem.

Mathscraft gives students and teachers the opportunity to experience this process for themselves, by grouping them with research mathematicians, including ACEMS CIs, AIs, postdocs and students.

In a Mathscraft session, there are up to 10 groups: each comprising three students (Years 7-10), one teacher and one mathematician. The groups are given mathematical problems and are guided through the following process (steps may be visited more than once):

- Here’s something to play with.
- What pattern do you see? Are you sure the pattern is there? Does it always happen?
- Find a way to convince yourself that it’s true. Be sure beyond all doubt (you won’t be told if you’re right or not!).
- Why is the pattern occurring?
- What other questions can you ask? What has the process made you think about, beyond the given problem?

What if they could experience what ACEMS believes mathematics is truly about:

What’s important about Mathscraft?

- The problems and process mimic the mathematics that is done by research mathematicians.
- The focus is on noticing and understanding mathematical structures, by utilising techniques learnt some years before. The focus is not on learning new content and using it to answer simple questions.
- The sharing of ideas, even before they are fully formed, is encouraged, both within groups and across groups. Ideas grow from other ideas, and this often leads to a solution to a problem. This reflects the fact that mathematics is an (internationally) collaborative discipline. There are multiple directions to go in and no “finish line”.
- The participants are given the opportunity to interact with working research mathematicians, to see how they approach a new problem and what they do when they get stuck. They collaborate and share the joy of discovering things (usually the mathematicians haven’t seen the problems before either!).

Teacher Professional Development workshop, 23-27 November 2016

As mentioned above, ACEMS wants students in Australia to experience the joy and passion of mathematics.

In collaboration with MATRIX (see pages 102-103), ACEMS brought together 17 high school mathematics teachers from



across Australia, to train them in running MathsCraft sessions. This five-day workshop was held at MATRIX in Creswick, and was organised and conducted by Anthony, Anita and Nigel. During the workshop the teachers tackled the same sorts of problems that are given to students in the sessions, and were encouraged to analyse their experiences.

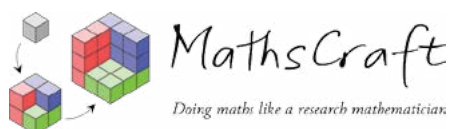
On the second morning a MathsCraft session was held with school groups from the local area, including 18 students and five teachers from five schools.

During the workshop there were always at least three mathematicians present to work with the teachers on the problems. In total, nine mathematicians took part, including three ACEMS staff (Director Peter Taylor, Deputy Director Jan de Gier and Outreach Officer Anita Ponsaing) and three ACEMS PhD students (Kate Saunders, Peter Braunsteins and Jason Whyte).

When it was over, every teacher we talked to was moved by their experience. They all said they wanted to go back to their schools and begin to do things differently when it came to teaching mathematics. They also said they wanted to share their experiences with their colleagues and students. The MathsCraft seed was planted.

Now, it will grow. In 2017, each of the 17 teachers who attended will run two MathsCraft sessions for schools in their local area, with assistance and research mathematicians provided by ACEMS. It's our hope that others who attend these workshops will share their experiences with their local schools.

This is just the beginning, but we believe in the future of this program and what it can do. We want more students around Australia to experience the true joy of what mathematics really involves!



The workshop was a resounding success, with all participants giving 7/7 "Extremely worthwhile" when asked to rate the experience.

QUOTES FROM THE WORKSHOP ATTENDEES

"In all my years of teaching I have never learnt so much in the time available. I wish we could have more exposure to this type of learning/teaching."

"Seeing how mathematicians work has shown me how valuable different representations are to the thinking process."

"It is very important to recognise that this event was likely more valuable than all of my previous PD combined."*

"Amazing. Exhausting, fun; really, really hard work..."

"It's exceeded every expectation."

"I like the fact that we've been sent to bed each night struggling with at least one problem."

"This is a highlight in my professional career."

"It's just been really, really good PD... it's actually something I can use, rather than sitting listening to people talk about what you could do."

* Professional Development

WHY ARE CORNFLAKES ATTRACTED TO EACH OTHER; WHY DON'T GROWN TREES TOUCH; SILVER AND GOLD UNDERWATER; AND MORE— THE NATIONAL SCIENCE QUIZ

ACEMS WAS PROUD TO BE A DRIVING FORCE
IN THE CREATION OF AUSTRALIA'S FIRST-
EVER NATIONAL SCIENCE QUIZ.

The event took place on Sunday 1 May at The University of Melbourne. A sold-out crowd—more than 400 people—filled the Copland Theatre at The Spot.

The National Science Quiz was hosted by Charlie Pickering, comedian and host of *The Weekly* on the ABC. Charlie's unique combination of presenting and comedy experience, as well as his genuine interest in science and technology, made him a perfect fit for the event.

He was joined on stage by expert panellists, including:

- musician, writer, actor and radio host Red Symons
- author, science journalist and television presenter Tanya Ha
- astrophysicist and science communicator Alan Duffy
- Victorian Lead Scientist Leonie Walsh
- mathematician and statistician Terry Speed, winner of the 2013 Prime Minister's Prize for Science.

The group answered a series of thought-provoking questions, using humour, some good scientific and mathematical reasoning, and some help from the audience. Some of the questions included:

- If you let cornflakes float on milk they attract each other. What causes this?
- A scale with a silver crown on the left and a gold crown on the right is in balance. What happens if you put the scale underwater?
- Mature trees don't tend to be right next to each other, nor have touching branches. How do they avoid each other as they are growing?

The Quiz was based on an annual televised event in the Netherlands called *Nationale Wetenschapsquiz*. The aim of the event was to engage the public in STEM content in an entertaining manner.

The School of Mathematics and Statistics at The University of Melbourne, the Centre of Excellence for Biosecurity Risk Analysis (CEBRA), the ARC Centre of Excellence for Particle Physics at the Terascale (CoEPP), and the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO) all co-sponsored the event with ACEMS.



Charlie Pickering hosting the National Science Quiz



Terry Speed, Red Symons, Tanya Ha, Alan Duffy, Charlie Pickering and Leonie Walsh



Five panellists with host Charlie Pickering



Nobel prize winner and Australian National University Vice-Chancellor Brian Schmidt beaming in a question



A laser demonstration

STAKEHOLDER ENGAGEMENT REPORT

2016 WAS A BUSY YEAR FOR ACEMS IN TERMS OF ENGAGEMENT WITH INDUSTRY AND OTHER END-USERS. IN ADDITION TO WORKING WITH THE CENTRE'S OFFICIAL PARTNER ORGANISATIONS, ACEMS ESTABLISHED THE INDUSTRY AFFILIATE PROGRAM, WHICH ENABLES COLLABORATING ORGANISATIONS TO BECOME ACEMS MEMBERS; SEE [PAGE 114](#) FOR A SUMMARY. FURTHERMORE, CENTRE MEMBERS CONDUCTED 36 BRIEFINGS, OF WHICH SEVERAL TRANSLATED INTO PROJECTS. THESE ACTIVITIES ARE SUMMARISED IN THIS STAKEHOLDER ENGAGEMENT REPORT ([PAGES 110-116](#)), WITH THE ORGANISATIONS INVOLVED IN BRIEFINGS AND SOME OF THE CENTRE'S NEW PROJECTS LISTED ON [PAGE 113](#).

ACEMS recognises the importance of research engagement, translation and impact, and endeavours to take a leading role in these activities among the mathematical sciences community in Australia. For mathematical sciences, research engagement and translation have the potential to innovate technologies, optimise processes, quantify evidence, and model/predict future events. There is thus clear opportunity for the mathematical and statistical sciences to significantly impact the bottom line and effectiveness of industry, government and applied research entities.

In 2016 ACEMS invested in building its capabilities in regards to impact and engagement and expanded the Stakeholder Engagement Officer (SEO) role from a 0.5 to 0.8 full-time equivalent (FTE) position; this will increase to 1.0 FTE at the start of 2017. The SEO's role is to support existing relationships, engage new partnerships and foster the soft skills necessary for effective industry engagement amongst the Centre's members.

ENGAGEMENT WITH PARTNER ORGANISATIONS

Partner Organisations (POs) are an important part of the ACEMS Industry Engagement ecosystem. They are:

- AT&T Labs
- Australian Bureau of Statistics (ABS)
- Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Australian Institute of Marine Science (AIMS)
- Mathematics of Information Technology and Complex Systems (Mitacs)
- Roads Corporation of Victoria (VicRoads)
- Sax Institute

ACEMS works closely with the POs in an ongoing relationship to develop a deeper understanding of the quantitative challenges and collaborative opportunities in these organisations. The engagements between ACEMS and the POs occur through two main channels: through brokerage by the Stakeholder Engagement Officer, Jessie Roberts, and through direct contact with the Centre researchers. The 2016 engagement activities with these POs are summarised over the next two pages.



AUSTRALIAN INSTITUTE
OF MARINE SCIENCE

AIMS

ACEMS has had a close relationship with AIMS since its inception. The relationship was evidenced in 2015 by the establishment of a pair of postdoctoral researchers, one located at AIMS (Carla Ewels) and one at the QUT node of the Centre (Paul Wu), with the aim of pursuing joint research projects, increasing collaboration and putting in place greater opportunities for networking.

Paul's project was on developing a way to identify optimal timing of anthropogenic stressors, such as dredging, to maximise resilience of marine ecosystems, such as seagrass. Carla's project was on developing an agent-based model to better understand the movement and impact of crown of thorns, one of the greatest threats to coral reefs across the world. Paul and Carla completed the terms of their appointment at the end of 2016, but they have both been retained by their respective organisations as researchers with crossover projects. The outputs of the joint activity have included: seminars presented at ACEMS and AIMS locations, and at four professional conferences; six coauthored journal articles; and two new substantive funded research projects.

ACEMS was sorry to bid farewell to the AIMS Partner Investigator (PI), Dr Julian Caley, in 2016. Collaborations are now in the capable hands of Dr Ken Anthony as the incoming PI. Ken is a Principal Research Scientist within the Decision Support Team and has been with AIMS since 2011. He brings with him a strong passion for ecosystem resilience and has been working with ACEMS over the past two years.

In 2016 ACEMS celebrated the graduation of its first jointly supervised ACEMS/Partner Organisation PhD student. Julie

Vercelloni was jointly supervised by ACEMS and AIMS researchers on the topic of semiparametric hierarchical modelling of coral cover on the Great Barrier Reef (GBR). Her work revealed the variation in coral cover loss and recovery across the GBR and the impact of various threats such as crown of thorns and cyclones. Julie is now working with the Global Change Institute at The University of Queensland, with continued strong links to both ACEMS and AIMS.

The Centre welcomed a new joint ACEMS-AIMS PhD student Pubudu Thilan in 2016. Pubudu's thesis will focus on "Adaptive design for marine monitoring". This project will be supervised by Erin Peterson and James McGree at the ACEMS-QUT node, and Ken Anthony at AIMS.

An example of the new research projects that arose from the ACEMS/AIMS collaboration is "Monitoring through Many Eyes". This project involved researchers from AIMS (led by Dr Ken Anthony) and ACEMS (led by Erin Peterson, Kerrie Mengersen and Julie Vercelloni) in collaboration with a larger QUT team of researchers, and was funded by the Cooperative Research Centre for Spatial Information and the Queensland Department of Natural Resources and Mines. The project was a first of its kind that used citizen science and virtual reality to explore the health of the GBR, as well as how citizens evaluate beauty in underwater environments. Discussions are in progress with the Great Barrier Reef Fund to extend and embed the project into ongoing GBR monitoring programs. For more about this project, see [page 117](#).



CSIRO

In 2016 connections between ACEMS and CSIRO continued to broaden. ACEMS Research Fellow Tomasz Bednarz was appointed 50:50 ACEMS/CSIRO, and ACEMS Research Fellow Dr Steven Psaltis and Chief Investigator Ian Turner were appointed as CSIRO Visiting Scientists. These important partnerships are fostering greater collaboration between the ACEMS and CSIRO research interests.

In addition to collaborations between the organisations, ACEMS and CSIRO co-supported the Big Data Visual Analytics conference chaired by Tomasz Bednarz (<http://www.bdva.net/2016/>). This conference was highly successful and brought together a wide range of industry partners and academics to explore the current research opportunities within visual analytics.



ABS

ACEMS has enjoyed strong support and close links with the ABS since its inception. A major activity in 2016 was a collaborative contribution to an international United Nations Global Working Group (UNGWG) on the use of remotely sensed data for official statistics. ACEMS worked with the ABS on the development of the report, with a focus on methodology and a case study on crop identification and crop yield. A series of workshops are planned to disseminate the findings of the UNGWG among National Statistics Organisations (NSOs) globally in 2017.

SAX INSTITUTE



The ACEMS-Sax Institute partnership strengthened in 2016. The Sax Institute PI Timothy Churches changed employers in 2016 and Mark Bartlett was welcomed into the ACEMS network.

Dr Joanna Wang (see [page 123](#)) continued to work in a co-funded postdoctoral position at the University of Technology Sydney, under the supervision of Chief Investigator Louise Ryan. Joanna spends 50% of her time working on projects for the Sax Institute and 50% working on research outputs. Over the last two years she has developed a deep understanding of the research problems relevant to the Sax Institute, and her research outputs have become increasingly informed by the problems she is working on at the Sax Institute.

In order to explore new collaborations, ACEMS and the Sax Institute co-hosted a full-day workshop with researchers from both organisations. Two potential research projects around predictive population modelling with ACEMS Associate Investigator Dr Nicole White were identified; these projects will leverage the *45 and Up* data set. Negotiations for data access are currently underway and the Centre looks forward to launching these projects in 2017.

VICROADS



A strong collaboration with VicRoads was established early in the life of ACEMS, led by CIs Jan de Gier from The University of Melbourne and Tim Garoni from Monash University. This collaboration resulted in a substantive research project on improved methods for modelling traffic flow. Outputs from this project include research papers, media articles and a published online model called CEASAR (Cellular Automata Simulator for Arterial Roads). Quoting from the website (www.ceasar.acems.org.au), "CEASAR is a network traffic simulator which incorporates realistic traffic signal systems such as the Sydney Coordinated Adaptive Traffic System (SCATS)." The formal project ended in 2015 but collaboration continued into 2016 with a view to scoping continued research opportunities.

In 2016 the Centre welcomed the joint ACEMS-VicRoads PhD student, Samithree Rajapaksha whose thesis will focus on "Simulating Bus and Tram Priority in Traffic Flow".

AT&T



In 2016 Dr Walter Willinger, the AT&T Partner Investigator, moved to a new external position. Dr Jennifer Yates will be welcomed as the new PI in 2017 as ACEMS continues to explore and re-define a new research focus. Enthusiasm remains high on both sides of this partnership and the Centre looks forward to exploring new research opportunities between ACEMS and AT&T in 2017.

MITACS



In 2016, ACEMS and Mitacs commenced discussions with the view of developing an international exchange program between Australia and Canada. The program will provide an opportunity for Mitacs and ACEMS Higher Degree Research students to undertake industry internships in an international context under the supervision of an international research organisation. The Centre looks forward to putting this mutually beneficial exchange into place in 2017.

```
); % iteration counter
while sigma > eps
    t = t+1;
    x = mu + sigma*randn(N,1);
    SX = S(x); % Compute the performance.
    sortSX = sortrows([x SX],2);
```

“ACEMS offers ‘expertise of a range of researchers and experts from across multiple universities, with a single agreement and a single ‘one stop’ interface into academia.’” **”** Wayne Power, Arms & Combat Unit, DST Group.

OTHER ENGAGEMENT

The mathematical and statistical sciences have the potential to provide significant value to Australian industry and other end users. Whether it is innovating technologies such as modelling bitcoin chains, optimising processes like reducing donor wait times for the Red Cross Blood Service, understanding systems and patterns such as differences in cancer incidence and survival rates across Queensland in collaboration with the Cancer Council Queensland, or predicting future events such as extreme weather patterns, mathematics and statistics has the potential to guide better decision making in government, improve business efficiencies and profits, and improve research methods within other research disciplines.

However, challenges exist in connecting the expertise within mathematical and statistical departments to industry and end-users. This is where ACEMS can play a leading role, working with industry partners to link the expertise within the Centre to problems in the real world. The Centre’s activity is clearly seen in the 36 briefings to industry affiliates or other end-users conducted in 2016, and the 10 collaborative projects with new partners that emerged from some of these briefings; see [page 116](#) for more.

BRIEFINGS

- Boeing Australia
- Great Barrier Reef Foundation
- Australian Red Cross Blood Service
- Meshed
- The New Zealand Institute for Plant & Food Research Limited
- DST Group
- Open Data Queensland
- IBM Research
- QUT/PwC Chair in Digital Innovation
- rOpenSci
- Mackay Regional Council
- Queensland Cyber Infrastructure Foundation (QCIF)
- Forest and Wood Products Australia
- PWC Assurance

- Australian Agricultural Company
- Biosecurity Australia
- Winton Capital Group
- Australian Taxation Office
- PwC Brisbane
- Commonwealth Bank of Australia
- Mathematics Association of South Australia
- Société Internationale de Télécommunications Aéronautiques
- Australian Border Force
- ISS Australia
- Queensland Airports Limited
- Brisbane Airport Corporation
- Great Barrier Reef Marine Park Authority
- Queensland Ports Authority
- Australian Institute of Sport
- Healthy Waterways
- Electoral Districts Boundary Commission of South Australia
- The Satellite Surveying, Mapping, and Geoinformation Organisation of China
- Bitcoin Group Ltd
- Surf Life Saving Queensland
- BMT Oceania
- Centre for Energy Technology, The University of Adelaide

Examples of end-users that ACEMS conducted projects with as a result of the briefings

- DST Group - Arms & Combat Unit
- Australian Red Cross Blood Service
- BMT Oceania
- Centre for Energy Technology, The University of Adelaide
- Department of Agriculture and Fisheries
- Australian Agricultural Company
- Cancer Council Queensland
- Forest and Wood Products Australia
- Bitcoin Group Ltd
- Great Barrier Reef Foundation

THE INDUSTRY AFFILIATE PROGRAM

The Industry Affiliate Program (IAP) allows industry collaborators to connect with ACEMS without binding long-term contracts. As an IAP member, organisational employees can attend ACEMS workshops and events, and are welcomed into the ACEMS network. IAP members also receive a bi-monthly engagement newsletter to keep them up to date with ACEMS activities and opportunities and are invited to have a yearly research planning session with select ACEMS academics.

Membership of the Industry Affiliate Program is available to all organisations that are active collaborators of ACEMS. The program was launched in November 2016 and five organisations were formally

invited to become members:

- the Australian Institute of Sport
- the Australian Red Cross Blood Service
- the Australian Agricultural Company
- the Australian Tax Office, and
- Cancer Council Queensland.

The 2016 engagement activities with these Industry Affiliate Organisations are summarised below. The Centre looks forward to expanding the program in 2017.

AUSTRALIAN RED CROSS BLOOD SERVICE (RCBS)



During 2016, the Centre continued to build and deepen a collaborative partnership with RCBS. At the core of this ongoing collaboration is the ACEMS-RCBS co-funded postdoctoral position held by Dr Stephen Wright. As an applied statistician, Stephen spends 50% of his time in a research role at RCBS providing support around clinical trial design and statistical analysis. The other 50% of his time is spent at the University of Technology Sydney (UTS), under the supervision of ACEMS Chief Investigator Louise Ryan, exploring interesting methodological problems and long standing research questions arising from his work at RCBS. This novel mechanism for an on-going partnership was instigated by Louise and has been highly successful. This model enables real world problems to be identified that also push the frontiers of statistical research, and most importantly, being embedded in both organisations means that the research outcomes are utilised by RCBS to create impact on how they conduct their core business.

In 2016 the methodological challenges and long standing open research questions that have been explored in this partnership include:

- Use of predictive modelling to improve operational efficiencies and reduce the number of unnecessary tests within the blood manufacturing process.
- Understand the health outcomes of donors that donate regularly over a long period of time.
- Develop novel modern statistical methods for analysis of big data. For example, analysing risk factors associated with adverse events for blood donors—a problem that could not previously be analysed due to database processing limitations.

In addition to Stephen's work, ACEMS hosted a collaborative workshop with the RCBS researcher community. This workshop brought together 15 RCBS researchers and 15 researchers from across ACEMS' six nodes. From this workshop three collaborative research projects were identified and are currently undergoing approval with RCBS. These projects were: operations research for optimising donor wait times; predictive modelling to better predict and respond to outbreaks of infectious diseases; and use of graph theory to better forecast blood demand through the supply network.

AUSTRALIAN TAXATION OFFICE (ATO)



Australian Government
Australian Taxation Office

The ATO has engaged the Centre in a capacity-building role; two ATO staff will begin a six-month secondment in February 2017 with the aim of developing deeper technical expertise of statistical methodologies. The ATO secondees will explore "Big data technologies within large organisations" and the "Use of machine

learning techniques for client management"; these staff members will explore different techniques and solutions that build their data analytics skills. This collaboration with ACEMS provides the opportunity to learn about and try out new approaches and tools in an external environment.

“The partnership with ACEMS has assisted the Australian Agricultural Company in “transforming the promise of machine learning and big data analytics into tools that can be used internally, and to assist in making business decisions.””

Dr Matthew Kelly, Australian Agricultural Company.



CANCER COUNCIL QUEENSLAND

Under the leadership of ACEMS CI Kerrie Mengersen, the Centre is working with the Cancer Council Queensland to develop the National Cancer Atlas, which will use cutting edge spatial statistical methods to map how the burden of cancer varies geographically across Australia. A key focus of the Atlas is to develop statistical spatial models for the small counts in each of the geographical areas, while also providing measures of uncertainty around the modelled estimates.

This collaboration has enabled Cancer Council Queensland to access statistical expertise and internationally recognised researchers in the fields of spatial statistics. Insights from the Atlas will guide the allocation of screening programs, health campaigns, support services and other resources to the regions of Australia most in need.



AUSTRALIAN AGRICULTURAL COMPANY (AACo)

AACo is one of Australia's largest agricultural companies. ACEMS has delivered several projects that directly impact the AACo supply chain. Specifically, ACEMS student Zoe van Havre has utilised machine learning and image processing to automatically grade rib eyes, while Affiliate Member Miles McBain has utilised predictive

modelling to predict the weight gain and meat quality of Australian cattle. Further to this, ACEMS PhD students Brigitte Colin and Ben Fitzpatrick explored the use of satellite imagery to predict pastoral biomass, a collaborative project with the Cooperative Research Centre for Spatial Information.



AUSTRALIAN INSTITUTE OF SPORT (AIS)

The AIS has been working with ACEMS on topics around sports physiology. Predictive models of athlete performance using the countermovement jump were developed to characterise fatigue as a tool to support coaches and decision makers to optimise training. Separately, statistical analysis of postural control

experimental data revealed the prominent role that visual cues play in maintaining balance in addition to the inner ear. This work was undertaken by ACEMS Associate Investigator Dr Paul Wu, Chief Investigator Kerrie Mengersen, and ACEMS students Nicholas Sterkenburg and Lawrence Garufi.

EXAMPLES OF ENGAGEMENT WITH OTHER END-USERS

GREAT BARRIER REEF FOUNDATION (GBRF)

In collaboration with the Centre's Partner Organisation AIMS, and GBRF, a team of researchers led by Erin Peterson, Kerrie Mengersen and Julie Vercelloni has been using virtual reality headsets to immerse users in a 360-degree digital Great Barrier Reef. The project has allowed the GBRF to investigate how citizens perceive beauty and health on the reef, as well as engage the public in citizen science as recreational divers collect and donate geo-located images to the project. This powerful source of information allows the GBRF to cost-effectively investigate coral damage, water clarity, and marine populations. See the feature story [opposite](#) for more.

FOREST AND WOOD PRODUCTS AUSTRALIA (FWPA) & DEPARTMENT OF AGRICULTURE AND FISHERIES (DAF)

FWPA and DAF have been working with ACEMS to improve the understanding of variation in pine plantation timber properties across plantation sites. Working with ACEMS researchers Ian Turner, Steve Psaltis, Erin Peterson, Troy Farrell and Elliot Carr, the Centre is developing virtual log models. These virtual models will enable better understanding of timber properties and quality which in turn will optimise timber utilisation by enabling timbers to be targeted to premium markets, enabling products to be prioritised to the most profitable end use.

BMT OCEANICA & AIMS

ACEMS researcher James McGree worked with BMT Oceanica and AIMS to develop novel statistical methods for monitoring disturbances, such as cyclones and oil spills, on marine ecosystems. The output of this research resulted in a new software package called "E-power" which will be used by marine science researchers to plan cost effective and targeted monitoring programs for marine ecosystems.

DEFENCE SCIENCE AND TECHNOLOGY GROUP (DST GROUP)

ACEMS Associate Investigators Charl Ras, Mark Fackrell and Joyce Zhang worked with DST Group to explore the current methodologies in Operations Research for sensor placement optimisation. This important pilot project evaluated methodologies used in fields outside of the defence context to ensure best practices were being used internally.

SUPPORTING THE MATHEMATICAL SCIENCES COMMUNITY

ACEMS is committed to leading the way for the mathematics and statistics community in engagement and real-world impact. Working with the Australian Mathematical Sciences Institute (AMSI), in 2016 the Centre co-hosted the "Measuring research engagement and impact in the mathematical sciences" workshop. This workshop brought together invited leaders from mathematics, statistics and the ARC, and attracted delegates from around the country.

Beyond co-hosting this workshop, ACEMS expertise was embedded in the discussions and outcomes. ACEMS Director Peter Taylor, moderated the workshop and panel discussion, and Deputy Director Kerrie Mengersen was an invited speaker. A communique on measuring research engagement and impact was developed for the ARC as a result of the event, with Peter Taylor and ACEMS Stakeholder Engagement Officer Jessie Roberts numbered among the authors.

This highly valuable workshop will continue to run as a yearly event, co-hosted by AMSI and ACEMS.

A discussion about "Pathways to Impact" based on the communique is featured on [pages 120-122](#).

LOOKING AHEAD: RESEARCH IMPACT STRATEGIC PLAN

The research and funding landscape in Australia is changing. ACEMS has a strategic plan to ensure the Centre is continually producing mathematical and statistical research with measurable impact. This strategy will guide ACEMS in 2017 and beyond, aiming to embed translatable research at the core of the Centre's activities. This is considered in the context of the research pipeline (discussed on [page 121](#)) and the different approaches needed at each stage, from theoretical research to applied research, consulting, and education/training. The plan outlines goals and metrics for measuring impact and fostering a cultural change in the mathematical sciences that explicitly considers and recognises research translation.

'DRY DIVE' THE GREAT BARRIER REEF TO AID CONSERVATION EFFORTS

People can 'dry dive' into the Great Barrier Reef to help an ACEMS project that's developing unique ways to measure the aesthetic value of the world heritage site.

Researchers at ACEMS are using virtual reality headsets to immerse marine scientists, scuba divers and citizens into the underwater digital reef (360-degree surround image) to help understand what makes the reef beautiful.

The project, titled "Monitoring through many eyes" is aimed at the development of integrated citizen-science software for people to engage and provide valuable information about the marine ecosystem.

"People virtually visit the Great Barrier Reef and are asked about water clarity, the structure of the coral, coral damage, fish and other organisms they can see," Project Leader and spatial scientist Dr Erin Peterson said.

"It's not widely known but Australia is required to report to UNESCO regarding reef aesthetics."

The reef aesthetics experiment is being run by a team from ACEMS' QUT node, including Research Fellow Dr Erin Peterson and former ACEMS PhD student, now Associate Investigator, Dr Julie Vercelloni.

The team gathered information from experts at the Australian Institute of Marine Science and the Great Barrier Reef Marine Park Authority during a visit to Townsville, and from citizen scientists at a reef blitz event held on Moreton Bay.

"It is part of a larger project to build an interactive digital reef that integrates multiple types of data collected by professional monitoring programs, research institutes and private companies that makes use of all the available information."

Researchers say the sheer size of the marine park, which stretches 344,000 square kilometres off Australia's eastern coastline, makes traditional methods of collecting real-time data and conservation difficult.

They're working toward building software that allows crowd-sourced 2D and 360-degree imagery taken by recreational and professional divers to be uploaded and geo-located within the map of the digital reef.

"Thousands of underwater images are taken by divers each year and we can use this to contribute to data collection," Julie said.

"The additional information, combined with a dynamic, spatially continuous map about the reef's condition provides a quantum leap in the way we monitor. As a result, authorities could be quicker to respond to disturbances in the reef, or focus scarce professional monitoring resources to areas that are rarely visited by recreational divers."

The project is funded by the Cooperative Research Centre for Spatial Information and the Queensland Government, as well as the support of ACEMS.



ACEMS MEMBERS PLAY KEY ROLE IN AMSI INDUSTRY/MATHEMATICAL SCIENCES ENGAGEMENT TASK FORCE

AUSTRALIA'S LARGEST INDEPENDENT OIL AND GAS COMPANY,
WOODSIDE, HAS EMBRACED DATA SCIENCE AS THE KEY TO UNLOCKING
MORE THAN 30 YEARS OF COLLECTIVE ORGANISATIONAL INTELLIGENCE.
DATA SCIENCE IS BEING USED TO DERIVE INSIGHTS FROM DATA TO
IMPROVE DECISION MAKING AND DELIVER REAL-TIME OPTIMISATION.

Woodside's production facilities are rich in data—streaming 2,000 records per second from its operating assets, equating to more than 10 gigabytes per day. So who is best placed to interpret and harness this mass of data, to unravel and interpret its story? The answer is a mathematical scientist, preferably one with experience in statistics.

In Australia, however, that's becoming increasingly difficult. Employable mathematical scientists are thin on the ground. And not only is the number of students declining, but few have much experience of industry or the kinds of problems it needs to solve every day. For many large Australian companies in the age of Big Data—in banking and finance, media and retailing, resources, and biotechnology—this scarcity has become a major, urgent issue.

Several members of ACEMS have been involved in establishing an innovative pilot program—a corporate internship for maths students—as one part of a comprehensive, national approach to solving this challenge. The plan is that nine students will spend four weeks in early 2017 at Woodside headquarters in Perth working on its gas plant data. At the same time, the students will gain experience in working in a corporate environment and find out what real-world industry application has to offer.

It all started in 2015 as an initiative of the Australian Mathematical Sciences Institute (AMSI), when a delegation went to consult industry about the decline in mathematical science enrolments in Australia, and to explore the impact of this decline across firms in various industry sectors. Nigel Bean, ACEMS Deputy Director and Chief Investigator from the University of Adelaide was part of the group.

“Before we'd even opened our mouths our industry contacts were saying, ‘Thank goodness you're here. We've got a real crisis on our hands already. We cannot recruit anywhere near enough of the graduates that we need, with the kind of critical thinking and problem-solving skills that mathematicians have,’” Nigel says.

So in October 2016, AMSI and industry collaborated to establish the Industry/Mathematical Sciences Engagement Task Force comprising eight senior mathematicians, eight senior members of industry, and two people with a foot in both camps. It is chaired by ACEMS Affiliate Member Dr Mark Lawrence and has an engine-room of ACEMS Chief Investigators—Nigel, ACEMS Director Peter Taylor from The University of Melbourne, Ian Turner from the Queensland University of Technology, and Kate Smith-Miles from Monash University. Already it has made rapid progress.



Woodside's Pluto liquefied natural gas (LNG) onshore plant. Images courtesy of Woodside Energy Ltd



Nigel, for instance, has been working on the student internship initiative with Shaun Gregory, Senior Vice President and Chief Technology Officer at Woodside, in a team which also includes Peter and Ian, and other Woodside senior managers. They based their upcoming program on a similar, pre-existing program that Woodside had run previously with graduate students from the Massachusetts Institute of Technology.

The nine students, ranging from second-year undergraduate to Masters level at four Australian universities, will be organised into three teams and will spend from mid-January to mid-February 2017 working on different challenges that the gas plant data could help to resolve. The company expects to use the results of their work in commercial decisions to improve the efficiency of the plants' operations and also as a basis for further work.

Other companies have already shown interest in setting up similar programs, says Nigel.

"As planned by the Task Force, Woodside will write up the playbook of what they do, so that other companies can undertake similar programs for mathematical science students."

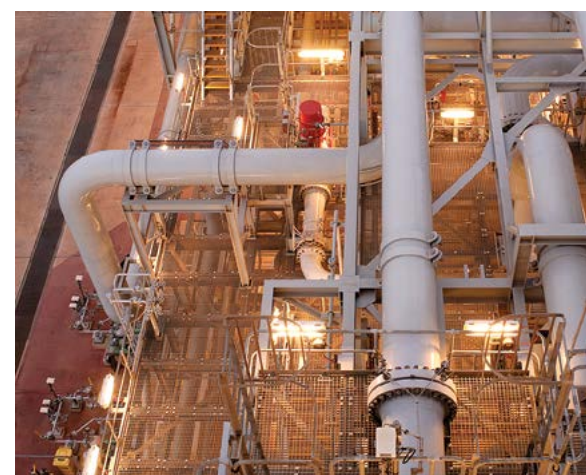
The internship program is part of one stream of work undertaken by the Task Force to improve the development of the skills that industry needs, particularly the ability to structure and tackle the kind of hard, open problems that constantly arise, often involving large amounts of "messy" data.

Other work streams include: changing the general attitude to maths in schools and the community, in part by establishing a national awareness program about the rapidly increasing demand

in industry for mathematical skills; gaining broad commitment and support for the mathematical sciences at senior levels of government and industry; and on building broad, effective engagement between industry and the mathematical sciences.

The work of the Task Force could affect the whole approach to mathematics in Australia, says Nigel, including the way courses are taught, the skills mathematicians acquire, and the value and importance that Australian society places upon those skills.

"I look at this as potentially the most significant thing I will do in my working life," Nigel says.



PATHWAYS TO IMPACT

IN 2017 THE AUSTRALIAN RESEARCH COUNCIL (ARC) WILL PILOT NEW METHODS TO MEASURE THE IMPACT OF UNIVERSITY RESEARCH, AND IN 2018 THEY WILL IMPLEMENT THESE MEASURES OF IMPACT MORE BROADLY ACROSS THE AUSTRALIAN RESEARCH FUNDING LANDSCAPE. THE AIM IS TO ENCOURAGE UNIVERSITIES TO TAKE INTO CONSIDERATION THE ECONOMIC AND SOCIAL BENEFIT OF ACADEMIC RESEARCH, AND TO ENSURE A RETURN ON INVESTMENT FOR RESEARCH FUNDED BY THE AUSTRALIAN TAXPAYER.

In response to these incoming changes ACEMS, in collaboration with the Australian Mathematical Sciences Institute (AMSI), hosted the workshop “Measuring Research Engagement and Impact in the Mathematical Sciences” in September 2016. The workshop was fundamental in pushing forward necessary discussions around how the mathematical sciences can enhance engagement and impact. ACEMS looks forward to hosting this workshop again in 2017, and continuing to explore how impact and engagement can be enhanced in the mathematical and statistical sciences. The

ideas expressed below are a direct result of the discussions from that workshop.

Impact for the mathematical and statistical sciences can be thought of in two high-level categories. First, mathematics and statistics are foundational sciences, and pushing the boundaries of mathematical and statistical principles has a flow-on effect to all fields that use quantitative methods. Second, applied to problems in the real world, mathematical and statistical expertise and research outputs can help with the design of innovative technologies and platforms, optimise systems, model future events, and help understand relationships. Such outputs are all highly-valuable to business, government and applied research communities.

The nature of mathematical and statistical research must therefore be considered when benchmarks and metrics for research impact and research translation are defined. Within these disciplines lead times from theory to impact are typically very long. End-users are not only industry, government or the public, but more commonly researchers in cognate and applied fields. In addition, research outputs are generally ‘soft’ products, which have flow-on effects that can transform technology and research platforms, but can be difficult to quantify and measure. This article therefore frames research impact specific to the mathematical and statistical sciences.

WHAT IS IMPACT?

The ARC defines research impact as “the demonstrable contribution that research makes to the economy, society, culture, national security, public policy or services, health, the environment, or quality of life, beyond contributions to academia.”

For ACEMS, it is important to acknowledge that the impact of mathematics and statistics is much broader and far-reaching than direct collaborations. Mathematics and statistics are enabling disciplines that support other applied research. Research outputs from mathematics and statistics continually innovate methodologies used by applied

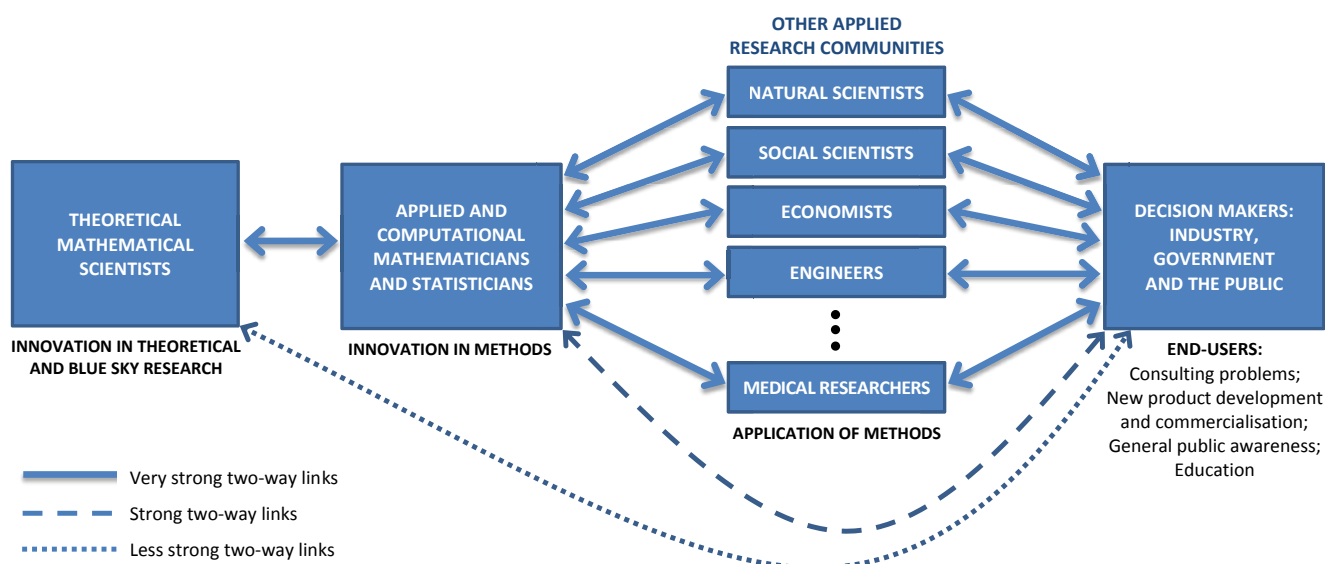


Figure 1: linear model of the research process

researchers, which then flows onto the final end user. For example, prior, fundamental research in Hidden Markov Models played a crucial role in enabling the mapping of the human genome.

WHERE DOES IMPACT OCCUR?

For the purposes of this discussion, ACEMS views impact in the context of a research pipeline (see Figure 1), where all but the last position of the pipeline represents a specific research community. Each community accesses the output of the preceding community and influences their research agenda by posing questions of importance; in this way the communication is very much bidirectional. All research communities engage with industry, government and other end users to different degrees. As a generalisation, the volume of that engagement with end-users increases along the pipeline.

Within this framework, the theoretical research community outputs new fundamental mathematical and statistical results. The applied mathematics and statistics research communities translate these fundamental results into methodologies for applied problems. Applied researchers in other fields then apply these proven methodologies to gain insights about systems, relationships and other events of interest in these fields.

Figure 1 is of course a simplification. Individual researchers might simultaneously be part of multiple research communities, and thus the environment is more akin to a network. In this network, researchers move between communities, and at times work on theoretical, methodological or applied problems. This serves to enhance communication in both directions between communities.

There are three main points where translation occurs within the system. They are:

1. Translation within the mathematical sciences
2. Translation to other disciplines in science, engineering, social science, economics, medical science and other 'client' disciplines
3. Translation to end-users in business, industry and government.

The first of these recognises (i) that ACEMS has a fundamental aim of building bridges within the mathematical sciences, between mathematics, statistics, mathematical physics and machine learning; (ii) that ACEMS has a fundamental aim of encouraging collaboration across the whole spectrum from theory to methods and computing, to applied practice; and (iii) ACEMS is part of a wider mathematical sciences field.

The second of these recognises that mathematics and statistics are foundational supports for many other fields, and translation of ACEMS outputs to researchers in these fields will not only grow capability and innovation in this wider community, but also reach the very wide range of end-users who engage with these fields.

The third of these is the more traditional view of 'impact' and acknowledges that ACEMS researchers in both applied and theoretical fields engage directly with business, industry and government to develop new methods and insights directly influenced and fueled by 'real-world' challenges.

HOW IS ACEMS ENSURING RESEARCH PRODUCES WIDER ECONOMIC AND SOCIAL BENEFIT?

ACEMS has invested in supporting external engagements through the employment of a Stakeholder Engagement Officer (SEO) whose responsibilities include: supporting existing collaborations, engaging new partnerships and coordinating skills development opportunities for interested ACEMS members.

Pathway 1: Direct collaborations with industry and non-research end-users

ACEMS members connect directly with industry and business end-users across the Centre's network. These projects are detailed in the Stakeholder Engagement Report (see [pages 110-116](#)). The engagements are fostered through the SEO who provides administrative, contractual, project management and networking support when required. The SEO position also provides an avenue



Filming for the Big Data Analytics MOOC: ACEMS Deputy Director of Stakeholder Engagement, Professor Kerrie Mengersen (right) and Stakeholder Engagement Officer Jessie Roberts (top)



for industry, government or other end-users to engage ACEMS and connect to an academic with the relevant expertise to suit their problem.

Pathway 2: Transdisciplinary research and collaborations with other research communities

Translating research outcomes to impact within this pathway occurs through two mechanisms. First, there are transdisciplinary collaborations where ACEMS researchers collaborate directly with researchers in other fields to tackle methodological challenges where solutions do not currently exist. Second, ACEMS provides training opportunities to researchers in disparate fields to develop the technical expertise required to apply the modern experimental methodologies required to conduct leading edge research. The Big Data Analytics MOOC delivered in 2016 is just one example of this type of training (see [pages 84-85](#)).

Further to this, with the aim of fostering collaborations with the Centre's Partner Organisations and Industry Affiliate Organisations, ACEMS hosts collaborative workshops that bring together ACEMS researchers with applied researchers from other fields. These workshops provide applied researchers with an opportunity to discuss their methodological challenges with mathematical and statistical experts, as well as exposing ACEMS researchers to potentially interesting methodological problems. In 2016 ACEMS hosted workshops with the Red Cross Blood Service and the Sax Institute, both of which resulted in new research projects.

The addition of Kate Smith-Miles as an ACEMS Chief Investigator will further enhance ACEMS' capability in this area. Kate is a leader in transdisciplinary research within the mathematics community and brings a wealth of experience in regards to how best to foster these types of collaborations.

Other mechanisms

ACEMS acknowledges that it has a role in promoting cultural change around impact, engagement and research translation. To foster the translation of research outputs into economic and social benefit, researchers must be aware of the commercialisation process and be rewarded for engaging with it. To encourage this, ACEMS has decided to:

- Develop, deploy and evaluate novel mechanisms for partnerships between business and academia. These have included co-funded postdoctoral positions (with the Red Cross Blood Service and the Sax Institute) and collaborative workshops between ACEMS researchers and existing or new partners.
- Provide funds for ACEMS members to attend industry events.
- Provide opportunities, in the form of training and industry exposure for Higher Degree Researchers (HDRs), Early Career Researchers (ECRs) and other ACEMS members to develop skills in consulting, networking, commercialisation, technology transfer, and collaborative/transdisciplinary research skills.
- Develop strategies to enhance, and plan for, research translation or 'deployment' in all contract research and transdisciplinary research projects.
- Conduct 'Inside Out' initiatives that support ACEMS researchers to identify end-users that could benefit from their research outputs, and develop research action plans for connecting with these end-users.
- Engage students in AMSI's industry internships.
- Host secondment places where employees from ACEMS industry partners spend time in a research role within one of the ACEMS nodes.

ACEMS STATISTICIAN GETTING THE BEST OF BOTH WORLDS AS SHE TEAMS WITH ACEMS PARTNER ORGANISATION

“It’s like marrying the theory and the methodological aspect with the applied work into one coherent piece.”

What is statistics? If you ask ACEMS Postdoctoral Research Fellow Joanna Wang, it’s the art of data.

Joanna said she’s very lucky, because she gets to work with her ‘art’ in two very different ways.

The first is on a theoretical level at UTS with ACEMS. The other is with ACEMS Partner Organisation the Sax Institute.

Joanna works three days a week at Sax and is involved with several projects, including the institute’s highly-publicised ‘45 and Up Study.’ The ongoing study follows one in 10 people from New South Wales, aged 45 and above. It looks into a variety of workplace, lifestyle and health issues, with the goal of helping the government make more informed decisions about healthcare.

Joanna is involved with the institute’s Analysis for Policy (A4P) team.

“We deal with government agencies to try to help them formulate a practical problem they might have into a research question, to see if data from the 45 and Up Study can answer that question,” Joanna said.

Because the study’s cohort is so large, one of the issues is ‘no responses,’ or other missing data. Joanna works on the problem with ACEMS Chief Investigator Professor Louise Ryan at UTS to see if that impacts any of the conclusions of the study.

“I take those issues and the two days I’m working at UTS are where I work with Louise on these more theoretical issues,” Joanna said.

“So it’s like marrying the theory and the methodological aspect with the applied work into one coherent piece.”

For Joanna, it’s the best of both worlds.

Joanna studied applied mathematics and statistics at The University of Sydney. She also received her PhD there in statistics,

focusing on financial econometric models. From there, she went to UNSW where she worked as a lecturer, and with UNSW’s Transport and Road Safety Research group.

She’s been with ACEMS at UTS for the last two years, and loves working with Louise.

“Joanna’s work with the Sax Institute is an excellent example of what I like to call the ‘virtuous cycle of collaboration,’” Louise said.

“Working on compelling real world problems has motivated Joanna to think about some interesting technical challenges. Solving these has allowed her to not only contribute to the body of statistical theory and knowledge, but also to provide a better practical solution to the problem at hand. This kind of problem-based research makes being a statistician fun and helps us to make real world contributions.”

Joanna was born in Shanghai, China but moved to Australia when she was 12.

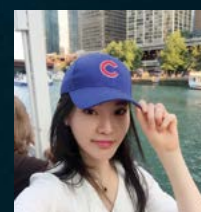
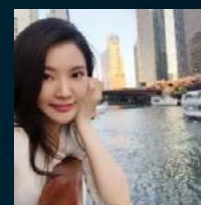
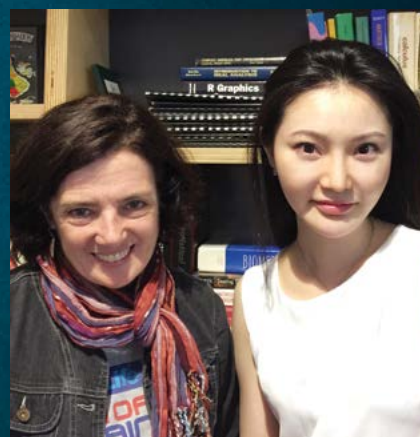
In December 2016, Joanna returned to China for a faculty seminar presentation at Peking University, where she talked about the 45 and Up Study. It was a great opportunity to share both aspects of her work.

Joanna has also recently attended two different statistics conferences in the United States, including the Joint Statistical Meetings in Chicago in August.

ACEMS looks forward to seeing where her love for the art of data will take her next as she moves forward in her career.

Left: Joanna with ACEMS Chief Investigator Louise Ryan

Right: Joanna in Chicago for the Joint Statistical Meetings



COMMERCIALISATION AND TECHNOLOGY TRANSFER

IT IS GENERALLY ACCEPTED THAT *COMMERCIALISATION* IS THE PROCESS OF DEVELOPING A PRODUCT THAT HAS A FINANCIAL VALUE, AND *TECHNOLOGY TRANSFER* IS THE PROCESS OF DISSEMINATING TECHNOLOGICAL OUTPUTS FROM THEIR PLACE OF ORIGIN TO THE WIDER MARKET.

ACEMS has identified three areas in which it can play an important leadership role in commercialisation and technology transfer (CTT):

- (i) *promoting discussion* about these issues in the context of the mathematical sciences
- (ii) *action* in undertaking CTT activities in the Centre
- (iii) *training* ACEMS members in skills and understanding about CTT in the mathematical sciences

Discussion about CTT:

Commercialisation and technology transfer of research in the mathematical sciences has been a topic of continued interest and discussion globally. ACEMS recognises that it has an important role to play in this discussion.

In September 2016, jointly with the Australian Mathematical Sciences Institute (AMSI), ACEMS hosted a forum on Measuring Research Engagement and Impact in the Mathematical Sciences. This workshop, at which the Acting CEO of the Australian Research Council (ARC) Leanne Harvey was an invited speaker, attempted to address the difficult problem of how mathematical scientists should engage with the pathway to research impact in the wider society. Following this

forum, a group of mathematical scientists, including ACEMS Director Peter Taylor and Stakeholder Engagement Officer Jessie Roberts, co-authored a submission on how translation and impact could be measured for the mathematical sciences. This submission is the basis of the discussion of 'Pathways to Impact' that appears on [pages 120-122](#) of this report.

ACEMS intends to lead, and participate in, further discussions on this topic in 2017. Along with AMSI, it has expressed interest and support for the mathematical sciences to be a part of a pilot study by the ARC for measuring these important features. The Professional Development plans, developed by ACEMS for its members (see below), are based upon the recognition that today's mathematical scientists cannot afford to ignore the pathways to impact of their work. It is intended that these plans will evolve in light of subsequent experience and maintain alignment with cognate organisations such as AMSI.

Action in CTT:

In the context of ACEMS, the primary output of research is new knowledge in mathematical and statistical theory and methodology. Commercialisation of this knowledge occurs in two ways:

- Transfer of knowledge to business, government and other agencies for

further development into products, processes, applications or services, for example through contract research;

- Commodification of knowledge in the form of subject matter experts; for example through commercial consulting.

A primary focus has been on the engagement with Partner Organisations and creation of an Industry Affiliates Program to facilitate the transfer of knowledge.

The model that ACEMS has adopted is that contract research and commercial consultancies are registered with ACEMS but administered through the researchers' own universities.

Such services have been provided by ACEMS members to a range of commercial organisations in 2016. Contract research activities are discussed in more detail in the section on Stakeholder Engagement ([pages 110-116](#)). Some examples of commercial consultancies are discussed in the blue boxes.

ACEMS members have provided legal advice as consultants and expert witnesses. For example, CI Kerrie Mengersen acted as an expert witness for a legal firm on a large class action involving a medical device. Her involvement in the preparation of material and appearance in court assisted in a successful outcome for the plaintiffs.

*ACEMS/AMSI Workshop on Measuring
Research Engagement and Impact in the
Mathematical Sciences*

*(L to R) Professor Geoff Prince, Professor
Tim Marchant, ACEMS Chief Investigator
Professor Kerrie Mengersen, Professor Jacqui
Ramage and ACEMS Director Professor
Peter Taylor (discussion leader)*



ACEMS members have also provided expert advice for large corporate reviews. For example CI Kerrie Mengersen participated in a substantive review for Chevron of their world-class biosecurity surveillance system on Barrow Island in Western Australia. The resultant surveillance system has been adopted for the next phase of development of the major gas facility on the island. CI Mengersen also participated in an advisory group to develop a biosecurity surveillance plan for varroa destructor, an exotic pest that is of great concern for the Australian bee industry.

ACEMS Director Peter Taylor was engaged to write a report explaining the principles of Bitcoin mining, to be included in a prospectus for Bitcoin Group Pty Ltd as they were seeking to list on the Australian Stock Exchange.

Training in CTT:

As mentioned on [pages 118-119](#) of this report, ACEMS members have been heavily involved in the AMSI Industry/Mathematical Sciences Engagement Task Force. A major activity of this Task Force has been to discuss with executives—sitting at the highest level in Australian companies in a range of industries—the needs of industry for graduates with quantitative skills. The take home message was that industry wants graduates who

- Can engage in high-level logical and critical thinking
- Have a practical ability to do problem structuring and solving, often beginning with “messy data”
- Have data analysis skills, and an ability to work effectively with data
- Have an ability to work collaboratively, in multi-disciplinary teams
- Have excellent communication skills, and
- Are able to write computer code.

The Task Force was thinking specifically about students at undergraduate and Honours level when it wrote this. However, ACEMS believes that the principles apply equally at PhD and even at postdoctoral level.

There is a further need for researchers at this level to have an awareness of issues such as knowledge transfer, intellectual property and commercialisation, and for a Centre like ACEMS to have some members who are expert in these areas.

With these needs in mind, ACEMS has commenced the development of a Professional Development (PD) plan for its early career members.

The plan is based on identification of gaps in existing training opportunities and consideration of ACEMS-led courses in required areas. It comprises two components: a Foundation Skills component and an Extension Skills component.

The Foundation Skills component broadly focuses on developing the skills needed by almost anyone working in the field, roughly speaking the skills listed above as identified by the AMSI Task Force. It comprises seminars and workshops on topics such as training in programming, media skills, the use of reproducible and collaborative research tools, research translation and business development, and commercialisation and impact within an academic environment.

The Extension Skills component recognises that some members of ACEMS have additional needs and interests with respect to professional development. The Centre plans to put in place specialist seminars and workshops for these members, with such topics as, protecting IP as an early career academic, preparing for a career outside academia, selling your research, and selling your skills.

The ACEMS PD plan commenced in late 2016 and will be rolled out during 2017. As indicated above, the topics incorporated in the plan, and the list of activities, will evolve during the course of the year in line with ACEMS members’ interests and external alignment with organisations such as AMSI and the ARC. Stronger linkages with the technological universities’ Industry Doctoral Training Centre (IDTC) and AMSI Intern programs will also be explored.

OUTREACH REPORT



*Mathscraft Workshop at QUT
facilitated by Anthony Harradine
(standing in blue shirt)*

It was another stellar year for the Centre in terms of its outreach activities. Centre members organised and participated in many different activities during 2016 which were targeted at three key groups:

- schools and their students
- the general public, and
- the mathematical sciences research community.

An overview of these activities is given below, and the highlights of the outreach to each of these groups are summarised on [page 10](#).

2016 OUTREACH OVERVIEW

- 1 Big Data Analytics Massive Open Online Course (MOOC) with over 115,000 enrolments, 30,000 learners and 4,000 fully participating learners across two runs ([pages 84-85](#))
- 22 different schools visited with 71 separate visits and 119 activities undertaken (these figures include 6 schools visited as part of CSIRO's Mathematicians in Schools program, and 10 schools visited as part of ACEMS regional tours)
- 1 National Science Quiz ([pages 108-109](#))
- 5 National Science Week events ([page 129](#))
- 4 Mathscraft events across four states involving 36 different schools (approximately 180 participants) ([page 127](#))
- 1 Mathscraft teacher training event, involving 17 teachers from different schools ([pages 106-107](#))
- 3 World Science Festival Brisbane events
- 2 high school work experience students ([page 128](#))
- 27 other events
- 40 public talks ([page 131](#))

Reef Blitz at
Moreton Bay



ACEMS regional
outreach tour to
South Australia



OUTREACH TO SCHOOLS AND THEIR STUDENTS

Mathscraft: Doing maths like a research mathematician

Introduced in late 2015, ACEMS flagship outreach program to school students is Mathscraft; see [page 106](#) for an overview of this program. In essence, the program enables mathematics teachers and their students to experience the process of ‘doing maths like a research mathematician’ in a fun and interactive workshop. A mathematical scientist—usually an ACEMS member—is paired with a teacher and three of their students, and they work on a series of challenging problems; the mathematician is there to ask thought-provoking questions that are often open-ended, rather than directly help to solve the problems. In this way, participants gain insight into the nature of research in the mathematical sciences.

Mathscraft workshops are invariably rated highly by both teachers and students with regular feedback that it has been transformative: participants will look at problems differently, and teachers intend to incorporate this style of approaching problems into their teaching methods.

In June 2016, the program was expanded nationally with one workshop held in each ACEMS-node city—Melbourne, Brisbane, Sydney and Adelaide—involving a total of 36 different schools and approximately 180 participants. The workshops were organised by ACEMS and facilitated by ACEMS Affiliate Member Anthony Harradine. As with the five Victorian-based workshops held in 2015, interest in the events was far greater than could be accommodated.

Recognising that the increasing demand for Mathscraft workshops was much greater than Anthony had the capacity to facilitate, ACEMS embarked on a further expansion to include training teachers to run Mathscraft sessions at their own schools with participants invited from nearby schools.

Anthony, with assistance from ACEMS Outreach Officer Anita Ponsaing, ran the first Mathscraft teacher professional development workshop in late November 2016 over five days. The workshop was held at MATRIX in Creswick for 17 teachers from across New

South Wales, Queensland, South Australia and Victoria. Teachers participated on an invitation-only basis, with the only requirement being that they must run two Mathscraft sessions in 2017.

During the workshop there were always at least three mathematicians present to work with the teachers on the problems. In total, nine mathematicians took part, including three ACEMS staff (Director Peter Taylor, Deputy Director Jan de Gier and Anita) and three ACEMS PhD students (Kate Saunders, Peter Braunsteins and Jason Whyte).

The training workshop received rave reviews: all teachers gave the workshop the top rating in the feedback survey, confirming that the workshop was a resounding success. See [pages 106-107](#) for more details about the teacher professional development workshop.

School visits

In addition to outreach to school students through the Mathscraft program, ACEMS members also visit schools. During 2016, 22 different schools were visited on 71 separate occasions with a total of 119 activities undertaken; these figures include six schools visited as part of CSIRO’s Mathematicians in Schools program, and 10 schools visited as part of ACEMS regional tours.

Centre members that regularly participated in the Mathematicians in Schools program were Chief Investigators Phil Pollett, Tim Geroni and Peter Taylor, Associate Investigator Yoni Nazarathy, and Research Fellows Craig Anderson and Ross McVinish. Combined, they visited six different schools on 51 separate occasions with a total of 63 different activities undertaken.

ACEMS regional outreach tours

In October 2015, ACEMS undertook a tour of schools in Far North Queensland to visit students and run maths-themed engagement activities. This trip was extremely well received with schools asking for repeat visits in the future, and the Cairns-based Business Liaison Association offered a financial contribution for a repeat visit to the region in 2016.



Mathscraft “Doing Maths like a Research Mathematician” training event for teachers, held at MATRIX in Creswick



In April 2016, ACEMS undertook a second outreach trip, this time a tour of schools in regional South Australia. During the week-long trip through the towns of Whyalla, Port August and Port Pirie, ACEMS Outreach Officer Andrew Stephenson and ACEMS PhD student James Walker ran 29 workshops at five schools, for a total of 559 students from Years 5-11, and two professional development workshops, for a total of 17 teachers. The visits were extremely well received by both students and teachers, and all schools expressed a strong desire for a repeat visit in the future. The positive feedback received from the five South Australian schools during the tour mirrored that received from schools visited on ACEMS first outreach trip through Far North Queensland in 2016.



National Science Week: Maths Arcade in Melbourne

In May-June 2016, ACEMS took up the Business Liaison Association’s offer and made a repeat visit to Far North Queensland. The trip was a joint venture with The University of Queensland’s School of Mathematics and Physics, which houses ACEMS’ UQ node. This tour promoted both mathematics and physics, and was undertaken by Andrew Stephenson, ACEMS PhD student Morgan Grant and a UQ physics PhD student. During the week-long trip, the team ran 22 sessions at six schools for a total of 701 students, which included 14 mathematics workshops for a total of 352 students. The trip also included a professional development session for teachers. Once again the response from schools was extremely positive, with many offering to pay for future visits. The Business Liaison Association also expressed its desire to help support additional future trips.

School work experience students

ACEMS Chief Investigators Jan de Gier and Peter Forrester each hosted a high school student for one week of work experience.

Jan’s student began his work experience by attending a Mathscraft session. He then worked on selecting appropriate problems from nrich.maths.org for future Mathscraft sessions. See [pages 106-107](#) for more information about the Mathscraft program, and to appreciate why identifying appropriate problems is not easy yet essential.

Peter’s student began by learning about the use of linear algebra in the Global Positioning System (GPS), working from some survey articles. By the second day, she was already using the mathematical typesetting language LaTeX to prepare seminar slides on this topic, which she later presented to Peter and ACEMS Research Fellow Jesper Ipsen. Later she worked on a topic from Peter’s research: the Euclid algorithm for the greatest common divisor, and its relation to the Lagrange-Gauss algorithm for lattice reduction. In relation to both these algorithms she did programming using Mathematica, which was quite remarkable, since she had no prior programming experience; the student learned new skills and was able to appreciate the mathematics.



National Science Week: Hackathon in Brisbane

National Science Week: Spot the Bull S...cience in Sydney



National Science Week: Mathematics of Juggling in Melbourne

OUTREACH TO THE GENERAL PUBLIC

The National Science Quiz

ACEMS ran an ambitious public outreach event in May 2016, called the National Science Quiz (NSQ). The fun-filled panel show was based on an annual Dutch television show called *Nationale Wetenschapsquiz*, and was hosted by comedian and television host Charlie Pickering. Charlie presented a series of thought-provoking questions to a panel that included a mix of scientists and communicators. The event also featured live demonstrations of questions and answers, and other forms of entertainment; see [pages 108-109](#) for more details.

Although the NSQ was organised solely by ACEMS, the event's costs were shared with four sponsors: the School of Mathematics and Statistics at The University of Melbourne; the Centre of Excellence for Biosecurity Risk Analysis (CEBRA); the ARC Centre of Excellence for Particle Physics at the Terascale (CoEPP); and the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO).

The 2016 event was so popular that it sold out—more than 400 seats!—before doors opened. The NSQ was a huge success with both the audience and on-stage participants giving positive feedback. In 2017, ACEMS looks forward to expanding the NSQ by hosting it in multiple states and larger venues.

Big Data Analytics MOOC

The commitment of ACEMS to translating research outcomes and expertise is evidenced in a major undertaking by the ACEMS research team at QUT, to develop a massive open online course (MOOC) on modelling and analysis of big data. This MOOC was developed with FutureLearn and attracted around 115,000 enrolments over two runs during 2016, with 30,000 of these translating to learners and 4,000 fully participating to completion; see [pages 84-85](#) for more details.

Talks open to the public

During 2016, Centre members delivered 40 presentations—including talks, lectures, seminars and colloquia—that were open to the public to attend. These presentations are summarised on [page 131](#).

National Science Week

In August 2016, ACEMS was involved in five National Science Week events across three cities:

- Hackathon (Brisbane)
- Mathematics of Juggling (Melbourne)
- Maths Arcade (Melbourne)
- Spot the Bull S...cience (Sydney), and
- STEM for Schools (Brisbane).

In Brisbane, ACEMS sponsored a Hackathon, which was organised by ACEMS Stakeholder Engagement Officer Jessie Roberts and ACEMS Affiliate Member Miles McBain, while ACEMS Research Fellow Tomasz Bednarczyk spoke at a QUT Science Week professional development event for teachers called 'STEM for Schools'. ACEMS Associate Investigator Anthony Mays ran a 'Mathematics of Juggling' street show at The University of Melbourne, as well as a fun-filled gaming Maths Arcade. In Sydney, ACEMS sponsored a Science Nation event called 'Spot the Bull S...cience'; the humorous panel event featured five scientists, including ACEMS Research Fellow Craig Anderson.

Across these five events ACEMS engaged hundreds of people from a very broad cross-section of the public.

World Science Festival Brisbane

In February, ACEMS participated in three events at the World Science Festival held in Brisbane:

- Regional Program in Townsville
- Street Science, and
- SALON event panel member.

The first was at the road show event held at the Museum of Tropical Queensland in Townsville, where ACEMS Outreach Officer Andrew Stephenson ran activities such as a demonstration of topology and knot theory, and using binary numbers to "read



Professor Xiao-Li Meng of Harvard University presenting



One of the breakout groups at STEMS2016

STEMS2016: PUTTING STATISTICS INTO STEM IN THE AGE OF DATA

CIs Louise Ryan and Scott Sisson, in collaboration with the Statistical Society of Australia, ran an event in June 2016 called “STEMS2016: putting statistics into STEM in the age of data”. ACEMS was a major sponsor of the event, contributing \$5,000. The focus of the conference was how to transform statistics education at all levels from school, through university and on to the graduate level. There was an amazing turnout with representation from the Chief Scientist’s Office, the Commonwealth Bank, and the Australian Curriculum, Assessment and Reporting Authority (ACARA). The keynote speaker was Professor Xiao-Li Meng, Dean of the Graduate School of Arts and Sciences at Harvard University. As a follow-up from STEMS2016, the organisers are now working with ACARA to design an innovative new course for Years 11 and 12 focused on data science.

peoples’ minds” for schools and the public over two days. Andrew and ACEMS PhD student Morgan Grant ran the activities above again for the ‘Street Science’ exhibit as a part of the main World Science Festival program in Brisbane. Finally, ACEMS Deputy Director Kerrie Mengersen was a panellist in a World Science Festival discussion event called ‘From simplicity to complexity: complex systems across science’, held at the Queensland Museum.

OUTREACH TO THE MATHEMATICAL SCIENCES RESEARCH COMMUNITY

ACEMS and its personnel engaged the mathematical research community through a variety of activities. Some of these activities and ACEMS involvement are discussed in other parts of this annual report, including:

- organised or co-organised research workshops and conferences (page 100)
- supported the mathematical research institute MATRIX (pages 102-103)
- supported relevant workshops/conferences proposed in Australia (page 87)
- supported the Australian Mathematical Society’s Women in Mathematics Special Interest Group (page 87)
- co-organised the ‘ACEMS/AMSI Workshop on Measuring Research Engagement and Impact in the Mathematical Sciences’ (see pages 116 and 120-122), and
- contributed to the new decadal plan for mathematical sciences in Australia launched in early 2016 (page 56).

OTHER OUTREACH EVENTS

ACEMS and its personnel engaged the public through a wide variety of other avenues, such as through the Centre’s host universities programs, and through other existing outreach and engagements programs and events. In total, ACEMS members were involved in 27 other outreach activities during 2016, including:

- several university- or faculty-based Open Days
- various Women in Mathematics\Statistics\STEM events
- aMATHing Day (Adelaide)
- ‘How’s the World Feeling’ Data Hack (Brisbane)
- Mathematical Association of Victoria ‘maths camp’ (Melbourne)
- ‘Maths Prepared’ briefing (Canberra)
- QUT’s ‘STEM camp’ (Brisbane)
- Reef Blitz (Moreton Bay) (see page 117 for more information about this event)
- Residential Indigenous Science Experience (Melbourne)
- Schools Mathematics Olympics (Melbourne)
- National Schools Poster Competition (displayed and awarded at the Australian Statistical Conference in Canberra)
- Science Nation’s ‘Great Debate’ (Sydney)
- ‘Statistics in Stilettos’ breakfast event (Sydney)
- ‘STEMS2016: Putting Statistics into STEM in the Age of Data’ colloquium and workshop (Sydney) (see box above), and
- ‘Tentastic’ early childhood numeracy program (Adelaide).

PUBLIC TALKS

Centre members delivered 40 presentations that were open to the public to attend, including some talks that were repeated in multiple locations. These presentations are summarised below.

MEMBER	TITLE	LOCATION
Craig Anderson	Inspiring science: diamonds and sporting statistics	Sydney
Tomasz Bednarz	Big data, maths and visual communication	Brisbane
Tomasz Bednarz	Creating virtual reality	Brisbane
Marcela Cespedes	Wombed approaches to detect spatial patterns of neurodegeneration consistent with progression towards Alzheimer's disease	Brisbane
Aurore Delaigle	Methodology for deconvolution when the error distribution is unknown	Oxford (UK), Princeton (USA), New Brunswick (USA), Melbourne, Canberra and Brisbane
Aurore Delaigle	New methods for analysing partially observed functional data	Sydney
Aurore Delaigle	Some problems of functional data analysis in statistics	Melbourne
Peter Forrester	The Raney distribution and random matrix theory	Fukuoka (Japan)
Peter Forrester	Invariant measures, volumes and random lattices	Singapore
Benoit Lique	A unified regularized group PLS algorithm scalable to big data	San Sebastien (Spain)
Benoit Lique	Type-II generalized family-wise error rate formulas with application to sample size determination	Pau (France) and Melbourne
Benoit Lique	Bayesian variable selection regression of multivariate responses for group data	Bordeaux (France)
Benoit Lique	BIG-SIR: a Sliced Inverse Regression approach for massive data	Pau (France) and Brisbane
Benoit Lique	Group and sparse group partial least square approaches applied in genomics context	Brisbane
Benoit Lique	Statistical methods for analysing high-dimensional data and massive data	Melbourne
Benoit Lique	A tutorial for penalized regression models	London (UK)
Benoit Lique	A tutorial for PLS and Bayesian variable selection	London (UK)
Yoni Nazarathy	Switching between partially observable channels	Paris (France) and Tel Aviv (Israel)
Giang Nguyen	All roads lead to Rome: from stochastic fluid processes to Brownian motions	Sydney (at two different locations) and Melbourne
Chris Oates	The role of the statistician in numerical analysis	Sydney
Chris Oates	Stein operators on Hilbert spaces	London (UK) and Sydney
Chris Oates	Probabilistic meshless methods	Sydney and Adelaide
Louise Ryan	But I'm a data scientist too, aren't I?	Melbourne
Louise Ryan	A statistician's perspective - STEMS 2016	Sydney
Matthew Sutton	Sparse group subgroup PLS for genomics	Sydney
Peter Taylor	Parrondo's games: when two losing games can be combined to create a winning game	Melbourne
Joanna Wang	A Bayesian nonignorable selection model for logistic regression with missing outcomes: an application to the <i>45 and Up</i> Study	Sydney
Joanna Wang	<i>45 and Up</i> Study: a platform for health services and policy relevant research	Beijing (China)

ACEMS ANNUAL RETREAT

IT'S THE LAST WORD IN THE NAME OF OUR CENTRE, AND ISN'T EVEN INCLUDED IN THE ACEMS ACRONYM.



The word “frontiers,” though, emerged as a key theme

at the 2016 ACEMS retreat, held from 2–4 November at UTS.

Centre Director Peter Taylor challenged the group to think about that word as the Centre moves forward, in everything from research to collaborations and outreach, and how members engage with the public and industry.

The retreat was well attended by:

- 18 chief investigators;
- 18 associate investigators;
- 21 postdoctoral research fellows;
- 42 graduate students;
- eight professional staff; and
- five guests.

The Acting CEO of the ARC, Leanne Harvey, addressed ACEMS members. She talked about the significance of Centres of Excellence, saying “they are prestigious to get, really hard to get, and really important to Australia.”

This was followed with a talk by Kate Smith-Miles from Monash University, who was soon to be an ACEMS chief investigator. Kate introduced herself and her research to everyone at the retreat.

A key focus of the retreat was the upcoming mid-term review of the Centre

by the ARC in August 2017. A half-day was devoted to mock review interviews of separate groups of chief investigators, postdoctoral researchers, PhD students and professional staff.

Interspersed throughout the program, ACEMS professional staff officers in charge of stakeholder engagement, communication and outreach—Jessie Roberts, Tim Macuga and Andrew Stephenson—discussed the progress that has been made in their respective portfolios. Tim engaged the help of Robert Button from UTS to present a session on the importance of science communication.

The retreat also featured a three-minute student research talk competition. Five student finalists selected from a group of 29 who competed at the student retreat earlier in the week presented their talks to the ACEMS members who attended the main retreat. All five students received ACEMS travel grants for making it to the finals. See [pages 134–135](#) for more on the ACEMS Student Retreat.

The technical theme of the retreat was simulation. Three tutorials on this topic were presented by Chief Investigator Dirk Kroese, soon-to-be Chief Investigator Scott Sisson, and Associate Investigator Joyce Zhang.

The post-retreat evaluation was generally favourable, but also confirmed some important challenges that will continue to be addressed by the Centre in 2017.

Left: Chair of ACEMS' Governance Advisory Board, Dr Ron Sandland, talking about the mock review interviews

Right: ACEMS Director Peter Taylor with Leanne Harvey, Acting CEO of the ARC



Left: ACEMS Chief Investigators:

Back Row (L-R): Phil Pollett (UQ), Dirk Kroese (UQ), Matt Roughan (UoA), Louise Ryan (UTS), Scott Sisson (UNSW), Nigel Bean (UoA), Peter Taylor (UoM), Ian Turner (QUT), Tim Garoni (MU)

Front Row (L-R): Aurore Delaigle (UoM), Jan de Gier (UoM), Kerrie Mengersen (QUT), Matt Wand (UTS), Kevin Burrage (QUT). Attended, but not pictured: Robert Kohn (UNSW), Kate Smith-Miles (MU), Peter Forrester (UoM), Tony Pettitt (QUT). Did not attend: Peter Bartlett (QUT)



Left: ACEMS members at the 2016 Annual Retreat

Right: Soon-to-be ACEMS Chief Investigator Kate Smith-Miles introducing her research to ACEMS members



ACEMS STUDENT RETREAT

MORE THAN 40 STUDENTS FROM NINE UNIVERSITIES, INCLUDING ALL SIX OF ACEMS' NODES, ATTENDED THE CENTRE'S SECOND ANNUAL STUDENT RETREAT. THE EVENT WAS HELD FROM 31 OCTOBER TO 2 NOVEMBER AT UTS AND FOCUSED ON PROFESSIONAL DEVELOPMENT.

One area that received a lot of attention at the retreat was communication, and how students could better communicate their research.

Antony Green and Robyn Williams were the highlight of the retreat. Antony Green has been with the ABC since 1989, serving now as an election analyst. Robyn Williams, of course, is one of the country's best-known science communicators, and is the host of Radio National's *The Science Show*.

The retreat also featured a half-day session on media and communications training. The training was run by ACEMS Communications and Media Officer Tim Macuga, and by Alvin Stone, who is the Media and Communications Officer for the Australian Research Council's Centre of Excellence for Climate System Science. The session highlighted the importance of communications skills and the benefits for researchers in being active science communicators.

Keeping with the communications theme, the students were then asked to present three-minute talks about their research. A total of 29 students presented talks on their research, and were scored by their peers. The top five speakers were then asked to give a repeat presentation of their talks at the ACEMS main retreat later that week; see [pages 132-133](#) for the story about that retreat. Those five students were:

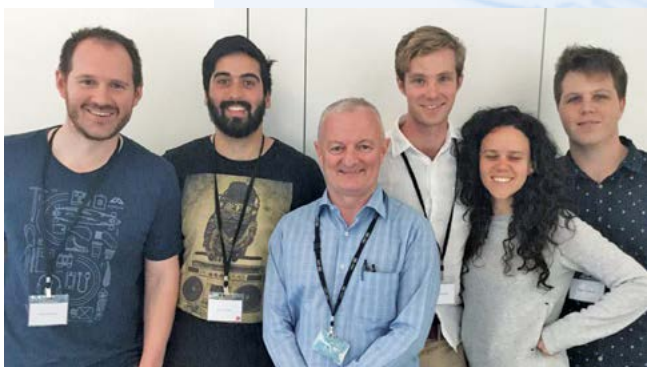
- Abhishek Bhardwaj (ANU)
- Peter Braunsteins (UoM)
- Robert Salomone (UQ)
- Shrupa Shah (UoM)
- Winnie Xie (UQ)

At the main retreat Shrupa, Peter and Robert were named co-winners of the competition, and each received a \$2,000 travel grant from ACEMS. Winnie and Abhishek each received a \$1,000 travel grant for being named finalists.

The students also communicated their research through a poster competition. A total of 25 students presented a poster on their research. Anthony Ebert from QUT won that competition, and received a \$1,000 ACEMS travel grant.

The final day of the retreat focused on career planning and life after a PhD. Dr Melanie Roberts from IBM Research spoke to the students about pursuing a career in industry, ACEMS Postdoctoral Fellow Dr Craig Anderson talked about transitioning from being a PhD student to becoming a postdoctoral researcher, and ACEMS Director Peter Taylor spoke about a life in academia. The three talks were followed by a Q&A panel discussion.

Feedback from the student retreat was extremely good, with the students giving overwhelmingly positive comments on the professional development sessions, and the vast majority of attendees indicating that they would give a talk at future student retreats.



ACEMS students with Antony Green



Robyn Williams
presenting at
the ACEMS
Student Retreat



Dr Ron Sandland with poster competition
winner Anthony Ebert (QUT)

Azam Asanjarani during the poster
competition



Left: Three-minute
talk finalists with
the competition
judge: (L-R)
Abhishek Bhardwaj,
Shrupa Shah, Dr
Ron Sandland, Peter
Braunsteins, Robert
Salomone and
Winnie Xie

ACEMS INFRASTRUCTURE

HIGH QUALITY INFRASTRUCTURE IS PROVIDED AT ALL SIX ACEMS NODES. THE RESEARCH SPACES AT THE LARGER NODES ARE ESPECIALLY OUTSTANDING.

The Queensland University of Technology (QUT) team comprising Chief Investigators, students, postdoctoral researchers, professional staff and a number of Associate Investigators work

on a dedicated floor for ACEMS in Y-Block, a brand new building with purpose-built meeting, collaboration and communication facilities. ACEMS QUT also has access to top of the range visualisation facilities in the form of the Cube ([see page 146](#)).

The statistics group at the University of Technology Sydney is located in a new award-winning building. ACEMS Chief Investigators have offices, with open-plan space for their students and postdoctoral researchers nearby. It creates an excellent collaborative and team atmosphere.

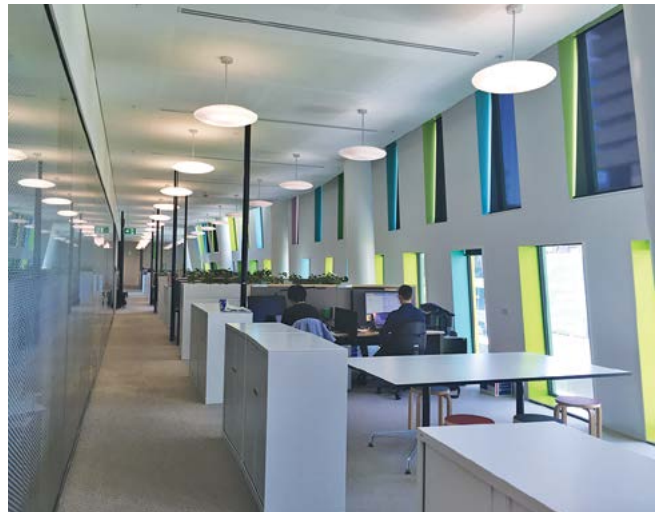
The infrastructure at The University of Adelaide is also excellent; a small wing of the School of Mathematical Sciences is earmarked for Centre staff — two Chief Investigators and two postdoctoral researchers — with one office per staff member collocated along the same corridor.

The ACEMS spaces at The University of Melbourne were renovated during 2015 and include new meeting rooms, teleconference facilities, and dedicated offices for visitors and professional staff. All ACEMS members are located on the same floor with students and postdoctoral researchers located near their supervisors. The node sits within the School of Mathematics and Statistics, where the building was renamed in December 2016 to the Peter Hall Building in honour of ACEMS' Founding Director.

Standard, but high quality, infrastructure is also provided by The University of Queensland and The University of New South Wales.



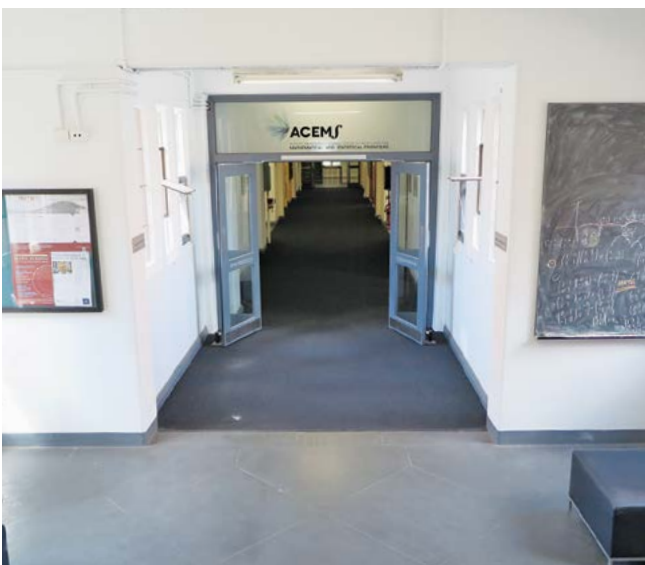
ACEMS Teleconference Room at The University of Melbourne



ACEMS UTS open-plan workspaces in the new award-winning Science and Graduate School of Health Building



An ACEMS workspace and meeting room at QUT



The ACEMS mezzanine in the 'Peter Hall Building', recently renamed in honour of ACEMS' Founding Director



The heritage-listed Peter Hall Building at The University of Melbourne, renamed in December 2016

MEDIA RELEASES AND MEMBERS IN THE MEDIA

ACEMS AND ITS MEMBERS WERE MENTIONED IN 21 MEDIA RELEASES DURING 2016, INCLUDING 13 ISSUED BY THE CENTRE. THESE MEDIA RELEASES HIGHLIGHTED VARIOUS ACHIEVEMENTS AND ACTIVITIES RELATED TO THE CENTRE.

1. Ghent University, "Ugent reikt eredoctoraten uit op Dies Natalis", 15 January 2016: <http://www.ugent.be/nl/actueel/nieuws/eredoctoraten-2016.htm>
2. ACEMS, "ACEMS Associate Investigator wins prestigious honour at ANZIAM 2016", 15 February 2016: <http://acems.org.au/acems-associate-investigator-wins-prestigious-honour-at-anziam-2016/>
3. ACEMS, "ACEMS plays a prominent role in release of 10-year maths plan for Australia", 18 March 2016: <http://acems.org.au/acems-plays-a-prominent-role-in-release-of-10-year-maths-plan-for-australia/>
4. ACEMS, "'Giving teeth' to technology to save jaguars in Peru", 2 April 2016: <http://acems.org.au/giving-teeth-to-technology-to-save-jaguars-in-peru/>
5. Queensland University of Technology, "New technology breathes new life into Amazon's big cat species", 4 April 2016: <https://www.qut.edu.au/news/news?news-id=103176>
6. Queensland University of Technology, "Spatial science and statistics turns the tide for cold-water biodiversity", 6 April 2016: <https://www.qut.edu.au/news/news?news-id=103207>
7. ACEMS, "Adelaide student looks to protect your 'Browserprint'", 1 July 2016: <http://acems.org.au/adelaide-student-looks-to-protect-your-browserprint/>
8. ACEMS, "ACEMS Deputy Director returning to Amazon to continue work on jaguar conservation", 11 July 2016: <http://acems.org.au/news/acems-deputy-director-returning-to-amazon-to-continue-work-on-jaguar-conservation/>
9. ACEMS, "From UTS, to Google, to Harvard - an ACEMS student's amazing journey", 13 July 2016: <http://acems.org.au/cathy-yuen-yi-lee/>
10. The University of Adelaide, "Can we protect against computers being fingerprinted?", 18 July 2016: <https://www.adelaide.edu.au/news/news86322.html>
11. ACEMS, "MIT Aeronautics and Astronautics Professor highlights QUT ACEMS workshop", 27 July 2016: <http://acems.org.au/karen-willcox-mit/>
12. ACEMS, "Mixing maths and economics turns out to be the right formula for Melbourne ACEMS student", 2 August 2016: <http://acems.org.au/ellen-muir-columbia-univ/>
13. ACEMS, "ACEMS UQ student already building cross-node collaborations", 5 September 2016: <http://acems.org.au/liam-hodgkinson/>
14. Cancer Council Queensland, "Breast, bowel survival gap significant in small areas", 28 September 2016: <https://cancerqld.org.au/news/breast-bowel-survival-gap-significant-in-small-areas/>
15. Queensland University of Technology, "'Dry dive' the Great Barrier Reef to aid conservation efforts", 2 November 2016: <https://www.qut.edu.au/news/news?news-id=111356>
16. ACEMS, "ACEMS researcher receives prestigious award from The University of Melbourne", 23 November 2016: <http://acems.org.au/michael-wheeler-deans-award/>
17. ACEMS, "ACEMS statistician getting best of both worlds as she teams with ACEMS Partner Organisation", 4 December 2016: <http://acems.org.au/joanna-wang-uts-sax/>
18. ACEMS, "ACEMS Deputy Director is first woman to receive prestigious statistics award", 6 December 2016: <http://acems.org.au/acems-deputy-director-is-first-woman-to-receive-prestigious-statistics-award/>
19. ACEMS, "QUT awards ACEMS Deputy Director with title of 'Distinguished Professor'", 9 December 2016: <http://acems.org.au/qut-awards-acems-deputy-director-with-title-of-distinguished-professor/>
20. The University of Melbourne, "Richard Berry Building renamed Peter Hall Building", 9 December 2016: <http://newsroom.melbourne.edu/news/richard-berry-building-renamed-peter-hall-building>
21. The University of New South Wales, "Thais Rodrigues wins EJC Pitman Prize at the Australian Statistical Conference", 9 December 2016: <https://www.maths.unsw.edu.au/news/2016-12/thais-rodrigues-wins-ejc-pitman-prize>

DURING 2016, ACEMS AND ITS MEMBERS WERE MENTIONED IN 73 PRINT AND ELECTRONIC ARTICLES, AND 12 RADIO AND TELEVISION STORIES, SOME OF WHICH WERE SYNDICATED TO MULTIPLE NEWS OUTLETS. THESE ARTICLES AND STORIES HIGHLIGHTED VARIOUS ACHIEVEMENTS AND ACTIVITIES RELATED TO THE CENTRE.

Radio and television stories

- Kerrie Mengersen appeared on Channel 11's Scope TV television program to talk about the use of statistics and virtual reality technology to help save animal populations around the world. The broadcast was uploaded to Scope TV's Youtube channel and can be viewed at <https://www.youtube.com/watch?v=sMBcCenqITs>.
- Kerrie Mengersen and Tomasz Bednarz appeared on Channel 7 News to talk about using virtual reality technology to help preserve jaguars in the Amazon. The broadcast was uploaded to QUT's 'TheQUTube' Youtube channel and can be viewed at <https://www.youtube.com/watch?v=taKCz7mpcio&feature=youtu.be>.
- Further success of using virtual reality technology for conservation was reported by the ABC in November. Erin Peterson and Julie Vercelloni featured in a recorded interview which was aired on ABC Radio Australia and 612 ABC Brisbane radio. Excerpts of the interview were included in two electronic and print articles which are available from the ABC website: <http://www.abc.net.au/news/2016-11-02/how-dry-diving-the-great-barrier-reef-could-help-save-it/7987206> <http://www.radioaustralia.net.au/international/2016-11-02/how-dry-diving-the-great-barrier-reef-could-help-save-the-world-heritage-site/1630078>
- Matthew Roughan gave multiple short live radio interviews about the Browserprint project, including with: National ABC 891 on Afternoons with Sonya Feldhoff; ABC Radio Kimberly on the morning program with Vanessa Mills; 89.7 Eastside Radio Sydney on the drive program with Eric Gyors; and Radio 6PR.
- Adrian Barnett gave a recorded radio interview with Terri Begely on 612 ABC Brisbane's morning program warning of the stress that heat places on the body during the hot summer months. Excerpts of the interview were included in the ABC News article "Heatwave conditions: Australians urged not to be superheroes during summer heat": <http://www.abc.net.au/news/2016-01-14/people-urged-not-to-be-superheroes-during-heatwave-conditions/7086230>
- Craig Anderson appeared on the ABC 702 Sydney Mornings with Wendy Harmer program to talk about his article in The Conversation "How predictable are Australia's big sporting leagues?": <https://theconversation.com/how-predictable-are-australias-big-sporting-leagues-54944>
- Kerrie Mengersen gave a recorded interview with reporter Annie Guest from the ABC's PM radio program in January 2016. The news item discussed the recent findings of ACEMS and other researchers that women with breast cancer that live in rural areas may be less likely to have additional treatment such



ACEMS Chief Investigator Kerrie Mengersen during an interview with the ABC

as radiotherapy. After further discoveries made by Professor Mengersen and collaborators later in 2016, additional electronic and print media releases were made in September and October. The full news story with the PM program, including a transcript and recording, can be found on the ABC's website at <http://www.abc.net.au/pm/content/2015/54392374.htm>.

- Kerrie Mengersen gave an interview with Robyn Williams which aired on the ABC Radio National on The Science Show program in May 2016. She discussed how mathematics and statistics are helping to estimate populations of rare animals around the world including jaguars in the Peruvian Amazon. The full interview and transcript is available from the ABC website at <http://www.abc.net.au/radionational/programs/scienceshow/math-used-to-estimate-populations-of-elusive-plants-and-animals/7452198>.

Print and electronic articles

- Adrian Barnett: "Heatwave conditions: Australians urged not to be superheroes during summer heat", 14 January 2016. *ABC News*: <http://www.abc.net.au/news/2016-01-14/people-urged-not-to-be-superheroes-during-heatwave-conditions/7086230>
- Kerrie Mengersen: "How an eighteenth century statistician is helping find MH370", 14 January 2016. *Intellasia.net*: <http://www.intellasia.net/how-an-eighteenth-century-statistician-is-helping-to-find-mh370-2-492690>
- Kerrie Mengersen: "Rural Queensland breast cancer patients opting out of radiation therapy: study", 21 January 2016. *ABC News*: <http://www.abc.net.au/news/2016-01-21/rural-breast-cancer-patients-choose-mastectomies-over-radiation/7100840>
- Kerrie Mengersen: "Pasien kanker payudara di pedesaan kecil peluangnya untuk sembuh", 21 January 2016. *Tempo.co*: <https://www.tempo.co/read/abc/2016/01/21/20160121214206/pasien-kanker-payudara-di-pedesaan-kecil-peluangnya-untuk-semuh> *Tribunnews.com*: <http://www.tribunnews.com/australia-plus/2016/01/21/pasien-kanker-payudara-di-pedesaan-kecil-peluangnya-untuk-semuh>



ACEMS Chief Investigator Kerrie Mengersen (L) talking about the project to help save jaguars with a virtual Peruvian jungle (pages 14-17) and camera trap images (R) of jaguars taken during August and September 2016

- QUT Node: "MOOC Watch: Free online course explains big data", 11 March 2016.
Australian Financial Review: <http://www.afr.com/technology/apps/education/mooc-watch-new-free-online-course-explains-big-data-20160310-gnfxbx>
- Kerrie Mengersen: "World Science Festival Brisbane 2016: Live blog day five - Why airports are like blackholes", 13 March 2016.
Brisbane Times: <http://www.brisbanetimes.com.au/technology/sci-tech/world-science-festival-brisbane-2016-live-blog-day-five-20160313-gnhmil.html>
- Craig Anderson: "How predictable are Australia's big sporting leagues?", 17 March 2016.
The Conversation: <https://theconversation.com/how-predictable-are-australias-big-sporting-leagues-54944>
- Peter Hall: "A stats boffin the world knew as Mr Martingale", 21 March 2016.
The Age: <http://www.theage.com.au/comment/obituaries/a-stats-boffin-the-world-knew-as-mr-martingale-20160321-gnn8g1.html>
The Canberra Times: <http://www.canberratimes.com.au/comment/obituaries/a-stats-boffin-the-world-knew-as-mr-martingale-20160321-gnn8g1.html>
The Sydney Morning Herald: <http://www.smh.com.au/comment/obituaries/a-stats-boffin-the-world-knew-as-mr-martingale-20160321-gnn8g1.html>
- Peter Taylor, Nigel Bean, Mark Fackrell, Malgorzata O'Reilly: "Hospitals don't need increased funding, they need to make better use of what they've got", 22 March 2016.
Business Daily: <http://www.businesses.com.au/reports/latest-business-news/415957-hospitals-don-t-need-increased-funding-they-need-to-make-better-use-of-what-they-ve-got>
The Conversation: <https://theconversation.com/hospitals-dont-need-increased-funding-they-need-to-make-better-use-of-what-theyve-got-54815>
- Kevin Burrage, Kerrie Mengersen: "Saving the Amazonian jaguar", 01 April 2016.
Gates Cambridge: <https://www.gatescambridge.org/news/saving-amazonian-jaguar>
- Kevin Burrage, Kerrie Mengersen, Erin Peterson: "On the jaguar's trail", 02 April 2016.
The Australian: <http://www.theaustralian.com.au/special-features/amazon-jaguars-where-the-bloody-hell-are-they/news-story/6e8a1f018b978a0f6afe40882a509d99>
- Kerrie Mengersen: "Realidade virtual pode ajudar cientistas a proteger especies", 04 April 2016.
Notícias ao Minuto: <https://www.noticiasao minuto.com/tech/565969/realidade-virtual-pode-ajudar-cientistas-a-proteger-especies>
- Kerrie Mengersen: "Scientists are using virtual reality to help conserve jaguars", 04 April 2016.
Democratic Underground: <http://www.democraticunderground.com/110848899>
Mental Floss: <http://mentalfloss.com/article/78147/scientists-are-using-virtual-reality-help-protect-jaguars>
- Kerrie Mengersen: "Here's how virtual reality is saving endangered animals", 04 April 2016.
Fortune.com: <http://fortune.com/2016/04/04/virtual-reality-saving-endangered-animals/>
- Kerrie Mengersen: "Virtual reality is helping scientists to protect endangered jaguars", 04 April 2016.
Mashable: <http://mashable.com/2016/04/04/virtual-reality-jaguars/#hjLFZZzAfZqE>
Tech Investor News: <http://www.techinvestornews.com/Tech-News/Tech-Bloggers/virtual-reality-is-helping-scientists-to-protect-endangered-jaguars>
#Follownews: <https://www.follownews.com/virtual-reality-is-helping-scientists-to-protect-endangered-jaguars-1102>
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Former ACEMS PhD student, now Associate Investigator,
Julie Vercelloni with a virtual reality headset used to 'dry dive'
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ACEMS Chief Investigator Kerrie Mengersen filming with Scope TV

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ACEMS Chief Investigator Kerrie Mengersen during an interview with the ABC



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Australia Plus: <http://www.australiaplus.com/international/study-and-innovation/how-dry-diving-the-great-barrier-reef-could-help-save-it/7987206>
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Tribunnews.com: <http://www.tribunnews.com/australia-plus/2016/11/03/menylami-keindahan-great-barrier-reef-tanpa-perlu-basah>

2016 KEY PERFORMANCE INDICATORS

RESEARCH FINDINGS

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Number of research outputs	45 journal articles 20 other	<i>Refereed written outputs:</i> 141 journal articles 1 book (new edition) 3 book chapters 22 refereed conference papers <i>Other written outputs, including non-refereed contributions:</i> Another 45 outputs were produced by Centre members, including non-refereed conference papers, unpublished reports, and other contributions to journals	Pages 152-159
Quality of research outputs	80% of publications will be in peer reviewed, international journals CI recognition through awards and honours, particularly those from abroad	All listed journal articles were in internationally recognised and fully refereed scientific journals Numerous CIs recognised through awards, high-citation counts, and leadership roles in the national and international mathematical sciences community	2016 awards listed on pages 34-35 See CI short biographies on pages 40-46 for a glimpse of other types of recognition, including previous major awards, citation history, and roles in the mathematical sciences community
Number of invited talks/papers/keynote lectures given at major international meetings (including those held in Australia)	25	51	
Number and nature of commentaries about the Centre's achievements	5 media releases 3 articles	21 media releases (13 by ACEMS) 73 print and electronic articles 12 radio and television stories 25 YouTube videos	Media releases on page 138. Articles and stories on pages 139-143. YouTube videos can be accessed via the ACEMS website
Citation data for publications	200	814	Page 153

RESEARCH TRAINING AND PROFESSIONAL EDUCATION

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Number of professional training courses for staff and postgraduate students attended	4	18 professional training/development courses, including 3 offered by ACEMS	The three courses offered by ACEMS are listed on page 86
Number of Centre attendees at all professional training/development courses offered by the Centre (including courses offered for external stakeholders and clients)	16	104	Page 86
Number of new postgraduate students working on core Centre research and supervised by Centre staff (including PhD, Masters by research, and Masters by coursework)	12 PhD 4 MSc by coursework	30 PhD 5 Masters by research 6 Masters by coursework	Page 36
Number of new postdoctoral researchers recruited to the Centre working on core Centre research	4	4	Page 36
Number of new Honours students working on core Centre research and supervised by Centre staff	8	3 Honours (plus 31 Vacation Students)	Page 36
Number of postgraduate completions and completion times, by students working on core Centre research and supervised by Centre staff	7 PhD (4y FTE) 4 MSc (2y FTE)	8 PhD completions ($\leq 4y$ FTE) 4 PhD completions ($> 4y$ FTE) 3 Masters by research completion ($\leq 2y$ FTE) 6 Masters by coursework completions ($\leq 2y$ FTE) 1 Masters by coursework completions ($> 2y$ FTE) 3 Honours completions	
Number of Early Career Researchers (within five years of completing PhD) working on core Centre research	18	36	Page 36
Number of students mentored	30	181	Students listed on pages 29-30 . Breakdown of enrolments by student type on page 36
Number of mentoring programs offered by the Centre (including programs for students, new staff, external stakeholders and clients)	6	6	Pages 80-81

INTERNATIONAL, NATIONAL AND REGIONAL LINKS AND NETWORKS

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Number of international visitors and visiting fellows	18	71	Pages 97-98
Number of national and international workshops held/organised by the Centre	2	16	Page 100
Number of visits to overseas laboratories and facilities	18	57	Page 96
Examples of relevant interdisciplinary research supported by the Centre	Publications, reports and high profile activities in relevant areas of application, where Centre staff have played a key role. More than 50% of projects will be interdisciplinary	<p>Case studies and publications</p> <p>Numerous conferences and workshops organised or sponsored by the Centre</p> <p>All projects involving Partner Organisations (POs) and Industry Affiliate Organisations (IAOs)</p>	<p>Case studies: pages 14-17, 24-25, 38-39, 54-55, 62-63, 68-69, 76-77 and 82-83.</p> <p>Publications: pages 152-159.</p> <p>Conferences and workshops: pages 87 and 100.</p> <p>POs and IAOs: see the Stakeholder Engagement Report on pages 110-116</p>

ACEMS has access to top of the range visualisation facilities in the form of the Cube at QUT (pages 136-137)



2016 KEY PERFORMANCE INDICATORS

END-USER LINKS

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Number of government, industry and business community briefings	5	36	Page 113
Number and nature of public awareness/outreach programs	15 school visits Participate in 5 events during National Science Week 6 other public activities/events	22 different schools visited with 71 separate visits and 119 activities undertaken 5 National Science Week events 1 Big Data Analytics Massive Open Online Course (MOOC) 1 National Science Quiz 4 Mathscraft events involving 36 different schools (approximately 180 participants) 1 Mathscraft teacher training event, involving 17 teachers from different schools 32 other activities/events	See the Outreach Report, (pages 126-130) and special features on the Big Data Analytics MOOC (pages 84-85), the National Science Quiz (pages 108-109) and Mathscraft (pages 106-107)
Currency of information on the Centre's website	Review of website structure with goal of improving in line with emerging web technologies	A website working group was established to review and improve the website in 2016. Consequently a major overhaul of the Centre's website is planned for 2017	See the Communications and Media Report, pages 90-91
Number of website hits	1,500 Active social media engagement (measured by tweets, re-tweets and similar measures)	27,750 web sessions 17,616 website users 67,774 website page views 673 Twitter followers 457 tweets 595 re-tweets of ACEMS tweets 277 Facebook followers 191 Facebook posts 154 new photos 88 YouTube subscribers 25 new videos	See the Communications and Media Report, pages 90-91
Number of talks given by Centre staff open to the public	15	40	Page 131

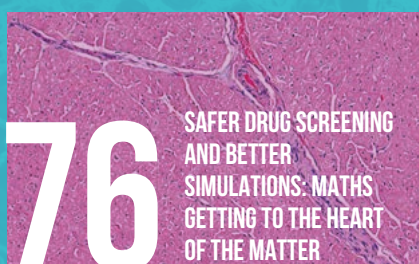
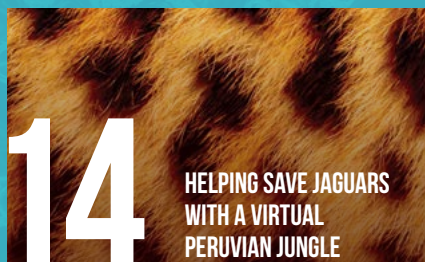
ORGANISATIONAL SUPPORT

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Annual cash contributions from Administering and Collaborating Organisations	\$365,699 UoM \$315,579 QUT \$101,948 UoA \$151,886 UTS \$101,948 UQ \$61,604 UNSW	\$365,699 UoM \$315,580 QUT \$101,948 UoA \$299,949 UTS \$100,479 UQ \$30,802 UNSW	Page 164
Annual in-kind contributions from Administering and Collaborating Organisations	\$352,322 UoM \$485,760 QUT \$87,936 UoA \$474,851 UTS \$81,224 UQ \$43,700 UNSW	\$1,064,982 UoM \$1,229,247 QUT \$425,733 UoA \$976,350 UTS \$318,051 UQ \$284,421 UNSW	Page 164
Annual cash contributions from Partner Organisations	Nil	Nil	
Annual in-kind contributions from Partner Organisations	\$172,728 AIMS \$140,718 ABS \$75,000 VicRoads \$30,000 AT&T Labs \$25,277 Mitacs \$13,740 Sax Institute \$10,992 CSIRO	\$195,000 AIMS \$164,500 ABS \$7,500 VicRoads \$0 AT&T Labs \$0 Mitacs \$102,887 Sax Institute \$14,500 CSIRO	Page 164
Other research income secured by Centre staff (list research income from ARC grants, other Australian competitive grants, grants from the public sector, industry and CRCs and other research income separately)	\$1,500,000 ARC Grants \$0 Other ACG \$100,000 Public Sector \$50,000 Industry	\$2,063,642 ARC Grants \$0 Other ACG \$359,263 Public Sector \$1,272,043 Industry and CRC	Pages 160-162
Number of new organisations collaborating with, or involved in, the Centre	4	5	See the Industry Affiliate Organisations on pages 114-115
Level and quality of infrastructure provided to the Centre	High quality of research spaces, adequate space and other infrastructure at all institutions	High quality of infrastructure is provided at all six ACEMS nodes	Pages 136-137

2016 KEY PERFORMANCE INDICATORS

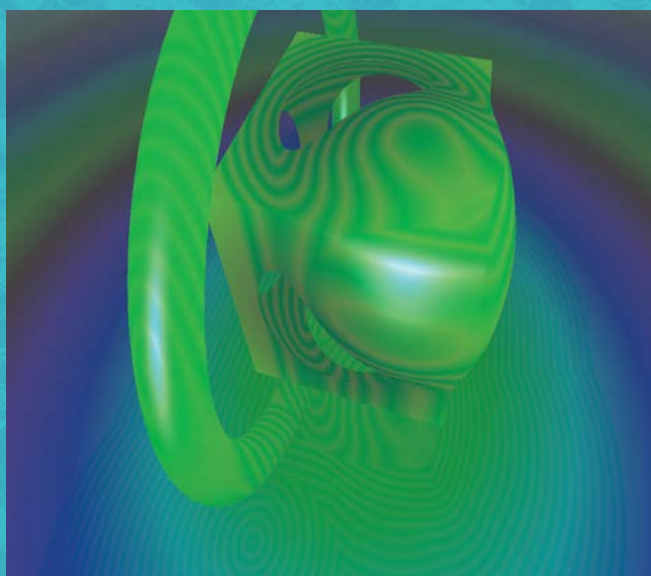
NATIONAL BENEFIT

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Contribution to the National Research Priorities	<p>Case studies detailed in Annual Report of how the Centre is contributing to relevant National Research and Innovation Priorities including:</p> <ul style="list-style-type: none"> • Contribution to Frontier Technologies: Breakthrough Sciences • Smart Information Use 	Eight new case studies featured in the 2016 Annual Report	Case studies: pages 14-17, 24-25, 38-39, 54-55, 62-63, 68-69, 76-77 and 82-83.



STAFF RECOGNITION

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Prizes, awards, other prestige measures of Centre researchers and students for excellence of research quality, outreach and scientific contribution	15	35 (includes 10 awarded by ACEMS)	Pages 34-35



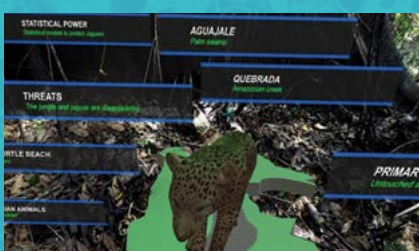
ACEMS Research Fellow Tomasz Bednarz and some of the images produced in his visualisation research



ACEMS Research Fellow Associate Professor Tomasz Bednarz and his research were recognised several times during 2016. Tomasz was awarded:

- CSIRO's Corporate Citizen Award
- A Recognition of Service Award from the Association for Computing Machinery (ACM), and a
- Pioneer Member Award from the ACM Special Interest Group on Computer Graphics and Interactive Techniques (SIGGRAPH).

Tomasz currently holds a joint appointment with ACEMS Partner Organisation CSIRO (see page 111) and contributed to the case study project "helping to save jaguars with a virtual Peruvian jungle" (page 16).



2016 KEY PERFORMANCE INDICATORS

SCIENTIFIC OUTCOMES

PERFORMANCE MEASURE	TARGET FOR 2016	OUTCOME IN 2016	DETAILS IN ANNUAL REPORT
Centre-recognised leadership in discoveries and insights relating to mathematical modelling, statistical analysis and subsequent applications	These are difficult to specify in advance but will be highlighted in Centre Annual Reports	<p>Eight new case studies featured in the 2016 Annual Report</p> <p>Numerous prestigious prizes and awards for Centre researchers and students</p>	<p>Case studies: pages 14-17, 24-25, 38-39, 54-55, 62-63, 68-69, 76-77 and 82-83.</p> <p>Awards and prizes: pages 34-35</p>



ACEMS Deputy Directors Jan de Gier and Kerrie Mengersen (top left) and Director Peter Taylor (bottom left) at the ACEMS/AMSI workshop "Measuring research engagement and impact in the mathematical sciences" in September 2016 (see [pages 116 and 120](#))

ACEMS members 'dry diving' the Great Barrier Reef ([page 117](#))



Camera trap image of a jaguar taken during September 2016 (see the full case study on [pages 14-17](#))



PUBLICATIONS

BOOKS AND BOOK CHAPTERS

In 2016, Centre members published three book chapters and one new edition book.

1. Asanjarani, A. and Nazarathy, Y. (2016) A queueing approximation of MMPP/PH/1. In Do, T.V., Takahashi, Y., Yue, W. and Nguyen, V.-H. (Eds.), *Queueing theory and network applications* (pp. 41-51). Switzerland: Springer International Publishing. doi:10.1007/978-3-319-22267-7.
2. Erhardt, R. and Sisson, S.A. (2016) Modelling extremes using approximate Bayesian computation. In Dey, D. and Yan, J. (Eds.), *Extreme Value Modelling and Risk Analysis* (pp. 281-306). Boca Raton, FL: Chapman & Hall/CRC Press.
3. Hall, P. (2016) Contributions of Rabi Bhattacharya to the central limit theory and normal approximation. In Denker, M. and Waymire, E.C. (Eds.), *Rabi N. Bhattacharya: Selected Papers* (pp. 3-13). Switzerland: Springer International Publishing. doi:10.1007/978-3-319-30190-7_1
4. Rubinstein, R.Y. and Kroese, D.P. (2016) *Simulation and the Monte Carlo method* (3rd ed.). New York, NY: John Wiley & Sons Inc.

REFEREED JOURNAL ARTICLES

In 2016, 141 articles by Centre members were published in scholarly refereed journals. This figure only includes ACEMS publication outputs; Centre members' outputs solely from other projects and grants are not included in this list.

By the end of 2016, Centre publications have already achieved 814 citations; this includes 75 citations across 35 journal articles that were published during 2016. See the table on [page 153](#) for a breakdown of the citation data by year.

1. Amarasinghe, P., Liu, A., Egodawatta, P., Barnes, P., McGree, J. and Goonetilleke, A. (2016) Quantitative assessment of resilience of a water supply system under rainfall reduction due to climate change. *Journal of Hydrology*. **540**, 1043-1052, doi:10.1016/j.jhydrol.2016.07.021.
2. Anderson, C., Lee, D. and Dean, N. (2016) Bayesian cluster detection via adjacency modelling. *Spatial and Spatio-temporal Epidemiology*. **16**, 11-20, doi:10.1016/j.sste.2015.11.005.
3. Anees, A., Aryal, J., O'Reilly, M.M. and Gale, T.J. (2016) A relative density ratio-based framework for detection of land cover changes in MODIS NDVI time series. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*. **9**(8), 3359-3371, doi:10.1109/JSTARS.2015.2428306.
4. Arbel, J., Mengersen, K. and Rousseau, J. (2016) Bayesian nonparametric dependent model for partially replicated data: The influence of fuel

spills on species diversity. *The Annals of Applied Statistics*. **10**(3), 1496-1516, doi:10.1214/16-AOAS944.

5. Ashcroft, M.B., Casanova-Katny, A., Mengersen, K., Rosenstiel, T.N., Turnbull, J.D., Wasley, J., Waterman, M.J., Zúñiga, G.E. and Robinson, S.A. (2016) Bayesian methods for comparing species physiological and ecological response curves. *Ecological Informatics*. **34**, 35-43, doi:10.1016/j.ecoinf.2016.03.001.
6. Ashley Steel, E., Sowder, C. and Peterson, E.E. (2016) Spatial and temporal variation of water temperature regimes on the Snoqualmie river network. *Journal of the American Water Resources Association*. **52**(3), 769-787, doi:10.1111/1752-1688.12423.
7. Asmussen, S., Jensen, J.L. and Rojas-Nandayapa, L. (2016) Exponential family techniques for the lognormal left tail. *Scandinavian Journal of Statistics*. **43**(3), 774-787, doi:10.1111/sjos.12203.
8. Baade, P., Cramb, S., Dasgupta, P. and Youlden, D. (2016) Estimating cancer survival – improving accuracy and relevance. *Australian and New Zealand Journal of Public Health*. **40**(5), 403-404, doi:10.1111/1753-6405.12610.
9. Baade, P.D., Dasgupta, P., Dickman, P.W., Cramb, S., Williamson, J.D., Condon, J.R. and Garvey, G. (2016) Quantifying the changes in survival inequality for Indigenous people diagnosed with cancer in Queensland, Australia. *Cancer Epidemiology*. **43**, 1-8, doi:10.1016/j.canep.2016.05.002.

10. Ballard, P.G., Bean, N.G. and Ross, J.V. (2016) The probability of epidemic fade-out is non-monotonic in transmission rate for the Markovian SIR model with demography. *Journal of Theoretical Biology*. **393**, 170-178, doi:10.1016/j.jtbi.2016.01.012.
11. Bateman, H., Eckert, C., Geweke, J., Louviere, J., Satchell, S. and Thorp, S. (2016) Risk presentation and portfolio Choice. *Review of Finance*. **20**(1), 201-229, doi:10.1093/rof/rfv001.
12. Bean, N.G., Eshragh, A. and Ross, J.V. (2016) Fisher Information for a partially observable simple birth process. *Communications in Statistics - Theory and Methods*. **45**(24), 7161-7183, doi:10.1080/03610926.2014.978024.
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CITATION DATA FOR REFEREED JOURNAL ARTICLES

		YEAR OF PUBLICATION			TOTAL
		2014	2015	2016	
NUMBER OF PUBLICATIONS INCLUDED IN CITATION COUNT*		9	178	141	328
NUMBER OF PUBLICATIONS WITH AT LEAST ONE CITATION		9	140	35	185
NUMBER OF CITATIONS BY YEAR OF CITATION	2014	1	1**	0	2
	2015	34	137	0	171
	2016	83	483	75	641
TOTAL CITATIONS BY YEAR OF PUBLICATION		118	621	75	814

Please note that the figures quoted are sourced from the bibliographic database Scopus. Scopus is held in high regard by librarians for its ease of use and accurate albeit sometimes modest citation numbers in comparison to other bibliographic databases, such as Google Scholar.

* This citation data relates to refereed journal articles only and does not include citation information for books, book chapters or conference proceedings. As bibliographic databases also rely on regular database updates via APIs, manual data entry and so forth, and as only a selection of our journals' citation information could be retrieved from the Scopus database, the figures quoted are a conservative lower bound. Despite our modest approach to reporting our citation figures, the Centre's total citation numbers of 814 are well above the 200 citations required at review.

** ACEMS defines 'year of publication' as the year that a published work appears in print. As there is often a delay between the article being published electronically and appearing in print, it is possible for articles to be cited before being published in print.

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REFEREED CONFERENCE PROCEEDINGS

In 2016, Centre members had 22 conference papers published in scholarly refereed conference proceedings. This figure only includes ACEMS publication outputs; Centre members' outputs solely from other projects and grants are not included in this list.

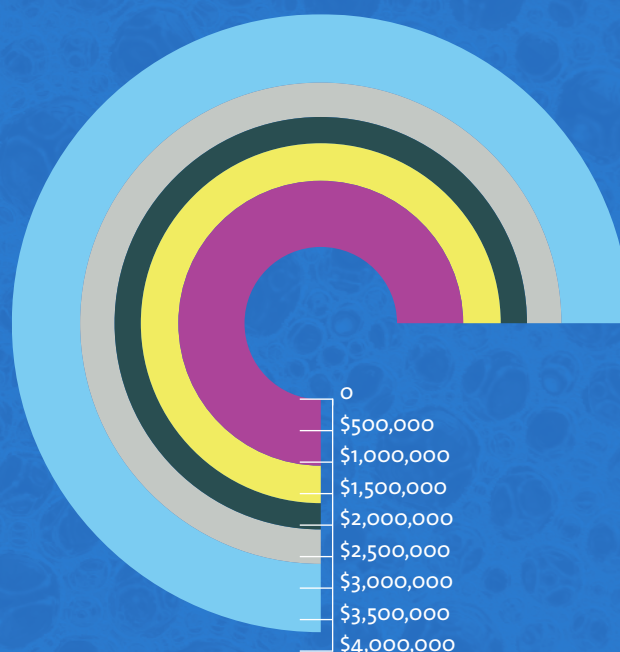
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GRANTS AND OTHER RESEARCH INCOME

ACEMS members attracted \$3,694,948 in additional support during 2016, well exceeding the Centre's targets for other research income secured by Centre members.

NEW FUNDS IN 2016

FUNDING CATEGORY	TOTAL AMOUNT (\$)
ARC DECRA	1,050,852
ARC DISCOVERY	595,500
ARC LINKAGE	417,290
CRC	546,947
OTHER	1,084,359
TOTAL	3,694,948



ACEMS Chief Investigators:

Back Row (L-R): Phil Pollett (UQ), Dirk Kroese (UQ), Matt Roughan (UoA), Louise Ryan (UTS), Scott Sisson (UNSW), Nigel Bean (UoA), Peter Taylor (UoM), Ian Turner (QUT), Tim Garoni (MU)

Front Row (L-R): Aurore Delaigle (UoM), Jan de Gier (UoM), Kerrie Mengersen (QUT), Matt Wand (UTS), Kevin Burrage (QUT)

Not pictured: Peter Bartlett (QUT), Peter Forrester (UoM), Robert Kohn (UNSW), Tony Pettitt (QUT), Kate Smith-Miles (MU)

The following two tables list grants that were active in 2016. The total value of these grants is \$35,948,669. All of this income is over and above the income specified in the Centre agreement.

ACTIVE ARC GRANTS

NEW IN 2016

GRANT TYPE	ARC GRANT ID	ACEMS INVESTIGATOR/S	TOTAL VALUE OF GRANT (\$)
ARC DECRA	DE160100690	Black, A.	373,316
ARC DECRA	DE150101044	Hautphenne, S.	315,000
ARC DECRA	DE160100584	Rubinstein, B.	370,000
ARC DECRA	DE150101842	Yang, Q.	345,000
ARC DECRA	DE160100958	Wheeler, M.	307,536
ARC Discovery Project	DP150103588	Barbour, A.	310,700
ARC Discovery Project	DP140102201	de Gier, J.	330,000
ARC Discovery Project	DP140100125	Delaigle, A.	415,000
ARC Discovery Project	DP140102613	Forrester, P.	390,000
ARC Discovery Project	DP140100559	Garoni, T.	300,000
ARC Discovery Project	DP150102345	Hegland, M.	225,900
ARC Discovery Project	DP140103220	Hyndman, R. and Athanasopoulos, G.	335,000
ARC Discovery Project	DP140101110	Jensen, I., Clisby, N. and Guttman, A.	370,000
ARC Discovery Project	DP150100828	Burrage, K.	367,391
ARC Discovery Project	DP150104630	Kohn, R. and Carter, C.	333,581
ARC Discovery Project	DP150104292	Koo, B. and Anderson, H.	262,400
ARC Discovery Project	DP140101956	Kroese, D.	280,000
ARC Discovery Project	DP150101728	Martin, G.	277,000
ARC Discovery Project	DP140102319	Ross, J.	343,000
ARC Discovery Project	DP150101459	Barbour, A., Pollett, P. and Ross, N.	591,800
ARC Discovery Project	DP150103710	Rubinstein, B.	216,000
ARC Discovery Project	DP150103675	Turner, I. and Burrage, K.	359,198
ARC Discovery Project	DP140100441	Wand, M.	375,000
ARC Discovery Project	DP140101186	Warnaar, O.	340,000
ARC Discovery Project	DP140101259	Welsh, A.	351,000
ARC Discovery Project	DP150104595	Williamson, R.	426,700
ARC Discovery Project	DP160101325	Farrell, T.	290,000
ARC Discovery Project	DP160104292	Wang, Y.	305,500
ARC Future Fellowship	FT130100098	Delaigle, A.	736,000
ARC Future Fellowship	FT130100254	Ross, J.	619,381
ARC Future Fellowship	FT130100972	Clisby, N.	583,999
ARC Laureate Fellowship	FL110100281	Bartlett, P.	2,940,536
ARC Laureate Fellowship	FL150100150	Mengersen, K.	2,435,586
ARC Laureate Fellowship	FL130100039	Taylor, P.	2,750,000
ARC Laureate Fellowship	FL140100012	Smith-Miles, K.	2,830,000
ARC Linkage Projects	LP140100282	Mengersen, K.	877,736
ARC Linkage Projects	LP140100923	Mengersen, K.	686,929
ARC Linkage Projects	LP140100489	Roughan, M.	194,873
ARC Linkage Projects	LP140100152	Taylor, P., Fackrell, M. and O'Reilly, M.	410,000
ARC Linkage Projects	LP160100707	Turner, I.	417,290
ARC Linkage Projects	LP140101063	Smith-Miles, K.	421,276

OTHER ACTIVE GRANTS AND RESEARCH INCOME

NEW IN 2016

INCOME SOURCE	ACEMS INVESTIGATOR/S	TOTAL VALUE OF INCOME (\$)
Australian Agricultural Company Limited	Mengersen, K. and Bednarz, T.	658,200
Australian Bureau of Statistics	Pettitt, T.	400,000
Being Alive IP Pty Ltd	Mengersen, K.	22,395
Bill and Melinda Gates Foundation	Ryan, L.	949,406
BMT Oceanica Pty Ltd	Mengersen, K. and McGree, J.	5,000
Boeing Defence Australia Ltd	Perez, T.	150,000
Cooperative Research Centre for Spatial Information	Mengersen, K.	50,000
Cooperative Research Centre for Spatial Information	Mengersen, K.	410,000
Cooperative Research Centre for Spatial Information	Mengersen, K.	339,400
Cooperative Research Centre for Spatial Information	Bednarz, T.	105,947
Cooperative Research Centre for Spatial Information	Mengersen, K.	291,000
Cooperative Research Centre Data to Decisions	Bean, N.	668,377
Cooperative Research Centre Data to Decisions	Bean, N.	661,262
Cooperative Research Centre for Optimising Resource Extraction	Burrage, K.	150,000
Cooperative Research Centre for Spatial Information, Queensland Department of Natural Resources and Mines	Peterson, E.	410,000
Cotton Research and Development Corporation	Peterson, E.	299,960
CSIRO Scholarship	Pettitt, T.	40,000
CSIRO Scholarship	Turner, I.	50,000
Defence Science and Technology Group	Perez, T.	30,000
Defence Science and Technology Group	Roughan, M.	40,000
Environmental Protection Agency Victoria	Peterson, E.	42,114
Fitzroy Basin Association Inc	Mengersen, K.	216,466
Forest and Wood Products Australia Ltd (FWPA) - Research and Development Scheme	Turner, I.	99,896
Healthy Waterways	Mengersen, K. and Wu, P.	34,995
Horticulture Innovation Australia Limited - R&D Strategic Investment Funding Call	Mengersen, K.	58,500
Hunter Industrial Medicine Pty Ltd	Mengersen, K.	40,000
Joint Research Appointment of Biostatistician	Ryan, L.	421,666
Monash Graduate Research Industry Partnership	Garoni, T.	78,900
National Computational Merit Allocation Scheme	Jensen, I.	12,000
NHMRC Centres of Research Excellence	Mengersen, K.	2,674,052
Plant Biosecurity Cooperative Research Centre Limited	Mengersen, K.	111,000
Plant Biosecurity Cooperative Research Centre Limited	Mengersen, K.	230,000
Queensland Government	Bednarz, T.	10,800
QUT Institute for Future Environments	Peterson, E.	49,563
Royal Brisbane Women's Hospital Research Scholarship	McGrath, M.	25,000
Sax Institute	Ryan, L.	330,000
Southeast Queensland Healthy Waterways & Catchments Partnership	Peterson, E.	150,000
The Yield Technology Solutions Pty Ltd	Perez, T.	221,141
ViCBiostat Visiting Fellowship	Anderson, C.	2,000

ACEMS FINANCES

FINANCIALLY, ACEMS HAS HAD A SOMEWHAT SLOW START, PARTLY DUE TO THE LENGTHY ILLNESS AND SUBSEQUENT UNTIMELY DEATH OF ACEMS FOUNDING DIRECTOR PETER HALL.

However, the Centre has made significant progress in allocating additional resources where needed to ensure that the aims and objectives of the Centre are met. To this end, the year 2016 saw a substantial increase in expenditure over 2015, from \$2,476,783 to \$3,390,173, as can be seen in the 2016 Financial Statement on [page 164](#).

In particular, ACEMS hired additional new postdoctoral fellows, offered more student scholarships and stipends, sponsored various activities of benefit to the mathematical sciences community, significantly increased outreach and stakeholder engagement activities, organised workshops and conferences, and took part in a number of other important initiatives.

This growth in personnel and activities has led to the growth in expenditure, and ACEMS will maintain and build on this progress in 2017 and beyond. As a result, the Centre estimates that expenditure will significantly increase again in 2017 to \$4,698,506, reducing the adjusted surplus.

CHALLENGES AND OPPORTUNITIES

As is very common in academia, there have been substantial hiring delays in appointing postdoctoral fellows during the life of the Centre; this has been a major contributing factor to earlier surpluses. Nevertheless, work done in late 2016 will translate to several new appointments during 2017. Moreover, with the addition of Professors Scott Sisson and Kate Smith-Miles as Chief Investigators, additional postdoctoral fellows and students will be welcomed to the ACEMS research team in 2017 and beyond.

Following the 2016 main retreat and student retreat (see [pages 132-133](#) and [134-135](#), respectively) the Centre's postdoctoral researchers requested their own retreat. Consequently, ACEMS will now hold a postdoctoral fellow retreat in parallel to the student retreat, and these will both immediately precede the main annual retreat for all Centre members. As these retreats are typically held in November each year, a three-day dedicated postdoctoral fellow workshop is already planned for March 2017.

The four new research themes have also presented an additional opportunity for general research workshops. These will be offered in addition to the focused research workshops that are typically dedicated to particular topics. These new workshops will be organised throughout 2017.

Finally, to facilitate new – and sometimes bold – programs that arise throughout the year, ACEMS sets aside funds for strategic operations. For example, activities that were previously funded in this way include the Mathscraft program in 2015, and MATRIX and the National Science Quiz in 2016. Once the pilot activities have demonstrated their success, their ongoing support is transferred to the appropriate budget, such as outreach or sponsorships. This ensures that the Centre is able to act quickly when exciting opportunities arise, and doesn't restrict Centre members from proposing bold (and possibly resource intensive) new ideas that haven't been budgeted previously.

2016 FINANCIAL STATEMENT

Statement of income and expenditure for year ended 31 December 2016, preceding calendar years and estimated budget for 2017

REPORTING PERIOD	2014	2015	2016	2017
INCOME				
ARC Income*	2,943,492	2,996,205	3,047,140	2,858,143
Node/University Contributions				1,120,246
The University of Melbourne	526,400	377,013	365,699	
Queensland University of Technology	159,336	476,006	315,580	
The University of Queensland	98,280	100,479	100,479	
The University of Adelaide	47,870	98,110	101,948	
The University of New South Wales	60,227	59,251	30,802	
University of Technology Sydney	-	147,636	299,949	
Other Income		75,000	17,817	
TOTAL INCOME	3,835,605	4,329,700	4,279,414	3,978,389
EXPENDITURE				
Salaries	226,747	1,816,017	2,599,067	3,281,506
Travel, Accommodation and Conferences	53,417	317,124	345,015	535,000
Consultants, Materials and Provisions	109,324	37,907	17,727	7,500
Scholarships and PhD Stipend Top Ups	4,790	139,803	188,721	265,000
Marketing, Outreach and Sponsorship	6,007	96,965	42,776	164,500
Sponsorships**			129,593	125,000
Equipment	17,974	15,875	18,710	20,000
Other	180,643	53,092	48,563	100,000
Strategic Operations				200,000
TOTAL EXPENDITURE	598,903	2,476,783	3,390,173	4,698,506
BALANCE	3,236,702	1,852,917		
Six-month ARC/Uni Contribution Carry Forward***	-1,699,382	-159,336		
CLOSING BALANCE AT END OF THE YEAR	1,537,321	1,693,581	889,242	-720,117
Previous year carry forward		1,537,321	3,230,902	4,120,144
ADJUSTED SURPLUS AT END OF THE YEAR	1,537,321	3,230,902	4,120,144	3,400,026
SIX-MONTH ARC/UNI CONTRIBUTION CARRY FORWARD TO 2021	1,699,382	1,858,718	1,858,718	1,858,718

* 2017 ARC Budget as per original ACEMS Funding Agreement – indexation is not included

** Sponsorships reported separately from 2016

*** Six-month carry forward to 2021 due to July 2014 start. Funds from the ARC, UoM, UNSW and UQ were received in 2014, and from QUT in 2015

IN-KIND REPORT 2016	TOTAL AMOUNT (\$)
The University of Melbourne	1,064,982
Queensland University of Technology	1,229,247
The University of Queensland	318,051
The University of Adelaide	425,733
The University of New South Wales	284,421
University of Technology Sydney	976,350
ACEMS members from other universities/institutions	149,385
Australian Bureau of Statistics (ABS)	164,500
Australian Institute of Marine Science (AIMS)	195,000
Sax Institute	102,887
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	14,500
Roads Corporation of Victoria (VicRoads)	7,500
AT&T Labs	0
Mathematics of Information Technology and Complex Systems (Mitacs)	0
TOTAL	4,932,556

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