University of South Australia

Institute for Telecommunications Research

Connected. Reliable. Real Solutions.

Annual Report 2010

Vision

Advancing human knowledge in the transmission, processing and use of information, enabling high impact technologies that deliver economic, social, cultural, environmental and health benefits.

Mission

To conduct world class fundamental research, partnered with industry, to deliver leading edge technologies in a vibrant research education environment.

Values

Technology transfer
Leveraging basic research outcomes, we value the applied and experimental development of new technologies and delivery to market in partnership with industry.

International
We value researchers and research outcomes that are internationally renowned and we conduct our business on the international stage.

Engagement
We engage internationally and locally with end users, industry, government agencies, and like-minded research organisations.

Collaboration
We value multidisciplinary collaborative research leading to outcomes far beyond what we can achieve on our own.

High quality research
We value internationally competitive research, undertaken by active researchers at the forefront of their fields.

Education
We believe that our highest value and longest lasting achievements are delivered through high quality, industry-relevant education and training of higher degree students, engineers and staff.

Impact and benefit
We expect our research outcomes to have high impact and to deliver benefit to society.

End user context
We value breakthrough fundamental research that enables new technologies, applications and commercialisation opportunities.

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Director's Report

2010 was a momentous year for the Institute for Telecommunications Research (ITR), with the commencement of several large-scale programs of research.

ITR was awarded close to $5 million under the Australian Space Research Program as lead institution for work towards a National Space-Based Wireless Sensor Network. This project, worth over $12 million, brings together a strong international industry focussed consortium to design a new low earth orbit microsatellite system to provide cost-effective two-way communications to remote sensors and devices. Leveraging ITR's strengths in software defined radio (SDR), the project will deliver an innovative flight-ready SDR payload capable of supporting multiple applications. As the largest single project conducted at ITR since the days of the Cooperative Research Centres for Satellite Systems (CRCSS), this signals a bright future for ITR and for space research in Australia.

In other space-related activities, in addition to continuing our daily reception services for the SPOT satellites, ITR provided tracking services for the SpaceX NASA COTS Demo 1 launch (maiden flight of the Dragon spacecraft, on a Falcon 9 launch vehicle). We look forward to early 2011, when ITR is scheduled to contribute to the tracking network for the second Autonomous Transfer Vehicle (ATV2 Kepler) launch to the International Space Station.

Another highlight of 2010 was our strong result In the Australian Research Council (ARC) Excellence in Research for Australia (ERA) exercise. ITR has a long history of high-quality basic research leading to high-impact, commercially valuable outcomes. ITR research outputs contributed strongly to the area of Electrical and Electronic Engineering at UniSA, which was awarded a ranking of "4, above world standard". ITR increased its total publication outputs by 30% and simultaneously increased the proportion of papers published in the top-ranked A* and A journals to 81%.

2010 saw the commencement of two major ARC-funded Discovery Projects: A five-year project, Communication and Information Storage Mechanisms in Complex Dynamical Brain Networks, including a prestigious Australian Research Fellowship for Dr Mark McDonnell, and Robust Transmission, Identification and Key Agreement in Communications Networks, including an Australian Postdoctoral Fellowship awarded to Dr Siu-Wai Ho.

In the area of High Speed Communications, ITR continued development of highly innovative Free Space Optical (FSO) systems, including the establishment of a 12km hybrid microwave/FSO test range and a 2 Mbit/s FSO codec.

ITR, in collaboration with spin-off Cohda Wireless, commenced a major trial of Dedicated Short Range Communications in a project funded by the South Australian Motor Accident Commission.

Two new staff joined us in 2010. Dr Jahangir Hossain (who joined us from Institut National de la Recherche Scientifique, Canada), and Associate Professor Kutlu Dogancay, who joined ITR as an Institute member under the UniSA framework of cooperation between ITR and the School of Electrical and Information Engineering. Dr Ingmar Land was promoted to Senior Research Fellow. Strong growth in student numbers continued into 2010. Twelve new graduate students commenced during 2010 (compared to seven in 2009).

The Institute has always been an energetic research environment, and these major new programs commencing in 2010 certainly raise the intensity of activity. It is without doubt an incredibly exciting time to be at ITR.

Professor Alex Grant
Director ITR

Advisory Board Report

2010 proved to be another successful year for the Institute with its portfolio of world class fundamental research, applied research strongly supported by industry partners, both nationally and internationally, and a growing postgraduate student environment.

During 2010 the ITR Advisory Board reviewed the constitution of the Board. The Board adopted the approach to expand its representation to include key industry sector and government leaders.

The Institute has managed to retain its position as a leader in telecommunications research within its area of Satellite Communications, High Speed Data Communications, Flexible Networks and Computational and Theoretical Neuroscience.

ITR focused on increased business development and collaborative arrangements. As a result, in November 2010, ITR was successfully awarded a $5 million grant for the Australian Space Research Program from the Department of Innovation, Industry, Science and Research.

It has been an exciting year at the ITR and I look forward to continuing as Chairman of the Advisory Board and to the Institute's continued growth.

Neil Bryans
Chairman ITR Advisory Board

25 Year Anniversary

During 2010 the Institute for Telecommunications Research celebrated its 25 year anniversary.

Formally recognised as a University research Institute in 1994, the ITR builds on antecedent organisations going back over 25 years. From humble beginnings, housed in temporary huts hidden behind the Charles Todd building of the then South Australian Institute of Technology Levels Campus, to a nationally and internationally recognised Institute with world-class researchers and facilities, the journey has been remarkable. Today, with over 60 dedicated research staff and students, ITR is Australia's largest University research Institute specialising in the areas of wireless and satellite telecommunications technology.

Since its foundation, the Institute has had a long and proud history of working with local and international industrial, defence and government partners to deliver commercial-grade hardware and software solutions for challenging communications problems. Building strongly on this heritage of applied research and development, the Institute has also emerged as a theoretical powerhouse.

Our research staff and postgraduate students not only work with their international collaborators to tackle the fundamental mathematical aspects of modern telecommunications, they also work together with our highly skilled engineering team to deliver new communications technologies that are only made possible by breakthrough science. This is a unique characteristic of the Institute – strong connections between theory, application and commercialisation.

Our 25th anniversary was a wonderful opportunity to reflect on the successes of our Institute, and to celebrate all of the staff and students that have made it such a special research environment.

Looking forward, the future is exciting! From remote sensing using satellites for climate change and earth resource monitoring through to gigabit indoor wireless communications and saving lives through vehicle-to-vehicle communications, our ultimate focus is to make the world a better place through novel use of information.

"Our 25th anniversary is a wonderful opportunity to reflect on the successes of our Institute…"

Professor Alex Grant, Director ITR

The mathematical and engineering expertise of staff at ITR provides an environment conducive to new ideas and technologies.

Computational and Theoretical Neuroscience

Dr Mark McDonnell
The Computational and Theoretical Neuroscience Laboratory is a grouping of research staff, students and interdisciplinary collaborators hosted at the ITR with the primary aim to explore and explain how electrical and chemical signals are used in the brain to both represent and process information.

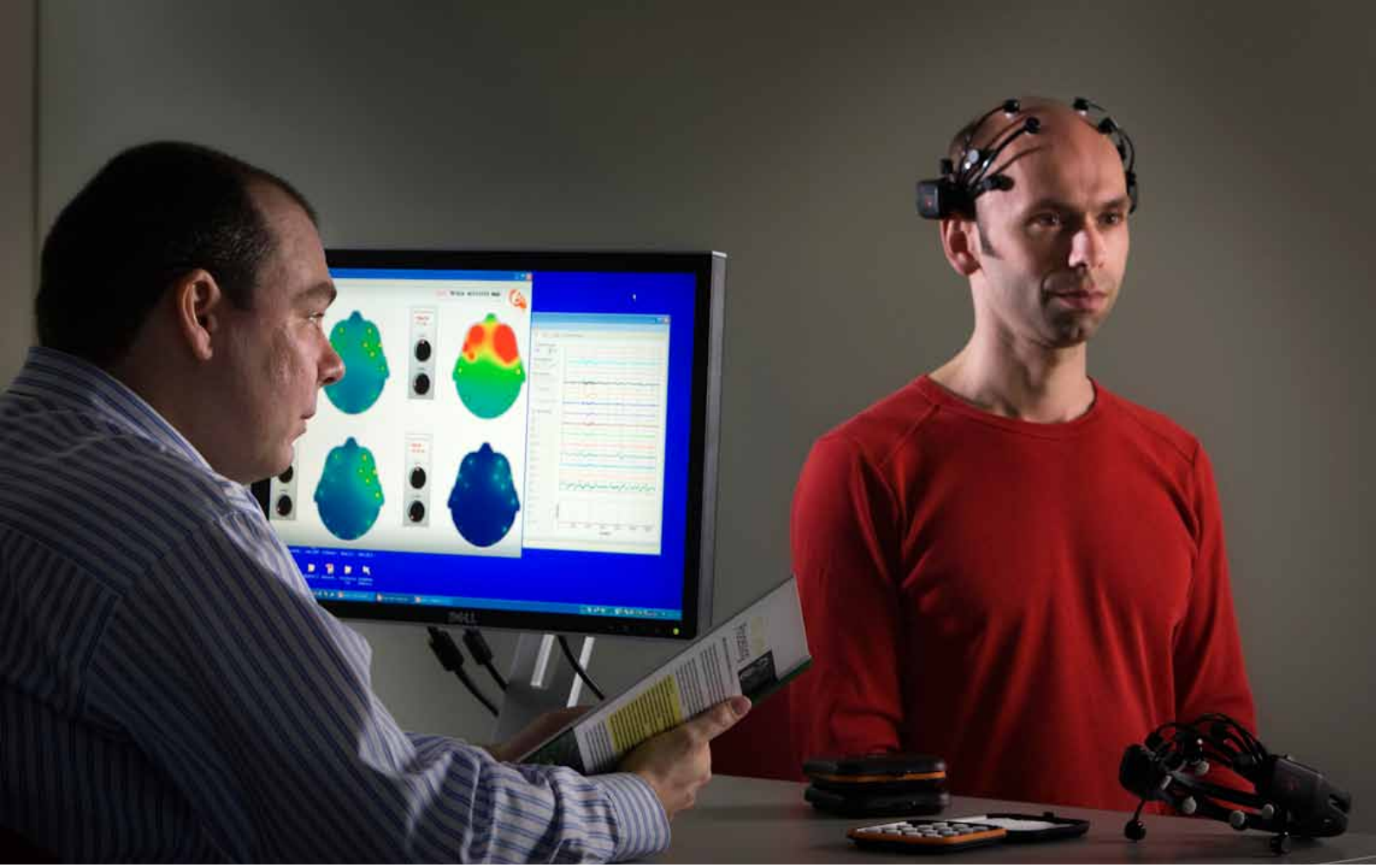
The Lab works collaboratively with experimental neuroscientists and biologists from across the world to provide expertise in mathematical modelling, signal processing and computational techniques, and develops associated research inspired by their projects.

The research applies engineering approaches to answer fundamental scientific questions about information processing in neurobiology. A particular emphasis is on reverse-engineering the biophysical mechanisms exploited by neurons and networks of neurons to "communicate" with each other and to perform computations.

Amongst the many outcomes of the research undertaken, the ultimate aim is to develop new methods for biologically-inspired artificial intelligence.

Key Research Areas
The Laboratory's research aims to achieve the following outcomes::

- Produce mathematical and computational models of biological systems that lead to new knowledge in neuroscience
- Formulate testable hypotheses regarding computation and communication in neural systems
- Design and develop new methods and tools that are useful for model development and hypothesis testing
- Create new biomedical engineering and biologically inspired technology.



2010 Achievements

Laboratory Principle Investigator, Dr Mark McDonnell commenced an ARC Discovery Project that included a five-year Australian Research Fellowship.

Titled "Communication and information storage mechanisms in complex dynamical brain networks", the project will focus on the repetitive oscillations that are often observed in measurements of brain signals.

While mathematical approaches have discovered how these oscillations arise in brain networks from complex interactions between large numbers of neurons, their role in brain function remains a largely unresolved and fundamentally important question.

A novel approach will assess the hypothesis that oscillations allow communication of information between separate brain regions.

Mathematical and computational models of modulation and memory storage/ retrieval in oscillatory brain networks will be produced, and assessed using communications- engineering metrics. Findings will potentially lead to innovative ideas for future medical bionics and brain machine interfaces.

Other highlights for the Laboratory included the publication of three refereed journal papers and one refereed conference paper, and the commencement of new PhD student Sean Wong.

The Laboratory continues to harness and expand its extensive collaborative links both within Australia and internationally. In support of these, visits by Professor Lawrence Ward, University of British Columbia Canada, Mr Ashutosh Mohan, Australian National University, and Mr Felix Li, University of Melbourne, were highlights of the year.

Dr McDonnell also visited and worked with collaborators at Australian National University, University of Melbourne and Flinders University, as well as presented at the International 2010 Neural Coding conference, Cyprus, and Cochlear Ltd in Sydney.

Personnel at the Laboratory included two PhD students (Brenton Prettejohn and Sean Wong), an international research intern (Alexey Moroz, of Moscow Institute of Physics and Technology), five honours students and two casual research assistants.

Flexible Networks

Associate Professor Linda Davis

Communications and sensor networks are becoming ubiquitous, demanding versatile and flexible communications technologies to underpin commercial, defence and specialised applications. These include:

» Data transfer and internet browsing
» Defence communications and surveillance
» Emergency services deployment
» Network security
» Remote sensing
» Voice communications.

Key Research Areas

The overarching purpose of flexible networks is to deliver seamless interconnectivity for the user and simple, scalable and sustainable networks. Drawing on research and engineering expertise in emerging wireless standards, system analysis and simulation, information theory, communication theory, signal processing, protocol design and optimisation, and software and firmware implementation, the flexible networks sector has research, development and commercial projects in:

» Ad hoc and mesh networks
» Cooperative communications
» Cross-layer optimisation
» Flexible and reconfigurable radio implementations
» Hybrid fixed and mobile wireless, satellite and wireline networks
» Power efficient algorithms and architectures
» Routing and security using network coding
» Software defined radio.
» Vehicle-to-vehicle, dedicated short-range communications .

The flexible networks sector of ITR represents a range of pure fundamental and applied research as well as technology development and our challenge is to further integrate these activities going forward. Emerging research topics and technologies of particular interest in 2011 include distributed data compression, passive radar, energy-efficient communications and software-defined radio for satellite and terrestrial systems.

The Flexible Networks sector represents a range of pure fundamental and applied research as well as technology development.

Network Coding for Robust and Secure Data Transmission
Network coding offers new possibilities by replacing routing with coding at the network layer. This approach has the potential to deliver highly robust networks that are impervious to link/node failure, and to simplify the problem of maintaining reliable operation in highly dynamic ad hoc networks. Network coding also has the potential to deliver provably secure network transmission which protects against both eavesdropping and tampering or jamming.

Research in the area of network coding was boosted in 2010 by the commencement of an ARC Discovery Project "Robust Transmission, Identification and Key Agreement in Communication Networks" with Dr Terence Chan, Professor Alex Grant, and their international collaborators, Professor Ning Cai (Xi'an University, China) and Professor Raymond Yeung (Chinese university of Hong Kong). As part of this project Dr Siu-Wai Ho was awarded an ARC Postdoctoral Fellowship. His work is focussing on the foundations of information theory, data security and biometric security and privacy.

The work of Professor Alex Grant, Dr Terence Chan, Dr Badri Vellambi and Dr Roy Timo on the ARC Discovery Project "Efficient Data Transport Using Network Coding" was complemented by research collaboration with Defence Science and Technology Organisation (DSTO). This work has made progress in quantifying the performance gains available via network coding, and to design simple coding strategies for practical implementation.

During 2010, ITR hosted visitors including Associate Professor Stefan Moser (National Chiao Tung University, Taiwan), and Professor Gerhard Kramer (University of Southern California, now at TU Munich).

In 2011 our research will focus on the security aspects of network communications. Specific topics of interests include error-free perfectly secure communication, robust and secure distributed storage network and partial packet recovery.

Software Defined Radio
The South Australian Networking Laboratory (SANLab) projects involved several researchers and engineering staff developing capability in Mobile Ad-hoc Networks (MANET) and their applications. SANLab also connects to ITR's satellite communications sector with the development of the Satellite Network Access Point.

SANLab is primarily funded through the South Australian Premier Science and Research Fund and, through building capability and developing technologies for MANET, assists Defence research and industry in developing innovative and leading edge wireless networking solutions. ITR is in partnership with the Centre for Defence Communications and Information Networking (CDCIN) at the University of Adelaide, BAE Systems, Cisco and the Australian Submarine Corporation (ASC). A key focus for ITR is the development of capability in software-defined radio.

SANLab continued to build ITR's capability in software-defined radio and model-based design using Lyrtech technology. A first phase transceiver design and hardware-in-the-loop demonstration was presented at the 2010 Australian Communication Theory Workshop. Combined with ITR's expertise in reconfigurable radio firmware, ITR's SDR efforts sparked much interest amongst Australian communications and defence industry, resulting in several commercial and consulting projects.

Vehiclular Communications
ITR commenced work in collaboration with Cohda Wireless on a major South Australian on-road trial and demonstration of vehicle-to-vehicle and vehicle-to-infrastructure communications for cooperative road safety and traffic management in 2010. This project, funded by the Motor Accident Commission, was supported by the South Australian Government Department of Transport, Energy and Infrastructure (DTEI).

A fleet of 10 Dedicated Short Range Communications (DSRC) - equipped vehicles will record periodic snapshots of their position, speed, heading and acceleration. This data will be uploaded to roadside equipment located at the DTEI Traffic Management Centre. Snapshots are taken every few seconds and also triggered by events such as heavy braking or stop-start conditions. This information has the potential to provide valuable information about road conditions and traffic flow, congestion, road safety 'black spots', intersection queue lengths and travel times.

On-road demonstrations to be conducted in 2011 will give participants first-hand experience of co-operative safety applications including intersection collision warning, emergency electronic brake light and roadworker alerts.

Research into high-speed data communications focused on new techniques suitable for FSO or hybrid FSO/RF communications.

High Speed Data Communications

Professor Bill Cowley

Research over the last several decades has improved our understanding of how to transmit digital information in the radio frequency (RF) spectrum and, in some cases, it is almost possible to achieve the theoretical limit in spectrum efficiency. Despite these advances, the RF spectrum is becoming increasingly crowded as the demand for higher bandwidth wireless communication services increases. Unguided optical communications, commonly called FSO links, is an emerging method of transmitting data at very high rates. FSO links are receiving increasing attention in high data rate and/or secure communications applications, including satellite, defence and the provision of flexible broadband services.

ITR research into high-speed data communications focused on new techniques suitable for FSO or hybrid FSO/RF communications. In addition, we continued to support the Earth Resource Satellite Demodulator (ERSDEM) product.

Free Space Optical Communications

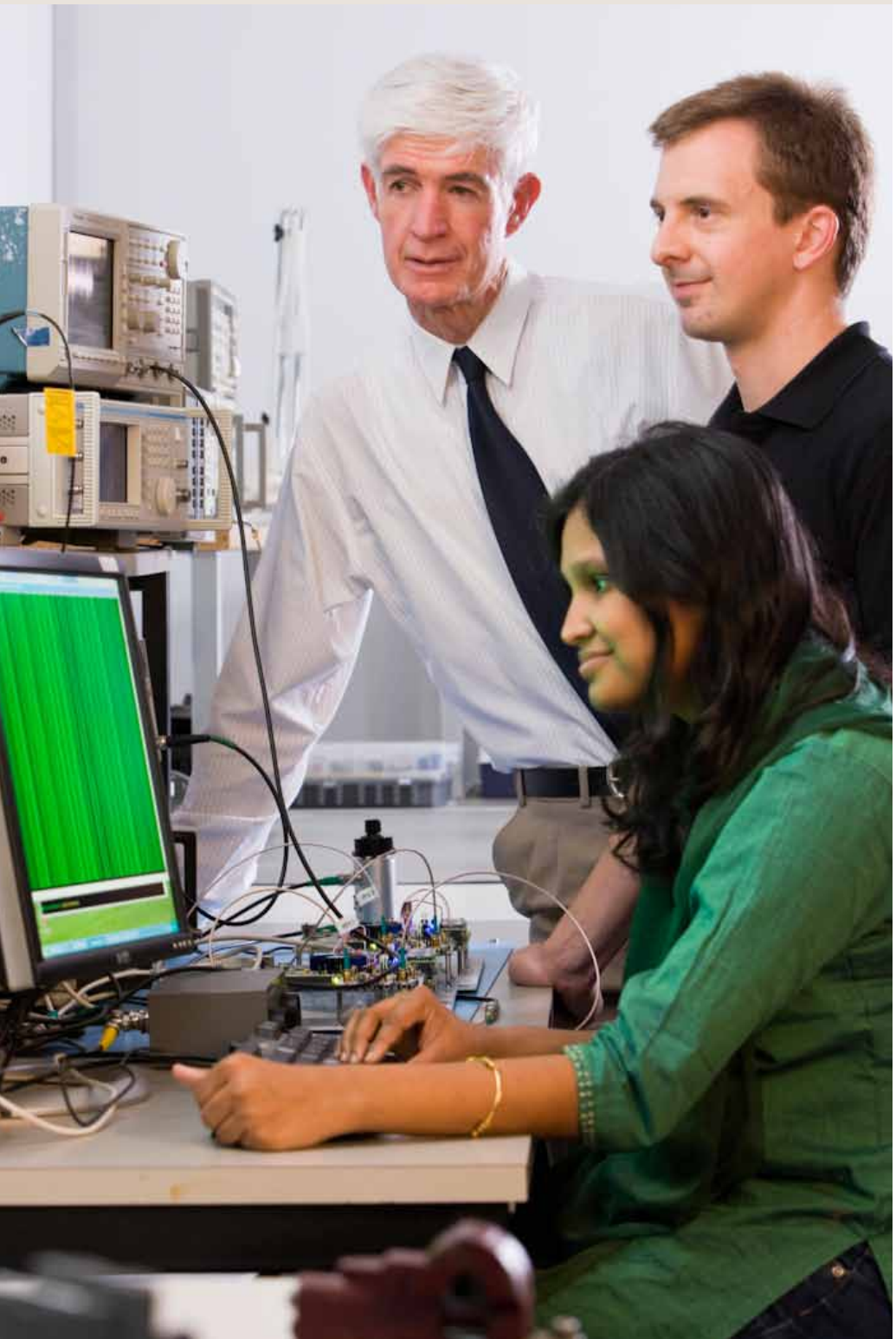
In 2010 we continued a research project started in 2009, "Channel Coding for High-Speed Free-Space Optical and Radio Frequency Communications", funded by The Sir Ross and Sir Keith Smith Fund and Cisco Systems. This project includes collaboration with DSTO and the German Aerospace Agency (DLR), plus former ITR Research Fellow Dr Albert Guillen i Fabregas from Cambridge University. Along with several ITR staff, three postgraduate students worked on FSO topics this year.

While FSO links have great potential for both terrestrial and satellite broadband communications, they are affected by atmospheric scintillation and poor weather such as clouds and fog. ITR is applying advanced coding methods to dramatically improve the performance of FSO communications. This includes the use of multiple optical channels and hybrid approaches, using both RF and FSO channels, so that as the quality of individual channels varies, the best overall performance can be obtained.

Progress was achieved in three tasks of this project. Dr Nick Letzepis collaboratively derived new information theory results that consider both ergodic and block fading channel models and demonstrate the benefits of multiple FSO channels, and/or RF plus FSO channels, in terms of error rates or outage statistics. This work has resulted in multiple Institute of Electrical and Electronics Engineers (IEEE) journal publications, including a special issue of Journal on Selected Areas in Communications (JSAC). The new results allow performance benefits to be quantified as a function of channel fading distributions.

Secondly, we completed the establishment of a 12 km test range to measure RF/FSO channel statistics. These statistics are not currently available and will be invaluable for designing real systems. Our test range includes 37 GHz RF and 1550nm laser transmissions.

In the third task, a 2 Mbit/s real-time FSO modem and codec architectures was designed and evaluated, both in loopback tests on the bench and, with assistance from DSTO, over the 12 km test range mentioned above. The results of these tests are to be published in January 2011. We see great potential in higher-speed FSO codec designs, both for delay constrained and unconstrained channels.



Ngara Project
ITR contributed to the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Ngara Backhaul Project aiming to provide over 10Gbps wireless connection as a complementation for optical network. ITR will work with the CSIRO to implement part of the system in FPGA. The implementation of the project exemplifies both ITR's ability of delivery high speed signal processing system and collaboration with other research institutes.

The project employs the state of art model based FPGA implementation technology. Comparing to the conventional Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL) based FPGA implementation, the model based design methodology provides advantages including faster design from algorithm to implementation, model re-use, Simulink debugging and testing tools and accessible graphical output. By verifying the Model based design in practical high speed system, the project implementation provides solid ground for ITR's software defined radio research.

Satellite Communications Projects
ITR has designed at least three generations of high-speed Earth Resource Satellite Demodulator (ERSDEM). The most recent version allows symbol rates of 500 Msym/s in single channel mode with a wide range of modulation and coding options. In addition it supports a four channel mode since multiple downlinks are popular with recent remote sensing satellites. ERSDEM uses parallelism and pipelining, implemented in large FPGAs to achieve this performance. The current ERSDEM was designed during an ARC Linkage Project and since then ITR has continued to assist Satellite Services BV in the Netherlands to commercialise this product.

International Space University
Other activities included assistance with planning and delivery of lectures, workshops and team projects in the Southern Hemisphere Space Studies Program (SH-SSP). UniSA and the International Space University will run a five-week multi-disciplinary live-in program at the beginning of 2011.

The need for high-speed, secure and bandwidth efficient satellite communication links is increasing every year.

Satellite Communications

Associate Professor Adrian Barbulescu
Satellite communications in the first decade of the 21st century remains the technology that provides key communication infrastructure for many applications across diverse industries, concerning not only economical but also environmental and national security issues. ITR therefore continues to put a constant effort to be at the forefront of this technology by developing its capability to design, implement and test satellite equipment under more and more stringent constraints on power and availability, and increased bandwidth requirements. The key areas were:

- Optimisation of waveform design for high levels of interference
- Development of robust synchronisation algorithms
- Efficient implementation of complex receivers in FPGA hardware
- High quality satellite image receiving operations.

Multi-user Detection
One of the key achievements in 2010 was the development of a substantial intellectual property portfolio in multiuser detection (MUD) technology. MUD technology takes advantage of today's increased available computational power to iteratively process each user and cancel its "noise" contribution to all the other users. This enables the MUD-based network to support a larger number of users than conventional systems. This is a key factor for decreasing the per user cost of spectrum, enabling new business models for remote sensing and connectivity.

The potential application of the MUD technology to low to medium data rate communications is huge. New schemes will be able to serve tens of thousands of remote sensors and control equipments with very little human intervention or monitoring.

ITR has been creating its own intellectual property in this area by developing libraries in MATLAB, C and VHDL programming languages with scores of basic MUD modules. This allows ITR to quickly customise various blocks according to the specific customer needs and speed up the delivery time of a new proof of concept product. A flexible MATLAB framework enables quick waveform optimisation function of system traffic constraints for both civil and military environments.

Satellite Hardware Projects
A number of satellite developers and demonstrators were undertaken for industry partners in 2010 that focussed on various modulation and coding schemes for applications in numerous medium to high speed users. These outcomes were demonstrated on off-the-shelf hardware to ratify the simulation results achieved for new algorithms.

X-Band Satellite Reception Facility
ITR continues to maintain and upgrade its X-band steerable satellite reception facility and receives daily earth resource satellite data from the French Spot satellites, SPOT 4 and SPOT 5. The station is capable of receiving data from a large number of current and future planned satellites, and will undergo upgrades to its demodulator receivers in the near future. It is one of few available X-band facilities in Australia.

S-band Reception Facility
In December 2010, ITR provided tracking services for the Space X NASA COTS Demo 1 launch. This was the maiden flight of the Dragon spacecraft, launched on a Falcon 9 rocket. ITR is contracted to contribute to the tracking network for the second Autonomous Transfer Vehicle (ATV2 Kepler) launch to the International Space Station (scheduled for 2011).

Satellite Network Access Point
The Satellite Network Access Point (SNAP) platform was updated with two new Datum System modems capable to run at up to 30 Msym/s and coding rates 15/16. SNAP achieves higher bandwidth utilisation through traffic aggregation, traffic management/shaping, turbo-code based transmission techniques and cost effective wireless last-mile distributions.

Targeted at rural communities, SNAP is capable of aggregating different existing communication standards. The platform caters for various types of users and applications within the community, such as medical services, educational applications, financial services and residential users.

Competitive Research Grants

ARC Discovery: Robust Transmission, Identification and Key Agreement in Communications Networks

Dr Terence Chan and Professor Alex Grant: 2010–2013
Australian Post Doctoral Fellowship Dr Siu Wai Ho: 2010–2013

It is vital to provide efficient and robust communications in networks. This project aims to determine the fundamental limits and costs of robust transmission, identification and key agreement in unreliable or compromised networks. The research will propose a new approach based on network coding to embed reliability in the core of the network. Expected outcomes of the research, which will impact the information and communication technology industry, are:

» Contributions to the theory of provably robust networks
» Efficient and robust data transmission, identification and key agreement schemes in networks.

ARC Discovery Communication and Information Storage Mechanisms in Complex Dynamical Brain Networks

Australian Research Fellowship - Dr Mark McDonnell: 2010–2014

Repetitive oscillations are often observed in measurements of brain signals. While mathematical approaches have discovered how these oscillations arise in brain networks from complex interactions between large numbers of neurons, their role in brain function remains a largely unresolved and fundamentally important question. A novel approach will assess the hypothesis that oscillations allow communication of information between separate brain regions. Mathematical and computational models of modulation and memory storage/retrieval in oscillatory brain networks will be produced, and assessed, using communications-engineering metrics. Findings will potentially lead to innovative ideas for future medical bionics and brain-machine interfaces.

ARC Linkage: Cooperative Mesh Networks For Municipal Wireless Access

Professor Alex Grant and Dr Nick Letzepis: 2007–2009

This project will extend the theory and engineering practice of robust mobile networks by developing and demonstrating novel methods for relaying and decoding of information in a wireless mesh network. Specific project innovations will be to develop cooperative coding strategies for transmission using relays, reduce bottlenecks caused by medium access control and routing, and increase reliability and throughput via network-wide joint processing of received signals. Targeted scientific and commercial outcomes include contributions to the theory of information transmission and practical coding and decoding methods for mesh networks, and a hardware prototype demonstrating the resulting benefits in real world operating conditions.

ARC Discovery: Adaptive Broadband Wireless Communication

Professor Bill Cowley: 2008–2010

The performance of broadband wireless communication networks is limited by available resources, such as frequency bandwidth and transmission power. Also, the time varying features of wireless communication channels adversely affect performance. Transmission schemes, adapting to instantaneous channel characteristics can significantly improve performance. The aim of this project is therefore to determine fundamental limits for broadband wireless communication systems and to develop practical adaptive transmission schemes for achieving these limits. A theoretical design framework for practical adaptive schemes will be developed, resulting in fundamental contribution to information theory and new designs for future broadband wireless applications.

ARC Discovery: Efficient Data Transport Using Network Coding

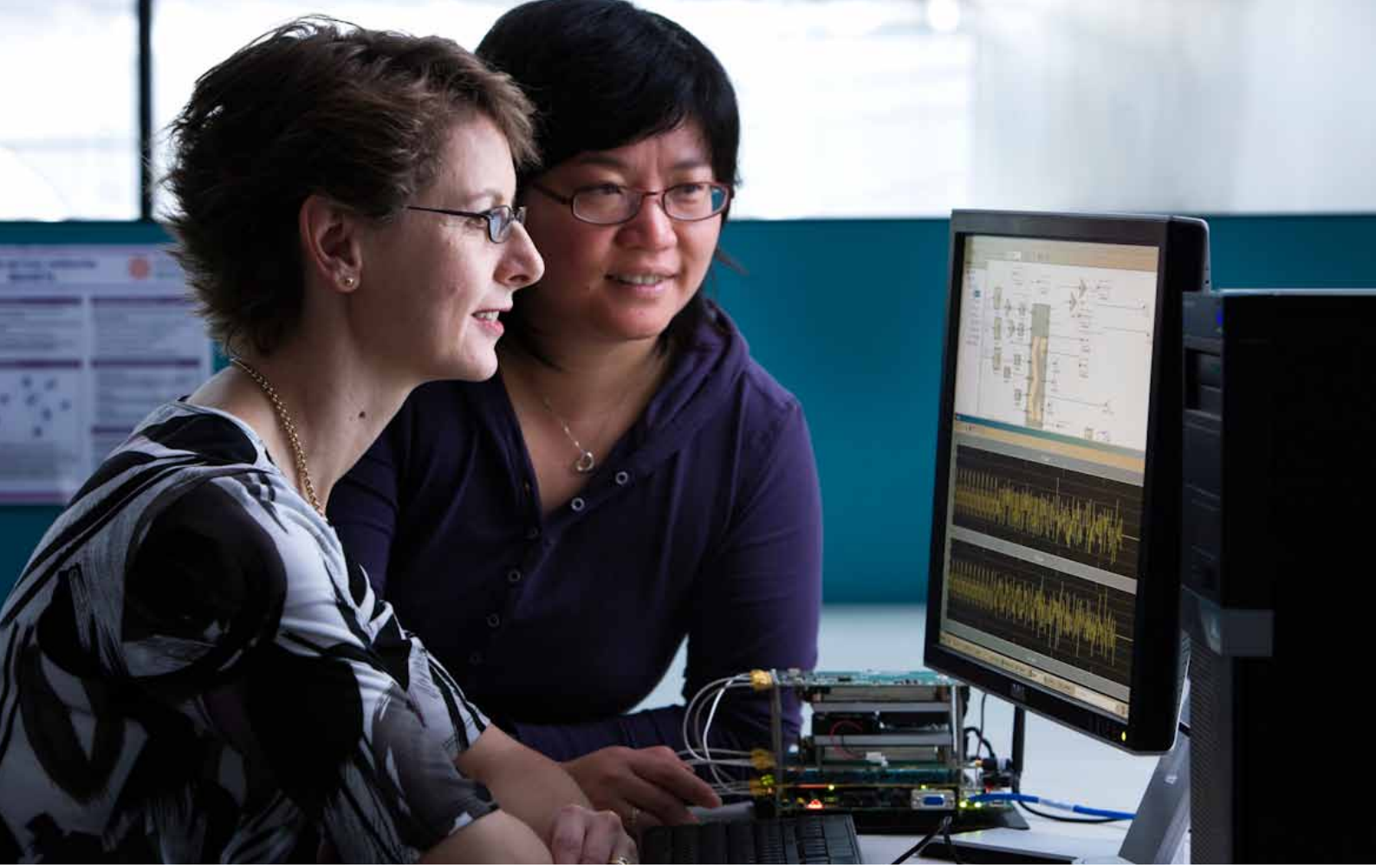
Professor Alex Grant and Dr Terence Chan: 2008–2012

This research aims to understand the relation between resource allocation and service quality in communication networks. Network coding changes the way we think about networks by allowing network nodes to perform coding, rather than just routing. Performance increases are predicted for distributed storage, content distribution and multimedia streaming. The project focuses on network coding to increase throughput and to reduce management overhead in wired and wireless multimedia networks. Targeted outcomes include contributions to network coding theory, deeper understanding of performance, complexity and resource trade-offs, practical network coded data transport schemes, and new network designs which balance the available resources to deliver required quality of service.

ARC Discovery: Broadband to the Bush: Polarization as a New Resource in Wireless Cross-layer Design

Associate Professor Linda Davis: 2007–2009

'Broadband to the Bush' is a national priority – more than 1.6 million homes, small businesses and not-for-profit organisations in rural, regional and remote Australia are set to benefit from roadband access to phone networks and the internet. The immediate challenges lie in overcoming poor download speeds and area coverage, as well as expensive access. This research will deliver cost and power efficient receiver architectures to provide end-user utility, and will train postgraduate researchers across traditional discipline boundaries in mathematics and engineering. The project represents an important contribution to frontier technologies in information and communications technology for building and transforming Australian industries.



ARC Discovery: Efficient Transmission Strategies for Cooperative Wireless Ad Hoc Networks

Dr Ingmar Land and Professor Lars Rasmussen: 2009–2011

This project investigates new methods for cooperation in wireless networks, with a focus on coding strategies for wireless relaying. These technologies offer the potential to greatly improve the performance and coverage of fourth generation wireless data networks. The proposed research is in areas of great commercial interest, addressing new directions and technologies for future wireless networks. Applied development of the outcomes will lead to valuable intellectual property for commercial exploitation.

ARC Linkage: Satellite Data Communications for Remote Sensing and Broadband Connectivity

Associate Professor Linda Davis, Professor Alex Grant, Dr Nick Letzepis and Dr Ingmar Land: 2009–2012

The remote, distributed location of many of Australia's primary industries precludes the use of consumer oriented terrestrial wireless broadband services. In many instances, satellite communications provides the only feasible means of connectivity for telemetry, supervisory control and data acquisition, tracking and fleet management. Meteorology, remote sensing, irrigation, mining, oil and gas exploration, and fisheries are just a few examples of high value applications of particular significance to Australia. This project will develop bandwidth efficient satellite communications technologies that greatly reduce cost and pave the way toward new market opportunities for broadband access and telemetry applications.

ARC Discovery: Markov Field Theory Applied to Sensor Networks Analysis and Design

Dr Sylvie Perreau and Dr Aruna Jayasuriya: 2007–2009

Performance of commercial deployment of sensor networks often falls well below the expectations due to the lack of theoretical understanding of these networks. The aim of this project is to develop a theoretical framework to analyse sensor networks based the theory of Random Markov Fields which captures the spatial relationships between nodes. The theoretical framework will be instrumental in evaluating the performance of existing protocols used in sensor networks as well as developing new high performance protocols. This project will benefit the deployment of effective and efficient sensor and ad hoc networks in the area of military, emergency services and agricultural applications.

Industry Sponsored Projects

Inter-Satellite Links Investigation
This project studied a number of different aspects relating to links that can be used for inter-satellite communications. This included orbit modelling, adaptive link analysis, link design and initial work in identifying potential preliminary designs and a review of antenna technologies.

Network Coding for Wireless Networks
This project aims to work with, and assist, clients by improving knowledge in the area of network coding – an emerging area in network information theory. Areas of interest included understanding network performance that is achievable with multiple traffic sources, in particular, networks with error free point-to-point links.

Co-Channel Speaker Separation – Speech Enhancement by Acoustic Beam Forming
In this DSTO-funded project an array of several microphones, together with suitable amplifiers and a sampling system with PC interface, were used to explore the performance of signal processing techniques for noise suppression by beam forming. Signals were recorded in real acoustic environments such as teleconference scenarios and processed offline using MATLAB. The degree of wanted signal enhancement, plus the effects of reverberation and speaker movement, was explored.

Dedicated Short Range Communications Interoperability Study
Funded by Austroads, this study provided technical information to define the need, sharing requirements and present results from modelling and field trials in relation to interoperability issues in the area of intelligent transport systems access to spectrum for dedicated short-range communications in the 5.850 to 5.925 GHz band. The study outcomes were used to provide key technical input to the discussion within the Australian Communications and Media Authority and the broader community in the case for dedicated spectrum allocation in the future.

The South Australian Networking Laboratory
SANLab is primarily funded through the South Australian Premier Science and Research Fund. This will assist the Defence community in developing innovative and leading edge solutions and capability in MANET technologies. ITR is in partnership with Defence Communications and Information Networking (CDCIN) at the University of Adelaide, BAE Systems, Cisco and ASC. A key focus for ITR is the development of capability in the area of software defined radio.

Coding for Hybrid Free Space Optical/ RF Channels
Funded by the Sir Ross and Sir Keith Smith Fund, this project targeted FSO communication links as a broadband link alternative for both terrestrial and satellite broadband communications where radio frequency spectrum is limited. Unfortunately FSO links are affected by atmospheric scintillation and poor weather, such as clouds and fog. ITR is applying advanced coding methods to dramatically improve the performance of FSO communications, including the use of multiple optical channels and hybrid approaches using both RF and FSO channels so that as the quality of individual channels varies, the best overall performance can be obtained.

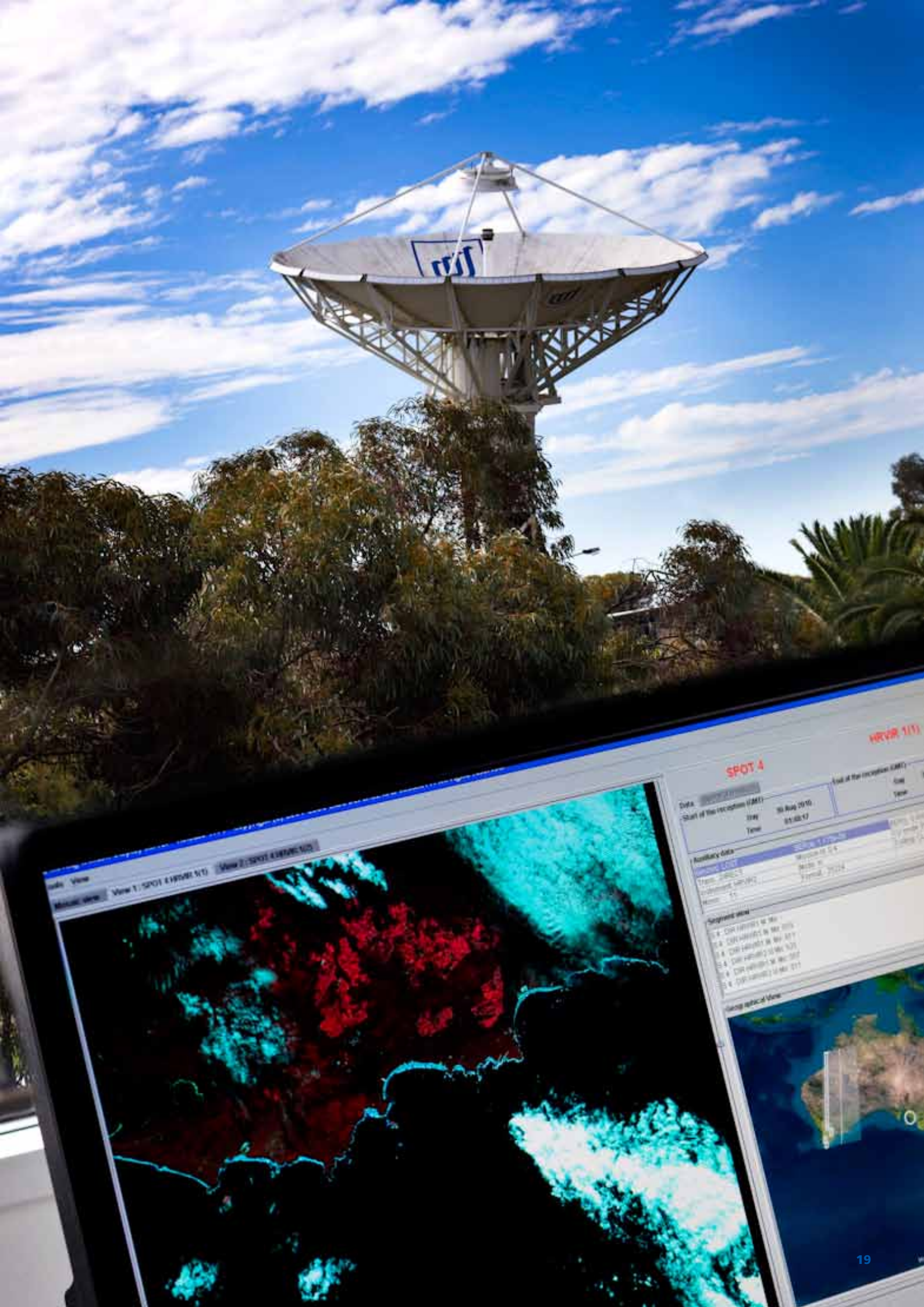
Motor Accident Commission Dedicated Short Range Communications Trial
Dedicated Short Rage Communications combines Global Positioning System (GPS) and wireless connectivity. It enables vehicles to communicate with each other, and with infrastructure, to avoid possible collisions. In partnership with Cohda Wireless, this DSRC trial includes both vehicle-to-vehicle and vehicle-to-infrastructure applications. The trial demonstrated cooperative safety applications and record data from a vehicle fleet that is relevant to road safety and traffic conditions.

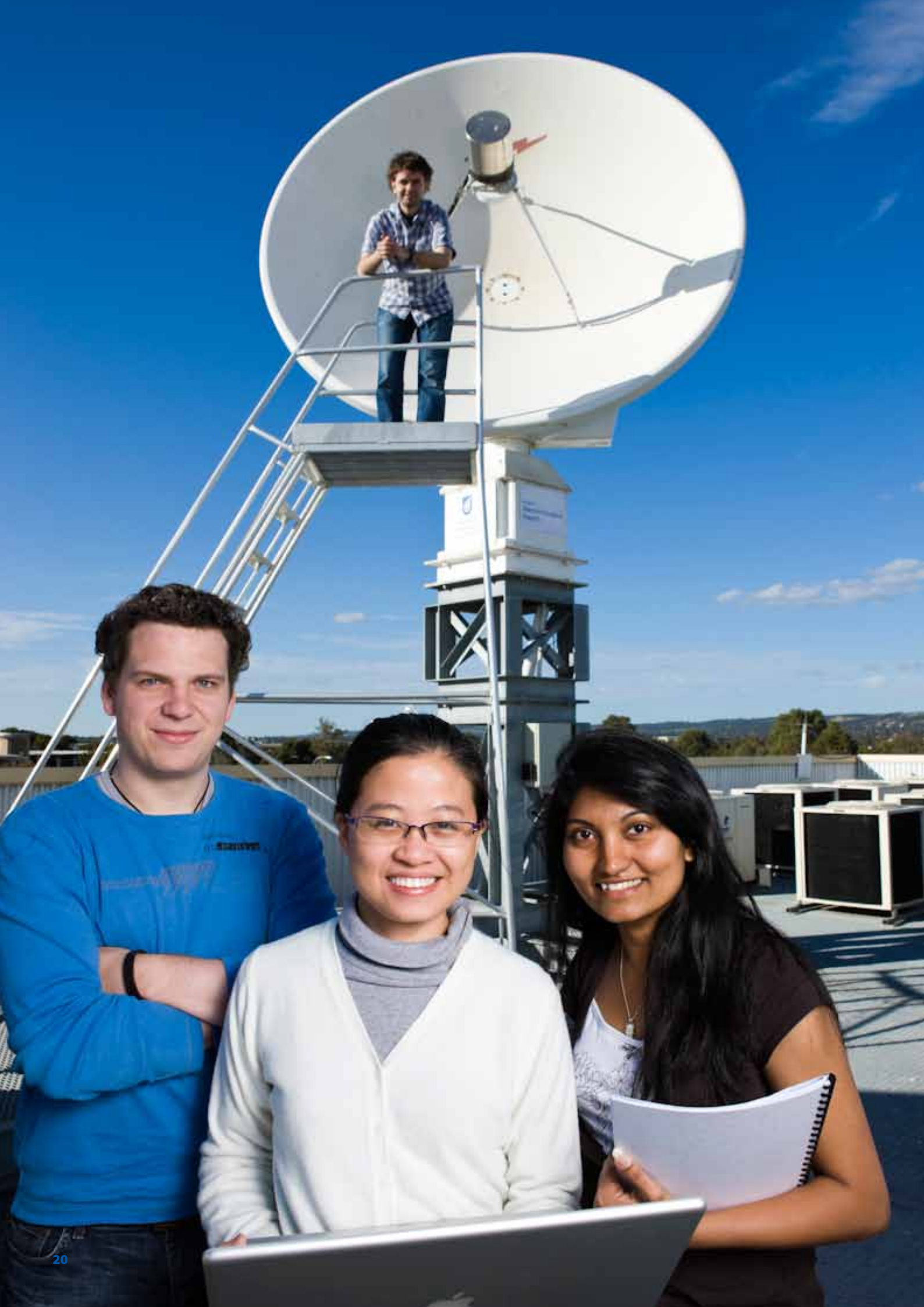
Ngara Backhaul Project
Funded by CSIRO, this project involved implementing an outer transceiver using high speed FPGAs as part of a larger development program being undertaken by CSIRO. The project intended to demonstrate very high speed (10 Gbps) wireless backhaul.

SpaceX Dragon Spacecraft and Falcon 9 Launch Vehicle
ITR tracked the inaugural launch of the SpaceX Dragon Spacecraft which is designed to carry cargo to and from the International Space Station for future National Aeronautics and Space Administration (NASA) missions after the Space Shuttle retires. ITR tracked the spacecraft and received telemetry data that provided valuable information for the SpaceX team to be used for future launches.

Arithmetic Operators to Enhance Digital Signal Processing Performance
This investigation, funded by DSTO, studies fundamental attributes of FPGA processors and associated issues that contribute to overflow, underflow, and bias that may occur in computations.

Improving Frequency Assignment Strategies
Funded by DSTO, this research project aims to improve the understanding of frequency assignment strategies that are immune to intermodulation distortion.


SPOT 4



Space-Based National Wireless Sensor Network

In November 2010 ITR was awarded $5 million under the federal government's priority program – the Australian Space Research Program (ASRP). Matched with an investment from partners, including COM DEV Canada (leading manufacturer of space hardware), South Australian company SAGE Automation, as well as DSTO, CSIRO and Australian Institute for Marine Science, the project will be worth more than $12 million over 2.5 years.

Sensor data gathering is critical for Australia's environment, resource and security issues, and our vast land and marine territories are best served from space. This project will deliver a space-ready communications payload and complete ground system for demonstration in marine monitoring, Defence sensor monitoring and industrial automation scenarios.

The concept of a cost-effective Space-Based National Wireless Sensor Network is to address Australia's needs for ecosystem management, monitoring of climate change, Defence and National security, and support of industries such as mining and agriculture. This delivers clear National benefit in alignment with Australia's research priorities.

Many remote sensors and devices have modest data rate needs and do not require broadband real-time communications. This market is not well served by existing satellite services, which are either too expensive, do not provide suitable data capabilities, or are receive only. While Australia makes use of Argos and various other commercial systems, equipment/service cost and suitability has greatly limited utilisation. Existing systems are under foreign control, limiting applicability for Defence and National security.

Microsatellites can provide cost effective data retrieval enabling adoption and widespread deployment of two-way communications to large numbers of remote sensors and devices beyond the range of terrestrial communications.

This project will deliver a complete architecture for remote sensor data gathering via Low Earth Orbit (LEO) satellites, emphasising key technology enablers, and addressing Australian requirements to be developed in collaboration with end users. Deliverables include space-ready hardware/software for an innovative software defined radio, ground station facility, and experimental ground terminals interfacing to wireless sensor networks.

Benefits of the proposed software defined radio payload include in-flight reconfiguration for each orbit, supporting multi-service and dual-use missions; in-orbit upgrade; on-board processing enabling advanced sensor and control applications; wide range of data service options enabling a broad user base; flexibility to accommodate new services post launch.

A functional demonstration, targeting scenarios of National priority, will use an aircraft as a LEO surrogate. Sensor data will be relayed via the aircraft and ground station to an end user. Command and control messages will also be sent to devices. This project provides a testbed for dual-use operation. Subsequent stages (beyond the scope of the ASRP funding) could deliver on-orbit operations by 2013, and several achievable pathways to launch have been identified. In support, the project will deliver new international partnerships and a phase A study defining subsequent mission phases up to launch and on-orbit operation.

National benefit is delivered by designing and demonstrating a system for Australian needs, engaging with industry and government end users including Defence, CSIRO, Australian Institute of Marine Science (AIMS), Terrestrial Ecosystem Research Network (TERN) and Integrated Marine Observing System (IMOS). The project establishes a value creation chain consisting of value added service providers, space component suppliers, and ground equipment suppliers and integrators. The project builds significant, persistent Australian space capability, generating intellectual property and enabling technologies. These outcomes offer significant near-term commercialisation prospects, inserting Australia into the global space supply chain, and builds capability in rigorous space engineering processes. The project promotes an ongoing program of internationally significant space research and development in Australia, nurturing the next generation of experts in internationally recognised areas of strength: satellite communications and sensor networks.

University of South Australia | Institute for Telecommunications Research

COM DEV

SAGE Deliver certainty

CSIRO

Australian Government | Australian Institute of Marine Science

Australian Government
Department of Defence
Defence Science and Technology Organisation

Achievements and Awards

ITR Postgraduate Awards

Michael Miller Award
Founded by UniSA in 2005, the Michael Miller Medal is awarded annually to the graduate from the ITR, as determined by the judging panel, who has delivered the most outstanding PhD thesis.

The medal is awarded based on the creativity and originality of the research, the student's comprehension of the field, the significance and utility of the research as a contribution to or application of knowledge, and the impact of the thesis through the number and level of international publications and presentations.

The ITR winner of the 2010 Michael Miller Medal was Dr Khoa Nguyen. The title of Dr Nguyen's thesis was "Adaptive Transmission for Block-Fading Channels". His thesis provided greater understanding on the optimal performance of wireless communication systems. The thesis developed practical adaptive transmission schemes, which promise to greatly improve the reliability of wireless communications with low-latency requirements and stringent constraints on power and bandwidth resources.

Dr Nguyen is now employed by ITR and continues his research in the area of anytime information and coding theory, which serves as the foundation of communication technology for wireless automation and control systems.

UniSA Internal Grants

Research Leadership Program
Dr Terence Chan and Dr Mark McDonnell.
Research SA Fellowship Program
Dr Siu Wai Ho and Dr Mark McDonnell.

Publications

Articles Published in Scholarly Refereed Journals

Y. Abramovich, G. Frazer and B Johnson, "Iterative Adaptive Kronecker MIMO Radar Beamformer: Description and Convergence Analysis", *IEEE Transactions on Signal Processing*, vol. 58, no. 7, pp. 3681-3691, 2010.

Y. Abramovich, G. Frazer and B. Johnson, "Noncausal Adaptive Spatial Clutter Mitigation in Monostatic MIMO Radar: Fundamental Limitations", *IEEE Journal on Selected Topics in Signal Processing*, vol. 4, no. 1, pp. 40-54, 2010.

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R. Arablouei, K. Dogancay and S. Perreau, "Proportionate Affine Projection Algorithm With Selective Projections for Sparse System Identification", *Asia-Pacific Signal and Information Processing Association Annual Summit and Conference*, (Singapore), pp.362-366, December 2010.

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T. Chan and A. Grant, "On Capacity Regions of Non-Multicast Networks", *IEEE International Symposium on Information Theory*, (Austin, USA), pp. 2378-2382, June 2010.

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Y. Chen, J. Zhang and A. Jayalath, "Are SC-FDE Systems Robust to CFO?", *IEEE Wireless Communications and Networking Conference*, (Sydney, Australia), pp. 1-6, April 2010.

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H. Harms, L. Davis and J. Palmer, "Understanding the Signal Structure in DVB-T Signals for Passive Radar Detection", *IEEE Radar Conference*, (Washington DC, USA), pp. 532-537, May 2010.

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S.K. Kambhampati, G. Lechner, T. Chan and L. Rasmussen, "Check Splitting of Root-Check LDPC Codes Over ARQ Block-Fading Channels", *IEEE Australian Communications Theory Workshop*, (Canberra, Australia), pp. 123-127, February 2010.

L. Lai, S.-W. Ho and H.V. Poor, "Privacy-Security Tradeoffs in Reusable Biometric Security Systems", *IEEE International Conference on Acoustics, Speech and Signal Processing*, (Dallas, USA), pp. 1722-1725, March 2010.

I. Land, A. Graell i Amat and L. Rasmussen, "Bounding of MAP Decode-And-Forward Relaying", *IEEE International Symposium on Information Theory*, (Austin, USA), pp. 938-943, June 2010.

G. Lechner, "The Effect of Cycles on Binary Message-Passing Decoding of LDPC Codes", *IEEE Australian Communications Theory Workshop*, (Canberra, Australia), pp. 43-47, February 2010.

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N. Letzepis, K. Nguyen, A. Guillen i Fabregas and W. Cowley, "Hybrid Free Space Optical and Radio Frequency Communications: Outage Analysis", *IEEE International Symposium on Information Theory*, (Austin, USA), pp. 2048-2052, June 2010.

L. Luo, J. Zhang and L. Davis, "On Performance Limits of Coded Asymmetric OFDM Systems Over Multipath Fading Channels", *IEEE Australian Communications Theory Workshop*, (Canberra, Australia), pp. 19-23, February 2010.

S. McMillan, Y. Abramovich and B. Johnson, "Expected Likelihood for Temporally Correlated (over-sampled) Training Data: Experiment Results", *European Signal Processing Conference*, (Aalborg, Denmark), pp. 1063-1067, August 2010.

K. Nguyen, N. Letzepis, A. Guillen i Fabregas and L. Rasmussen, "Outage Diversity of MIMO Block Fading Channels with Causal Channel State Information", *IEEE International Symposium on Information Theory*, (Austin, USA), pp. 2168-2172, June 2010.

N. Cai, T. Chan and A Grant, "The Arbitrarily Varying Channel when the Jammer Knows the Channel Input", *IEEE International Symposium on Information Theory*, (Austin, USA), pp. 295-299, June 2010.

R. Subramanian and F. Fekri, "Throughput Performance of Network-Coded Multicast in an Intermittently-Connected Network", *IEEE International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks*, (Avignon, France), pp. 212-221, May/June 2010.

R. Subramanian, I. Land and L Rasmussen, "The Influence of Error Propagation on the Capacity of Wireless Networks", *IEEE Allerton Conference on Communication, Control and Computing*, (Monticello, USA), pp. 1488-1495, September/ October 2010.

R. Timo, T. Chan and A. Grant, "Rate Distortion with Side Information at Many Receivers", *IEEE International Symposium on Information Theory*, (Austin, USA), pp. 16-20, June 2010.

N. Torabkhani, B. Vellambi Ravisankar and F. Fekri, "Throughput and Latency of Acyclic Erasure Networks with Feedback in a Finite Buffer Regime", *IEEE Information Theory Workshop*, (Dublin, Ireland), pp. 1-6, August/September 2010.

B. Vellambi Ravisankar and R. Timo, "Multi-Terminal Source Coding: Can Zero-Rate Encoders Enlarge the Rate Region?", *International Zurich Seminar on Communications*, (Zurich, Switzerland), pp. 21-24, March 2010.

S. Yang, S.-W. Ho, J. Meng and E-h. Yang, "Optimality of Subspace Coding for Linear Operator Channels Over Finite Fields", *IEEE Information Theory Workshop*, (Cairo, Egypt), pp. 400-404, January 2010.

S. Zhao, R. Timo, T. Chan, A. Grant and D. Tuninetti, "The Impact of Side-Information on Gaussian Source Transmission Over Block-Fading Channels", *IEEE International Conference on Communications*, (Cape Town, South Africa), pp. 1-5, May 2010.

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Director	**Prof Alex Grant**
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Associate Research Professor Satellite Communications	**Assoc Prof Adrian Barbulescu**
Associate Research Professor Wireless Communications Technologies	**Assoc Prof Linda Davis**
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Senior Research Fellow	**Dr Ingmar Land**
Senior Research Fellow	**Dr Mark McDonnell**
Senior Research Fellow	**Dr Sylvie Perreau**
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Research Fellow	**Dr Gottfried Lechner**
Research Fellow	**Dr Nick Letzepis**
Research Fellow	**Dr Lin Luo**
Research Fellow	**Dr Khoa Nguyen**
Research Fellow	**Dr Andre Pollok**
Research Fellow	**Dr Ramanan Subramanian**
Research Fellow	**Dr Sudharshan Srinivasan**
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Research Engineer	**Mr Ricky Luppino**
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Human Resources and Student Coordinator	**Mrs Sarah Armour**
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National Research Network Program Administrator	**Mrs Christine Thursby**

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Professor Lars Rasmussen

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Dr Steven Pietrobon

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Mr Jeff Kasparian
Business Manager, ITR

Visitors to ITR

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University of New South Wales, Australia

Dr Wei Zhang
University of New South Wales, Australia

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Universität Karlsruhe, Germany
Supervised by Associate Professor Linda Davis.

Mr Thomas Crignon
Telecom Bretagne, France
Supervised by Dr Ingmar Land.

Mr Tony Flaadt
Telecom Bretagne, France
Supervised by Dr Gottfried Lechner.

Mr David Freiburghaus
Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland
Supervised by Dr Lin Luo.

Ms Erin Hammons
International Space University, France
Supervised by Professor Bill Cowley.

Mr Timinere Mackintosh
International Space University, France
Supervised by Associate Professor Adrian Barbulescu.

Mr Bernd Holfeld
Dresden University of Technology, Germany
Supervised by Dr Badri Vellambi.

Mr Alexey Moroz
Moscow Institute of Physics & Technology, Russia
Supervised by Dr Mark McDonnell.

Mr Heng Liu
Southwest Jiaotong University, China
Supervised by Dr Lin Luo.

Ms Nayeema Sadeque
Lund University, Sweden
Supervised by Dr Ingmar Land.

Work Experience

Wen-Cheng Huang
1 February – 31 October 2010
Supervised by Dr Siu Wai Ho.

Jie Dong
5 July - 29 October 2010
Supervised by Dr Terence Chan and Dr Siu Wai Ho.

Minor Thesis Students

Ms Darshi Dehipitiya
Supervised by Dr Roy Timo and Dr Gottfried Lechner.

Mr Sameera Perera
Supervised by Dr Ingmar Land.

Students and PhD Topics

Name	Research Topics
Mr Imran Ali	Signal Processing For Capacity Improvement Of Multiuser-MIMO-OFDM Communication Systems
Mr Reza Arablouei	Partial Update Techniques For Adaptive Memo Channel Equalisation
Mr Andrew Beck	Efficient Narrowband Multiuser Communications
Mr Hamid Dadkhahi	Wireless Network Coding
Mr Volkan Dedeoglu	Positioning And Target Tracking In Sensor Ad-Hoc Networks
Mr Rajan Kadel	Codec Design For Block Fading Hybrid FSO/RF System
Mr Muhammad Khan	Fundamental Limits Of Hybrid FSO/RF Communications
Ms Afsana Khatoon	Channel Modeling And Adaption For Hybrid Free-Space Optical And Radio Frequency Communications
Ms H.K.Jeewani Kodithuwakku	Decoder-Aided Synchronization For Code Division Multiple Access (CDMA) Satellite Communications
Mr Rob Milner	Improvements In Iterative Coded CDMA Reception
Mr The Anh Ngo	Releasing Congestion In Mesh Networks By Relays
Mr Khoa Nguyen	Adaptive Transmission For Block-Fading Channels
Mr Brenton Prettejohn	Consensus Formation And Robustness In Complex Dynamical Networks
Mr Andre Pollok	Multi-Antenna Techniques For Millimetre-Wave Radios
Mr Rehan Qureshi	Ad-Hoc Interconnected Mobile Networks: Architecture And Optimisations
Mr Daniel Salmond	Impact Of Delay And Robustness On Network Coding
Mr Satyajitsinh Thakor	Network Coding Capacity Bounds
Ms Thuy Tran	Acoustic Beamforming Methods For Speech Separation
Mr Mike Tran	Information Theoretic Security For Networks
Ms Chinthani Uduwerelle	Information Theoretic Approach To Network Security
Mr Vince Wang	Reliable And Efficient Coding For Asynchronous Satellite Communications
Ms Anuradha Wickramasooriya	Code Design For Relaying With Compress-Forward
Mr Udara Wijetunge	Stochastic Routing Optimisation In Wireless Sensor Networks
Mr Sean Wong	Modelling Brain Function With Hierarchical Temporal Memory Suprathreshold Stochastic Resonance
Mr Ahmad Zarikah	Wireless Network Coding
Mr Josh Zheng	Information Theoretical Analysis Of Dataflow In Vehicular Networks

	Masters Topics
Mr Mike Anderson	Robust Power Control For Multiservice CDMA Mobile Telecommunications Networks
Mr Shamim Ahmed Joarder	Energy Minimisation In CDMA Based Mobile Ad-Hoc Networks
Mr Sri Kambhampati	ARQ Coding Over Block Fading Channels
Mr Kagiso Magowe	Information Theory For Distributed Storage
Mr Jerry Zhu	Energy Efficient Communication Networks
Mr Ahmad Zubair	Security In Cognitive Radio Networks

2010 THESES: Masters (Research) and Doctoral

The Completion of Requirements was certified by the University of South Australia's Research Degrees Committee for the following ITR Postgraduate Research students in 2010.

ANDERSON, Michael
Masters (Research)"Robust Power Control for Multiservice CDMA Mobile Telecommunications Networks"

KAMBHAMPATI, Sri
Master of Engineering (Telecommunications) "ARQ Coding over Block Fading Channels"

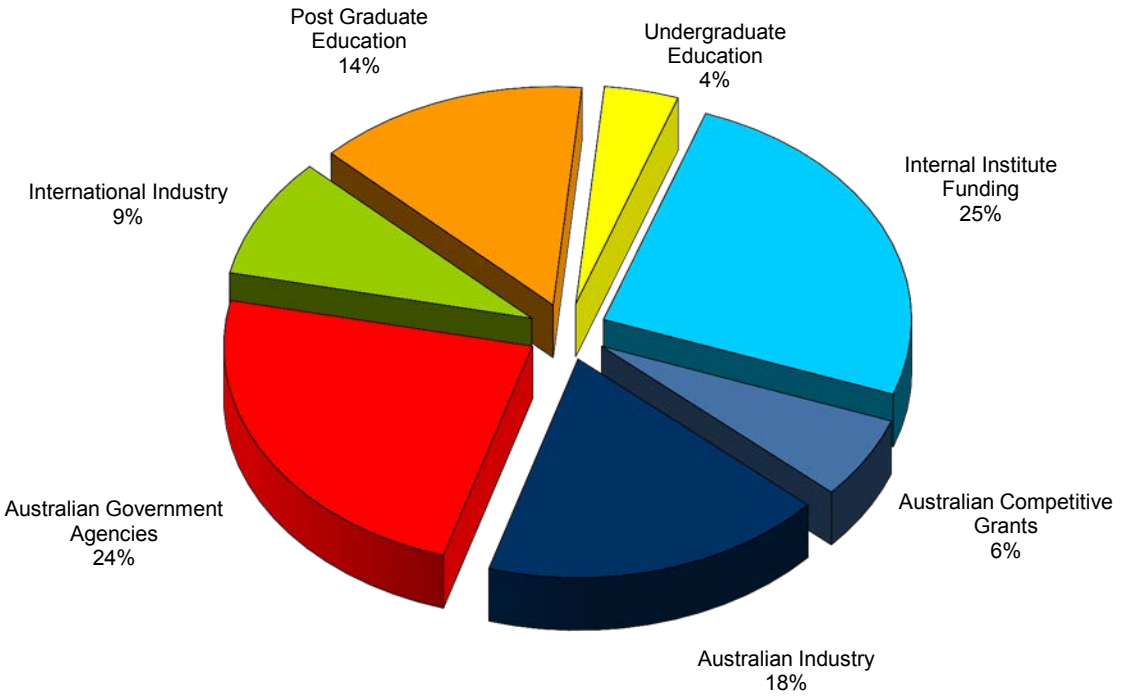
MILNER, Robert
Doctor of Philosophy "Improvements in Iterative Coded CDMA"

POLLOK, Andre
Doctor of Philosophy "Multi-Antenna Techniques for Millimetre-Wave Radios"

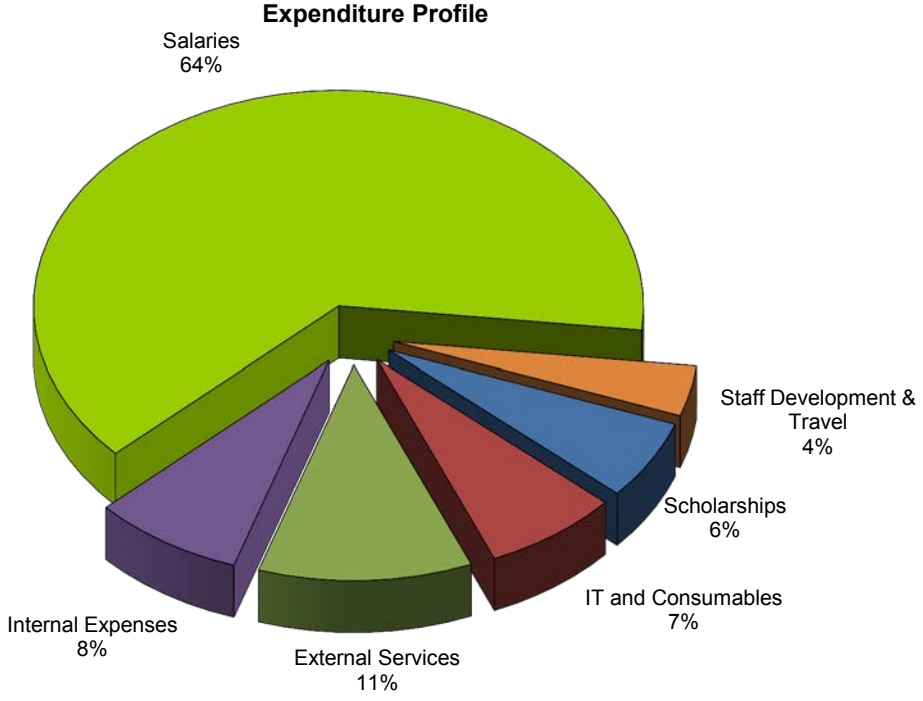
QURESHI, Rehan
Doctor of Philosophy "Ad Hoc Interconnected Mobile Networks: Architecture and Optimisations"

Income Profile

2010 Revenue: $3.861 million



Expenditure Profile



ITR Foundations and Success

The ITR was founded in 1994 and at that time was one of only two key research concentrations at UniSA. ITR originated from the Digital Communications Group that commenced in the mid-1980s within the School of Electronic Engineering, where its research foci were mainly in the areas of modulation and coding, and satellite and mobile communications. Today, fundamental and applied research, proof of concept development and commercialisation activities all play an important part in ITR's success. Strong national and international relationships and collaborations with the telecommunications business community ensure our work has a high degree of relevance to the problems facing the wireless communications industry.

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