21st Century Trailblazers

The Network. The Research. The Achievements.

AARNet made history with Australia's very first international Internet connection through a 56 kilobit per second satellite link that connected the University of Melbourne and the University of Hawaii in June 1989. This was the first known direct live overseas link with Australia. Fast track to 2016 and the same connection to the United States is nearly 2 million times faster, operating at 100 gigabits (Gbps) per second thanks to the continued and far-sighted commitment of Southern Cross Cable Network to support Australian research and education.

The landmark partnership with AARNet began in December 2003, with Southern Cross Cable Network agreeing to generously sponsor dual 10Gbps undersea circuits between Australia and the West Coast of the United States for the Southern Cross Trans-Pacific Optical Research Test bed (SXTransPORT). SXTransPORT is a high capacity fibre optic connection linking AARNet to research and education networks around the world. This network connection to the United States remains AARNet's most important international service. Continuous regular upgrades over the past decade, to 40Gbps in 2012 and 100Gbps in 2016, ensure AARNet provides a network to the scientific community without technological or cost barriers and ahead of demand.

SXTransPORT has provided Australian researchers and scientists with an unprecedented opportunity to collaborate in research areas such as astronomy, particle physics and science of great significance to Australia and the international community. Many of these collaborative efforts would not have been possible without SXTransPORT and the assistance of Southern Cross Cable Network.

Cover: watercolour by Steve Dixon

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An enduring partnership: Australia's Academic and Research Network and Southern Cross Cable Network

"For nearly three decades, AARNet has provided a world class network, one that enables Australian innovative research and education outcomes, and which in turn sustains the nation's global competitiveness. Our long- term partnership with Southern Cross Cable Network has delivered the seamless international connectivity researchers increasingly depend on to contribute to the world's collective research capabilities. This international connectivity underpins the advancement of science and innovation and will only continue to rise in importance."

GERARD SUTTON AO
Chair, AARNet Board

"SXTransPORT has placed Australia at the forefront of the world's research and education by providing a high bandwidth corridor connecting Australia to the United States and the rest of the world since 2003. Southern Cross is proud to be a long-term supporter of Australia's scientific and research endeavours through its partnership with AARNet. By also extending the network to connect to REANNZ, the SXTransPORT project is an example of a truly exciting initiative in which all partners have worked together collaboratively to bring about great achievements for Australia and New Zealand."

ANTHONY BRISCOE
President & CEO, Southern Cross Cable Network

"Australia's remote location on the planet means that AARNet's provision of international connectivity is critical in today's increasingly collaborative, data-intensive and globalised research world. For more than a decade, the generous support of Southern Cross Cable Network and upgrades to the SXTransPort links across the Pacific, together with funding from the Australian Government, have been fundamental to ensuring Australian scientists collaborate on major international projects and make leading contributions to global science and research endeavours."

CHRIS HANCOCK
CEO, AARNet

Cables: courtesy CERN

Particle Physics

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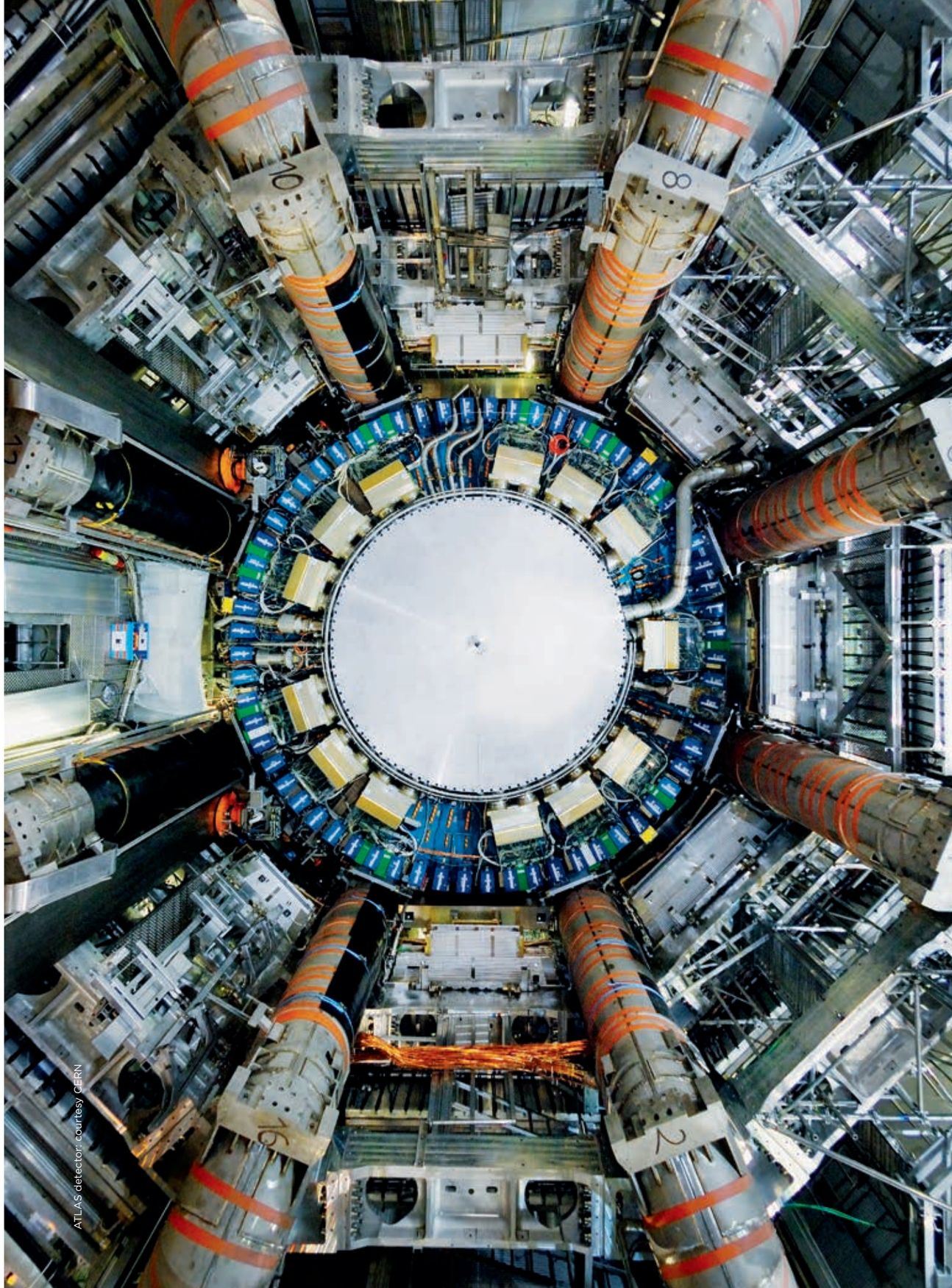
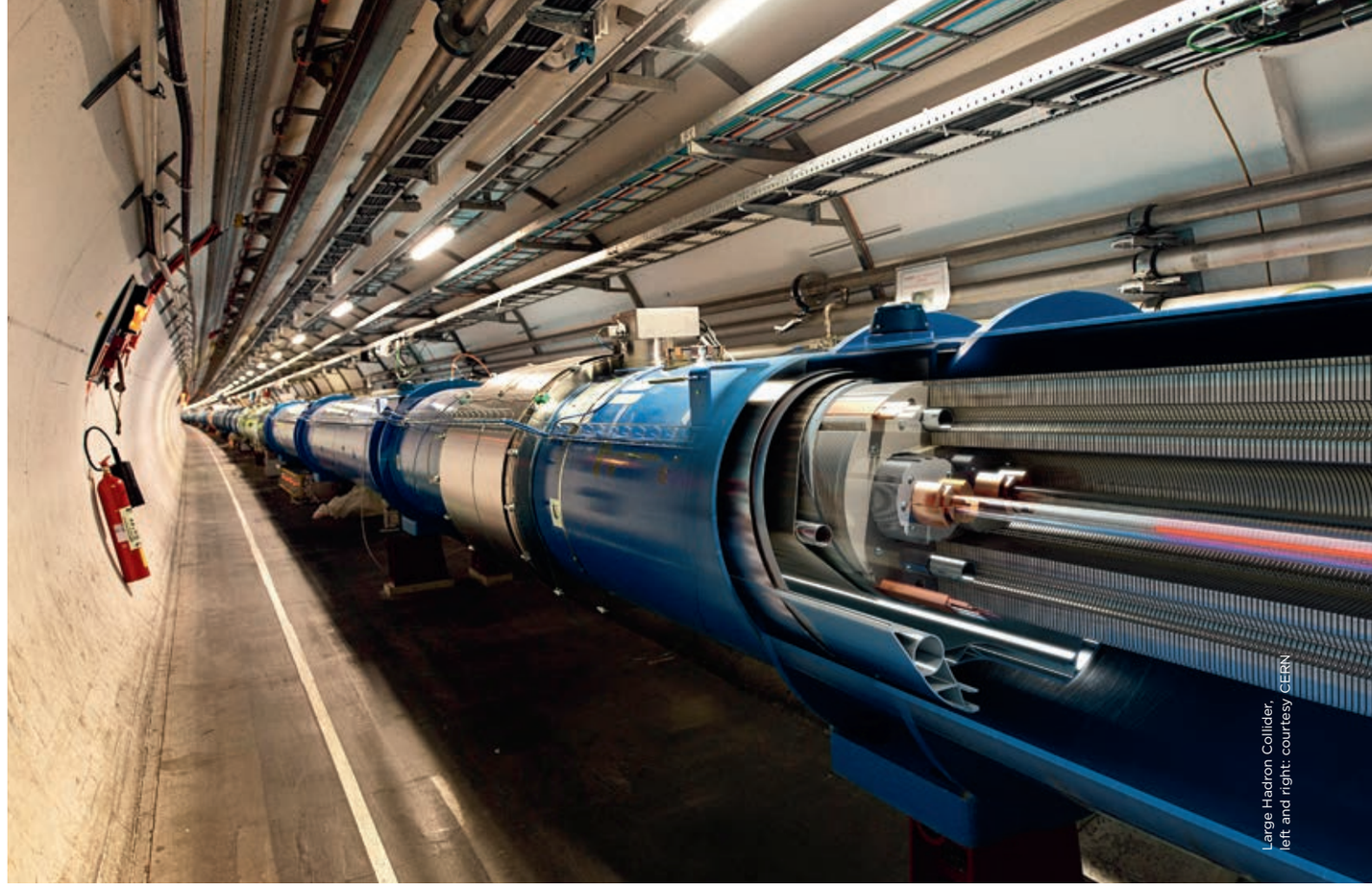
Understanding the Universe

Australian scientists participate in global high energy physics, advanced computing and accelerator science initiatives, including the ATLAS experiment at the Large Hadron Collider (LHC) at the CERN (European Organisation for Nuclear Research) laboratory in Geneva, Switzerland.

Physicists are recreating the conditions of the Universe just after the 'Big Bang'. They are searching for new discoveries in the head-on collisions of protons of extraordinarily high energy and these discoveries will change our understanding of energy and matter. Following the discovery of the Higgs boson, data from the ATLAS experiment allows in-depth investigation of the boson's properties and the origin of mass.



ATLAS detector courtesy CERN



Large Hadron Collider,
left and right: courtesy CERN

A GLOBAL COLLABORATION

Data processing for some 500 trillion collisions at the LHC requires fast and reliable research networks spanning the globe with processing facilities distributed over those networks. The day never ends for the ATLAS experiment – it is a true global collaboration involving thousands of scientists from more than 177 universities and laboratories worldwide.

AUSTRALIA'S INVOLVEMENT

The Australian Research Council Centre of Excellence for Particle Physics (CoEPP) based at the University of Melbourne is Australia's leading research centre in high-energy physics. The Centre is a collaborative research venture between the University of Melbourne, the University of Adelaide, the University of Sydney and Monash University.

Through its work on the ATLAS experiment at the LHC in CERN, CoEPP researchers contributed to the Higgs boson discovery in 2012 and provided valuable, and essential, resources to the Worldwide LHC Computing Grid (WLCG). The WLCG consists of 170 computing centres in 42 countries, linking up national and international grid infrastructures.

The mission of the WLCG project is to provide global computing resources to store, distribute and analyse the ~30 Petabytes (30 million Gigabytes) of data annually generated by the LHC. The CoEPP research computing team provides grid-connected storage and computing resources via its ATLAS Tier 2 grid site.

"It's a very exciting time for physicists. The Higgs boson discovery is a milestone for the physics community, and for human understanding of the fundamental laws that govern the Universe. As scientific discoveries go, this is up there with finding a way to split the atom. Australian research groups have been part of this for the best part of 25 years," says CoEPP Director Professor Geoffrey Taylor.

THE ROLE OF NETWORKING

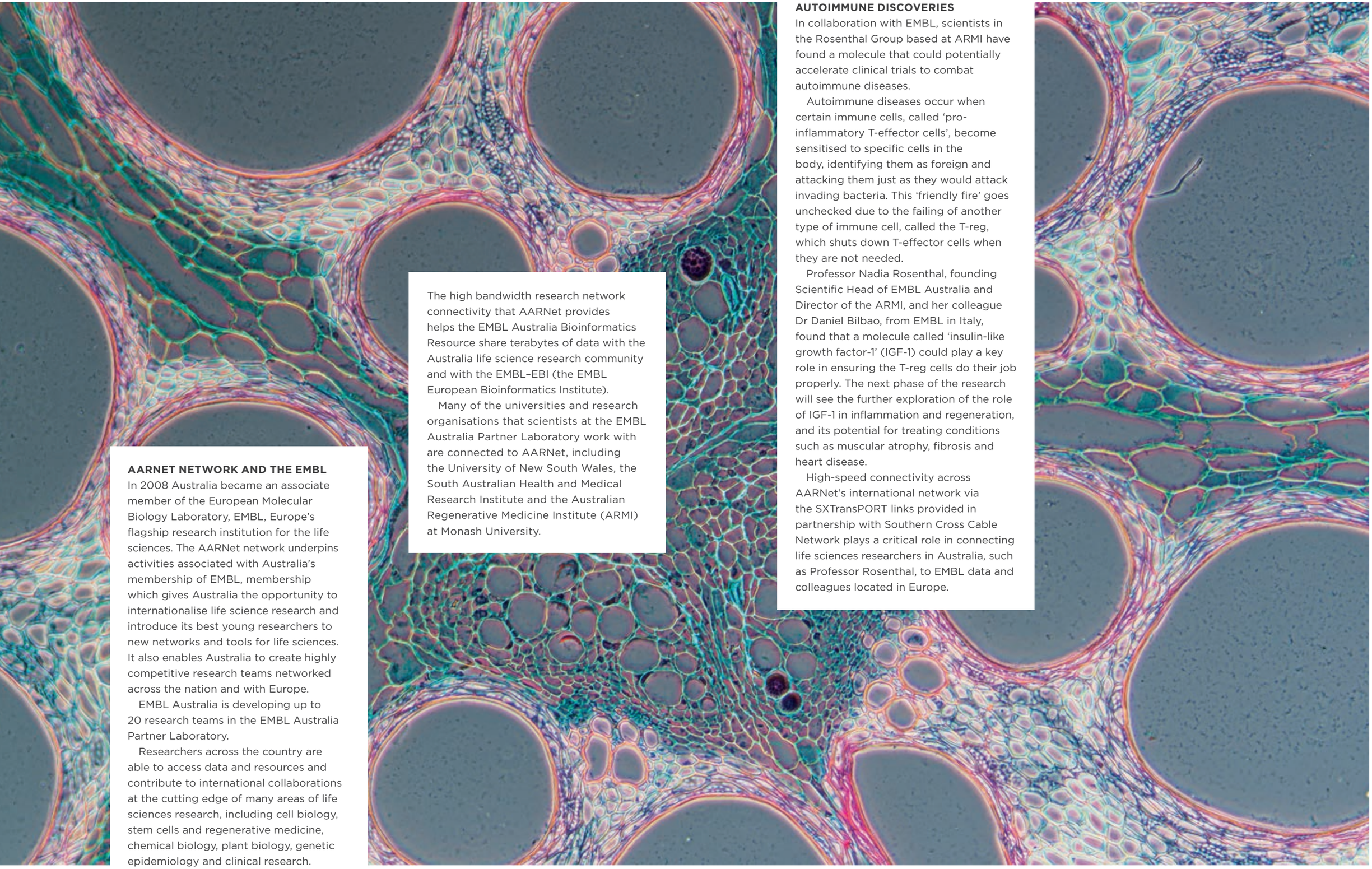
"The site's high availability and reliability has been achieved as a direct consequence of the stellar performance of the underpinning network connectivity between the AARNet and corresponding WLCG Tier 1 site at TRIUMF (Canada's national laboratory for particle and nuclear physics) across the AARNet Southern Cross Cable Network trans-Pacific SXTransPORT link. Sustained transfer rates of High Energy Physics data sets greater than 7Gbps between North America and Australia are not uncommon," says Professor Taylor.

AARNet provided CoEPP connectivity to the WLCG during the famous first run of the LHC and now for its second run, where even greater demands are placed on the underlying computing infrastructure. Dr Taylor says greater network bandwidths to Australia will be crucial in order for CoEPP to continue to provide meaningful contributions to the computational power needed for the physics analyses.

As CoEPP continues to achieve international recognition for Australia in the field of high-energy physics, its collaborative capacity and contribution to worldwide projects relies ever more on the capabilities of the networking infrastructure connecting Australian researchers and resources to the world.

Life Sciences

Moving terabytes of data for EMBL Australia



AARNET NETWORK AND THE EMBL

In 2008 Australia became an associate member of the European Molecular Biology Laboratory, EMBL, Europe's flagship research institution for the life sciences. The AARNet network underpins activities associated with Australia's membership of EMBL, membership which gives Australia the opportunity to internationalise life science research and introduce its best young researchers to new networks and tools for life sciences. It also enables Australia to create highly competitive research teams networked across the nation and with Europe.

EMBL Australia is developing up to 20 research teams in the EMBL Australia Partner Laboratory.

Researchers across the country are able to access data and resources and contribute to international collaborations at the cutting edge of many areas of life sciences research, including cell biology, stem cells and regenerative medicine, chemical biology, plant biology, genetic epidemiology and clinical research.

The high bandwidth research network connectivity that AARNet provides helps the EMBL Australia Bioinformatics Resource share terabytes of data with the Australia life science research community and with the EMBL–EBI (the EMBL European Bioinformatics Institute).

Many of the universities and research organisations that scientists at the EMBL Australia Partner Laboratory work with are connected to AARNet, including the University of New South Wales, the South Australian Health and Medical Research Institute and the Australian Regenerative Medicine Institute (ARMI) at Monash University.

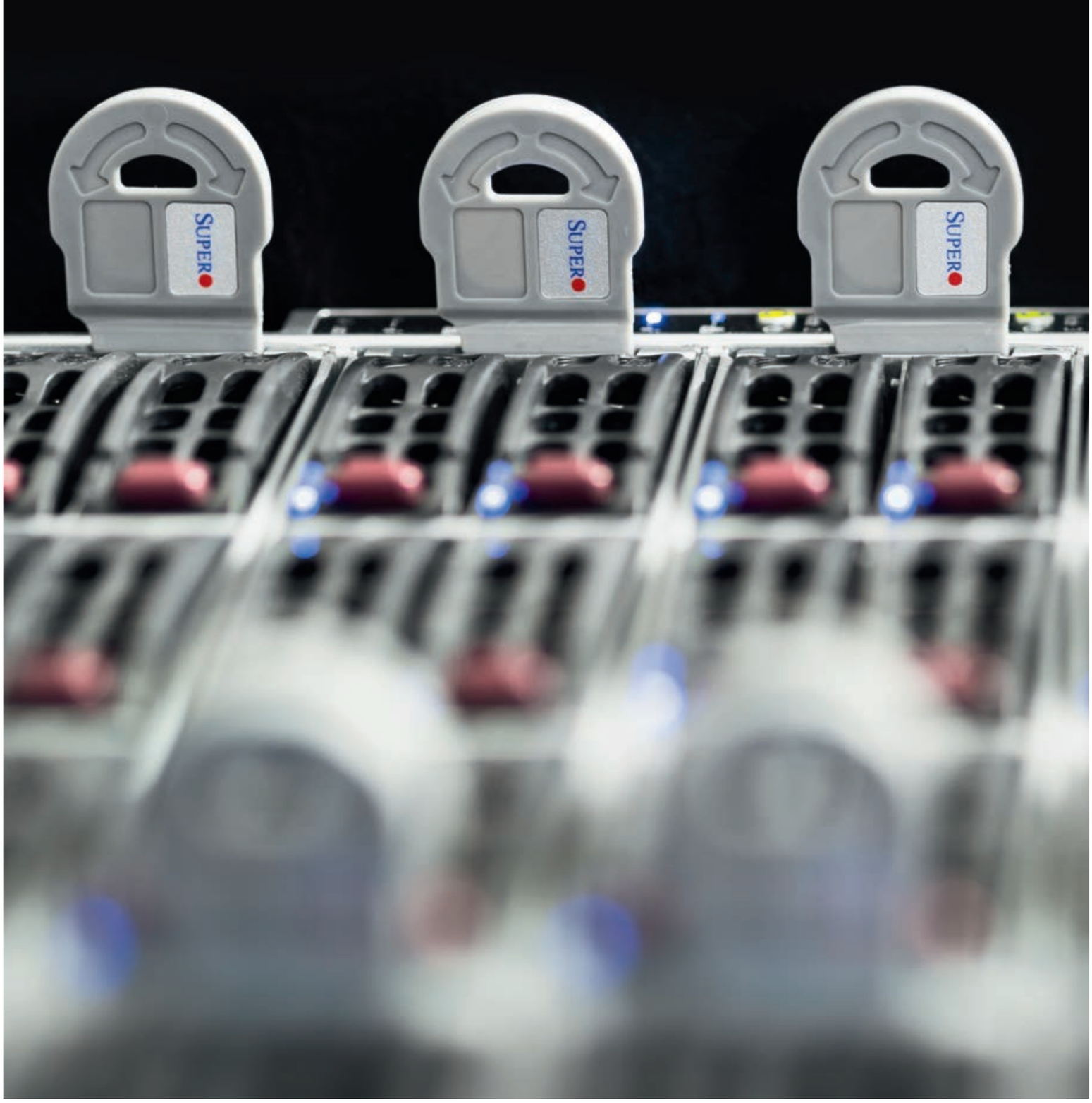
AUTOIMMUNE DISCOVERIES

In collaboration with EMBL, scientists in the Rosenthal Group based at ARMI have found a molecule that could potentially accelerate clinical trials to combat autoimmune diseases.

Autoimmune diseases occur when certain immune cells, called 'pro-inflammatory T-effector cells', become sensitised to specific cells in the body, identifying them as foreign and attacking them just as they would attack invading bacteria. This 'friendly fire' goes unchecked due to the failing of another type of immune cell, called the T-reg, which shuts down T-effector cells when they are not needed.

Professor Nadia Rosenthal, founding Scientific Head of EMBL Australia and Director of the ARMI, and her colleague Dr Daniel Bilbao, from EMBL in Italy, found that a molecule called 'insulin-like growth factor-1' (IGF-1) could play a key role in ensuring the T-reg cells do their job properly. The next phase of the research will see the further exploration of the role of IGF-1 in inflammation and regeneration, and its potential for treating conditions such as muscular atrophy, fibrosis and heart disease.

High-speed connectivity across AARNet's international network via the SXTransPORT links provided in partnership with Southern Cross Cable Network plays a critical role in connecting life sciences researchers in Australia, such as Professor Rosenthal, to EMBL data and colleagues located in Europe.



SDN Testbed

Building more intelligent networks

THE AUSTRALIA WIDE-AREA SDN TESTBED

Established by AARNet in collaboration with nine universities and CSIRO Data61, the Australia Wide-Area SDN Testbed is an innovation platform for developing high-speed technologies.

Software Defined Networking (SDN) is an emerging technology with the potential to revolutionise the way networks are provisioned and managed. SDN offers solutions for improving network flexibility and reducing costs via software-based management and control.

The programmability of SDN promises to make networks more dynamic, for example, able to respond to changing conditions such as congestion or link failure.

At its core, SDN is about abstracting lower level networking functionality (hardware and control) from higher level applications and operating systems. This abstraction enables smarter application design and better integration across cloud service providers, while those applications and service providers remain agnostic to the hardware running the network underneath them.

Based on open standards, the Testbed infrastructure consists of a core of four interconnected NoviFlow OpenFlow-enabled switches at AARNet backbone sites in Sydney, Melbourne, Perth and Seattle controlled by virtual machines in Sydney and Melbourne.

SDN equipment installed at CSIRO Data 61 and participating universities (University of New South Wales, University of Technology Sydney, Macquarie University, University of Adelaide, Royal Melbourne Institute of Technology, Swinburne, University of Queensland, University of Wollongong and Australian National University) is interconnected by AARNet to create a national wide-area SDN testbed environment with the ability to peer with similar testbeds in the USA and Europe.

INTERNATIONAL CONNECTIVITY

The Seattle presence enables AARNet to interconnect the testbed with similar testbeds operated by Internet2 and ESnet research networks in the United States, as well as with the global OpenFlow network facility recently deployed by ON.LAB, boosting opportunities for Australian researchers to run experiments with their US-based counterparts.

International connectivity to Seattle is provided by AARNet in partnership with Southern Cross Cable Network via the SXTransPORT submarine optical fibre links.

“Connecting to Seattle enables us to examine network behaviour at genuine intercontinental scale, and will enable us to explore how and if SDN works across progressively larger geographical areas and to examine ways we can make more efficient use of our international links,” says AARNet Chief Technology Officer David Wilde.

“This is about building a network that can more intelligently shift connect compute resources to data storage, or move data without taking congestion paths.”

Food Security

Tackling the problem of feeding the world

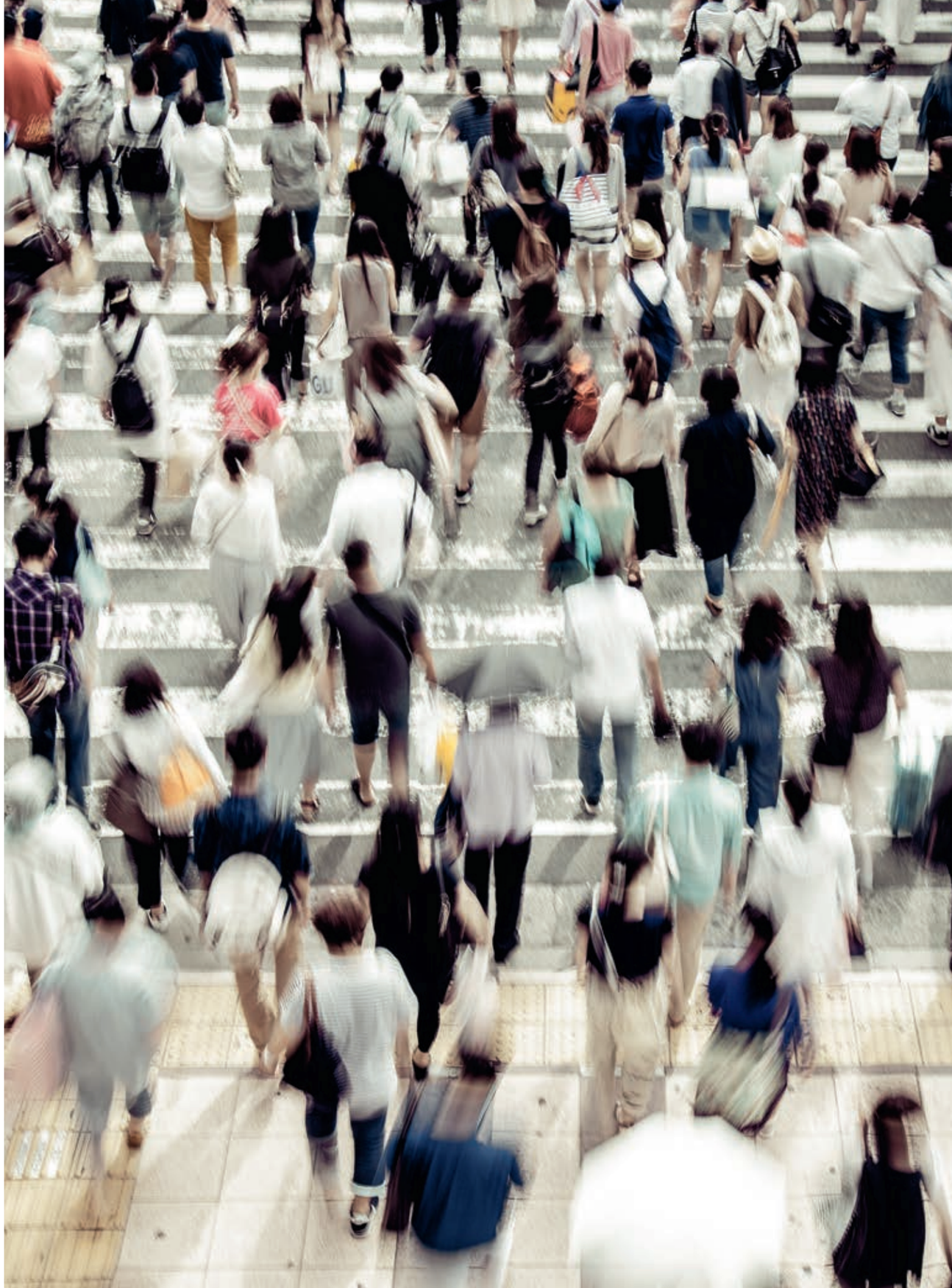
Feeding the world's growing population is one of society's greatest challenges.

According to the Food and Agriculture Organisation of the United Nations, food security exists when "all people at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life."

In the world today, there are three interconnected threats to food security: the human population and per capita consumption of food is on the rise; land, water and other agricultural resources are in limited supply; and environmental conditions are increasingly unpredictable.

The AARNet network underpins the work of Australian scientists contributing to global interdisciplinary research efforts aimed at finding solutions for mitigating these threats and future proofing food production for Australia and the world.

Australian scientists are contributing to developing plants that are able to efficiently obtain the resources provided by nature and by farmers, particularly in harsh and changing environments, in order to generate greater yields. For example, they are working on wheat, which is one of the most important staple crops, providing a fifth of the daily calories in human diets.



RAISING THE YIELD POTENTIAL OF WHEAT

Australian Research Council (ARC) Centre of Excellence in Plant Energy Biology researchers at the Australian National University, University of Western Australia and University of Adelaide are participating in a project to address a key component of a global future food security solution by attempting to increase the energy efficiency of wheat. This research forms part of the International Wheat Yield Partnership (IWYP) plan, a collaboration between G20 nations, to raise the genetic yield potential of wheat by up to 50% by 2020.

Working with ARC Centre of Excellence for Translational Photosynthesis researchers and scientists from the International Maize and Wheat Improvement Centre in Mexico, the team is using a novel approach that combines cutting edge molecular techniques with traditional breeding. They are aiming to exploit the energy systems of wheat plants to dramatically improve their yield.

CONNECTING RESEARCHERS ACROSS THE GLOBE

AARNet's trans-Pacific interconnect to the global network of research and education networks, provided in partnership with Southern Cross Cable Network, removes the barrier of distance for researchers working on the IWYP project and other collaborative initiatives.

"With the world's population estimated to reach 9.6 billion by 2050, making staple foods - wheat, grains and rice - higher yielding, more resilient to climate variability and also more nutritious is vital. We can't delay. Collaboration on a global scale is needed to have those three producing the bulk of the food in the world, or there'll be problems," said researcher Professor Barry Pogson from the ARC Centre of Excellence in Plant Energy Biology and Chair of the Global Plant Council.

The Centre's international partners also include the Max-Planck Institute for Molecular Plant Physiology in Germany and the Salk Institute for Biological Studies in the United States, among other leading research organisations worldwide. These partners share the aim of improving the sustainable productivity of plants to help meet the world's demand for food into the future.

Climate Science

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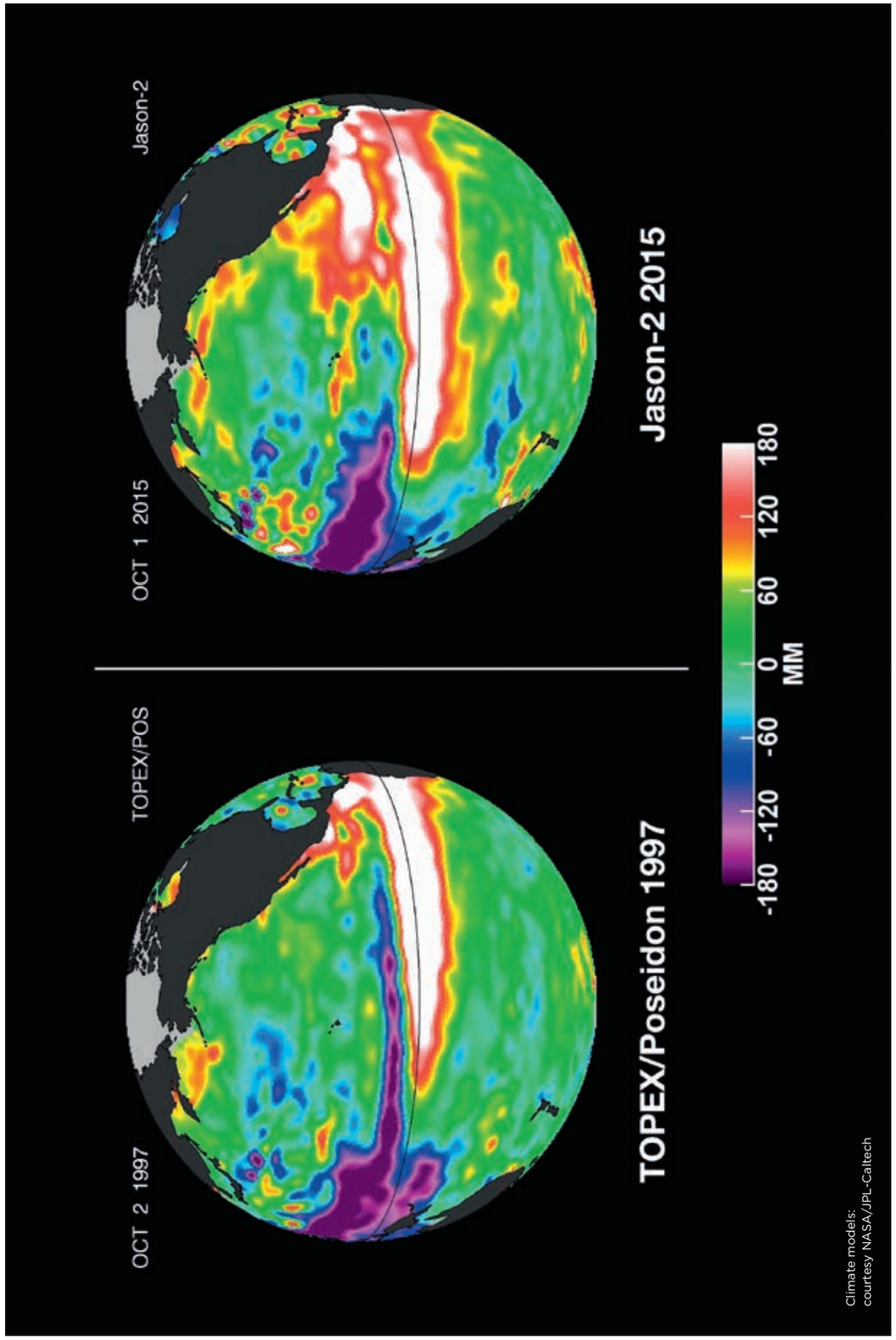
Modelling the impact of climate change



Climate models:
courtesy NASA/JPL-Caltech

CLIMATE MODELLING RESEARCH

Climate modelling research has always been an international collaborative effort, particularly in the area of evaluating climate models, and Australian climate scientists have made significant contributions to the field over many years.

Climate is a complex system, involving the atmosphere, land, oceans, rivers and lakes, snow and ice, and living things, powered by the sun. Climate models use quantitative methods to simulate the interactions between these various components of the Earth's climate system. They are used to project future climate and to understand and predict the impact of human activities on climate.

Australian climate scientists have participated in a number of coordinated assessments of the performance of climate models. These have fed into the intergovernmental assessments undertaken through the United Nations Intergovernmental Panel on Climate Change (IPCC).

For these co-ordinated assessments, the World Climate Research Program Coupled Model Intercomparison Project designed a series of experiments and data archives for the simulations the experiments produced.

EARTH SYSTEM GRID FEDERATION

To manage the ever-increasing terascale volumes of data from these experiments, and to support climate and environmental science in general, the Earth System Grid Federation (ESGF) was established. ESGF nodes are distributed across the globe and are interconnected by high performance research networks.

The ESGF allows scientists to easily access data and analyse models in not only their own countries but in other countries. For example, scientists in Australia, and all over the world, are able look at a range of features, phenomena and events across all the available climate models to see how well the models simulate El Niño, or rainfall, in Australia.

The ESGF node in Australia is located at the National Computational Infrastructure (NCI) at the Australian National University.

Australia's past and future contributions to assessments for the IPCC rely on AARNet. Since 2008, data has been transferred between NCI and the ESGF node at the Lawrence Livermore National Laboratory in California via the AARNet Southern Cross Cable Network SXTransPORT links to the United States.

"Access to a reliable, high bandwidth trans-Pacific network is vital for enabling Australian scientists to participate in climate modelling research. Massive amounts of data need to be moved around the world and synchronised and if we didn't have the confidence in the AARNet network we couldn't participate," said Dr Ben Evans, Associate Director NCI.

Health & Medicine

Improving how complex diseases are treated

AARNet-connected research institutions are making significant contributions to advancing health and medical research in Australia and globally.

In the field of genomics, global research initiatives are generating new insights into the genetic causes of diseases such as cancer, diabetes, heart disease, and congenital disorders, and promises to transform healthcare.

The Garvan Institute of Medical Research is home to the Kinghorn Centre for Clinical Genomics, the largest genome sequencing centre in the southern hemisphere. A specialised high capacity network, designed by AARNet in collaboration the University of New South Wales and The Garvan, connects the Centre to computing resources and researchers located in Australia and overseas.

"There are more than 70 Garvan bioinformaticians working with local and international collaborators on genomic data, and we have mind-bogglingly large amounts of genomic information that needs to be moved over the AARNet network for analysis and storage at the NCI (National Computational Infrastructure) supercomputing facility in Canberra. The volume of data is increasing exponentially so we require a scalable network to meet our needs into the future," said Dr Warren Kaplan, Garvan's Chief of Informatics.

"The reality is, we at Garvan are moving towards being very connected to the world and we see AARNet as the provider of the underlying fabric that makes it all happen."

FORGING NEW FRONTIERS IN NEUROSCIENCE RESEARCH

The AARNet network underpins the work of researchers at the Queensland Brain Institute based at the University of Queensland, who have contributed to the discovery of three new genes underlying neurological and psychiatric disorders.

Professor Naomi Wray from the Institute's Centre for Neurogenetics and Statistical Genomics is involved in international collaborations that involve complex analyses of millions of DNA data points on tens of thousands of people.

"New laboratory technologies of recent years generate huge volumes of genetic data which have led to new understandings for complex and debilitating disorders." Professor Wray said. "Samples are collected from research across the globe, but analyses are conducted in a central analytical lab such as ours," she added.

For many years, access to AARNet has helped scientists such as Professor Wray contribute to international research efforts that advance the understanding and treatment of neurological diseases and mental illness.

BRINGING SCIENTISTS TOGETHER TO TACKLE BIG QUESTIONS

Through collaborations with Australia's leading experts in bioengineering, nanotechnology, stem cell biology, advanced molecular analysis and clinical research, the Stem Cells Australia (SCA) initiative has enhanced Australia's global impact in the field of stem cell research.

SCA was established in 2011 by the University of Melbourne, Monash University, University of Queensland, University of New South Wales, Walter and Eliza Hall Institute, Victor Chang Cardiac Research Institute, Florey Neuroscience Institute and the Commonwealth Scientific and Industrial Research Organisation.

Funded by the Australia Research Council, SCA focuses on exploring the fundamental mechanisms involved in stem cell regulation and differentiation, and translating this knowledge into innovative biotechnological and therapeutic applications.

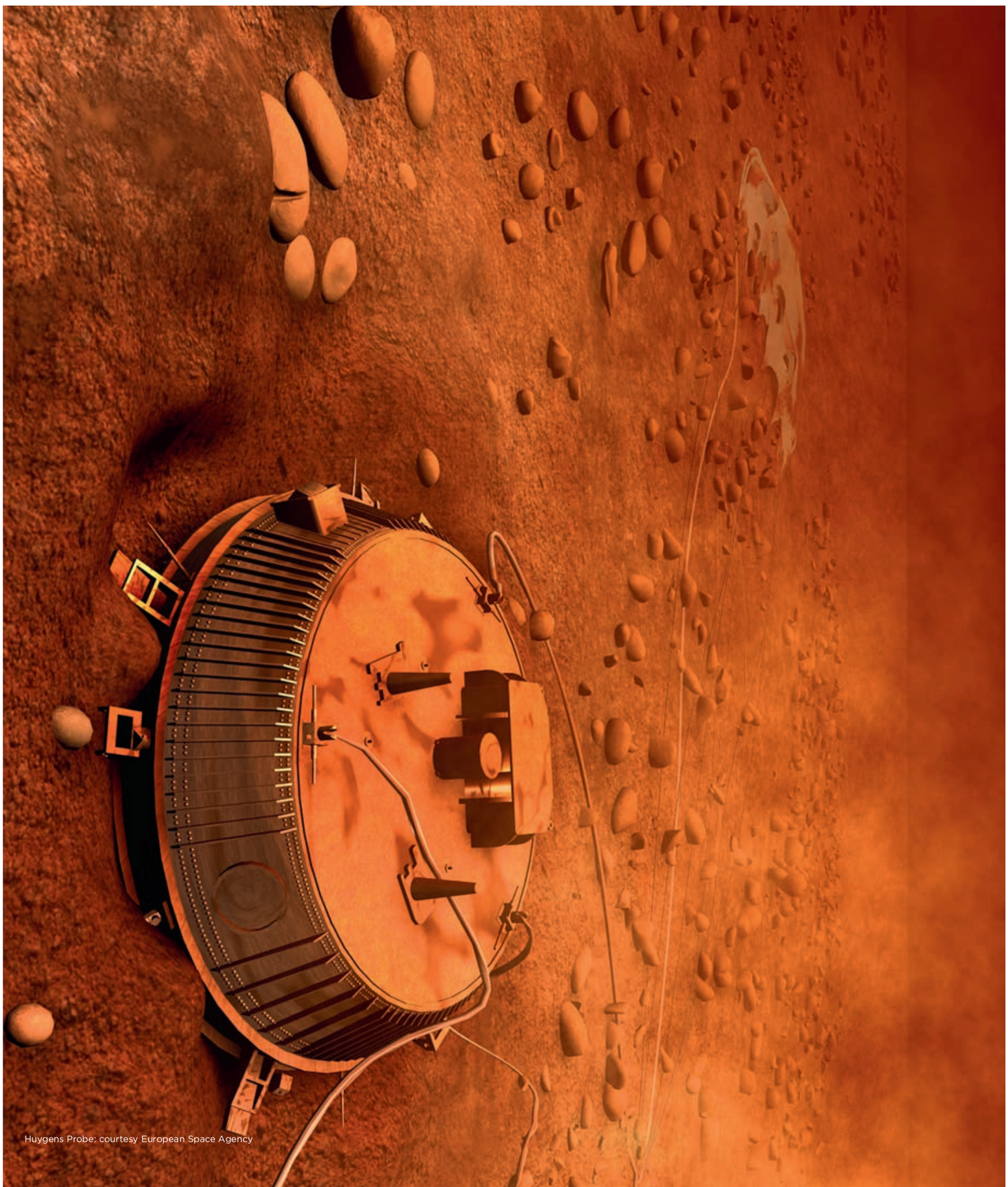
SCA research is driven by international partnerships and collaborations and the volume of data being generated, collected and analysed continues to grow.

AARNet is instrumental in facilitating these collaborations by providing reliable high capacity network infrastructure to connect member universities and many other national and international research partners.

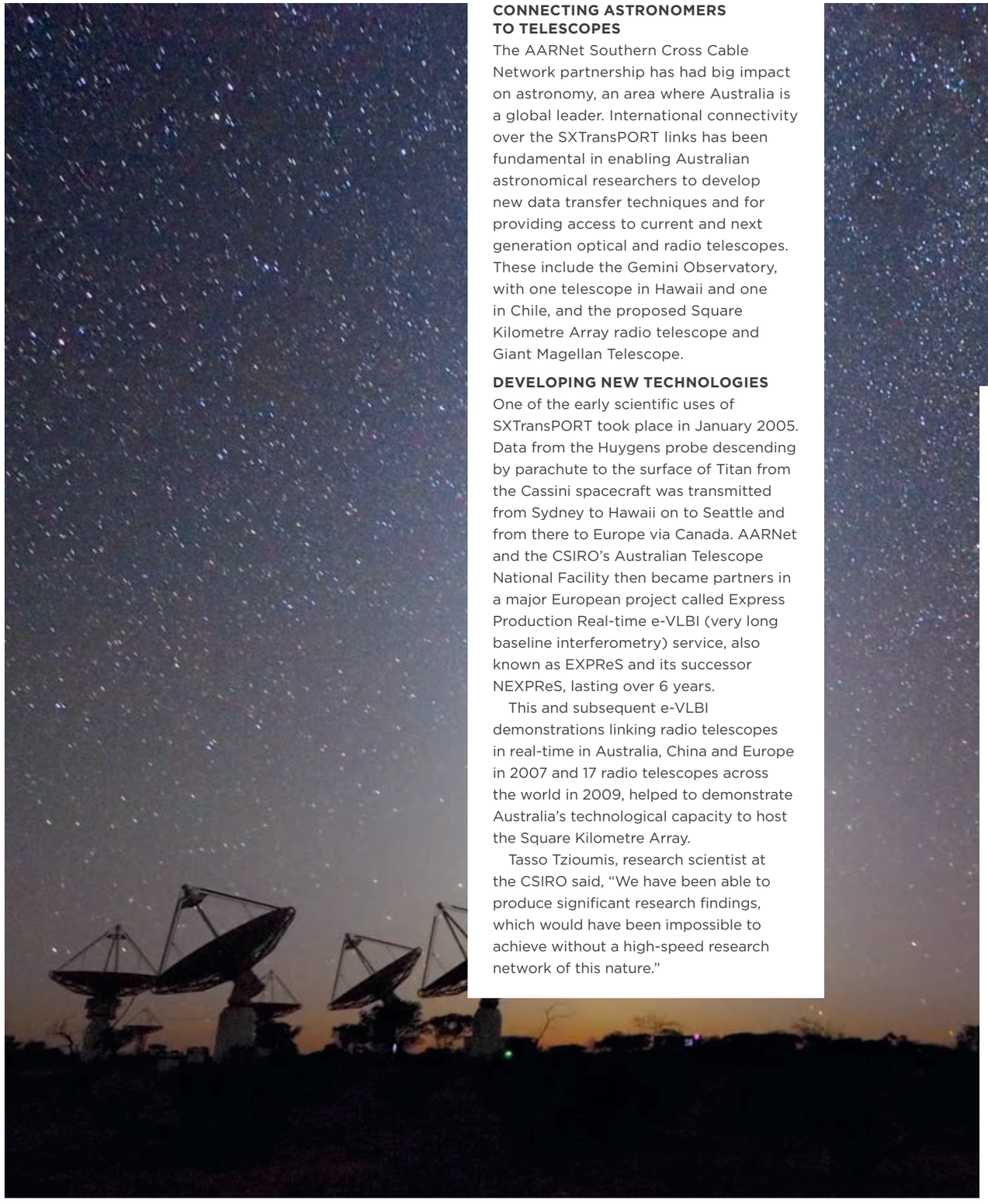
The trans-Pacific connection to the United States, operated in partnership with the generous support of Southern Cross Cable Network, is AARNet's most important international service, enabling Australian researchers to compete globally, and opening up new and innovative research possibilities for improving health outcomes for all people.

Astronomy

Exploring mysteries of dark energy, gravity and life elsewhere



Huygens Probe: courtesy European Space Agency



CONNECTING ASTRONOMERS TO TELESCOPES

The AARNet Southern Cross Cable Network partnership has had big impact on astronomy, an area where Australia is a global leader. International connectivity over the SXTransPORT links has been fundamental in enabling Australian astronomical researchers to develop new data transfer techniques and for providing access to current and next generation optical and radio telescopes. These include the Gemini Observatory, with one telescope in Hawaii and one in Chile, and the proposed Square Kilometre Array radio telescope and Giant Magellan Telescope.

DEVELOPING NEW TECHNOLOGIES

One of the early scientific uses of SXTransPORT took place in January 2005. Data from the Huygens probe descending by parachute to the surface of Titan from the Cassini spacecraft was transmitted from Sydney to Hawaii on to Seattle and from there to Europe via Canada. AARNet and the CSIRO's Australian Telescope National Facility then became partners in a major European project called Express Production Real-time e-VLBI (very long baseline interferometry) service, also known as EXPReS and its successor NEXPReS, lasting over 6 years.

This and subsequent e-VLBI demonstrations linking radio telescopes in real-time in Australia, China and Europe in 2007 and 17 radio telescopes across the world in 2009, helped to demonstrate Australia's technological capacity to host the Square Kilometre Array.

Tasso Tzioumis, research scientist at the CSIRO said, "We have been able to produce significant research findings, which would have been impossible to achieve without a high-speed research network of this nature."

THE SQUARE KILOMETRE ARRAY PROJECT

The Square Kilometre Array (SKA) project is an ambitious global scientific and engineering project to build the world's largest and most sensitive radio telescope co-located in remote desert regions of southern Africa and Western Australia. Australia and New Zealand collaborated to establish the SKA candidate site in Western Australia and also to build the Australian SKA Pathfinder (ASKAP) telescope now located there.

The SKA project is currently in the design and pre-construction phase. More than 250 scientists and engineers from 18 countries and nearly 100 institutions, universities and industry are involved in 'work packages' for different elements of the design. AARNet is working with CSIRO in Signal and Data Transport.

When the SKA is operational, hundreds of thousands of antennas will hugely increase the ability of astronomers to explore the far reaches of the universe and address mysteries around dark energy, gravity and life elsewhere.

To enable Australia's participation in the SKA project, AARNet expanded its network across the Nullabor, from Adelaide to Perth and on to the Murchison Radio Observatory (MRO), the future home of the SKA in remote outback Western Australia. The newly deployed Australian Government-funded terrestrial network is capable of transmission speeds of up to 8 Terabits per second.

To develop technologies for the SKA, two precursor telescopes, the ASKAP and the Murchison Widefield Array (MWA), have been built and are now operating at the MRO. The ASKAP is an innovative new radio telescope consisting of 36 identical 12-metre wide dish antennas. The ASKAP uses revolutionary Phased Array Feed technology, developed in Australia by CSIRO, to survey the sky with a much wider field of view. The MWA is a collaboration between institutions in Australia, India, New Zealand and the United States. A key aspect of the telescope is that all the individual dishes will be used together to form one huge 'virtual telescope', using interferometric techniques similar to VLBI.

AARNet interconnects the telescopes at the MRO with the Pawsey supercomputing facilities in Perth for the computer processing required to extract useful information from the signals. Fast reliable research network connectivity is critical for processing the deluge of data generated from the new radio telescopes. Astronomers from around the world are dependent on international connectivity over the SXTransPORT network for accessing these new telescopes and other telescopes that are part of the Australian Telescope National Facility.

ASKAP: courtesy Alex Cherney/Terrastro

Looking ahead

International collaboration is a fundamental tenant of modern research and the volume of data being generated, collected and analysed will continue to grow in leaps and bounds. Global science projects such as the Large Hadron Collider and the Square Kilometre Array will continue to depend on scalable interconnectivity between research and education networks around the world for their science outcomes, as will international collaborations such as the European Molecular Biology Laboratory and the Earth System Grid Federation. The ongoing partnership between AARNet and Southern Cross Cable Network will ensure Australia's participation in the open exchange of data to support the planet's research and education challenges.

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