Australia and New Zealand CRC for Spatial Information Annual Report 2016-17

Australian Government
Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme
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Statement Of Purpose

The Australia and New Zealand Cooperative Research Centre for Spatial Information (CRCSI) is an unincorporated joint venture set up under the Cooperative Research Centres Programme of the Australian Commonwealth Government through the Department of Industry and Science. The purpose of the CRCSI is to build critical mass in research ventures between end users and researchers tackling clearly articulated, major challenges for end users using the fundamental spatial technologies of global navigation satellite systems, spatial data infrastructures, data fusion and rapid spatial analytics. The CRCSI conducts collaborative research and education in the spatial disciplines. In doing so the CRCSI seeks to accelerate the take-up of spatial science by key end users, spawning major innovation and productivity advances in the key industry sectors of defence, built environment, health, agriculture, natural resources and climate change.

This report has been prepared in accordance with the 2016-17 Cooperative Research Centres Programme Annual Report Guidelines and is submitted to comply with the requirements of Section 4 of the Guide.

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1. Executive Summary

1.1 Research Achievements

In the following section, we profile a selection of some of the CRCSI's research achievements for 2016-17. The focus is on activities that have delivered or promise to deliver significant impacts.

Positioning

This year has seen the completion of two significant projects in the Positioning Program: together they will revolutionise how 3D spatial information is collected and managed. The Earth's crust is far from stable. The Australian Plate has one of the highest rates of tectonic drift in the world, at 7cm per year. New Zealand spans the boundary between two tectonic plates making earthquake activity a common and sometimes devastating reality. All this movement means coordinates that define location change over time. Until recently, this reality could often be ignored. But with the emergence of high accuracy, absolute positioning techniques such as Precise Point Positioning (PPP) and its derivatives, incompatibilities between measurement systems and locally defined geodetic reference frames have become evident. In this context, the CRCSI has been working with partners to design and implement a time-variable frame of reference – otherwise known as a dynamic datum. Our research has developed the technical solutions and software tools to enable the realisation of this new datum. In parallel, the need to transform GNSS-derived height information into a meaningful and practical frame of reference has driven a second project to develop a new geoid model for Australia and, for the first time, to augment that model with uncertainty estimates to allow users to better understand the accuracy of the transformed heights and their fitness for purpose. Both projects have placed the CRCSI's work at the forefront of international research and are helping to equip partners for the new era of time-variable location information.

Rapid Spatial Analytics

Over the last year, the CRCSI, in collaboration with Geoscience Australia (GA) and RMIT University developed new software to automate workflows for spatial data, enabling rapid analysis and simple reuse of workflows. Called Open Spatial Analytics (OSA), the software is an innovative solution for sharing location intelligence, enabling anyone to create, share, adapt, and remix spatial analytics, using scientific workflows.

Currently, spatial analytics algorithms and processes are usually locked away within software documentation and manuals, along with the minds of the experts and programmers. OSA helps spatial analysts to collaborate and share the "how" more easily. Although the project only began in mid-2016, rapid progress has been made using the free and open-source Knime platform. The OSA team has built a cloud based, open analytics workflow platform that can integrate spatial data and operations from most open source and proprietary software (including PostGIS, QGIS, GeoTools, Grass, WMS/WFS, R, Docker). Ongoing research is laying the foundations for new and advanced capabilities for spatial workflows, including: massive parallelisation of spatial operations; scaling to national and big spatial data; managing the provenance of analytics; supporting business workflows and data custodianship; integrating machine learning capabilities; enabling intuitive user interfaces and self-documentation of workflows and; automated workflow-as-a-service deployment.

To test whether our new tool will create impact by saving time, effort and if it can enable workflows to be shared, we took GA's Laser Imaging Detection and Ranging (LiDAR) data to create a new workflow for the national digital elevation model. Using this model has demonstrated the value of our OSA tool and we will continue our work to improve the robustness of the software.

Spatial Infrastructures

This year we have worked with our partners to redefine the next generation of spatial data infrastructures (SDI). Together, we have provided an international benchmark for the new operating model and architecture for the provisioning of spatial information. An outline of how we will succeed has been encapsulated in the *Towards a Spatial Knowledge Infrastructure* White Paper, published in March 2017. This publication drew on research activities involving the Semantic Web, automation and spatial supply chain theory along with global technology trends, to deliver a bold and clearly defined strategic vision for the future of the program and more importantly spatial infrastructure development and research globally. The paper looks critically at what will be required of SDI in the coming decade and charts a course of action to get us from the current SDIs to a distributed Spatial Knowledge Infrastructure (SKI).

Governments will continue to play a significant role in the creation and evolution of the spatial technology sector and will continue to be a key player in shaping our future data infrastructures, including simplifying access to spatial data and driving technology standards that will enable future innovation. However, the government's role is likely to change over the next decade, with all levels of government shifting to a procurement approach with a greater emphasis on external service organisations rather than in-house technology and expertise.

This transition will only be possible through close collaborative work across the sector. The CRCSI has a key role in building awareness and appreciation of these solutions within the geospatial community. And we are proud to be a part of this community, working with stakeholders towards the creation of a Spatial Knowledge Infrastructure.

Agriculture, Natural Resource and Climate Change

The CRCSI, in partnership with Meat and Livestock Australia, has delivered a spatial innovation strategy to enable the differentiation and digital enablement of red meat products, delivered through coordinated investment in location-based technology and services. This strategy has been designed with a focus on directly increasing the value of Australian red meat products through product differentiation, quality, and effective decision making. By directly aligning spatial technologies with the strategic investment imperatives set through the red meat sector's strategic plans, such as the Meat Industry Strategic Plan (MISP), an independent study produced a conservative estimate of almost $600M in improvements to the industry by 2030.

The CRCSI and MLA created the Australian Livestock Spatial Innovation Program (ALSIP), a pilot investment program which aims to demonstrate the value of a collaborative approach to end user-driven innovation in location technologies in the livestock sector. ASLIP provides an excellent example of how the Livestock Spatial Innovation Strategy can be implemented. The ALSIP team coordinated a call for pilot projects in late 2016 to examine the appetite across organisations to invest and collaborate. The call for projects resulted in 20 projects being proposed, bringing in a total cash contribution to the ALSIP program of $1.7M. The top five projects were funded through a combination of industry, CRCSI and MLA funding and are divided into three categories: Free Flowing Information, Animal Location, and Communications.

Health

The health sector has increased its uptake of spatial information and enabling technologies to a much greater extent over recent years. This is due to an elevated awareness of the valuable insights and effectiveness spatial provides as evidenced in a recent paper entitled, *Location Matters – Realising the value of people-centred spatial information to inform policy*. However, our world has arrived in a digital age where new data sources from environmental sensing, satellite imaging, precision positioning (indoors and outdoors), sensor telecommunications and medical wearable technology are abundant. To harness this data, from cells to cities, new methods must be developed and traditional data collection must be augmented with this new data.

Our *Sensing City* project is pushing this frontier as it seeks to demonstrate the cross-sector benefits arising from interlinking seemingly disparate or previously unlinked data sets to show how the Internet of Things (IoT) can transform healthcare. This study is the first of its kind. It introduces smart health technology to objectively measure and monitor health outcomes of chronic obstructive pulmonary disease patients using citizen science approaches. Underpinning the research – location enabled inhalers to determine high risk locations.

The project is ongoing; its anticipated outcomes include: guidance for policy formation, creation of models for rapid intervention through new patient care systems such as tele-health and new spatio-temporal models combining real-time environmental data and patient health data.

Sensing Cities is being piloted in New Zealand and Sweden and is building strong international relationships. It is also laying the foundation for this new area of research: real-time data streaming for improved health outcomes.

Built Environment

The Rapid Analytics Interactive Scenario Explorer (RAISE) project made significant progress towards creating an open, cloud based software platform for land valuation decision making. This allows planning departments and local councils to understand land valuation changes in near real time, and allows for the automated modelling to understand the financial uplift likely to occur when new infrastructure such as a train line is built. This planning toolkit has been explored across several local councils, and road tested in workshops with planning decision makers. Feedback has been overwhelmingly positive, and the co-design approach taken has resulted in a tool which is easy for planners to use and integrate in to their existing business processes.

In addition, RAISE represents an ideal example of collaboration, as the project is co-managed by the research and government sectors through UNSW and NSW LPI respectively, and the technical implementation is a collaboration between two universities and a private company, UNSW, QUT and Omnilink. This shows the power and benefits that can be rapidly realised by combining the experience, knowledge and innovative ideas within the government, university and private sectors.

Table 1: Awards received by the CRCSI community in 2016-17

Project	Name	Organisation	Award
CRCSI	Prof Wendy Lawson	UC	2016 SSSI Professional of the Year Award (awarded at Asia Pacific Spatial Excellence (APSEA) Awards, April 2017
CRCSI	Dr Peter Woodgate	CRCSI	International Society for Digital Earth (ISDE) Life Membership Award, Asia Pacific Spatial Excellence (APSEA) Awards, April 2017
CRCSI	Dr Graeme Kernich	CRCSI	2016 Victorian Spatial Excellence Awards, Professional of the Year Award, awarded to a practitioner who is working in any of the disciplines of the surveying and spatial sciences, whose professional achievements are acknowledged by peer citation as exemplifying the highest standards of excellence and ethical conduct.
CRCSI	Dr Graeme Kernich	CRCSI	Special Commendation for "Professional of the Year Award", Asia Pacific Spatial Excellence (APSEA) Awards, April 2017
CRCSI	AAM Pty Ltd	43PL	The 43PL Company Award 2016 for an individual or company that has made an outstanding contribution to the growth of the spatial industry
CRCSI	Daniel Hogg	UC	CRCSI Student Excellence Award 2016
CRCSI	Prof Kerrie Mengersen	QUT	CRCSI winner of the Research Excellence Award 2016
1.14	Dr Stavros Melachroinos & Dr Tao Li	GA/CRCSI	Best paper award at IGNSS 2016 http://www.ignss2016.unsw.edu.au/2016-wrap-up
2.24	Prof Peter Corke	QUT	QUT Distinguished Professor award for outstanding achievements in the field of Robotics. https://www.qut.edu.au/science-engineering/about/news/news?news-id=118802
2.24	A/Prof Jason Ford and Dr Troy Bruggemann	QUT	QUT Impact Case Study competition – runners up. Case study focused upon the FAS as a critical enabler for Fugro ROAMES product offering.
4.1	A/Prof Andrew Robson	UNE/Precision Ag Research Group	Winning the 2016 Royal Society of New South Wales's Poggendorff Lecture Award, in recognition of his "significant contributions to agricultural research, particularly in the use of remote sensing". The Poggendorff Lecture Award is presented by the Royal Society of NSW, which bestows "the oldest and most prestigious awards in Australia" in the field of science. The Award has only been bestowed by the Royal Society four times, and only once in the 21st century. https://blog.une.edu.au/news/2017/02/20/remote-sensing-champion-wins-poggendorf-award/
4.17	A/Prof Shlomo Geva, Dr Alan Woodley, A/Prof Richi Nayak, Ling-Xiang Tang, and Dr Timothy Chappell	QUT	Best paper award at IEEE Big Spatial Data 2016, Denver USA (cse.ucdenver.edu/~BSD2016/). Presented by A/Prof Shlomo Geva.
4.1/4.4	Prof Kerrie Mengersen	QUT	QUT award of Distinguished Professor – https://www.qut.edu.au/news/news?news-id=112596
4.1/4.4	Prof Kerrie Mengersen	QUT	2016 winner of the Statistical Society of Australia: Pitman Medal – http://www.statsoc.org.au/awards/pitman-medal/
4.2	Prof Clive Fraser	CRCSI	ASPRS Honorary Lifetime Achievement Award – 2017 ASPRS conference Baltimore USA 14/03/17 https://www.asprs.org/pers-journals/2017-award-winners.html
4.58	Dr Stephen Glackin	Swinburne University	The Vice Chancellor's Award for research excellence 2016 (as a group with other AHURI researchers)

Awards

CRCSI researchers and associated programs attracted a number of awards in the reporting period. Table 1 highlights these awards.

Commercialisation/Utilisation

The project outcomes achieved to date have yielded numerous success stories and this has been reflected in the better than anticipated impact numbers for CRCSI. A selection of these impacts is listed below. These include (earlier than expected) outcomes such as utilisation of the Flight Assist System (FAS) through the growth of Fugro Roames across Australia and internationally; increased evidence of both state and national government data access and data licencing policy changes related to our earlier Creative Commons work; enhanced use of elevation products released through the CRCSI partners; use of the CRCSI www.coastalrisk. com.au website; expanded continued use of CRCSI software tools by government agencies; researchers and industry (Barista, Vertical Datum Transformation Tool, LiDAR Quality Assurance Tool, VicRivers tools); an enhanced implementation of National Elevation Data distribution portal by Geoscience Australia; use of our software for adjustment of survey networks by all Australian governments; continued use of the HealthTracks™ tool inside WA Department of Health; policy acceptance and use of the Greyfields scenario planning tools inside government; rapid uptake (900 users) of the NRM Hub tool in the grazing industry; the acceptance of recommendations from CRCSI work in the move to a dynamic datum for Australia; enhanced funding to roll out Digital Earth Australia, a success story from earlier CRCSI work; and the use of the CRCSI research in shaping policy and resourcing decisions in Queensland Health.

The CRCSI to date has met 95 of its 118 utilisation milestones, or 80% in total. There are seven milestones which are behind schedule and require close attention. Three delayed milestones relate to the Health Program where there has been delayed deployment of software in other state government departments. Under the Spatial Infrastructures Program there are four unmet milestones as a result of delays in research progress. There are projects in place, resourced and underway to meet these milestones in 2017-18.

Education and Training

With the CRCSI nearing 2018 only one additional postgraduate student commenced in 2016-17, bringing the total cohort of active students to 22 at 30 June 2017. During the year six students completed their studies meaning the CRCSI has achieved 45 completed post-graduates since its inception in 2010. With 67 active and completed postgraduates the CRCSI has exceeded the Commonwealth target of having invested in (enrolled or graduated) at least 51 PhD and Masters students with our university partners by 30 June 2018.

SME Engagement

A key factor in the success of CRCSI to date has been the unique construct of 43pl and the meaningful connections between our research, industry and government partners. Using one measure, by our estimates we have applied $11.2M of direct funding to 43pl partners since inception in 2003.

43pl allows SMEs in the spatial information sector to purchase units through which they can participate in the CRCSI with appropriate flexibility. This permits each member SME to access CRCSI intellectual property and participate in all CRCSI activities at a reduced cost of involvement. 43pl (the company) assumes indemnity for each member SME, the administrative costs and Company Secretary function for the company are provided by the CRCSI. 43pl has its own elected Board with directors from across Australia and New Zealand. As at 30 June 2017, 43pl had 33 member companies, with several other companies engaged in the CRCSI as Other Participants or via

letters of exchange or MOUs. 43pl, its members and the other companies are deeply embedded in the activities of the CRCSI.

Industry engagement will be even more vital to the creation and success of a successor entity and this has been a key focus for the 43pl Board over the last 12 months, culminating in the recent formation of an Industry Leadership Group of 12 of the CRCSI's 43pl members, and including all Board members of 43pl, to design the best industry engagement model for the new entity.

The Leadership Group has formed working parties to specifically address: innovation, commercialization, realization of benefits, governance and engagement with SIBA-GITA, the spatial industry's business asssociation.

1.2 Risks and Impediments

Risks and impediments and strategies adopted to address the risks

The CRCSI maintains a comprehensive risk register which is reviewed annually by the Audit and Risk Committee and the Board and which was updated in March 2017. The register monitors 52 identified risks. A progress report on strategies to mitigate any risks which maintain a high residual impact rating is reported to the Board at every Board meeting. The high impact risks monitored by the Board are listed in Table 2.

Table 2: Risk and Mitigation Strategies

Risk	Mitigation Strategies
Intellectual property not protected/commercialised	Regular review of IP register. IP register used to develop the Business Development Strategy which seeks to actively manage the use of IP. The register is available for circulation to participants under confidentiality agreements.
Ensuring that partner investment is justified by 2018 and beyond and acknowledged as a sound investment	Continuous improvement monitoring of research programs and plan to ensure high impact utilisation of outputs. Measures include: Strategic Plan and annual Business Plans in place and quarterly project milestone monitoring.
Ensuring CRCSI creates wealth for its participants	Stakeholder Engagement Plans updated and monitored. Regular communication through formal mechanisms; Colleges, Program Boards, Project Management Groups, annual conference reporting and monitoring of impact tool.
Failure to deliver outcomes from one or more research programs	The Investment Committee and Program Boards provide a regular due diligence and review. Quarterly reports from each project leader to be reviewed by the Management and Board. Although there have been milestone achievement delays, no major points of failure evident. Mid-term reviews of every project are yielding improvements in quality.
Project mismanagement or misconduct	Increased scrutiny including heightened monitoring and review by the Project Board and CRCSI management. Board level project oversight to remediate including action and communication plans.
Quality and quantity of in kind commitment from participants is insufficient	In kind is monitored and reviewed quarterly for every project and organisation. Note that in kind is at the threshold required for useful input in projects but that industry commitment should now progressively increase as the emphasis on utilisation increases.
Failure to meet the key Commonwealth targets; including milestones and financial targets.	Quarterly monitoring of research programs and projects to ensure milestones are being achieved and mitigation strategies such as additional projects implemented. Utilisation projects being increasingly pursued with partners. Annual Business Plan in place.
Failure to develop and implement a sustainable business plan post CRC	Development of sustainable post 2018 plan and in principle commitment from current partners. Formal documentation of post 2018 future underway and core partner sign ups to occur in the last quarter of 2017.

1.3 End-User Environment

The key sectors for the CRCSI, the spatial industry and its partners – Government, Agriculture, Natural Resources and Climate Change, Asset Management, Defence, Utilities, Construction investment – have experienced improved economic and business conditions over the past 12 months. While one of our end-user Essential Participant organisations has withdrawn from the CRCSI due to the effect of a merger (Ergon Energy), the remaining end-user partners have maintained a strong project activity base. Ergon Energy has replaced its CEO, a significant number of its management team and the research group has also departed. The relationship with the CRCSI has ended due to a shift in strategic imperatives of Ergon (now Energy Queensland). One continuing collaborative project will be managed through to completion by late 2017.

We have previously reported that across the board, reductions in staff numbers over the life of the CRCSI have decreased the ability of partner organisations to both meet in kind obligations and implement developed solutions. This has not changed and there has also been a reduced commitment of in kind resources evident in our private sector partners. The flow-on effects to the CRCSI have included more focused recruiting of partners to projects through cash contributions, rather than in kind, as well as re-orienting delivery pathways from direct deployment in government agencies to the provision of outputs to service providers, who then enable utilisation within government. Notwithstanding this, the CRCSI partners and third parties contributed additional amounts over and above Commonwealth Agreement funding in 2016-17, reflecting the value of CRCSI activities.

Risks in relation to end users and the strategies adopted to mitigate risks

The CRCSI prepares and monitors individual partner engagement plans with its Essential and Other Participants. These set out the requirements for each company, government agency and university. They are reviewed annually. The collective knowledge from these plans makes an important contribution to the annual review of the CRCSI's Strategic Plan. The CRCSI reviews the nature of the engagement for every partner in every aspect of the CRCSI's activities from projects and utilisation activities, to Boards and Committees.

Opportunities for the CRCSI and strategies adopted to exploit these opportunities

The Program Boards meet regularly to review the strategic development within each research and application program and the Project Management Groups meet quarterly to review progress with respect to each project. These bodies are dominated by end users. These are two primary mechanisms for ensuring opportunities are identified early and mechanisms for adoption are pursued.

How the CRCSI's strategic direction aligns with the end-user environment

The CRCSI participants are organised into Colleges: government, research and education, and industry. This ensures the timely flow of views, knowledge and information, and aids the accountability of management to participants from all sectors and particularly to the respective end users. There were no major changes in the end-user environment that significantly affected the CRCSI's strategic direction. We are expecting that the recent evidence of gradual upturn in business, government and the spatial industry in 2016-17 will continue for 2017-18.

1.4 Impacts

Any substantial changes to the expected outputs, usages or impacts of the CRCSI

The CRCSI conducted a review of its outputs, usages and impacts in 2016-17 and made modifications to the Evaluation Impact Performance Tool to reflect project progress as well as capture new impacts which were not previously included in the tool. It is anticipated that the expected benefits will total $875M, at a benefit cost of 2.77, which has increased from the initial ratio of 1.63. In 2016-17, the total cumulative benefits to date ($325M) exceeded the total cumulative costs ($267M).

Changes in outputs which have led to the increased impacts were:

1. Positioning Program: Future benefits are anticipated as a result of the National Positioning Infrastructure and are estimated at $101M. This was initially estimated at $74M. The primary reason for the increase is that we have substantiated the likely impact on all major industries in Australia, where previously only three industry sectors were quantified. A comprehensive economic analysis conducted by ACIL Allen on behalf of the Commonwealth Government was released in 2014 and it formed the basis for this revised analysis. Benefits will flow through the accelerated uptake and utilisation of the National Positioning Infrastructure and avoided cost to the nation through the establishment of optimally deployed and networked positioning infrastructure. It is now recognised that these outputs will facilitate economic and social impacts across multiple industries including: mining, transport, maritime, aviation, land management and surveying, utilities and location-based services.

In addition, we have included the likely impact of our software developed to support the automated segmentation and subsequent phased least squares adjustment of survey networks of any size. The software is being utilised by all Australian governments and we are advised it now forms a critical part of routine datum maintenance processes.

2. Rapid Spatial Analytics Program: We estimate that there has been a total of $201M of benefits delivered to date via three impacts:

(1) $96M largely through the implementation of an improved version of the National Elevation Data Framework data distribution portal at Geoscience Australia (ELVIS), publicly downloadable sea level rise maps, a publicly available sea level rise visualisation tool, CRCSI commercial receipts, and implementation of the SAVBAT tool;

(2) $96M through the introduction of software and improved technology solutions at Ergon Energy resulting in a reduction of annual costs of the vegetation management program, and the benefits associated with their spinout company Fugro ROAMES; and

(3) $9M through labour savings from deploying more effective software solutions to more efficiently process data into information in government and industry.

Over the life of the CRCSI and until 2025, it is expected that the Program will deliver $452M of benefits relating to:

(1) $255M benefits resulting from the reduction of costs of the vegetation management program through the introduction of software and improved technology solutions Australia wide;

(2) $182M from the Urban Digital Elevation Modelling in High Priority Regions (Urban Digital Elevation Model-UDEM) project, commercial receipts and the use of the Savanna Burning Abatement Tool (SavBAT) tool; and

(3) $15M of benefits resulting from savings in labour used from deploying more effective software solutions into organisations to more efficiently process data into information. This cost-saving and efficiency gain will translate into either more productive capacity or a reduced labour requirement. The ability to process data into spatial information more quickly through automated processes will alleviate the largely manual processes that exist to date in identifying, extracting and compiling information from a multitude of spatial data sources.

The expected benefits from the program have increased from the initial forecast of $51M to $452M.

3. Spatial Infrastructures Program: An estimated $53M of benefits have been delivered to date through the influence/adoption of policy through Creative Commons frameworks. An estimated $108M of expected benefits will arise from the Program (up from original forecast of $42M) through more developed, expanded and nationally cohesive infrastructure as a result of adoption of new policies and online infrastructure technologies in government and industry, associated cost reductions and implementation of the Creative Commons framework, and industry growth impacts from access, rights and governance usage.

4. Applications Program: Although the general thrust of the activities has not changed, outputs have been better tuned to partner needs and re-phased to better match timelines that can be achieved in conjunction with partners. We estimate the Program has delivered benefits of $66M to date through:

(1) $40M in savings from increased staff efficiency and improved health services via new geospatial visualisation tools for staff who collate and analyse disease, risk factor and program information for preventative health and avoided monetary costs for early disease detection;

(3) $17M from the introduction of tool sets by skilled government agencies and research organisations for spatial analysis purposes which avoid labour costs that would otherwise be required to prepare, manipulate and extract spatial information. This also includes usage by corporate agriculture operations, farm managers and producers, agronomists and agricultural service providers, and natural resource management agencies who will directly increase farm profitability through improved efficiencies in water use, asset management, fertiliser application and on-ground monitoring; and

(3) $8M cost savings through the use of the sustainable urban development tool to avoid costs of capital infrastructure, greenhouse gas emissions, physical activity costs, private occupier costs and improved healthcare and productivity and efficiency improvement.

The Program plans to deliver $213M of expected benefits, up from $138M originally estimated.

2. Research

2.1 Performance Against Activities

Progress against the key challenges/outcomes

The CRCSI undertakes end-user driven research focused on the goal of "spatially enabling Australia and New Zealand". This goal is being realised through two strategic objectives, under which the research program has been designed and is being executed.

Objective 1: To undertake the research needed to enable the creation of a national network of Global Navigation Satellite System (GNSS) reference stations to support real-time positioning to an accuracy of ±2cm

The CRCSI is conducting the research needed to facilitate the creation of a coordinated National Positioning Infrastructure (NPI) which will take advantage of Australia's unique geographic location, giving it access to signals from all of the existing and emerging global and regional navigation satellite systems. The NPI will enable real-time, 3D positioning of people, vehicles, built infrastructure and natural assets based on a new method of PPP-RTK (Precise Point Positioning-Real-Time Kinematic). Realising the full potential of the NPI through PPP-RTK requires research to optimise the processing of multi-frequency, multi-GNSS signals in a robust, rigorous and efficient way. The CRCSI's approach to PPP-RTK is globally unique and promises benefits for end users in both the professional and consumer markets.

Key deliverables from research addressing Objective 1 include:

- New integer inference theory to allow the estimation and validation of a full or partial set of carrier phase ambiguities in a multi-GNSS, multi-frequency environment.
- An indigenous capability for computing and delivering real-time multi-GNSS orbit and clock products.
- PPP-RTK network parameter estimates and quality descriptors including; satellite and receiver clock errors, multi-frequency satellite and receiver code biases, multi-frequency satellite and receiver phase biases, slant ionospheric delays and zenith tropospheric delays.
- Algorithms for the implementation of PPP-RTK by end users.
- A methodology optimised for satellite delivery of the PPP-RTK augmentation message across Australia and New Zealand.
- A new approach to dynamic datum definition that will underpin operational implementation of the NPI and revolutionise the way spatial information is collected and managed into the future.

Objective 2: To undertake the research needed to enable the features and power of the Semantic Web to be optimally exploited in managing, maintaining and delivering spatial information

The National Innovation Systems Review sets out the benefits of improved access to raw spatial information and derived spatial information products currently held by government, but largely inaccessible to the broader community. The Semantic Web, coupled with developments in artificial intelligence and supply chain theory, emerge as components to the solution of this problem. The ability to structure data and then to undertake natural language queries, federate disparate data sets with different provenance and utilise the emerging power of crowd sourcing, opens up a range of possibilities to secure the

benefits of broadly accessible and fit-for-purpose spatial information. Adopting a supply chain approach enables the automation of many processes that are currently manual and therefore costly and time consuming to execute. The use of higher levels of the Semantic Web including; knowledge representation (ontologies) and rules (business, geometric, policy) will create efficiencies for data providers and custodians, and confidence to users in terms of reliability and fit-for-purpose data.

Key deliverables from research addressing Objective 2 include:

- **Improved semantic search and discovery** – New spatial search tools that use natural language queries to find relevant spatial data sets from disparate sources.
- **Automated data federation** – New methods to allow users to access data from any source and present it in a form which is consistent, avoiding the need for individual jurisdictions to align data formats and infrastructures.
- **Web services orchestration** – New methods to allow users to request spatial information that may not exist but which can be automatically generated. Orchestration tools will deliver what the user needs.
- **Crowdsourced and authoritative data integration** – New approaches to enable crowd-sourced data to be acquired and quality assured to modify authoritative data sets.
- **Querying big data** – Methods to allow users to run natural language queries on very large, remotely hosted data sets, such as the Landsat archive. Such data sets cannot be downloaded locally so analytical and computation processes have to run where the data is stored.
- **Spatial data supply chains for business processes** – Ontologies and rules that capture business processes to enable automation of decisions. Examples include; the conflation of data sets, and approval of new subdivisions. The ontologies and rules will be captured from documents, policies and information from expert interviews.

Summary of Research Activities by Program and the associated risks

A total of 25 new CRCSI projects were approved during 2016-17 and 20 projects were successfully completed. Table 4 shows the portfolio of active or completed projects with leveraged and co-funding by the CRCSI.

Table 4: CRCSI Projects: 2016 - 2017
**Newly funded CRCSI projects, ^completed projects, # project terminated early*

Project Number	Title	Start	Finish	Partners
1.02^	Next Generation Australian and New Zealand Datum	1/7/2012	30/6/2017	7
1.14	Development of Analysis Centre Software	1/7/2013	30/6/2018	1
1.18	Near RT Tropospheric Zenith Delay Estimation using GPS	1/7/2014	30/6/2016	2
1.19 #	Multi-GNSS PPP-RTK Network Processing	1/11/2014	31/3/2017	10
1.21	Ionospheric Modelling to support ambiguity resolution for PPP-RTK	1/7/2015	30/9/2017	5
1.22	Satellite Delivery of Augmented Positioning Data for PPP/PPP-RTK	1/9/2015	31/3/2018	5
1.23	Beidou precise orbit and attitude modelling for PPP-RTK	1/1/2016	31/3/2018	1

Project Number	Title	Start	Finish	Partners
1.24^	Development of AUSGeoid2020, the first in the world with uncertainty estimates as a function of location	1/4/2016	30/6/2017	5
1.26	SBAS Testbed	25/6/2016	31/3/2019	2
1.28 *	Integrity Monitoring for the Multi-GNSS Analysis Centre Software	1/4/2017	31/3/2019	4
1.29 *	Next generation vertical datums for Australia and New Zealand	1/6/2017	31/12/2018	6
2.02 ^	Topographic Mapping Feature Extraction	1/9/2010	31/12/2014	14
2.09 ^	LiDAR QA Tool	1/7/2012	30/6/2015	5
2.12^	Economic Value of Earth Observation from Space to Australia	01/6/2014	30/6/2017	1
2.17	Development of a mobile mapping QA Tool	1/10/2015	30/3/2017	1
2.21^	State of Environment Pilot for Digital Reporting System	4/1/2016	30/6/2017	2
2.22	Rapid Analytics Interactive Scenario Explorer	1/4/2016	30/9/2017	5
2.23 ^	Open Spatial Analytics	1/4/2016	30/9/2016	2
2.24	Aerial Robotics for Close Proximity Infrastructure Inspection	1/9/2016	28/2/2018	2
2.25 ^	AusCover Case Study	1/5/2016	31/8/2016	1
2.26	Australian Geoscience Data Cube (AGDC) User	1/7/2016	30/6/2018	1
2.28 *	Connecting Infrastructure Trial	1/9/2016	28/2/2017	1
2.29 *	Open Spatial Analytics Stage 2	6/2/2017	31/7/2017	3
2.30 *	A Wider User Base for QA4LiDAR	1/2/2017	30/9/2017	1
2.31 *	Victorian Coastal DEM	15/3/2017	30/4/2017	1
2.32 *	Upgrading spatial accuracy of the digital cadastre – pilot	1/3/2017	28/2/2018	1
2.35 *	VicRivers Extension	15/6/2017	30/8/2017	1
2.36 *	Geomedian Pixel-Composite Mosaics of Australia	28/6/2017	31/5/2018	2
3.01	Semantic Web Technologies for Next Gen Spatial Infrastructures	1/1/2013	30/9/2017	6
3.02	Semantic Web Technologies for Supply Chain Models	1/4/2014	31/3/2018	10
3.03	Semantic Web Technologies Developer	4/4/2016	3/4/2017	1
3.14 ^	Assessing EM-COP Crowd-sourcing for Vicmap Maintenance	22/6/2015	31/12/2015	2
3.16 *	Reducing consumer uncertainty in spatial data products through linked vocabularies	1/1/2017	31/3/2018	6
3.17 ^	SLIM System Improvements	12/12/2016	31/1/2017	4
3.18 *	The Living Learning Laboratory	1/2/2017	30/6/2018	2
3.19 *	Functions, benefits, and optimum accuracy for upgraded spatial cadastres in Australia & New Zealand	1/4/2017	30/6/2018	2
3.20 *	Implications of a dynamic datum on the cadastre	1/4/2017	31/3/2018	2
3.22 *	Automated Transaction Development for Norms	1/6/2017	31/11/2017	1
4.17	Big Data Solutions for Environmental Monitoring	1/4/2015	30/6/2017	5
4.18	Tools for Real-time Biomass Estimation in Pastures	30/8/2013	29/8/2017	5
4.19 ^	Natural Resource Management Spatial Hub: better management decisions in the Rangelands	1/7/2014	30/3/2016	20

Project Number	Title	Start	Finish	Partners
4.101^	Estimating live weight gain for Australia's cattle industry	17/9/2015	30/9/2016	3
4.103	Carbon accounting in diverse landscapes for carbon markets	1/7/2015	30/6/2018	1
4.104	Monitoring & Forecasting Framework for SE Australian Forests	1/10/2015	31/3/2018	2
4.105 ^	Monitoring through many eyes the Great Barrier Reef	1/10/2015	9/6/2017	2
4.109 ^	NRM Hub extension – MLA AWI	26/5/2016	26/5/2017	4
4.110 *	NRM Hub (Stage 3) – A sustainable business	1/7/2016	30/6/2017	2
4.111 *	Australian Livestock Spatial Innovation Program (ALSIP)	4/8/2016	31/3/2017	3
4.112 *	Myriota Water Tank Monitoring	1/1/2017	30/6/2017	2
4.115 *	Integrating spatial technologies in a mixed farming system to increase production efficiency of crop grazing	1/3/2017	30/6/2018	2
4.21 *	3D Point Clouds For Geospatial Intelligence Operations	1/7/2016	30/6/2017	1
4.22 *	GRYPHON: 3D Point Clouds for GI and ADF Ops	30/1/2017	31/10/2017	2
4.405 *	Utilisation of Spatial Cancer Models: A National Cancer	1/7/2016	30/6/2018	2
4.406 ^	CliniFace	1/4/2015	31/7/2016	1
4.408 ^	Identification of indoor localisation solutions for tracking patients in hospital environments to minimise cross-infection.	15/9/2016	31/12/2016	2
4.409 ^	Non-Invasive Spatial Techniques in Burn Assessment and Treatment	1/10/2016	31/3/2017	2
4.410 *	Improving equity of Hepatitis B treatment access and outcomes by informing spatial targeting of resources	1/10/2016	31/3/2018	2
4.411 *	Integrating MBS and PBS data into WA Health state-wide health policy and planning	1/11/2016	30/6/2017	2
4.412 *	Cliniface Stage 2 – Syndrome Classification and HPO Interoperability Extensions	1/8/2016	31/12/2017	2
4.413 ^	Spatial Capability Review for AIHW	5/12/2016	15/2/2017	1
4.49	RT Environmental Sensors to Improve Health in the Sensing City	1/10/2014	31/3/2018	3
4.53 ^	Barriers/Opportunities for Adoption of Spatial Tools in Planning	1/1/2013	30/6/2017	4
4.55 ^	Greening the Greyfields' – Modules 3 and 4	1/4/2013	30/6/2016	4
4.58 *	Developing and implementing the Greening the Greyfields frameworks and tools across Australia and New Zealand	1/7/2016	30/6/2018	3
9.48	Economic Value of Spatial Information in NSW	1/2/2016	31/8/2017	1

As illustrated in Diagram 1, the CRCSI's research program has three core research areas – Positioning, Rapid Spatial Analytics and Spatial Infrastructure. There are also four key application areas – Built Environment, Health, Agriculture, Natural Resources and Climate Change and Defence.

Diagram 1: The use of our research is central to the three research themes and the four research program areas.

The following sections summarise the primary activities and achievements of the CRCSI's research programs.

Program 1 (Positioning)

As the CRCSI enters its final year, a core deliverable for the Positioning Program will be the Analysis Centre Software (ACS), which will be ready for beta release by June 2018. The ACS will combine outputs from present and previous CRCSI research projects into a unified computational system to underpin the National Positioning Infrastructure (NPI). It will process data from all existing and emerging global and regional navigation satellite systems in support of a new positioning paradigm developed by the CRCSI, known as PPP-RTK (Precise Point Positioning–Real-Time Kinematic). The CRCSI's implementation of PPP-RTK is unique, offering users flexibility and efficiency, without compromising rigour. The ACS will be a state-of-the-art GNSS processing capability built from scratch and allowing users to perform real-time, ±2-5 cm, 3D positioning anywhere (outdoors) with high integrity and reduced dependence on ground infrastructure. In this respect the ACS and PPP-RTK taken together represent a significant advance over the common and widely deployed Network RTK (NTRK) approach to GNSS positioning. We believe PPP-RTK will become the positioning mode of choice for a wide range of users and applications in the future, even facilitating cm-level positioning by consumers using handheld devices such as a mobile phone.

A second major achievement for the Program has been work associated with the design and delivery of a new, time-variable (dynamic) reference frame for both Australia and New Zealand. The present datums for both countries are increasingly inadequate for the new era of ubiquitous satellite positioning and fail to take account of the practical realities of continental drift and crustal deformation from seismic and other events. A dynamic datum will accommodate temporal variations in location, ensuring that spatial information products are always aligned with a globally consistent reference frame. The work of the CRCSI to support the implementation of a dynamic datum has been conducted in close collaboration with all of the geodetic and mapping authorities of Australia and New Zealand, through the Inter-Governmental Committee for Surveying and Mapping (ICSM), and, in particular the activities of its Permanent Committee on Geodesy (PCG). The CRCSI has delivered a unique geodetic network adjustment capability that has the power to compute the entire geodetic network of Australia, comprising tens of thousands of stations and millions of measurements in a single solution. The DynaNet network

adjustment package offers several unique features and is set for release as an open source package through Geoscience Australia. Additionally, the research has explored barriers to the adoption of a dynamic datum, making recommendations to government geodetic agencies on how best to guide the challenging implementation process. Research has demonstrated that Australia and New Zealand occupy a world-leading position with regard to progress toward a time-variable reference frame and our work is informing the activities of other nations around the world.

A third output from the Program relates to the release of a new geoid model for Australia. The geoid is used to convert GNSS-derived heights (e.g. via the NPI and ACS) into the orthometric reference frame, which is required for most practical applications, such as civil construction and flood modelling. Australia and New Zealand lead the world in the generation of high accuracy, high resolution geoid models. In collaboration with partners, the CRCSI has advanced the science of geoid modelling by producing a new national solution accompanied by estimates of model uncertainty. This world-first achievement allows users to not only convert to the orthometric height system but to have a reliable estimate of model performance. The new geoid model will be made available by Geoscience Australia as a complement to the new dynamic datum. Additionally, the geoid uncertainty work has spawned a new CRCSI project, commenced in June 2017. Under this project, the research team will explore the design and adoption of a completely new vertical datum. Results from the project will be delivered in December 2018 and could again move Australia and New Zealand into a world-leading position through the adoption of a next generation vertical datum that overcomes the shortcomings of the present system.

In collaboration with partners in both the government and private sector, the CRCSI is investigating the question of how best to deliver the PPP-RTK solution to users. While PPP-RTK offers the potential to enable high accuracy positioning on a national basis, delivering the needed correction message generated by the ACS across a country as large and as remote as Australia is a serious challenge. On the one hand, a satellite delivery channel offers the potential to overcome the limitations of terrestrial communication infrastructure, but the limited bandwidth of such systems poses serious technical limitations given the size and temporal variability of the correction message. While not abandoning the notion of satellite delivery, CRCSI researchers have been working on a new "mixed mode" delivery model that couples satellite and terrestrial communications to overcome the bandwidth problem. Initial results have been very promising, and have been validated in trials in both the mining industry (Latrobe Valley) and the sugar industry (Mackay) in late 2016.

The Program has produced 15 published papers this year, which include nine refereed journal articles and six refereed conference papers, as well as three internal reports.

Up until March 2017, the Science Director for the Program was Professor Peter Teunissen. Professor Teunissen has made a major contribution to the Program and his departure represents a significant loss to the CRCSI. A replacement Science Director is currently being considered by the Program Board and CRCSI management.

Dr Chris Pigram, formerly Chair of the Program Board, has retired from his position as CEO of Geoscience Australia and consequently from the Board. He has been replaced by Dr Andrew Barnicoat, Chief of the Community Safety and Earth Monitoring Division of Geoscience Australia.

Program 2 (Rapid Spatial Analytics)

It is now 18 months since the first RSA projects started. The RSA Program focuses on shorter project life cycles and short communication bursts.

The rapid focus for the first phase of the RSA Program has generated considerable interest and partner engagement.

The RSA session at the CRCSI conference was packed with attendees lining up outside the door. The short five minute presentations followed by a panel session was highly interactive. Much of the discussion was focused on the need for near real-time and open analytics. The Program will continue to facilitate the push of real-time and open analytics for government and industry.

The current suite of projects tackle a breadth of applications across the CRCSI partner needs. The following seven projects were active during 2016-17.

- **Project 2.14/2.35** *Victorian River Lines Toolkit*
- **Project 2.17** *Automated Mobile LiDAR Quality Assurance – QA4MOBiLE*
- **Project 2.21** *Victorian State of the Environment, Digital Reporting System*
- **Project 2.22** *Rapid Analytics Interactive Scenario Explorer (RAISE)*
- **Project 2.23/2.29** *Open Spatial Analytics*
- **Project 2.24** *Aerial Robotics for Close Proximity Infrastructure Inspection*
- **Project 2.30** *Automated Airborne LiDAR Quality Assurance – QA4LiDAR Extension*

In 2016-17 the *River Lines Toolkit* developed an automated method to map the top and toe of river banks from large LiDAR and imagery data sets. This project met the target of automatically mapping 85% of Victoria's rivers to support its River Health program. Additionally, the project has examined methods to improve the assessment of vegetation structure for determining river health.

QA4MOBiLE is the second release in the QA4 suite of software. QA4MOBiLE is targeted at supporting road agencies to develop and quality assure their mobile LiDAR surveys. In June 2017 the CRCSI team developed and released a beta version of the software which included more than 40 different quality assurance checks.

The '*Victorian State of the Environment, Digital Reporting System*' project generated State of the Bays reporting indicators on water quality, beach condition and bird life that could be used to generate land accounts in support of environmental-economic accounting. The platform provides visualisations of environmental changes over time by creating virtual datacubes of relevant attributes and their natural or administrative context, which could be visualised and interrogated on map, chart and table simultaneously for decision making.

The *RAISE* project completed a beta version of the toolkit in 2016-17, along with three co-design workshops with project partners and stakeholders. This project has developed spatial models to automatically compute property valuations. The toolkit completed the integration of a hedonic pricing model (based on ordinary least squares regression) with an automated valuation model based on geographically weighted regression. Additionally, two usability workshops were held with end-user groups, valuers from NSW and city council planners. In May, the project integrated the PSMA Geoscape building data into the toolkit for 3D visualisations.

The *Open Spatial Analytic*s project has extended an open source scientific workflow platform (KNIME) to fully integrate a wide range of commonly used spatial operations and tools. These include open source libraries, such as GDAL and GeoTools, as well as links to spatial database systems such as PostGIS. The workflow tool has been to automate the creation of a coastal DEM for Geoscience Australia, with enhancements allowing deployment on the NCI supercomputer. Further testing and

enhancements were also used in the automation of workflows to generate the Queensland Cancer Atlas.

The *Aerial Robotics for Close Proximity Infrastructure Inspection* project has seen the rapid development of a customised solution regarding UAV asset inspection technology to augment and enhance current operations by Ergon Energy. The research team has created modifications to a commercial-off-the-shelf multi-rotor UAV to suit Ergon Energy. This included modifications to the autopilot and control inputs, as well as the integration of a multi-sensor rig to enable obstacle recognition and avoidance. The team has focused on the development of algorithms for wire and pole detection, control approaches for avoidance, and general 3D perception and motion modelling.

The RSA Program continues to be supported by Science Director, Professor Matt Duckham, Deputy Head of Geospatial Sciences at RMIT University, and the Program Board consisting of: Mr Simon Gilkes (Valuer-General of NSW, appointed as Chair), Ms Kate Williams (GHD), Mr John Blackburn (AAM) and Mr Brian Sloan (Department of Prime Minister and Cabinet).

Program 3 (Spatial infrastructures)

This Program comprises four active projects with direct links into one other major project in Program 4.1 (Agriculture, Natural Resources, and Climate Change). The focus for this year has been to create business focussed proof of concept tools to further establish strategic links with our partners and articulate the case and pathway towards the Next Generation Spatial Infrastructures. Program 3 and Program 2 have worked closely to articulate the vision of a Spatial Knowledge Infrastructure that merges the data and the analytics research to provide knowledge to the user. Additionally, the Program commenced a new project this year focussing on ways to bridge the communications gap between suppliers and users in terms of data quality and fitness for purpose of data.

The Spatial Infrastructures team has expanded this year to include researchers from QUT and a new full-time researcher at Curtin in addition to two part-time researchers, 10 PhD students and software and system design resources from 43pl company, Amristar. This year saw the completion of seven proof of concept software tools derived from the research outputs for evaluation, assessment and ultimately adoption by partners. This strategy has enhanced the Program's links to end users, and has provided utilisation pathways for the research and significantly increases the prospects of securing real-world utilisation and impact from the research. Agencies such as Landgate WA and Land Use Victoria, LINZ and Spatial Services NSW are engaged in the proof of concept trials.

This year has seen the Program consolidate the research and deliver hands-on Semantic Web training, deliver the new customer pull supply chain framework and created a visionary framework and transformational pathway towards a Spatial Knowledge Infrastructure (SKI). The new approaches will transform current supplier driven approaches delivering data and services to customer to create a network of data, analytics, expertise and policies that assist people (and increasingly machine-to-machine), whether individually or in collaboration, to integrate in real-time spatial information and tools to create spatial knowledge into everyday decision making and problem solving. The SKI in combination with new Semantic Web technologies will assist in connecting, integrating and analysing data and, as a consequence, drive new knowledge-based activities such as smarter transportation networks, responsive and resilient cities, and intelligent infrastructure planning. The common thread required for these knowledge-based solutions is the delivery of data and information in real time using machine to machine communications and on the fly predictive analytics. There is now a clear set of capabilities that needs to be developed to support the changing expectations of users and create the SKI.

The Program 3 Board has supported and guided the additional strategic activity delivered by the team to develop the SKI model that provides a five-year research and development outlook for the program. In April, a review of the research was conducted and highlighted a significant barrier to the broad adoption of Semantic Web techniques due to the limited Australian implementation and publication of spatial linked data upon which these solutions rely. In addition, there is a lack of well documented approaches to publishing spatial linked data as part of the Semantic Web that encompasses the required institutional arrangements (sometimes referred to as the social architecture), and the necessary best practices for combining existing technology solutions with spatial linked data to create the so-called web of data. The review also considered the current Semantic Web "environment", and identified organisations with existing solutions, capability, and institutional roles that could be leveraged to lower these barriers. Joint development activities have commenced that will leverage developments by ANDS, PSMA, GA, ABS, CSIRO, LINZ and the Government Linked Data Group to create a sustainable foundation for the creation of a knowledge infrastructure by creating a linked data infrastructure (e.g. data, policies, standards, tools and shared knowledge) to build from.

The Program produced nine published papers which were all refereed conference papers, three book chapters and one magazine article. The Associate Science Director for the Program is Dr David McMeekin and he is supported by Professor Geoff West, who continues in an Emeritus role, having retired from Curtin University in early 2016. The Chair of the Program Board is Mr Joseph Abhayaratna, Chief Technology Officer at PSMA.

Program 4.1 (Agriculture, Natural Resources and Climate Change)

Over the past 12 months, Program 4.1 has paid particular attention to strengthening the nexus between production agriculture and environmental management through the development and application of spatial tools and technologies, with a particular focus on the red meat value chain. Additionally, there has been a concentration on delivering existing project commitments, developing new proposals aimed at capitalising on previous investments and building new capabilities, and the preparation of a strategy to take the Program to 2018 and beyond. The Australian Livestock Spatial Innovation Program (project 4.111) developed an innovation strategy for Meat and Livestock Australia to guide investment in location technology, and included four pilot projects co-funded by the CRCSI. These pilot projects were selected from 20 possible proposals, submitted to the CRCSI after an Expression of Interest call. The four pilot projects chosen are:

Project 4.114 'Australian Beef Cattle Supply Chain Proof of Concept'

Project Leads: Ernst and Young, Meat and Livestock Australia, Queensland University of Technology

Core Benefits: A core tenet of ALSIP is that increasing the flow of information up and down the supply chain will lead to economic value. Demonstrating this value is the core of this project, and the effective use of spatial information (particularly through QUT Analytics) will be the key to this demonstration. This project creates a partnership between Australia's largest meat processor (JBS) and some very large cattle producers in Queensland (NAPCO, Emma Robertson, McDonald Holdings, NIPE, Brook Pastoral, O'Brien and Sons).

Project 4.116 'Demonstrating the value of animal location and behaviour data in the red meat value chain'

Project Lead: Central Queensland University

Core Benefits: If animals were tracked in terms of location and behaviour, the benefits for the industry could be substantial with applications ranging from reduced labour in checking stock, rapid disease detection, validated welfare status for market security and integration with satellite data to improve feed base efficiency. Whilst the potential is significant, the research and commercial endeavours to date have been fragmented, and the benefits have not been substantially measured or quantified. This project will provide direction and clarity to all participants in industry. This study will integrate several producer demonstrations and evaluations of spatio–temporal data with a sector-wide survey of participants and an industry level economic evaluation to prime the market and provide key research and commercial development directions.

Project 4.115 'Integrating spatial technologies in a mixed farming system to increase production efficiency of crop grazing'

Project Leads: Facey Group, University of New England, Landgate

Core Benefits: The optimal approach to grazing in a mixed farming system (cropping and grazing) has been proposed, but not fully tested. This project offers the opportunity to calibrate spatial measures of grazing patterns using sheep location, UAV and satellite data, and soil maps to calibrate measurements of crop yield. The overall aim is to maximise crop yields, which has the potential to add $100-$200/ha to farm profitability.

Project 4.112 'Low cost remote water tank monitoring using satellites to directly access sensor data'

Project Leads: Myriota, University of New England

Core Benefits: Monitoring of livestock watering points can be labour intensive and/or very expensive in locations where it is uneconomical or unfeasible to deploy traditional terrestrial communications infrastructure, or to visit sites in person. There is a need for cost-effective, truly remote and extensive data collection capability, suited to all types of terrain and land cover, to improve efficiencies and decision making in the red meat sector.

The project will demonstrate the ability to transfer small amounts of data (in this case water tank levels and geographic position) via satellite in remote locations at low cost. This demonstration will have broad-reaching implications for many other IoT/sensor devices which could be deployed across remote areas both in Australia and globally. As so many location, scanning and imaging devices require communications, demonstrating the viability of new and novel solutions will be key to scaling up technology deployment in remote areas.

Existing Projects

In addition to these new projects, the following projects continued their progress during 2016-17:

Project 4.101 'A Big Data Approach to Estimating Live Weight Gain for Australia's Cattle Industry'

investigates the extent to which stock and paddock records, remotely sensed variables, climate data and integrated or modelled outputs of these sensing platforms can be used to forecast animal-equivalent grazing days over the first month of the dry season. It is proposed to merge available data sets and apply statistical and machine-learning algorithms to investigate the predictive capabilities of the developed models and forecasts.

Project 4.103 'Improved high-resolution carbon accounting in diverse landscapes for participation in carbon markets' allows carbon storage potential of the landscape to be more accurately estimated using a range of data from ground-based, airborne and satellite-borne sensors and advanced modelling techniques.

Project 4.104 'Monitoring and Forecasting Framework for the Sustainable Management of South-East Australian Forests at the Large Area Scale': The project aims to create a framework that allows the integration of satellite time series with Victoria's forest monitoring and forecasting framework to: quantify annual impacts of land management, land use change, and natural processes on forest lands; establish a Land Use Cover Change (LUCC) monitoring structure and characterise uncertainties. The project has recently had a successful mid-term review and recommendation to continue without change to scope, budget or timeline as planned until April 2018. State-wide annualised spectral change maps were completed recently. These have been classified into large area disturbance and recovery mapping of the megafires, both of which are demonstrating highly encouraging results.

Project 4.19 'NRM Spatial Hub': The Farm-Map Analytics Pty Ltd company is in place and trading as FarmMap4D. Trading commenced on 25 May. Some 223 grazing properties have subscribed to the initial "foundation membership offer" to family farms. The initial business plan is now in action, and proceeding well towards planned targets.

Recently completed projects include:

- **Project 4.102** *'Maintaining ground cover in mixed farming systems'*
- **Project 4.13** *'Intelligence Bottler – Capturing spatial know-how for agriculture'*
- **Project 4.105** *'Monitoring through many eyes: spatially enabling people to protect the Great Barrier Reef'*
- **Project 4.17** *'Big data solutions for environmental monitoring'*
- **Project 4.18** *'Biomass Business II – Tools for real-time biomass estimation in Pastures'*

The Science Director for the Program is Professor David Lamb, Leader of the Precision Agriculture Research Group at University of New England (UNE) and the Program Manager is Mr Phil Delaney. Mr Phil Tickle, who has managed this program in the past, has recently moved to take an operational role in the NRM Spatial Hub business, FarmMap4D. The Chair of the Program Board is Dr Matthew Adams, Manager, Satellite Remote Sensing Services, Landgate WA.

Program 4.2 (Defence)

The Defence Program currently has two research projects underway, both being conducted for the Australian Geospatial Intelligence Organisation (AGO). The first is **Project 4.21** – *'Potential of 3D Point Clouds for Geospatial Intelligence Operations'*, the overall objective of which is to investigate new approaches to the processing and analysis of dense 3D point clouds. The second project investigates the real-time streaming and visual-isation of enormous 3D point clouds, maps and object models via standard web browsers.

Professor Clive Fraser is the Science Director for the Defence Program.

Program 4.4 (Health)

The Health Program's focus on stronger sector engagement resulted in a significant new partnership with the Commonwealth's health reporting agency, the Australian Institute of Health & Welfare (AIHW) and several other state and national health agencies including the Federal Department of Health through five new research projects.

The partnership with the AIHW focused on initiatives that elevate sector awareness of the value that spatial information can provide, particularly in policy development. Co-branding activities with AIHW, the Department of Prime Minister & Cabinet and the Western Australian Department of Health were also initiated in this period to assist with this objective. In addition, an output of the Program, the *Spatial Maturity Assessment Framework* was deployed at the AIHW delivering an implementation plan which is now being rolled out with the aim to make AIHW an exemplar organisation of spatial enablement.

The five new projects commenced this year are at various stages of completion.

'An Audit of Clinical Photography, Photogrammetry Tools and Spatial Techniques to Assist Burn Assessment' is the first stage in a collaboration with the Fiona Wood Burns Unit and aims to determine the viability of applying non-invasive spatial tech-niques (geometric and spectral analysis) to burn wound assessment. The integration of 3D imagery technology and subsequent automatic analysis, if viable, could provide a more accurate and objec-tive measurement of burn assessment significantly assisting clinicians to make timely decisions to optimise the chances of recovery and minimise scarring. Early findings indicate that spectral analysis in particular could be viable and further testing is underway.

For the first time, detailed primary health care data will be analysed and associations with selected hospitalisation examined to assess the value of these data to inform strategic planning and system policy development at the WA Department of Health. The project, *'Integrating Medicare Benefits Scheme (MBS) and Pharmaceutical Benefits Scheme (PBS) Data into WA Health State-wide Health Policy and Planning'* will map MBS and PBS utilisation data as well as rates of potentially preventable hospitalisations enabling spatial analyses to investigate the associations between primary health care utilisation and rates of potentially preventable hospitalisations.

With the increasing demand for hospital services, evidence for strategic planning and system policy development to reduce the dependence on hospital services is becoming increasingly important. Previous modelling for WA Health strategic planning has relied heavily on population and historical hospital utilisation data without regard to information on primary health care services which are an integral part of the health system. It is envisaged that this project will produce evidence to enhance the provision of primary health care services that are targeted to keep patients well in the community and reduce avoidable hospital admissions, illustrating the need for further ongoing access to such data.

'Cliniface Stage 2' commenced with the aim of extending the 3D-FAST tool delivered in Stage 1 by developing additional functionality enabling researchers and clinicians to determine if relationships exist between syndrome classification and patient genetic information. Clinician testing is underway with the aim of validating the tool's utility and enabling clinicians to steer development effort where most effective in a clinical setting.

The *'Improving Equity of Hepatitis B Treatment Access and Outcomes by Informing Spatial Targeting of Resources'* project began late in this period and has developed and documented models of human mobility for high-risk groups combining spatial data on transport infrastructure, population density and movement patterns [AURIN, ABS, Dept. Transport/Vicroads, SatNav tracking]. These models provide important relevant context to understand health service access and utilisation.

While this analysis is being finalised the next phase of the project is under way which includes the development of a probabilistic model of the patient care pathway based on available linked data resources. This process will identify barriers to case detection and service provision that limit current application of the National Hepatitis B Strategy, and inform prediction of future disease burden and treatment needs. Lessons learned will improve ongoing strategic rollout of effective therapies through this program to reduce health inequalities experienced by priority populations.

A project aimed at assessing *'Indoor Positioning Technology to Assist in Reducing the Risk of Cross Infection'* delivered a first stage report assessing and grading potential technology suitable for deployment in a hospital setting. The report revealed technology in this space is quite mature and did not warrant further CRCSI investment. The Health Program's staged approach to research is a risk mitigation strategy that ensures investment is focused where needed and impact outcomes most likely and in this case saved the Sydney Children's Hospital from over investment.

The *'Real time environmental sensors to improve health in the Sensing City'* project continued this period overcoming significant challenges due tocomplications with international partners. This project is breaking new ground by engaging innovative methods to capture real time environmental and health data. A new web-based App was developed to geovisualise environmental health data and development of a series of spatio-temporal exposure models is also underway. The models will be incorporated into an Application that will serve as an early warning system for patients suffering with Chronic Obstructive Pulmonary Disease and their clinicians. The outcomes of this project should provide a strong evidence base for increased government spending on air quality measurement infrastructure.

Professor Jim Codde, Director of the Health Research Institute at the University of Notre Dame was appointed this year as Science Director. Jim joins Professor Clive Sabel from Aarhus University, Denmark who is the Program's connection to international spatial health research. The Program continues to be chaired by Professor Tarun Weeramanthri, Executive Director of the Public Health Division, WA Department of Health.

The Program has produced three refereed journal articles, one conference paper and two reports in 2016-17.

Program 4.5 (Built Environment)

The new Built Environment Program is primarily focused on developing new spatial tools and strategies for use by professional planners, developers, infrastructure planners, administrators and the broader community to facilitate improved planning, re-development and investment decisions.

Project 4.55 '*Greening the Greyfields: Precinct visualisation and community engagement*' had been the core project within the Program, with a focus on the application of decision-making tools in the context of optimal redesign of the ageing suburbs of major cities in Australia and New Zealand.

This project has now transitioned to a utilisation phase through a new **project, 4.58** '*Developing and implementing the Greening the Greyfields frameworks and tools across Australia and New Zealand*'. This project is being completed in partnership with the CRC for Low Carbon Living, with a parallel project sharing some resources and focused on the process and creation of standards for urban regeneration focused community consultation.

The primary software outputs are all complete, comprising three software applications facilitating urban planning decision making. ENVISION provides a multi-criteria assessment of a variety of key indicators, as well as a predictor of future development locations and ultimately identify appropriate precincts for development. ESP then allows local councils, the community and developers to rapidly explore development scenarios in 3D, including financial, environmental and social impact assessment. REZONE is a planning capacity tool that explores the impact that zoning changes will have on expected population numbers and density.

The ESP code has been resealed as open source code in partnership with the Australian Urban Research Infrastructure Network, and is available for download now.

Christchurch City Council applied ENVISION and ESP to prioritise earthquake recovery efforts and plan for the future redevelopment of the city. ENVISION and ESP are also being actively used in Victoria by local councils and DELWP to design a new planning framework and renew several urban precincts. In Western Australia the tools have been used to inform the housing strategies and strategic plans in both Canning and Stirling Councils. The City of Stirling is also utilising the tools, particularly REZONE, to assist with transport and energy planning, investment and communication activities.

The most significant development in this project has been the use of the Greyfield planning approach in Plan Melbourne, the 35-year growth plan for the greater Melbourne region. Placement in such a significant planning document greatly increases the breadth of adoption pathways for this project.

Program 4.5 has replaced the role of Science Director with that of Smart Cities Director, a position held by Professor Chris Pettit from UNSW. The Program Manager is Phil Delaney.

2.2 Research Summary of Program Highlights

Positioning Program

The Positioning Program focuses on multi-GNSS enablement, which will be practically realised through the Analysis Centre Software (ACS) as a core deliverable from the research. The ACS aligns with the efforts of Geoscience Australia to build an indigenous GNSS processing capability as a fundamental component of the National Positioning Infrastructure (NPI). Broad-scale access to precise positioning will be facilitated by the NPI, seeding applications across a range of industries and opening up new opportunities including the consumer market and autonomous vehicles. The CRCSI is crucial to the NPI vision and its intent to deliver the economic, social and environmental benefits made possible through ready access to a precise positioning capability. Implementation of the CRCSI's approach to PPP-RTK, the adoption of a time-variable reference frame (dynamic datum) to support high accuracy national positioning, the generation of a national geoid model to enable reliable GNSS heighting, and the generation of geoid uncertainty estimates combine to enhance the functionality and availability of precise positioning in Australia and New Zealand and to realise the associated benefits. The Positioning Program continues to deliver research outcomes of practical value to partners while maintaining high quality research that places many of our activities at the forefront of international research.

Rapid Spatial Analytics Program

This program has initiated a significant amount of activity and industry engagement in its first phase of research. The focus for 2016-17 was on delivering high impact outcomes from the initial round of projects, and launching new projects in our partners' areas of interest. In 2017-18 the RSA Program will continue to seek new opportunities, whilst building the utilisation of project outcomes.

Spatial infrastructures Program

Program 3 has been undertaking research to design the next generation of Spatial Infrastructures. In line with other industry sectors and global trends, the focus has been on providing end users with the ability to "pull" the information they need to create knowledge and tools for their business and customers. This activity is increasingly being performed through machine to machine interactions. To enable these transactions to take place within geospatial supply chains, the Program has been leveraging Semantic Web technologies. Much of the thinking is encapsulated in the *Towards a Spatial Knowledge Infrastructure* White Paper (http://www.crcsi.com.au/spatial-knowledge-infrastructure-white-paper/), published in March.

Agriculture, Natural Resources, and Climate Change Program

The agriculture component of the Program targets better estimation of on-farm biomass, whether using handheld active optical sensors or remotely sensed information from satellites, while the natural resources management component has completed a demonstrator environmental reporting tool which provides non-specialist users with the ability to undertake complex spatial and temporal queries. Analysing grazing circles, which previously took hours or days to execute, now only takes minutes due to the development of an online property planning and information system (www.nrmhub.com.au). The project has delivered what might be a world-first capability that allows individual property managers to routinely analyse time-series Landsat data over the last 30 years.

In addition, this year saw major progress engaging with end-user markets through the development of the Australian Livestock Spatial Innovation Strategy, representing a strong commitment between the CRCSI and Meat and Livestock Australia to deliver location-based innovation along the red meat value chain over the coming years.

Defence Program

Current developments focus on automation within the 3D point cloud generation and analysis process, with interaction of the Program within the CRCSI being concentrated on data fusion, real-time data streaming and visualisation, feature extraction, 3D modelling and change detection.

Health Program

One of the significant highlights for the Health Program this period was the attainment of significant new partnerships with the Commonwealth's health reporting agency, the Australian Institute of Health & Welfare (AIHW) and several other state and national health agencies including the Federal Department of Health through five new research projects. These new partnerships suggest that the program is successfully achieving its goal of stimulating the spatial health ecosystem in Australia.

With this in mind the maturing Program has sought to deliver more sophisticated outputs including: human mobility models for high-risk groups (applied to Chronic Hepatitis B) which will aid in prediction of future disease burden and treatment needs; creation of new spatially enabled environmental and health data through innovative citizen science methods and geovisualised in a web-based App; advancement of 3D facial analysis software for assisting clinicians with disease diagnosis and extension of spatio-temporal exposure models which will be incorporated into an early warning system application for patients suffering with Chronic Obstructive Pulmonary Disease and their clinicians.

Built Environment Program

The Built Environment Program is pleased to announce Chris Pettit as Director of Smart Cities, a newly created position within the CRCSI. This position will be focused on the future direction of our activities in the Built Environment, as well as coordinating the application of existing project outputs, such as RAISE and '*Greening the Greyfields*'. The '*Greening the Greyfields*' project continues to be the leading project within the Program, with the focus now moving to utilisation of the project outputs, and measurement of the project impacts. The next phase will focus on creating and measuring processes for change with our partners, and will be run in parallel with the CRC for Low Carbon Living. The analytics and visualisation tools, linked with the strong relationships developed between the project team and key stakeholders, will lead to a strong, sustainable future for the project outputs, namely the ENVISON precinct identification tool, the ESP scenario planning tool and the visualisation tool, and the REZONE housing capacity analysis tool.

Extent to which the CRCSI is on target to achieve its research outputs

At the conclusion of the 2016-17 year, the CRCSI has completed 92% of its research milestones. There were four research milestones delayed, largely due to project commencement delays. On a program basis, overall progress can be summarised as:

- **Program 1 (Positioning):** 84% of milestones completed, with nine projects addressing outstanding milestones. The program is slightly delayed against original estimates.
- **Program 2 (Rapid Spatial Analytics):** 100% complete. The program achieved all its research milestones ahead of schedule.
- **Program 3 (Spatial Infrastructures):** 82% complete. The program is delayed approximately two years against the original schedule but is now proceeding well.
- **Program 4 (Applications):** 96% complete. The separate research programs: Agriculture Natural Resources and Climate Change (100% completed), Health (50%) and Built Environment (100%) are all proceeding well.

Key research achievements and evidence of the research quality

The quality of research being performed by the CRCSI is partially evidenced by the number of publications being prepared by CRCSI researchers in the form of books, book chapters, refereed journals, conference papers and reports for government and other partners. A full list of these publications is provided in Appendix 1. The emerging influence and uptake of a number of research outputs (as reported in Results) acts as a further indicator of quality and achievement. By this latter criterion, the CRCSI is increasing its impact as research activities reach maturity and deliver practical outputs for industry uptake. Recent calculations show that the return on the CRCSI's research investment to date is approximately 2.77:1 and this is forecast to grow as the Centre reaches the end of its current funding cycle.

The CRCSI is also having an identifiable influence on government policy formulation and decision making. Examples include:

- Progress toward a National Positioning Infrastructure capability. This has been most recently evidenced by a $12M investment from the Australian Government and a further $2M from the New Zealand Government to support the roll-out of a satellite based augmentation system for precise national-scale positioning;
- Formal adoption of a new geodetic datum for Australia and the release of a statement to the effect that Australia will transition to a time-variable reference frame by 2020;
- Cross-jurisdictional activity in support of a national spatial data infrastructure and a national, seamless cadastre;
- Advancement of the National Cancer Atlas and the engagement of cancer registries from all Australian states and territories;
- The adoption of the CRCSI's "greening the greyfields" approach to urban renewal by Plan Melbourne, Canterbury Earthquake Recovery Authority and other local municipalities.

Any issues, including technical or scientific impediments

There continues to be substantial growth in new technologies impacting on the spatial industry. Simple, low cost, and highly sophisticated devices are being regularly released. The consequence is unprecedented growth in the availability of spatial information and increasing consumer demand for real-time data products and services. Whether the sensor platform is a satellite with a

multi-million-dollar payload or a citizen with a smart phone or a personal health device, the availability, frequency, diversity and volume of spatial information continue to grow at an extraordinary rate. This "data deluge" and the "consumerisation of spatial" are leading to exciting changes in the discipline, opening up a range of new applications and new markets for spatial technologies and solutions.

From a research perspective, the challenge for the CRCSI is to keep abreast of the technologies and to respond quickly to end-user demands for ways of quickly and reliably extracting embedded information to create and deliver new knowledge in a timely and user-friendly manner.

The rate of technological change brings challenges to the design and delivery of the research program. Partner needs and expectations now require a more agile and responsive research capability. The CRCSI is responding to these needs through a more agile approvals process, an encouragement to pilot new research projects with a "fail early" strategy and shorter term projects focused on deliverables with direct utilisation and impact on partners. The parallel challenge is to maintain research quality and the support of research providers from the academic sector who are, sometimes, less motivated and challenged by the applied and responsive nature of the new research agenda.

Level of end-user involvement and evidence the research is meeting end-user needs

All CRCSI projects have end-user involvement. The Program Board structure in place since 2010, where each Board is chaired by an end user and is dominated by end-user members, ensures that new research is designed to meet the needs of partners. Mid-term project reviews and quarterly project management group meetings likewise facilitate engagement with partners and have been proven over time to raise levels of awareness and involvement in the research.

Any changes proposed to future research directions

With only 12 months to completion, no major changes to the research direction are envisaged. The CRCSI undertook a major review of its research program in 2014 which was fully implemented in 2015. The revised program has served the Centre well over the past two years, with the most significant change being the introduction of the new Rapid Spatial Analytics Program – which has been well received and supported by partners and is delivering meaningful outcomes.

The CRCSI is working on plans to continue beyond the cessation of CRC Programme funding and a new research plan is in preparation. This new plan will see some changes in emphasis, but will largely extend the current portfolio of activity. The current goal is to secure partner input to the plan and to refine its scope to ensure the ongoing support of partners beyond June 2018.

Publications

As shown in Appendix 1, 45 program related publications were produced in 2016-17, including 19 refereed journal papers, 21 refereed conference papers, and five internal reports. An additional seven general industry related papers were also published.

2.3 Education and Training

With the CRCSI nearing 2018, only one additional postgraduate student commenced in 2016-17, bringing the total cohort of active students to 22 at 30 June 2017. During the year six students completed their studies meaning the CRCSI has achieved 45 completed postgraduates since its inception in 2010. With 67 active and completed postgraduates the CRCSI has exceeded the Commonwealth target of having invested in (enrolled or graduated) at least 51 PhD and Masters students with our university partners by 30 June 2018.

A full list of CRCSI PhD and Masters students commenced, completed and withdrawn for 2010-17 is included in Appendix 2.

Extent to which the CRCSI is on target to achieve its education/training outputs

The CRCSI has exceeded its education and training targets.

Key risks, issues and strategies in place to address the risks and any unmet milestones

The milestones have been met.

Details of the education activities conducted during 2016-17

Postgraduate: The 2016 CRCSI Student Day was a 'solvathon' focused on blockchains in spatial technology. Paul X. McCarthy from Online Gravity and Mark Staples from Data61 facilitated discussion and inspired 20 PhD students to think creatively about how blockchain technology could be applied. The students divided into four teams with each team given the challenge to design an innovative use of blockchain tech in an application area relevant to current CRCSI research programs and initiatives. The teams came up with ideas relating to the red meat supply chain, health facilities in war zones, land administration and road tolling.

Professional Development: The CRCSI's post-graduate professional development is provided through a workshop attached to our annual conference. This year the workshop focused on blockchain technology and how its potential applies to spatial information. Paul X. McCarthy from Online Gravity and Mark Staples from Data61 facilitated the blockchain discussion and inspired the students to think creatively about how blockchain technology could be applied. The students divided into four teams with each team given the challenge to design an innovative use of blockchain technology in an application area relevant to current CRCSI research programs and initiatives. The group discussions highlighted the opportunities and issues with implementing blockchains in the CRCSI interest areas of red meat supply chain, health, land administration and cadastre, and transport infrastructure.

Evidence of the level of student involvement in the CRCSI activities

Students are involved in numerous CRCSI major projects. All students are invited to attend the CRCSI annual conference which has a specific session for students.

Graduate destinations

Graduates are tracked following completion. Of the student completions to date:

- Three are working for a 43pl member company e.g. Fugro Roames, Think Spatial
- 10 are working in non-member companies e.g. Geomatics Technologies, Electronic Arts
- 14 are in CRCSI partner research institutions e.g. QUT, Curtin University
- Six are working for other non-partner research institutions e.g. University of Oxford, University of Otago
- Five are working in government agencies or departments e.g. NICTA, CSIRO
- One is working for the CRCSI
- Four ex-student locations are unknown.

2.4 SME Engagement

SMEs are fully integrated into the CRCSI's activities with a unique structure for its consortium of companies.

Members purchase units in a unit trust (43pl Pty Ltd or '43pl') through which each can participate in

the CRCSI with appropriate flexibility. Importantly this firewalls the risk to the unit trust, which assumes the indemnity for each SME without obligating each SME to take out the costly levels of public liability and professional indemnity insurance required of each Essential Participant. It also permits each SME to enjoy equivalent 'Essential Participant' status and access the CRCSI Centre Intellectual Property and participate in all the activities of the CRCSI. A resourced set of strategies to engage with these companies is implemented through the Business Development team. The Company Secretary function and administrative support for 43pl are provided by the CRCSI.

The 43pl strategies are based on each company's expectations of engagement, which are reviewed regularly with each company. Key themes and strategies arising from these plans are explored further with the 43pl Board and merged into the CRCSI strategic planning process.

Examples of these strategies include:

- The annual conference, which is a confirmed highlight for many companies.
- Allied CRCSI Roadshows (Participants' Forums and Focus Workshops) around the regions, which bring the CRCSI culture to the regions and spread the benefits across Australia and New Zealand.
- Building clusters or ecosystems of activity, which create an environment where SMEs can more easily engage with customers and researchers.
- Matching company expertise and technology aspirations with current and developing projects, which brings companies, when ready, to engage with relevant innovation activities and the CRCSI's Intellectual Property.

A company from each jurisdiction provides a Director to the Board of 43pl following a process of nominations. These directors aid communication with members with the support of the CRCSI Communication Manager and the regionally located Business Development team. As at 30 June 2017, the 43pl Directors were: Mr David Sinclair (Independent Chair), Mr Mark Watt (Queensland), Mr Jim Curnow (SA and NT), Mr Nathan Eaton (WA), Mr Mark Freeburn (NSW & ACT), Mr Rob Rowell (Tasmania and Victoria) and Mr Simon Jellie (New Zealand & International). 43pl also has a representative presence on the CRCSI Board through Mr Malcolm McCoy from 43pl partner, AAM Group. The current membership of 43pl is 33. In addition, a further 15 organisations have contributed as third parties to CRCSI activities, most of them SMEs. The number fluctuates as companies merge, leave the industry, spin off new companies or choose to leave the CRCSI. Nearly 100 companies have benefitted from 43pl membership over the last 10 years.

The CRCSI also has an MOU with the Spatial Industries Business Association (SIBA). This body represents around 300 companies. SIBA and the CRCSI work closely together, particularly with respect to the development of new programs for encouraging innovation in the industry and in improving its skills capacity. The CRCSI also has close ties with the Geospatial Information and Technology Association (GITA) and the Australian Information Industry Association (AIIA). In December 2016, SIBA and GITA merged.

The 43pl value proposition includes the provision of:

- A cluster or ecosystem of spatial companies, clients and researchers that provides an open model of innovation, reducing the barriers to collaboration and R&D and a neutral ground to meet clients and suppliers.

- Project engagement and learning through 43pl participation being sought in every project.
- Involvement in commercial activities to provide services to the CRCSI projects, totalling $11M to dozens of companies over the last 10 years.
- Access to R&D initiatives and the CRCSI IP for commercialization, e.g. Scanalyse, a spin-off company from the CRCSI research and development.
- Skills development and capacity building, including the recruitment of the CRCSI postgraduate students.
- Meaningful networking into government and academia to bring the end user close to the researcher, allowing the 43pl company to participate where niche expertise can be best applied.
- Assisting companies develop submissions for grant funds for innovation and business development.
- Assisting with technical advice on the development of intellectual property.

All research outputs are available for companies to use internally under certain conditions. Opportunities to commercialise specific project outputs are presented to companies through expressions of interest in taking on the innovation, with the CRCSI Board selecting the most appropriate business case.

3. Results

3.1 Utilisation and Commercialisation

The CRCSI to date has met 95 of its 118 utilisation milestones to date, or 81% of the total.

The milestones achieved to date have yielded numerous success stories. These include: the earlier than expected and vastly expanded utilisation of the Flight Assist System (FAS) through the growth of Fugro Roames across Australia and internationally; increased evidence of both state and national government data access and data licencing policy changes related to our earlier Creative Commons work; enhanced use of elevation products released through the CRCSI partners; use of the CRCSI www.coastalrisk. com.au website; expanded continued use of CRCSI software tools by government agencies, researchers and industry (Barista, Vertical Datum Transformation Tool, LiDAR Quality Assurance Tool, VicRivers tools); an enhanced implementation of National Elevation Data distribution; use of our software for adjustment of survey networks by all Australian governments; continued use of the HealthTracks™ tool inside WA Department of Health; policy acceptance and use of the Greyfields scenario planning tools inside government; rapid uptake (of the NRM Hub tool in the grazing industry; the acceptance of recommendations from CRCSI work in the move to a dynamic datum for Australia; and the use of the CRCSI research in shaping policy and resourcing decisions in Queensland Health. Those milestones, achieved ahead of plan, were largely due to three reasons:

(1) Successful response of local government partners in trialling and adopting prototype software in relation to planning;

(2) Partners exceeding previous estimates for adoption – in particular research outputs in the energy industry related to Fugro Roames; and

(3) Achieving our targets for graduated students and publications quicker than anticipated.

Key risks, issues and strategies in place to address the risks and any unmet milestones

Most utilisation milestones set out for 2017-18 are on track and should be met. In general, the CRCSI is on track to meet its targets, however there are seven milestones which are behind schedule and require close attention. Three delayed milestones relate to the Health Program where there has been delayed deployment of software in other state government departments. Usage will build from the current usage base of the WA Department of Health and Queensland Cancer Council. The research outputs have already resulted in significant policy and resourcing impacts within these two organisations with significant ongoing benefits. The capacity of government health agencies to absorb and roll out the software has been the main impediment to broader utilisation progress. However we have alternate research projects with promising adoption outcomes underway. One project is the rollout of a National Cancer Atlas across all cancer councils. Another project has demonstrated the benefits of interlinking seemingly disparate or previously unlinked data sets to transform healthcare. This has promising adoption potential amongst project partners.

Under the Spatial Infrastructures Program there are four unmet milestones as a result of delays in research progress. There are projects in place, resourced and underway to meet three of these milestones. Another relates to student completions and should be met in 2017-18. It should be noted that four students are on leave of absence due to short term work placements in industry and with partners. They will be resuming late 2017 to complete their studies.

The strategies for ensuring uptake by end users of the research outputs and the current levels of uptake

The technology transfer and utilisation strategy are built into the CRCSI proposals before the CRCSI Board will approve funding and enter into a project agreement. Criteria for project funding approval include a requirement that prospective utilisers and/or end users have significant involvement in the project. There must be a clear and credible route to industry application. Moreover, the work plan has to reflect an appropriate degree of commercialisation capability and awareness.

Every project is governed by a project agreement which details intellectual property ownership, the proposed route to application, and the role to be played by the entities involved. All parties committing resources to a project sign the agreement.

Quarterly meetings of the Project Management Groups consider potential commercialisation.

Projects are structured to include end users and market channel partners early within the project proposal process. Utilisation cases are developed for consideration by the CRCSI Board with input from the Project Management Group and CRCSI Executive. If approved, the utilisation case is progressed through the CRCSI commercial agent, Spatial Information Systems Research Limited (SISR), with an expression of interest to develop the commercial proposition sought from the CRCSI participants.

Utilisation and commercialisation arrangements with industry, including SMEs and other end users

SISR is the legal owner of the CRCSI Intellectual Property (CIP), with the beneficial rights of the property belonging to the Essential Participants of the Centre in proportion to the annual cash contributions. SISR is responsible for the commercialisation of CIP including marketing, seeking potential licensees and other commercial applications. The CRCSI Board is guided by two principles when selecting organisations to lead the utilisation of the CRCSI research outputs. Firstly, preference is given to those participants who have played a lead role in the research and development phase. Secondly, the flow of benefits from the outcomes of the utilisation must be in the overall best interests of all CRCSI partners. The strength of the business case presented following an expression of interest process for utilisation is a key factor in helping the CRCSI Board with its final decision. The CRCSI strives to ensure the best commercialisation mechanism is available to the project partners while at the same time balancing the expectations of its Essential Participants. In the case where the CRCSI enters co-funding arrangements with partners, there is a clear understanding of the ownership and rights to CIP, as well as a defined mechanism for the adoption of any research outputs.

Details of any new or improved products, services or processes, and specific benefits to end users (including SMEs), the nature and scale

New benefits relating to partners from improved endeavours resulting from 2016-17 activities included:

More effective quality assurance processes for elevation data acquisition. The CRCSI has developed a quality assurance (QA) tool in partnership with State and Commonwealth Government organisations, who regularly acquire airborne LiDAR data (QA4LiDAR). By bringing

together a set of common checks into one software package and largely automating their implementation, QA4LiDAR simplifies the QA process and increases efficiencies for both the contracting agency, end user and LiDAR provider. QA4LiDAR replaces the time intensive manual tasks required when checking airborne LiDAR deliveries. It drastically reduces the time required to quality assure data sets, saves money, provides transparency, increases confidence in data quality, and ensures data is fit for purpose. It is currently being used operationally and in research projects by a number of CRCSI partners. QA4LiDAR has been used on 50 airborne LiDAR projects in Australia and the Pacific by 12 organisations from across local, State and Commonwealth Government, universities and the private sector. It has now led to the development of QA4MOBiLE, a quality assurance tool for vehicle mounted LiDAR data.

Improving elevation data. Incorporation of the data in a national Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid. This product is developed and distributed by Geoscience Australia through the new data portal and has contributed to the 12,000 downloads in the first year of use. The DEM has been derived from some 236 individual LiDAR surveys between 2001 and 2015 covering an area in excess of 245,000 square kilometres. These surveys are licensed under Creative Commons. It has been used as a base layer in the CRCSI website at www.coastalrisk.com.au which to date has attracted over 120,000 users.

Improved datum maintenance. From our Program 1 dynamic datum project there has been software developed to implement and test geodetic adjustment approaches within a dynamic datum infrastructure. The software supports the automated segmentation and subsequent phased least squares adjustment of survey networks of any size. The software is being utilised by all Australian governments and we are advised it now forms a critical part of routine datum maintenance processes.

Next generation datums. Australia's current geocentric datum will not be able to support the requirements of Australians in a spatially connected world. The first Datum Modernisation Roadmap was released in 2011 and the CRCSI followed up with a series of recommendations for the implementation process aligned to a modern Australian geocentric datum. These were accepted by the lead agencies ANZLIC and the Intergovernmental Committee on Mapping and Surveying (ICSM).

Better Housing Redevelopment Planning tools. The CRCSI researchers continued the development of a decision-making tool called ENVISION to predict where housing redevelopments are likely to occur. This tool assists planners with housing redevelopment decisions. The ENVISION Toolkit allows planners, landowners and developers to work together and collaborate urban designs to ensure the development of more sustainable, liveable and economically viable cities in ageing suburbs. In the ENVISION/ESP toolkit non-expert users can carry out an extensive workflow from redevelopment site identification scenario design, visualisation and assessment without the time expense of a consultancy to prepare the same. The toolkit serves up information from the perspective of landowners, developers, planners, utilities and infrastructure providers. It has been used by several councils across two states in Australia as well as New Zealand. It has also been used both by the Western Australian and Victorian governments.

Farm decision support tools. The CRCSI rolled out the Natural Resources Management Spatial Hub (www.nrmhub.com.au) which continues to create impact across rural Australia through its online mapping tool that allows farmers and land managers to map and analyse 30 years of data in just a few minutes. The data results create information knowledge that allows farmers to develop best practice applications to increase profitability on a paddock-by-paddock basis

and increase probability outcomes that can reduce the costs of capital borrowings. It has over 900 users across Australia.

3D Facial Analysis using photogrammetry. There is a local and global need for innovation to deliver the timely use of deeply precise 3D facial data in a manner aligned to clinician workflow, to aid diagnosis for the estimated 6-8% of the global population living with a rare disease. A 3D facial analysis and reporting tool (3D-FAST) aimed at assisting in the diagnosis and treatment of such diseases is under development and is expected to significantly improve on existing methods of automated facial analysis for assisting in syndromic diagnosis.

Improving image processing capability. The CRCSI through a consortium approach successfully established a large-scale data processing capability for data from Earth observation satellites at National Computational Infrastructure (NCI) and Geoscience Australia. Over 360 terabyte of data was processed during the project, which amounts to about 184,000 Landsat scenes. One of the most important outcomes of the project was that researchers established a national infrastructure for delivering Earth observation data in a usable form. This infrastructure is formed by the Australian Reflectance Grid 25. It consists of three computer services – a catalogue service, a web map service and a web coverage service – that comply with standards generated by the International Standards Organisation and the Open Geospatial Consortium. This is a particularly significant achievement as the first Australian standard that allows data from different jurisdictions to be generated or re-sampled to a consistent grid ready for modelling and analysis. The work was conducted in conjunction with the Australian and New Zealand Land Information Council (ANZLIC). Another significant outcome of the project was the creation of RSA software. RSA is an open-source, scalable raster data (real-world data such as thematic and pictures) storage program. The research of the Landsat archive was completed in 2013 and has since been superseded by the Australian Geoscience Data Cube (AGDC) programme. The development of the AGDC is an integral part of future data infrastructure within the CRCSI research programs such as Big Data Solutions for Environmental Monitoring, the NRM Spatial Hub as examples. This has now been further funded for Australian Government rollout and will deliver a unique capability to process, interrogate, and present Earth observation satellite data. It will track changes across Australia in unprecedented detail, identifying soil and coastal erosion, crop growth, water quality, and changes to cities and regions.

Status and current performance of existing spin-off companies

The CRCSI maintains a small equity stake in one company through the transfer of previous research efforts. Australian company, iintegrate Systems Pty Ltd (www.iintegratesys.com), is commercialising IndjiWatchTM (www.indji.com), a product based on 'HazWatch' which was an outcome of one of the first round the CRCSI projects. IndjiWatch is a product for fully automated monitoring and analysis of natural hazard information and enterprise spatial information dissemination. The company provides software and online services that enable its customers to transform massive amounts of real-time, location-based data into valuable, targeted information.

To commercialise the NRM Hub platform, the CRCSI formed a company in late 2016-17. With over 800 properties using the service it was deemed viable to develop a business to provide a trusted environment for creating, managing, analysing, accessing and sharing their digital farm map to help improve productivity and sustainability.

3.2 Intellectual Property Management

The effective management and utilisation of IP is fundamental to achieving the objectives set out in the Strategic Plan. The management of IP is guided by the following practices:

- Facilitation of rapid uptake (and capability) by end-user Participants and stakeholders for national benefit.
- Innovative use of IP including all Participants having a licence to use IP for internal research purposes.
- Endeavouring to make prior decisions about the commercial potential of investments in IP from research. Where an impact maximising an outcome of public good is sought or where there is no commercial uptake (and no national security or privacy issues) then the IP will be placed into the public domain.
- Operating an end-user uptake pathway with emphasis on partnering SMEs and government organisations, supported by research providers. Appropriate consideration is also given to the needs of corporate Participants.
- Use of an EOI process to seek utilisation plans from the CRCSI Participants for IP deemed by the Board to be ready for end-user adoption.
- Recognition of the substantial public benefits of the principle of open access.
- Preferentially supporting end-user Participants who have been active in research projects and who wish to utilise research outputs.
- Exercising judgement at all times to maximise the collective benefit to the CRCSI as a whole.

The CRCSI IP comprises any IP developed by the Participants in carrying out the activities of the CRCSI (normally via project agreements). The CRCSI IP is beneficially owned by the Essential Participants as tenants-in-common in proportion to respective participating shares in the CRCSI. The management of the CRCSI IP is the highest priority of the CRCSI.

Each Essential Participant has a non-exclusive, royalty-free licence to use the CRCSI IP for the purposes of the CRCSI activities and a non-exclusive, royalty-free, irrevocable right to use the IP to carry out internal research and development, and training or teaching.

The legal owner of the CRCSI IP is SISR, which holds the IP in trust for the CRCSI Participants. SISR is responsible for protecting, registering, patenting and utilising the IP. SISR is the company that has been established as the holder and utilisation agent of the CRCSI IP and is responsible for the utilisation of the CRCSI IP, including the marketing of the IP, the seeking of potential licensees of the IP, and seeking other users of the CRCSI IP for commercial purposes.

If SISR intends to utilise the CRCSI IP, it must advise each of the CRCSI's Essential Participants in writing and identify the particular CRCSI IP and the terms of the proposed utilisation. Each Participant must, within 10 working days of receipt of the notice, advise SISR whether it desires to utilise or participate in the utilisation of the IP. If no Participant desires to commercialise, then SISR is free to utilise the CRCSI IP. No CRCSI Participant can commercialise, dispose of or encumber any interests which it might hold in the CRCSI IP, except where authorised.

The CRCSI adopts the principle that researchers should be encouraged to actively participate in research, utilisation and commercialisation activities of the CRCSI and be rewarded for doing so. Accordingly, all financial incentives for researchers who are employees of participating organisations will be paid in accordance with the relevant policies and employment conditions of those organisations.

The CRCSI Intellectual Property Register is a vital element in ensuring that information and methods generated by the CRCSI are recorded and, where appropriate, developed for commercial benefit.

The CRCSI IP Register serves to facilitate the use of new developments either by way of utilisation, or by contributing to other research activities within the CRCSI. It also provides a mechanism which helps both to identify material which is the property of the CRCSI and should be treated as confidential, and to identify material which should be protected.

3.3 Communication

Internal communication activities undertaken during the period

The purpose of our communication is to:

1. Convey an accurate sense of what the CRCSI is doing and by whom to our partners and stakeholders.

2. Promote the CRCSI, our partners, our outputs and our benefits to the wider community building a sense of the novel and foundation spatial research we conduct that leads to improved wellbeing and social good across contemporary Australia and New Zealand.

3. Reinforce a sense of pride and achievement in the work we do. The content focus of our communication is based on four core areas:

    1. Investment in research across our program areas.

    2. Project and education outcomes, applications and adoption of new technologies.

    3. Commercialisation opportunities and intellectual property investment.

    4. Project summaries, achievements and awards.

We are to tell our stories in a practical applicable way to the private sector, government and our partners. Our conversations beyond the immediate spatial community will seek to grow the spatial value chain by substantially increasing the impact of our activities and those of our partners. The value and connectedness of the CRCSI relationship of collaborative research across the spatial information sector will underpin our words. The communication plan sits under the strategic direction of the CRCSI Strategic Plan 2015-2018 and focuses on the operational goals of the current business plan – strengthening relationships, leveraging expertise and commercialisation opportunities. The communication plan incorporates key messages with target audience messaging for partners and participants, the user community, and the broader community (citizens). Using a communication matrix, channels of communication are matched to target audience groupings.

Profile Raising

The challenge for the CRCSI communication relates to communicating directly to the user community (seeking them out and finding their communication space), and gaining traction from the broader community about the value of the CRCSI and its role in bringing about lasting spatial technologies to all Australians and New Zealanders. The communication plan highlights two specific channels in which to address this challenge.

1. **Focus workshops for the user community.** The workshops targeted the major clients and government contractors of 43pl members and the CRCSI participants and partners. Key program areas represented were:

    - Positioning
    - Rapid Spatial Analytics and Spatial Infrastructures
    - Agriculture and Natural Resource
    - Built Environment
    - Health

    The workshops were held around Australia and New Zealand. Each workshop hosted a selection of the research programs that target the interests of local partners.

2. **Media stories** to build general community awareness about spatial research and the work of the CRCSI. We would like these to show the impact and future research opportunities that involve spatial and how they will improve the social wellbeing of Australians and New Zealanders. These stories will also highlight our partnerships with government (all levels) and the impact of our work that delivers social benefit (social good) to the community through these government relationships.

Internal Communication

The CRCSI directly employs 37 people across Australia and New Zealand. We come together once a year at an annual conference. The management team holds monthly teleconferences and the business development team connects weekly.

During 2016-17, the CRCSI continued to circulate *The Lull*, our internal monthly newsletter to all CRCSI staff. These light-hearted communications look at life, at personalities and at what we do. They offer insight into how some of our employees are doing great things to help our partners or benefit the community.

Communication Activities

The CRCSI has five main communication activities to communicate success and research achievements.

CRCSI Website: The website front page has been refreshed to reflect a contemporary feel and connect more readily with our stakeholders and the general community. With flexibility in the rolling messaging and images on the home page, we are able to update this from time to time.

Spatial News: This e-newsletter is received by 3,000 subscribers, segmented into key groups. This newly segmented database allows the CRCSI to specifically target messaging and communication. There were four editions during 2016-17.

Participant Forums: These closed forums, held in conjunction with Board meetings, are designed to bring together regionally located Essential Participants and partners to showcase research outcomes, project opportunities and provide an update on the activities and future plans of the CRCSI. This year, the CRCSI held two forums in Wellington, New Zealand and Melbourne.

CRCSI Annual Conference: In 2016, this event was held in Sydney. The conference was themed *'Innovation to Transformation'*. We hosted 281 delegates over the one and a half days including 203 at the awards dinner. Feedback from the delegates was very positive with each session receiving good to excellent ratings in the evaluation. This comment provides a sense of some of the feedback: *"Set a high level of professionalism that we haven't seen before in the spatial industry"*.

The delegates represented the CRCSI Essential Participants, support partners and 43pl members. The three colleges were also well represented; government, research and education and industry.

The Student Day 'Solvathon' at the conference inspired the 20 PhD students to think creatively about how blockchain technology could be applied. The students then divided into four teams with each team given the challenge to design an innovative use of blockchain tech in an application area relevant to current CRCSI research programs and initiatives.

The conference was opened by the Hon. Victor Dominello MP, Minister for Innovation and Better Regulation, NSW Department of Finance, Services & Innovation. Keynote speakers included: Dr Hugh Williams (VP Engineering, Google), Mr Roland Slee, (MD Asia Pacific, Bravura Solutions); Dr Catherine Ball (CEO, Remote Research Ranges and Telstra Business Woman of the Year, 2015) and Mr Peter Biggs, Chief Executive (Assignment Group, New Zealand.

Other activities

The CRCSI attended as an exhibitor and program presenter at LOCATE17, the premier spatial industries conference in Australia. Attracting over 600 delegates from government, private sector, universities and research agencies, the event also hosted the Asia Pacific Spatial Excellence Awards. The following received awards: Professor Wendy Lawson (University of Canterbury and Chair of the CRCSI's Research and Education College) received the SSSI Award for 'Professional of the Year'; the ISDE President's Award to Dr Zaffar Sadiq Mohamed-Ghouse (the CRCSI's Director-NSW Business Development, Research & International Relations); the ISDE Life Membership Award to Dr Peter Woodgate (CEO of the CRCSI) and Professional of the Year Award to Dr Graeme Kernich (Deputy CEO of the CRCSI).

The CRCSI and 43pl member partner NGIS, won one of four Excellence in Innovation Awards at the 2017 CRC Association Conference, for their collaborative work. Held in Canberra on 24 May 2017, the CRC Association Awards for Excellence in Innovation recognise outstanding examples of the transfer of CRC research results, knowledge and technologies that have been developed for a wide range of users of research, including the community, companies and government agencies.

The award highlighted Coastal Risk Australia (CRA), a world-first website that empowers coastal communities to take action against climate change. Built with Australian expertise from the CRCSI and NGIS Australia, the high impact of CRA led to the development of Coastal Risk Vanuatu and Coastal Risk Tonga – two Pacific nations on the front line of climate change impacts. For the first time, people of Australia and the Pacific can visualise how their neighbourhoods could be vulnerable to rising sea levels.

The CRCSI was a finalist in the 2016 APSEA Awards, held in April 2017, with its NRM Spatial Hub initiative in the Innovation and Commercialisation category and also in the People and Community category for its work with 43pl partner, NGIS Australia on the Coastal Risk Australia project.

Social Media

The CRCSI continues to gain traction and extend our communication across two key social media platforms. LinkedIn (company page) has increased by 28 per cent to 300 followers who seek news and updates on workshops, employment and networking opportunities as well as our research outputs. Twitter has grown by 21 per cent to 749 followers. This is the most active of our social platforms, with retweets, likes and comments, @crcsi twitter attracts on average 283 profile visits per month with tweet impressions up to 11,800 in a single month.

YouTube

The CRCSI YouTube channel is used as a host for its video content and that of our partners to support and showcase the collaborative research we conduct. In October 2016, we shortened the corporate video to three minutes as a showpiece at our annual conference. The video continues to be included in staff email signature blocks as part of our branding.

CRCSI Awards

The third awards ceremony held at the CRCSI's 2016 annual conference in Sydney highlighted four individuals for their outstanding achievements. The 2016 Research Excellence Award went to Professor Kerrie Mengersen. Kerrie is a Research Professor in Statistics at Queensland University of Technology (QUT). Her skills in spatial and temporal statistical modelling are world class and have brought considerable value to the CRCSI on the National Cancer Atlas and Great Barrier Reef monitoring and management projects.

The 2016 Student Excellence Award was received by Dr Daniel Hogg from the University of Canterbury in New Zealand. Daniel's PhD identified spatio-temporal clusters of adverse mental health outcomes, such as mood and anxiety disorders, that could be related to different exposures to the 2010/11 Canterbury earthquakes.

The 2016 43pl Company Award went to AAM Pty Ltd. From being a foundation member of 43pl in 2003, throughout a 13-year partnership, AAM has contributed significantly to 15 CRCSI projects.

The 2016 CRCSI Chair's Award, recognising an outstanding achievement across any aspect of the CRCSI, went to Dr John Dawson. John is Section Leader-Geodesy at Geoscience Australia and has been the Program Manager of the CRCSI's Positioning Research Program since the inception of CRCSI-2 in 2010. John was instrumental in designing this research program.

4. Resources

4.1 Governance and Management

The CRCSI is an unincorporated joint venture (UJV) under the terms and conditions set out in the Commonwealth Agreement and the Essential Participants' Agreement. The CRCSI is governed, managed and operated by a single unlisted public company limited by guarantee, Spatial Information Systems Research Limited (SISR), which is wholly owned by the UJV. SISR acts as trustee of the CRCSI Intellectual Property, employs the management staff, undertakes contract research work and otherwise manages the Centre's operations. Diagram 2 summarises the CRCSI's governance structure.

SISR is a charitable organisation under Subdivision 50-B of the Income Tax Assessment Act 1998 and section 123E of the Fringe Benefits Tax Assessment Act 1986. The tax exempt status means that SISR will not be liable for company taxation and will not be required to complete a tax return. SISR will still be liable for Goods & Services Tax (GST) and has reduced Fringe Benefit Tax (FBT) at a 49% rebate.

Each Essential Participant may be a member of SISR and there are seven Essential Participants who have chosen to do so. They are:

- 43pl (43 Version 2 Pty Ltd)
- Curtin University
- Department of Environment, Land, Water and Planning, VIC
- Department of Finance, Services & Innovation, Spatial Services Division, NSW
- Landgate, WA
- Queensland University of Technology
- University of New England

There are 58 formal participants in the CRCSI from the government, private and research (university) sectors, with a further 43 Third Party organisations that have committed cash or in kind to the Centre over the period. Formal participants have been formed into three Colleges, one representing each of these three sectors; 43pl (with 33 SMEs), the Research and Education College (primarily universities), and the Government Agencies College managed by ANZLIC (the Australia New Zealand Land Information Council made up of government agencies at Federal, State and Territory levels).

The Colleges operate independently of each other and help represent the views of its respective members especially in the formation of policy, the development of strategy, nominations of candidate directors to the Board and the admittance of new participants. They also provide a vital mechanism for two-way feedback and communication.

The CRCSI has significant membership from New Zealand including a lead government agency, Land Information New Zealand (LINZ), the University of Canterbury, and one 43pl member company. As a result, the CRCSI is known as the Australia and New Zealand CRC for Spatial Information.

Board membership and key skills

The seven member skills-based Board met formally five times in 2016-17. The majority of Directors of the CRCSI are independent. The Board is responsible for the governance and operations of the CRCSI and SISR. The Board has adopted formal protocols, detailing its functions and responsibilities. These are reviewed annually. While the Board has overall control of the CRCSI, it has delegated a range of its powers, duties and responsibilities to Committees and Executive Management team. The Board is advised by: the Research Investment Committee, the Audit and Risk Committee, the Nominations and

Diagram 2: The governance structure of the CRCSI.

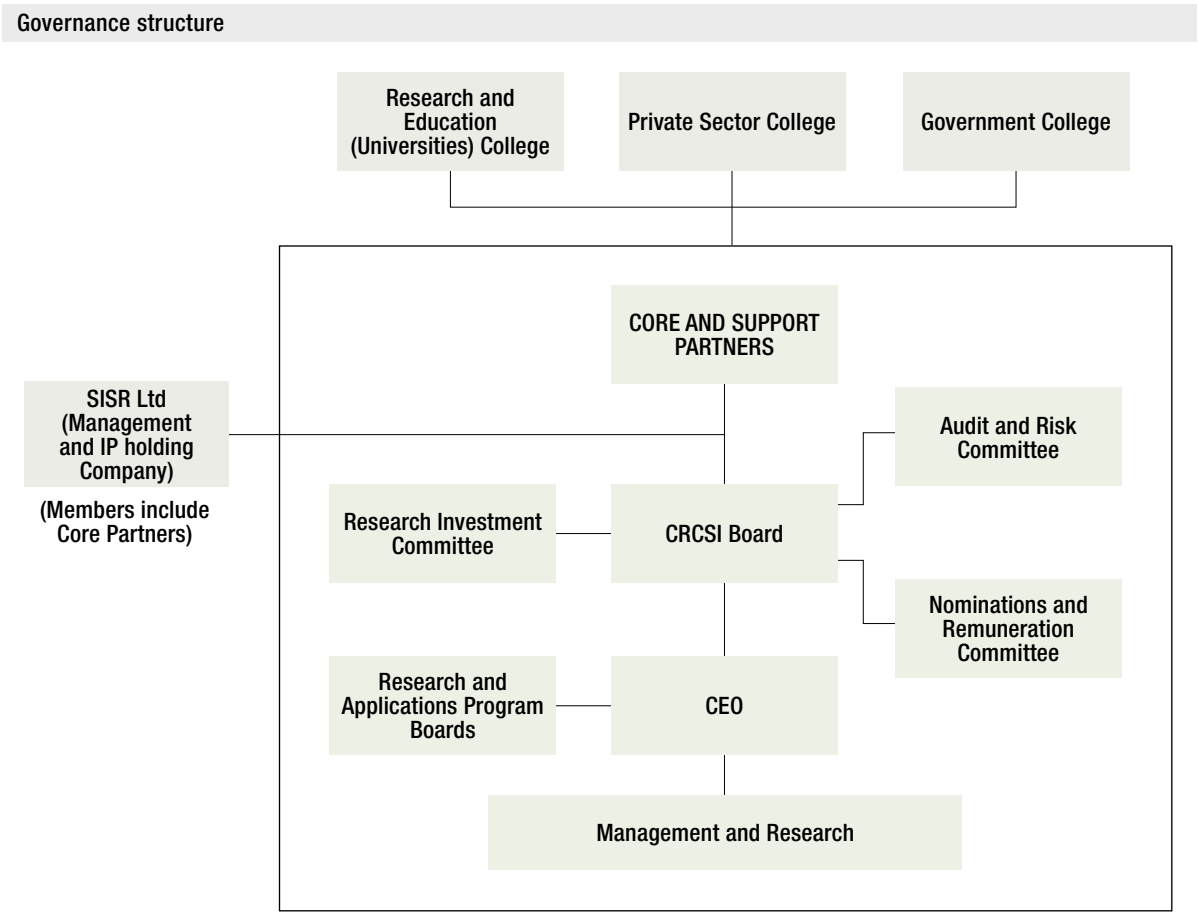


Table 6: Roles and Accountabilities within the CRCSI Governance Structure

Board	Executive	Science Directors	Project Leaders
Strategic Direction	Strategic Planning	Science and research excellence, project input and advice (project development; work quality; technical and commercial networks)	Research leadership
Policy	Operational Management	Internal links	Project stakeholder communication and relations
Budget	Business Development		Project management (staff and budget), meeting milestones and report
Strategic Plan Achievement	Commercialisation	Market interface	Internal liaison
CEO appointment	Adoption Pathways	Research utilisation	Adoption
	Relationships	International	
	International		

Remuneration Committee and Program Boards for most of the CRCSI's research and applications programs. A comprehensive suite of governance protocols, policies and guidelines has been implemented. The Board and supporting Committees review these periodically to assess the performance of the CRCSI and to ensure policies remain up to date and consistent with current regulatory requirements and best practice. An annual agenda of activities is maintained by the Board.

Table 7: Board and Committee membership during 2016-17

Committee Name: Audit & Risk Committee			
Name	**Role**	**Key Skills**	**CRCSI Affiliation**
Tina McMeckan	Chair	Board Director, Corporate Governance, Intellectual Property Management and Capital Raising	Independent
Malcolm McCoy	Member	Board Director, Current spatial industry experience from SME industry perspective, Corporate Governance	AAM Pty Ltd (43pl member)
Wayne Poole	Member	Financial management and audit corporate governance	RMIT University (Essential Participant)
Committee Name: Research Investment Committee			
Name	**Role**	**Key Skills**	**CRCSI Affiliation**
Graeme Wright	Chair	Board Director, Corporate Governance and Government experience	Curtin University (Essential Participant)
Steve Jacoby	Acting Chair	Board Director, Corporate Governance and Government experience	Qld Dept of Natural Resources & Mines (Essential Participant)
Arthur Berrill	Member/ Acting Chair	Current spatial industry experience – Industry sector	Independent, Scotiabank – Canada.
Rob Freeth	Member	Current spatial industry experience – Industry sector	Independent, Freeth Computing Consultants
Ed Garvin	Member	Current spatial industry experience – Industry sector	Omnilink Pty Ltd (43pl participant)
Ryan Keenan	Member/ Observer	Current spatial industry experience – Industry sector	Leica Geosystems, 43pl participant – (July-Oct 2016); CRCSI employee (Oct 2016-April 2017); and Independent, Locata Corporation (April 2017 onwards)
Scott Ramage	Member	Current spatial industry experience – Industry sector	AAM Pty Ltd (43pl participant)
John Trinder	Member	Current spatial industry experience – Industry sector	University of New South Wales (Other participant)
Peter Woodgate	Member	Board Director, Corporate Governance and Industry experience	CRCSI – CEO Ex Officio
Committee Name: Nominations and Remuneration Committee			
Name	**Role**	**Key Skills**	**CRCSI Affiliation**
Mary O'Kane	Chair	Board Director, Corporate and Academic sector experience	Independent
Colin MacDonald	Member	Board Director, Corporate Governance and Government experience	Independent
Steve Jacoby	Member	Board Director, Corporate Governance and Government experience	Qld Dept of Natural Resources & Mines (Essential Participant)

Notes:
1. From 1 July 2016, Prof G Wright is an independent member of the Board following his retirement from Curtin University.
2. Mr S Jacoby was Acting Chair of the RIC from October to December 2016.
3. Mr A Berrill was appointed as Acting Chair of the RIC from December 2016 until December 2017.

Table 6 summarises the roles and accountabilities within the CRCSI's Governance Structure.

Table 7 shows the Board and Committee membership during 2016-17. Management comprises an Executive and support staff, as well as Program Science Directors, Program Managers, and Project Leaders. Program Boards are program-wide panels tasked with the responsibility of reviewing the strategic direction of the research programs and making recommendations to the CRCSI Board with regard to the continuation, expansion, change in direction or termination of projects. These Boards are chaired by a lead end user and meet several times a year. It is a requirement of the CRCSI that the Program Board signs off on each project proposal before it is considered by the Research Investment Committee and the CRCSI Board. By signing off in this way, the Program Board is also attesting that if the research is successful then the end users intend to take up the research outputs for use beyond the CRCSI. On a project by project basis Project Management Groups then meet quarterly to review each project's progress. Reports from these meetings are referred to the relevant Program Boards and the CRCSI's Board. The Project Management Groups have the ability to recommend continuation, variation or termination of each project.

Directors

Mary O'Kane AC (Chair)

Mary is a consultant and company director. She is Executive Chairman of O'Kane Associates, advising governments and the private sector on innovation, research, education and development. She is also NSW Chief Scientist & Engineer. Mary was Vice-Chancellor of the University of Adelaide from 1996-2001 and Deputy Vice-Chancellor (Research) from 1994-1996. Mary has served on several boards and committees in the public and private sectors. She was Chair of the Australian Centre for Renewable Energy, a Director of FH Faulding & Co Ltd and was a Member of the Australian Research Council, the Cooperative Research Centres Committee and the Board of the Commonwealth Scientific and Industrial Research Organisation. She is currently Chair of the Boards of the Space Environment Management CRC and of the Institute of Marine and Antarctic Studies at the University of Tasmania. She serves on the boards of Business Events Sydney Ltd, the New Zealand Antarctic Research Institute, the Development Gateway, the Integrated Manufacturing CRC, and the Capital Markets CRC. Mary is a Fellow of the Australian Academy of Technological Sciences and Engineering and an Honorary Fellow of Engineers Australia.

Peter Woodgate

Peter was appointed to the position of CEO and Managing Director of the CRCSI in June 2003. He is the foundation Co-Chair of Australia's 2026 Spatial Industry Transformation and Growth Agenda; Co-Chair of the Australian Government's Space Cross-Sectoral Interest Group; Chair of the Global Spatial Network; Board Member of the UNESCO International Centre on Space Technologies for Natural and Cultural Heritage; Founding Chair of the Open Digital Earth Foundation; Board Member of AuScope Limited and Member of the Global Advisory Board of Geospatial Media. Peter was previously CEO of RMIT's Geospatial Science Initiative where he helped establish Spatial Vision Pty Ltd, RMIT's first ever spin-off, the Risk and Community Safety Research Centre and RMIT's Global Sustainability Institute. Peter has a Doctorate in Business Administration from RMIT University, a Masters of Applied Science from the University of New South Wales, a Degree in Forest Science from the University of Melbourne, and is a Graduate of the Mastering the Boardroom course of the Australian Institute of Company Directors.

Malcolm McCoy

Malcolm McCoy is a Business Development Consultant with AAM and has in excess of 25 years' experience as a director of survey and spatial companies and close to 40 years in the industry. He was previously Managing Director of Vekta, prior to it becoming part of AAM. Malcolm has a profound understanding of survey and spatial disciplines and has contributed to the profession at local, national and international levels. His areas of expertise are land and engineering surveying but also strategic planning, project management, and financial management.

Graeme Wright

Graeme retired as the Deputy Vice-Chancellor, Research at Curtin University in July 2016. He had held this position for the period 2011 – 2016 and has been awarded the title of Emeritus Professor in recognition of his contribution to the University. He has extensive knowledge and experience in education and research, including engagement with higher education policy at a strategic level. Graeme has previously held appointments in the vocational educational sector and more recently across higher education at executive level, and has a profound understanding of the university research environment and its application to industry and the community.

Graeme has extensive experience on Boards and Committees of research centres and CRCs, liaison with industry and negotiation of funding agreements, and broad research knowledge in spatial information sciences. He has been closely involved with the CRC for Spatial Information since 2003, then as a member of the Research and Education Advisory Committee and the CRCSI Board. Graeme was the inaugural Chair of the Research and Education College and chaired the Research Investment Committee from July to September 2016. Graeme led the engagement of Curtin with the CRCSI during its inception and his research background is in remote sensing.

Tina McMeckan

Tina has 20 years' experience as a company director and senior executive in listed and private companies, partnerships, not for profit entities and with government businesses. Her specific industry skills are in the energy sector and in the commercialisation of science and technology. Key competencies include corporate governance, risk management, enterprise development, and investment analysis. Tina has extensive board expertise in public and private utility infrastructure including power production, networks and retailing businesses in the gas and electricity industries. Currently she is a Director of the Global Carbon Capture and Storage Institute and Ausnet Services Ltd. Her other appointments as a Director have included Alinta Limited and United Energy Limited. Her significant experience in technology development includes past appointments as the Chair of the Centre for Eye Research Australia and as a Director of Circadian Technologies Ltd, Director of the Vision CRC, Member of the Funds Management Committee of the AusIndustry Research and Development Board and Member of the Victorian EPA Hazwaste Fund Advisory Panel.

Colin MacDonald

Colin MacDonald is Chief Executive of New Zealand's Department of Internal Affairs, Secretary for Internal Affairs, Secretary for Local Government, and the Government Chief Information Officer (GCIO). In his GCIO role, Colin is the ICT Functional Leader for government and works collaboratively across the state sector to transform government ICT to support radically transformed

public services. Colin is also responsible for the success of the Government's Better Public Services Result 10 initiative, which strives to improve citizens' digital interaction with government.

Colin has had more than 30 years of public and private sector experience in information technology and general management, beginning with studies in computer science at Glasgow University, and then starting his career in the UK. In New Zealand, he was previously Chief Executive of Land Information New Zealand, Deputy Commissioner Business Development and Systems at Inland Revenue, and Chief Operating Officer for the ANZ Banking Group (NZ).

Steve Jacoby PSM

Steve is the Executive Director of Land and Spatial Information (LSI) in the Department of Natural Resources and Mines (DNRM). The LSI division is responsible for spatial data, systems, services and infrastructure. Steve has chaired the Queensland Spatial Information Council (QSIC) since 2009, and represents the State Government on a number of spatial information expert panels, peak bodies, committees and boards. Steve commenced his career with Land Victoria as a trainee. Steve went on to lead the Department's Land Information Group for seven years. In 2003, he commenced with the Queensland Government as Chief Information Officer for the Department of Natural Resources and Water. Steve holds a Bachelor of Applied Science from RMIT University and a Research Master of Surveying Science (Information Technology) from The University of Melbourne. Steve is currently an Adjunct Professor with the Institute for Future Environments at the Queensland University of Technology (QUT). Steve was awarded the Public Service Medal for services to land and spatial information in the 2014 Queen's Birthday Honours List.

Board meeting dates and attendance

Table 8 sets out the number of Board and Board Committee meetings held and the number of meetings attended by each Director and/or Board Committee member.

Changes to board membership

There were no changes to Board membership during 2016-17.

Board committee membership, function, reporting arrangements and key skills

Audit and Risk Committee

The Audit and Risk Committee met three times in the period. Its function is to provide assistance and give advice to the Board to discharge its responsibilities pertaining to financial reporting, audit and risk management. The Committee has adopted a formal Charter outlining its functions and responsibilities. This three-member Board appointed Committee is comprised of two Board members and one member who has considerable accounting and auditing expertise, sourced from RMIT University (a CRCSI Essential Participant).

BDO (formally PKF Australia Ltd) were re-appointed as the external auditors and tax advisers for the CRCSI, SISR and 43pl for the reporting period. The performance of the external auditor is reviewed annually by the Audit and Risk Committee through consultation with the CRCSI Management, and a recommendation provided to the Board to determine reappointment for the following year.

Research Investment Committee

The purpose of the Research Investment Committee is to advise the Board on investment decisions relating to the Research Program, including utilisation issues, market applications of the science and technology within the activities, and any technical, research and education issues.

Table 8: CRCSI Board and Committee Meeting attendance in 2016-2017

Directors/Committee Members	Board of Directors		Audit & Risk Committee		Research Investment Committee		Nominations & Remuneration Committee	
Number of meetings held	5		3		6		1	
Directors	**Eligible**	**Attended**	**Eligible**	**Attended**	**Eligible**	**Attended**	**Eligible**	**Attended**
Colin MacDonald	5	4					1	1
Graeme Wright	1	1			2	2		
Mary O'Kane	5	5					1	1
Malcolm McCoy	5	5	3	3				
Peter Woodgate	5	5						
Tina McMeckan	5	5	3	3				
Steve Jacoby	5	4			3	1	1	1
Committee Members	**Eligible**	**Attended**	**Eligible**	**Attended**	**Eligible**	**Attended**	**Eligible**	**Attended**
Arthur Berrill					6	6		
Scott Ramage					6	5		
Rob Freeth					6	6		
Ryan Keenan					6	5		
Ed Garvin					6	4		
John Trinder					6	4		
Wayne Poole			3	3				

Notes:
1. Board meetings were held on 4 August 2016, 7 October 2016, 16 December 2016, 2 March 2017, 9 June 2017.
2. From 1 July 2016, Professor Graeme Wright is an independent member of the Board following his retirement from Curtin University. Professor Wright took a leave of absence from the Board and as Chair of the Research and Investment Committee effective 29 September 2016, for personal reasons.

Appointment to the eight-member Committee is by the CRCSI Board who has the right to vary membership numbers as required. The Committee met six times during the period to review research project proposals and initiatives. Funding recommendations for Board approval resulted in new projects in all four of the CRCSI research program areas. When the Committee meets it invites the Science Directors and Senior Executives of the CRCSI.

Nominations and Remuneration Committee

This Committee comprises three members and is chaired by the Chair of the CRCSI, Professor Mary O'Kane. It provides advice and recommendations to the Board on issues relating to Board composition and succession, annually reviews the performance of the CEO and senior executives, and oversees the establishment, maintenance, recruitment, retention and termination policies and practices for senior executives and independent Directors. The Committee meets periodically as needed.

Table 9: Time Commitments of Key Staff

Key Staff	Organisation	CRC Position/Role	Time
Peter Woodgate	CRCSI	Chief Executive Officer	100%
Graeme Kernich	CRCSI	Deputy CEO and Business Manager	100%
Phil Collier	CRCSI	Deputy CEO and Research Director	100%
Peter Teunissen	Curtin University	Professor and Science Director (Research Program 1: Positioning)	75%
John Dawson	Geoscience Australia	Program Manager Research Program 1	40%
Matthew Duckham	RMIT	Professor and Science Director (Research Program 2: Rapid Spatial Analytics)	46%
Nathan Quadros	CRCSI	Education Manager and Program Manager (Research Program 2: Rapid Spatial Analytics)	60%
Geoff West	Curtin University	Professor and Emeritus Science Director (Research Program 3: Spatial Infrastructures)	20%
David McMeekin	Curtin University	Associate Science Director (Research Program 3: Spatial Infrastructures)	20%
Ivana Ivanova	Curtin University	Associate Science Director (Research Program 3: Spatial Infrastructures)	17%
Matthew Wilson	University of Canterbury	Professor of Spatial Information (Research Program: Spatial Infrastructures)	50%
Kylie Armstrong	CRCSI	Program Manager (Research Program 3: Spatial Infrastructures)	80%
David Lamb	UNE	Professor and Science Director (Applications Program 4.1: Agriculture, Natural Resources and Climate Change)	20%
Philip Tickle	CRCSI	Program Manager (Applications Program 4.1: Agriculture, Natural Resources and Climate Change)	25%
Clive Fraser	CRCSI	Professor and Science Director (Application Program 4.2: Defence)	20%
Clive Sabel	Aarhus University	Professor and Science Director (Applications Program 4.4: Health)	5%
Jim Codde	University of Notre Dame	Professor and Science Director (Applications Program 4.4: Health)	2%
Paul Fievez	CRCSI	Program Manager (Applications Program 4.4: Health)	60%
Peter Newman	Curtin University	Professor and Science Director (Applications Program 4.5: Urban Sustainable Development)	10%
Phil Delaney	CRCSI	Program Manager (Applications Program 4.5: Urban Sustainable Development)	10%

Notes:
Application Program 4.3: Energy Utilities is yet to demonstrate a need for a Science Director
Geoff West retired from Curtin University in March 2016

4.2 Strategic Plan 2017-2018 (and beyond)

The CRCSI Strategic Plan is reviewed annually by the Board.

Vision: Spatially enabling Australia and New Zealand

The CRCSI will be widely recognised for undertaking high impact, collaborative research that leads to accelerated industry growth, improved social wellbeing and a more sustainable environment.

What success will look like

By 2018 the CRCSI will be recognised world-wide for its high impact of our research. A thriving spatial industry will acknowledge the central role of the CRCSI. We will be considered an essential partner for complex SI research collaborations both locally and internationally.

Our values

We will be strongly collaborative in our relationships, strive for excellence in our research, and always aim to be transformational in our impact.

Our strategic objectives

National Precise Positioning (Research Program 1)

Objective 1: To conduct research that solves the signal processing and economic impediments to the creation of a sparse, continental-scale, precise positioning multi-GNSS network operating at 2 cm (x and y) accuracies.

Rapid Spatial Analytics (Research Program 2)

Objective 2: To conduct research that improves the ability and efficiency of government and industry to rapidly create and value-add spatial information products, manually or through automation, from devices and cloud-based infrastructure.

Spatial Infrastructures for Australia and New Zealand (Research Program 3)

Objective 3: To identify and exploit the emerging capabilities of the Semantic Web to enable Foundation Spatial Data and their spatial data supply chains to create value-added applications.

Applications (Program 4)

Objective 4: To realise high impact use of the CRCSI's research in the following areas: **Agriculture, Natural Resources and Climate Change (4.1)** through the creation of a biomass and carbon monitoring system for high resolution and high frequency application on farms and through improved environmental monitoring; **Defence (4.2)** by adapting the capabilities of the CRCSI's research portfolio; **Health (4.4)** by helping agencies to spatially enable their clinical databases; and **Built Infrastructure (4.5)** to build new tools to support sustainable built infrastructure development.

Education (Program 5)

Objective 5: By 2018 the CRCSI will have at least 51 PhD and Masters completions through our university partners, all of whom have significant industry experience.

Industry Development And Sustainability (Program 6)

Objective 6: Industry development; assist our partners, in particular 43pl, develop and exploit CRCSI IP.

Objective 7: Commissioned research and other funding; generate an additional $11M of activity to June 2018 tackling complex research needs involving multiple partners from both public and private sectors.

Performance indicators

1. A solution for the impediments of multi-GNSS signal processing and economic arguments for a continent-wide, ubiquitous, sparse, precise positioning network.

2. Adoption by our partners of new methodologies and software tools that enhance the level of rapid automation of data fusion, feature extraction and analysis.

3. Wide recognition by our partners of the CRCSI's role in helping establish and value-add critical supply information chains.

4. High impact end-user applications adopted in each Application Program.

Strategic planning beyond June 2018

The CRCSI is synchronising its long-term planning to align with whole of sector initiatives such as the 2026 Spatial Agenda. Commitment is being sought from partners from government, research and industry towards the creation of a successor entity to the CRCSI, post 2018. Detailed programs, plans and budgets for the successor entity will be confirmed and founding partners expected to sign up by the end of 2017, subject to approval by the Governing Board.

4.3 Participants

Participant List (including Essential, Other and Third Party Participants)

A total of 101 CRCSI contributors, including Essential, Other and Third Parties have provided either cash or in kind contributions to support the CRCSI's activities for 2016-17. Of these, 45 Participants are equity holding partners in the Centre (12 Essential Participants and 33 43pl members) holding beneficial ownership rights in Centre IP based in proportion to aggregate cash contributions to the CRCSI.

A further 13 participants are Other (or support) Participants, and the remaining 43 Third Party Participants have entered into specific project agreements or been involved in other Centre activities within the period. For a full list of 2016-17 Participants see Table 10.

TABLE 10: CRCSI PARTICIPANTS 2016-17

Participant's Name	Participant Type	ABN or ACN	Organisation Type
43 Version 2 Pty Ltd	Essential	95 140 787 971	Industry / Private Sector
Curtin University	Essential	99 143 842 569	University
Department of Environment, Land, Water & Planning, VIC	Essential	90 719 052 204	State Government
Department of Finance, Services & Innovation, Spatial Services Division, NSW	Essential	84 104 377 806	State Government
Department of Natural Resources and Mines, QLD	Essential	46 640 294 485	State Government
Ergon Energy Corporation Limited	Essential	50 087 646 062	Industry / Private Sector
Geoscience Australia	Essential	80 091 799 039	Australian Government
Landgate, WA	Essential	86 574 793 858	State Government
Queensland University of Technology	Essential	83 791 724 622	University
Royal Melbourne Institute of Technology University	Essential	49 781 030 034	University
The University of New England	Essential	75 792 454 315	University
University of Canterbury	Essential	n/a	International
Australian Geospatial Organisation, Department of Defence	Other	68 706 814 312	Australian Government

Participant's Name	Participant Type	ABN or ACN	Organisation Type
Department of Health, WA	Other	13 993 250 709	State Government
Department of Lands, Planning and the Environment, NT	Other	84 085 734 992	State Government
Energex Limited	Other	40 078 849 055	Industry / Private Sector
Land Information New Zealand	Other	n/a	International
Office of Environment and Heritage, NSW	Other	30 841 387 271	State Government
Open Geospatial Consortium Inc	Other	n/a	International
Swinburne University of Technology	Other	13 628 586 699	University
The University of New South Wales	Other	57 195 873 179	University
University of Canberra	Other	81 633 873 422	University
University of Melbourne	Other	84 002 705 224	University
University of Twente	Other	n/a	International
Western Australian Agricultural Authority	Other	86 611 226 341	State Government
AAM Pty Ltd	43pl	63 106 160 678	Industry / Private Sector
Alexander Symonds Pty Ltd	43pl	93 007 753 988	Industry / Private Sector
Amristar Solutions Pty Ltd	43pl	35 098 156 560	Industry / Private Sector
Brazier Motti	43pl	58 066 411 041	Industry / Private Sector
Brown & Pluthero Pty Ltd	43pl	55 010 117 236	Industry / Private Sector
Business Aspect Pty Ltd	43pl	24 100 876 015	Industry / Private Sector
C R Kennedy & Co Pty Ltd	43pl	50 008 458 884	Industry / Private Sector
Earthmine Australia Pty Ltd	43pl	45 150 760 839	Industry / Private Sector
Eco Logical Australia Pty Ltd	43pl	87 096 512 088	Industry / Private Sector
EOMAP GmbH & Co.KG	43pl	n/a	Industry / Private Sector
e-Spatial Ltd	43pl	n/a	Industry / Private Sector
Fugro Spatial Solutions Pty Ltd	43pl	52 008 673 916	Industry / Private Sector
Gaia Resources	43pl	94 119 508 824	Industry / Private Sector
GHD Pty Ltd	43pl	39 008 488 373	Industry / Private Sector
GPSat Systems Australia Pty Ltd	43pl	47 056 077 902	Industry / Private Sector
Insight GIS	43pl	80 059 212 798	Industry / Private Sector
Jacobs Group (Australia) Pty Ltd	43pl	37 001 024 095	Industry / Private Sector
Land Equity International Pty Ltd	43pl	42 097 054 165	Industry / Private Sector
Leica Geosystems Pty Ltd	43pl	18 000 112 765	Industry / Private Sector
Mercury Project Solutions Pty Ltd	43pl	57 141 118 194	Industry / Private Sector
NGIS Australia Pty Ltd	43pl	56 061 264 793	Industry / Private Sector
Omnilink Pty Ltd	43pl	80 056 793 723	Industry / Private Sector
Photomapping Services	43pl	30 005 552 876	Industry / Private Sector
Position Partners Pty Ltd	43pl	56 130 367 065	Industry / Private Sector

Participant's Name	Participant Type	ABN or ACN	Organisation Type
PSMA Australia Ltd	43pl	23 089 912 710	Industry / Private Sector
Spatial Vision Innovations Pty Ltd	43pl	28 092 695 951	Industry / Private Sector
Spookfish Pty Ltd	43pl	95 603 648 264	Industry / Private Sector
Sundown Pastoral Co Pty Ltd	43pl	86 000 334 190	Industry / Private Sector
Superair	43pl	25 990 899 338	Industry / Private Sector
Think Spatial	43pl	65 711 887 042	Industry / Private Sector
Twynam Agricultural Group Pty Limited	43pl	12 000 573 213	Industry / Private Sector
VPAC Ltd	43pl	59 093 732 426	Industry / Private Sector
Whelans (WA) Pty Ltd	43pl	68 074 363 741	Industry / Private Sector
AACO Pty Ltd	Third Party	87 077 456 476	Industry / Private Sector
Arthur Berrill	Third Party	n/a	International
Australian Institute of Health and Welfare	Third Party	16 515 245 497	Australian Government
Australian National University	Third Party	52 234 063 906	University
Australian Wool Innovation Ltd	Third Party	12 095 165 558	Industry / Private Sector
Biosphere Reserve Foundation Ltd	Third Party	15 107 484 408	Industry / Private Sector
Bureau of Meteorology	Third Party	92 637 533 532	Australian Government
Bushfire and Natural Hazards CRC Ltd	Third Party	21 163 137 979	Industry / Private Sector
B Woolridge & Co	Third Party	56 579 217 361	Industry / Private Sector
Canary Advanced Solutions	Third Party	n/a	International
Cancer Council (QLD)	Third Party	48 321 126 727	State Government
Canterbury District Health Board	Third Party	n/a	International
Central Queensland University	Third Party	39 181 103 288	University
Christchurch City Council	Third Party	n/a	International
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Third Party	41 687 119 230	Australian Government
David Sinclair	Third Party	n/a	Industry / Private Sector
Department of Prime Minister and Cabinet	Third Party	18 108 001 191	Australian Government
Department of Science, Information Technology and Innovation (QLD)	Third Party	41 841 375 926	State Government
Department of Transport and Main Roads (QLD)	Third Party	39 407 690 291	State Government
Desert Channels Queensland Incorporated	Third Party	38 323 082 163	Industry / Private Sector
Dr Nik & Associates	Third Party	n/a	International
Facey Group Inc	Third Party	59 136 484 550	Industry / Private Sector
Freeth Computing Consultants Pty Ltd	Third Party	67 054 190 297	Industry / Private Sector
Future Position X	Third Party	n/a	International
Griffith University	Third Party	78 106 094 461	University
Hitachi Australia Ltd	Third Party	34 075 381 332	Industry / Private Sector

Participant's Name	Participant Type	ABN or ACN	Organisation Type
Intergovernmental Committee on Surveying & Mapping	Third Party	33 830 643 298	Australian Government
Gerard Coutts & Associates	Third Party	82 776 632 573	Industry / Private Sector
Japan Aerospace Exploration Agency	Third Party	n/a	International
Maroondah City Council	Third Party	98 606 522 719	State Government
Massachusetts Institute of Technology	Third Party	n/a	University
Meat and Livestock Australia Limited	Third Party	39 081 678 364	Industry / Private Sector
Monash University	Third Party	12 377 614 012	University
Murdoch University	Third Party	61 616 369 313	University
Murray-Darling Basin Authority	Third Party	13 679 821 382	Australian Government
Myriota Pty Ltd	Third Party	65 609 161 373	Industry / Private Sector
Parramatta City Council	Third Party	49 907 174 773	State Government
Resource Consulting Services Pty Ltd	Third Party	49 009 623 590	Industry / Private Sector
South West NRM Ltd	Third Party	95 111 225 293	Industry / Private Sector
Symbolix Pty Ltd	Third Party	62 997 546 845	Industry / Private Sector
The Department of Internal Affairs (NZ)	Third Party	n/a	International
University of Ontago	Third Party	n/a	International
WA Primary Health Alliance	Third Party	11 602 416 697	State Government

Note:
This list comprises organisations that have executed a formal Commonwealth Participant's agreement with the CRCSI or are actively participating in CRCSI projects.

Key relationships have also been forged with non-equity holding partners including all of Australia's leading spatial peak bodies; ANZLIC (Australia New Zealand Land Information Council) representing the government interests, SIBA-GITA (Spatial Industries Business Association and Geospatial Information Technology Association) representing the private sector interests and SSSI (Surveying and Spatial Sciences Institute) representing the spatial profession.

Changes to Participants

Ergon Energy withdrew as an Essential Participant in the Centre effective 25 June 2017.

The Northern Territory Department of Lands, Planning and the Environment and The University of Canberra joined the Centre as an Other Participant in 2016-17.

4.4 Collaboration

The CRCSI has a College system to facilitate communication, accountability and decision making across all Essential Participants and partners. The three Colleges are:

- Government College, led by ANZLIC
- Research and Education College
- SME College through 43pl

The Colleges are also the conduit for partners to explore the range of research opportunities and develop collaborative research proposals in conjunction with the CRCSI Program Managers and Science Directors. The Colleges have ongoing access to commercialisation and intellectual property opportunities as a result of the research results and outcomes.

CRCSI Collaboration with other CRCs and Growth Centres

Over the last 12 months, the CRCSI has collaborated with CRCs and Growth Centres. These collaborative activities have included:

1. Low Carbon Living CRC

CRCSI Built Environment Science Director, Professor Peter Newman and Project Leader, Professor Peter Newton provide shared expertise and hold senior roles with the LCL CRC.

This expertise and collaboration reflected in the ongoing '*Greening the Greyfields*' project (Built Environment Program) which involves the CRCSI and LCL CRC including financial and staff support from both CRCs.

2. Capital Markets CRC

Formal collaborations began in 2015 with the newly appointed CM CRC Health Program Manager being allocated office space in the CRCSI head office in Melbourne. This physical connection has led to closer networks and investigation into co-research opportunities within the Health Program.

3. Growth Centres

The CRC has been engaging with growth sectors through two key initiatives this year.

Firstly, CRCSI has been engaging with FIAL and METS Ignited to develop supply chain innovation strategies, in partnership with other value chain participants.

Secondly, the 2026 Spatial Industry Transformation and Growth Agenda, a whole of industry strategy driven by CRCSI and SIBA|GITA, has engaged with growth centres to profile key drivers across the sectors to help spatial businesses and research organisations better direct their efforts.

Participant and Partner Collaboration

The CRCSI has a nationally located business development network with managers located in key partner locations. The 10 business development managers are located in:

- Melbourne (head office) located close to Essential Participants DELWP, RMIT University and support partner, Swinburne University
- New Zealand (Wellington) at the office of support partner LINZ
- Canberra at the office of Essential Participant, Geoscience Australia
- Perth at the office of Essential Participants, Landgate and Curtin University, and support partner WA Department of Health
- Brisbane at the office of Essential Participant, Queensland University of Technology
- Sydney at the office of Essential Participant, Property NSW, formally Land and Property Information.

External linkages and how it contributes to the CRCSI overall

During 2016-17, the CRCSI collaborated with 101 organisations who formally contributed to the activities of the Centre. Involvement can range from significant contribution to one or more CRCSI funded projects, through to attendance at the annual conference or a program focused workshop.

National

There were 85 Australian based organisations who were participants in the Centre during 2016-17 and they are represented as follows:

- 13 organisations from research and education
- 21 organisations from government agencies
- 51 SME and corporate business

International

The CRCSI undertakes collaborative research work with organisations outside Australia. During 2016-17 the CRCSI collaborated with 16 international organisations. These are represented as follows:

- Four organisations from research and education
- Four organisations from government agencies
- Eight SMEs and corporate businesses

The linkages through the three Colleges to the research community and end users contribute to the CRCSI by ensuring project concepts leading into full proposals are collaborative across the participant spectrum. The business development team underpins this collaboration by ensuring proposed research concepts are congruent to key CRCSI deliverables. This approach to project development builds upon existing intellectual property and commercialisation opportunities. It also encompasses the education program and its current student cohort to continue to increase expertise and indigenous knowledge and capacity in the Australian spatial information sector.

4.5 Financial Management

Overview of the financial position and management of the CRCSI in relation to the activities.

The CRCSI was in a healthy financial position at the end of the 2016-17 year, with $13.1M cash at bank and has sufficient funding to meet its debts. The CRCSI finished the year with an operating deficit of $5.8M against a budget deficit of $8.5M. This is a favourable movement compared to budget, due to the lower than expected spend in research by $3.2M, and also under spend and savings within the Directorate, Business Development, Communication and Board expenditure areas. Total cash and in kind contributions were $26.0M for the period, favourable to budget by $1.0M, with favourable variances from cash and non-staff in kind contributions totalling $3.8M, offset by unfavourable staff in kind contributions of $2.8M. Cash received was 76% higher in 2016-17 than forecast in the Commonwealth Agreement. Table 11 summarises the 2016-17 Financial Statements.

BDO was reappointed as external auditors and the related financial reports and statements were prepared in accordance with the Australian Accounting Standards, International Financial Reporting Standards and Interpretations and Commonwealth Guidelines where required. At the conclusion of the audit process, no audit adjustments were required.

Concurrent to completion of current Commonwealth Agreement activities, the CRCSI has progressed with plans for the establishment of a post June 2018 entity as detailed in the wind up and exit sections of this report. With a go/no go decision expected in December 2017, the 2017-18 budget has been prepared with consideration to both transition and wind up scenarios.

TABLE 11: Financial Statements 2016-17

Financial Statement ($'000s)				
Funds (Cash)	**2015-16 Actual**	**2016-17 Actual**	**2016-17 Budget**	**2017-18 Budget**
Essential Participants	5,688	3,413	3,450	2,578
Other Participants	584	1,290	437	467
CRC Program	3,572	3,498	3,498	3,500
Commissioned Research/Other	2,791	4,940	3,305	4,659
Total Funds	**12,635**	**13,141**	**10,690**	**11,204**

Expenditure (Accrual)	**2015-16 Actual**	**2016-17 Actual**	**2016-17 Budget**	**2017-18 Budget**
Governance & Administration	1,793	1,980	2,201	2,241
Business Development	908	903	1,356	1,291
Research Program	8,423	9,379	11,771	13,580
Communications & Education	156	131	233	200
Total Expenditure	**11,280**	**12,393**	**15,561**	**17,312**

In Kind Statement	**Staff FTE in kind**			**Non-staff in kind ($'000s)**		
	Actual 2015-16	**Actual 2016-17**	**Budget 2016-17**	**Actual 2015-16**	**Actual 2016-17**	**Budget 2016-17**
Research Program 1	9.0	8.3	6.4	1,453	1,575	1,002
Research Program 2	2.2	5.2	12.3	447	800	951
Research Program 3	2.6	4.7	1.9	814	441	508
Research Program 4	15.1	12.2	20.4	2,045	2,187	1,237
Total	**28.9**	**30.4**	**41.0**	**4,759**	**5,003**	**3,698**

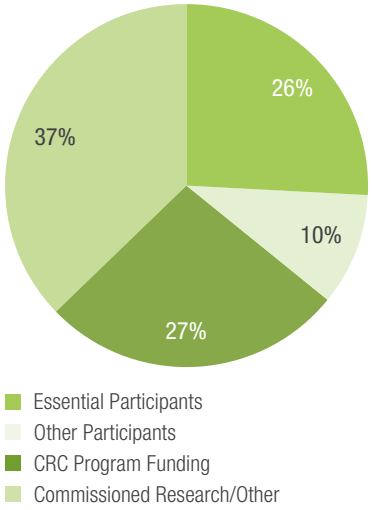
Total Contributions ($'000s)	**2015-16 Actual**	**2016-17 Actual**	**2016-17 Budget**	**2017-18 Budget**
Cash	12,635	13,141	10,690	11,204
Staff In kind	7,264	7,823	10,666	10,532
Non-Staff in kind	4,759	5,003	3,698	3,346
Total Contributions	**24,658**	**25,967**	**25,054**	**25,082**

Assessment of the financial performance overall, including the level of participant contributions, details of any issues experienced and the strategies implemented to address the issues

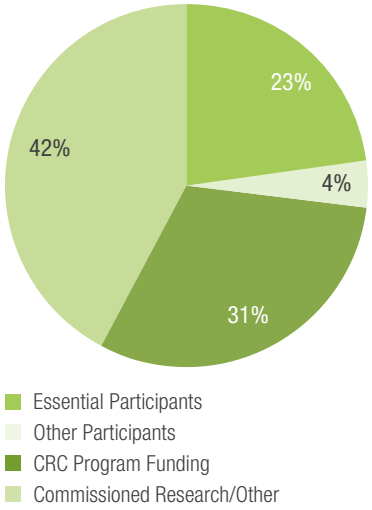
Comprehensive reporting of the CRCSI financials can be found in the Commonwealth online report and company statutory accounts. In summary, the CRCSI received total cash funding for 2016-17 of $13.1M, which was $2.5M above budget including additional contributions from Other Participants (+$0.8M) and other sources including other grants, Commissioned Research and Non-Participant Contributions (+$1.7M).

Included in other sources and classified as "Other Grants" is the first contracted payments from Geoscience Australia ($0.5M) and Land Information New Zealand ($1.2M), for the Satellite-Based Augmentation System (SBAS) Testbed Project, an Australian and New Zealand Government initiative to identify and quantify the benefits of SBAS technology. The 25 or so sub-projects the CRCSI is managing within this initiative, will run from January 2017 through to March 2019.

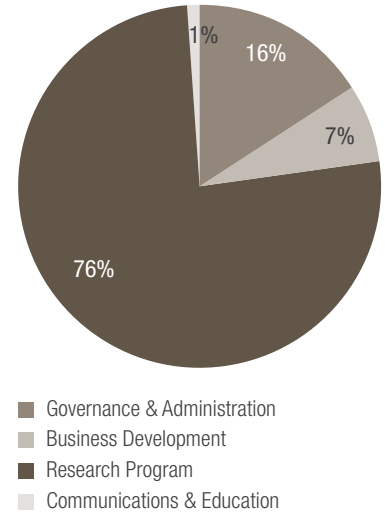
2016-17 Funding by Source



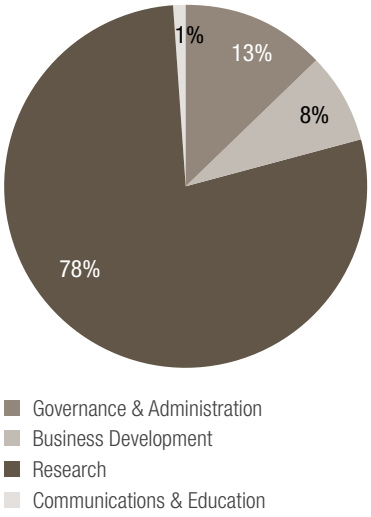
2017-18 Funding Budget



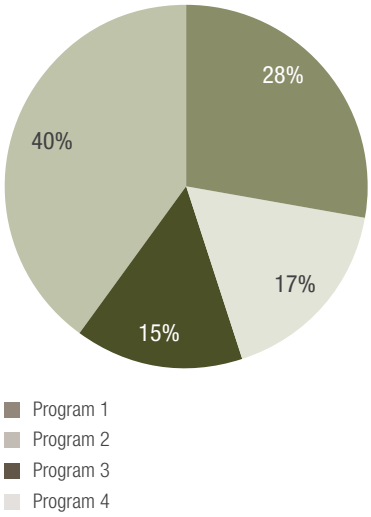
2016-17 Expenditure by Department



2017-18 Budget Expenditure



2016-17 Staff (FTE) In-kind



5. Other Activities

Coastal Risk Australia Tool

The Coastal Risk Australia Tool went live in 2015/16 at www.coastalrisk.com.au and was developed using the latest high resolution elevation data compiled from more than 200 Commonwealth, State and Local Government acquisitions. The release of the elevation data under Creative Commons licence was facilitated by the CRCSI in negotiation with the relevant states under a previous project. It has been viewed more than 3 million times by over 130,000 users.

Sea Level Rise Maps

The CRCSI developed a number of coastal maps indicating inundation against anticipated sea level rise scenarios for National Climate Change Adaptation Research Facility Coast Adapt product.

Collaborative Synthetic Aperture Radar Solutions for Australia – Forestry Demonstrator

This collaborative project with the United Kingdom explored the potential export of a robust, internationally comparable and sustainable National Forest Monitoring System (NFMS) service to public and private stakeholders within and outside Australia. Australian partners CRCSI and CSIRO and UK partners Catapult, Carbomap Ltd and the University of Aberystwyth addressed how such a service would enable a country to address all three components of measuring, reporting and verification to enable eligibility for the United Nations REDD+ program subsidies, and to also improve commercial provision of forest management services such as inventorying and commodity trading at a variety of scales.

Roadmapping Consultancies

The CRCSI completed two geospatial advisory roadmaps for its government partners. The CRCSI also commenced a data review and report on the digital uptake of health for one of its partners.

Geospatial Strategy

The CRCSI provided input and advice to the geospatial strategy development for Malaysia.

Scenario Planning

The CRCSI began development of a pilot scenario planning tool to integrate data from multiple state agencies to a common standard and provide fast, effective and broadly available modelling and visualisation functions.

Positioning and guidance in the Australian sugar industry

The CRCSI provided project oversight, contract and project management and coordination of partner organisations as well as technical guidance on precise positioning in agriculture.

6. Performance Review

The CRCSI Board and Management accepted all recommendations from the Performance Review in May 2013 and developed an implementation plan to address the recommendations. A regular update was provided to the CRCSI Board until all actions were complete and the final report was presented in 2014-15. The CRCSI Board has continued to monitor the ongoing outcomes from the Performance Review Implementation Plan as part of its annual strategic planning process.

Clark CRC Programme Review

This review addressed three principal questions of individual CRCs: 1) Are you meeting your funding targets; 2) Are you meeting your impact targets; and 3) How do you propose to work with Growth Centres? In its assessment report to the CRCSI in May 2016, Mr Clark concluded that *"The CRC Advisory Committee, (of which Mr Clark is the Chair), was pleased to see that the CRC for Spatial Information is meeting all of its obligations against the Commonwealth Agreement and is on track to achieve its stated outcomes."*

7. Additional Requirements

The following requirements from the CRC Programme 2016-17 Annual guidelines, will be submitted in a separate report for approval by 30 November 2017:

5.1. CRC future plans and transition arrangements

6.1. Wind-up plan

6.2. Exit report

8. Glossary and Acronyms

43pl	43 Pty Ltd, a company representing the CRCSI's SME consortium
ABI	Activity-Based Intelligence
ABS	Australian Bureau of Statistics
ACS	Analysis Centre Software
ADF	Australian Defence Force
AGDC	Australian Geoscience Data Cube
AGO	Australian Geospatial Intelligence Organisation
AIHW	Australian Institute of Health & Welfare
AIIA	Australian Information Industry Association
ALSIP	Australian Livestock Spatial Innovation Program
ANDS	Australian National Data Service
ANZLIC	ANZLIC – the Spatial Information Council formerly known as the Australia and New Zealand Land Information Council
APSEA	Asia Pacific Spatial Excellence Awards
AURIN	Australian Urban Research Infrastructure Network
AWI	Australian Wool Innovation Limited
CDMA	Code division multiple access
CEO	Chief Executive Officer
CIP	CRCSI Intellectual Property
CRA	Coastal Risk Australia
CRC	Cooperative Research Centre
CRC Programme	Secretariat of the Commonwealth CRC Programme
CRCSI	Australia and New Zealand Cooperative Research Centre for Spatial Information
CRCSI-1	Name given to the 1st funding round of the CRCSI 2003-2009
CRCSI-2	Name given to the 2nd funding round of the CRCSI 2010-2018
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CURTIN	Curtin University
DEM	Digital Elevation Model
DELWP	Victorian Government Department of Environment, Land, Water & Planning
EM-COP	Emergency Management Common Operating Picture
EOI	Expression of Interest
ESP	Envision Scenario Planner
ETC	Expert Technical Committee

FAS	Flight Assist System
FAST	Facial Analysis Streamlining for Clinical Translation
FDMA	Frequency division multiple access
FMV	Full Motion Video
FTE	Full Time Equivalent
GA	Geoscience Australia
GDA	Geocentric Datum of Australia
GIS	Geographic Information Systems
GITA	Geospatial Information and Technology Association
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GSN	Global Spatial Network
IoT	Internet of Things
IP	Intellectual Property
ICSM	Intergovernmental Committee on Mapping and Surveying
IRNSS	Indian Regional Navigation Satellite System
LGA	Local Government Area
LiDAR	Laser Imaging Detection and Ranging
LINZ	Land Information New Zealand
LPI	Land & Property Information NSW
LUCC	Land Use Cover Change
M2M	Machine to Machine
MBS	Medicare Benefits Scheme
MIT	Massachusetts Institute of Technology
MLA	Meat & Livestock Australia
MOU	Memorandum of Understanding
NAPCO	North Australian Pastoral Company
NCCARF	National Climate Change Adaptation Research Facility
NCI	National Computational Infrastructure
NEDF	National Elevation Data Framework
NFMS	National Forest Monitoring System
NICTA	NICTA National ICT Australia Ltd (NICTA),
NPI	National Positioning Infrastructure
NRM	Natural Resource Management

NRTK	Network RTK
PBS	Pharmaceutical Benefits Scheme
PPP-RTK	Precise Point Positioning – Real-Time Kinematic
QA	Quality Assurance
QUT	Queensland University of Technology
QZSS	Quasi-Zenith Satellite System
RAISE	Rapid Analytics Interactive Scenario Explorer
REDD	Reduce emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks)
REAC	Research & Education Advisory Committee of the CRCSI-1
RNSS	Radio Navigation Satellite Services
ROAMES	Remote Observation Automated Modelling Economic Simulation (Ergon)
RSA	Rapid Spatial Analytics
RT	Real time
RTK	Real-Time Kinematic
SavBAT	Savanna Burning Abatement Tool
SBAS	Satellite-Based Augmentation System
SIBA	Spatial Industries Business Association
SISR	Spatial Information Systems Research Ltd
SKI	Spatial Knowledge Infrastructure
SLIM	Strategic Land Information Management
SME	Small to Medium [sized] Enterprises
SSSI	Surveying & Spatial Sciences Institute
TERN	Terrestrial Ecosystem Research Network
UDEM	Urban Digital Elevation Model
UJV	Unincorporated Joint Venture
UK	United Kingdom
UM	University of Melbourne
UNE	University of New England
UNSW	University of New South Wales

9. Appendix 1 – Publications

Program 1: Positioning

Refereed Journal Papers

Khodabandeh, A., Teunissen, P. (June 2016). *Array-aided Multifrequency GNSS Ionospheric Sensing: Estimability and Precision Analysis*. IEEE Transactions on Geoscience and Remote Sensing, Volume: 54 Issue: 10 – http://ieeexplore.ieee.org/document/7497594/

Choy, S., Kuckartz, J., Demptster, A., Rizos, C., Higgins, M. (September 2016). *GNSS satellite-based augmentation systems for Australia*. GPS Solutions, DOI: 10.1007/s10291-016-0569-2 – http://link.springer.com/article/10.1007/s10291-016-0569-2

Odijk, D., Khodabandeh, A., Nadarajah, N., Choudhury, M., Zhang, B., Li, W., Teunissen, P. (December 2016). *PPP-RTK by Means of S-system Theory: Australian Network and User Demonstration*. Journal of Spacial Science Volume 62, 2017 – Issue 1 – http://www.tandfonline.com/doi/abs/10.1080/14498596.2016.1261373

Zaminpardaz, S., Teunissen, P., Nadarajah, N. (February 2017). *IRNSS/NavIC and GPS: A Single and Dual System L5 Analysis*. Journal of Geodesy DOI: 10.1007/s00190-016-0996-4 – http://link.springer.com/article/10.1007/s00190-016-0996-4

Zaminpardaz, S., Teunissen, P., Nadarajah, N. (April 2017). *GLONASS CDMA L3 Ambiguity Resolution*. Inside GNSS April 2017, Volume 21, Issue 2, pp 535–549 – https://link.springer.com/article/10.1007/s10291-016-0544-y

Zhang, B., Teunissen, P., Yuan, Y. (May 2017). *On the short-term temporal variations of GNSS receiver differential phase biases*. Journal of Geodesy Volume 91, Issue 5, pp 563–572 – doi:10.1007/s00190-016-0983-9 – http://link.springer.com/article/10.1007/s00190-016-0983-9

Zaminpardaz, S., Teunissen, P., Nadarajah, N. (May 2017). *Single-frequency L5 attitude determination from IRNSS/NavIC and GPS: a single- and dual-system analysis*. Journal of Geodesy, DOI: 10.1007/s00190-017-1033-y – https://link.springer.com/article/10.1007/s00190-017-1033-y

Li, W., Nadarajah, N., Teunissen, P., Khodabandeh, A., Chai, Y. (2017). *Array-aided single-frequency State-Space RTK (SS-RTK) with combined GPS, Galileo, IRNSS and QZSS L5/E5a observations*. Journal of Surveying Engineering, ISSN (print): 0733-9453 | ISSN (online): 1943-5428 – http://ascelibrary.org/doi/abs/10.1061/(ASCE)SU.1943-5428.0000227

McCubbine J., Featherstone, W., Kirby, J. (May 2017). *Fast Fourier-based error propagation for the gravimetric terrain correction*. Geophysics – 10.1190/geo2016-0627.1 – http://library.seg.org/doi/abs/10.1190/geo2016-0627.1

Refereed Conference Papers

Tengku, A., Kealy, A., Fuller, S. (September 2016). *Characterising High Precision GNSS Receiver Positioning Performance using Internal Receiver Uncertainties from Repeatable Real World Signals*. Proceedings of ION GNSS+ Conference 2016, Portland – https://www.ion.org/publications/abstract.cfm?articleID=14651

Li, T., Melachroinos, S. (December 2016). *Real-time cycle slip detection and repair for network multi-GNSS, multi frequency data processing*. Proceedings of IGNSS 2016, UNSW Sydney – http://www.ignss2016.unsw.edu.au/sites/ignss2016/files/u80/Papers/peer-reviewed/IGNSS2016_paper_14.pdf

Papanikolaou, T., Melachroinos, S. (December 2016). *Quantifying mis-modelling effects in the GNSS yaw-attitude determination*. Proceedings of IGNSS 2016, UNSW Sydney – http://www.ignss2016.unsw.edu.au/sites/ignss2016/files/u80/Papers/peer-reviewed/IGNSS2016_paper_15.pdf

Duong, V., Harima, K., Choy, S., Rizos, C. (December 2016). *Performance of Precise Point Positioning using Current Triple-frequency GPS Measurements in Australia*. Proceedings of IGNSS 2016, UNSW Sydney – http://www.ignss2016.unsw.edu.au/sites/ignss2016/files/u80/Papers/peer-reviewed/IGNSS2016_paper_5.pdf

Huang, P., Rizos, C., Roberts, C. (December 2016). *Inter-Pseudolite Range Augmented GNSS PPP Navigation for Airborne Pseudolite System*. Proceedings of IGNSS 2016, UNSW Sydney – http://www.ignss2016.unsw.edu.au/sites/ignss2016/files/u80/Papers/peer-reviewed/IGNSS2016_paper_10.pdf

Harima, K., Choy, S., Elneser, L., Kogure, S. (December 2016). *Local augmentation to wide area PPP systems: a case study in Victoria, Australia*. Proceedings of IGNSS 2016, UNSW Sydney – http://www.ignss2016.unsw.edu.au/sites/ignss2016/files/u80/Papers/peer-reviewed/IGNSS2016_paper_17.pdf

Internal Reports

ICSM website – *Modernising Australia's Datum* (animation) – https://vimeo.com/191566518

ICSM website – *Australia's Datum Modernisation – What you need to know* – http://www.icsm.gov.au/gda2020/DatumMattersFactSheet1.pdf

ICSM website – *Datum Matters – Know your data, know your datum* – http://www.icsm.gov.au/gda2020/DatumMattersFactSheet2.pdf

Program 2: Rapid Spatial Analytics

Refereed Journal Papers

Quadros, N. *Technology in Focus: Bathymetry LiDAR*. GIM International magazine Issue 10, Volume 30 October 2016 – https://issuu.com/geomarespublishing/docs/gim-international-october-2016

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Arnold, L. (2016). *Spatial Data Supply Chain and End User Frameworks: Towards an Ontology for Value Creation*. GEO Value Workshop, Paris France, on "Data to Decisions: Valuing the Societal Benefit of Geospatial Information". March 10-11, 2016. – https://www.researchgate.net/profile/Lesley_Arnold/publication/303022891_Spatial_Data_Supply_Chain_and_End_User_Frameworks_Towards_an_Ontology_for_Value_Creation/links/5735cab208ae9ace840adec3.pdf

Reed, T., Gulland, E-K., West, G., McMeekin, D., Moncrief, S. (2016). *Geographic Metadata Searching with Semantic and Spatial Filtering Methods*. Geoprocessing 2016, Venice, Italy – http://toc.proceedings.com/30338webtoc.pdf

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Baynam, G., Bauskis, A., Pachter, N., Schofield, N., Verhoef, H.,Palmer, R., Kung, S., Helmholz, P., Ridout, M., Walker, C., Hawkins, A., Goldblatt, J., Weeramanthri, T., Dawkins, H., Molster, C. (April 2017). *3-Dimensional Facial Analysis – Facing Precision Public Health*. Frontiers in Public Health – https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5385440/

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Marek, L., Campbell, M., Epton, M., Storer, M., Kingham, S. (July 2016). *Real-time environmental sensors to improve health in the Sensing City*. XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic – http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLI-B2/729/2016/isprs-archives-XLI-B2-729-2016.pdf

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McCulloch, K. (2017). *Improving equity of hepatitis B treatment access and outcomes by informing spatial targeting of resources*. Prepared for Project 4.410, 30 June 2017.

Campbell, M., Marek, L. S*mart City Scoping Report*. Not for public release.

Program 4.5: Built Environment

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Newton, P., Glackin, S. (2017). *Greyfield regeneration: a precinct approach for urban renewal in the established suburbs of Australia's cities*. Swinburne Research Bank – http://hdl.handle.net/1959.3/433386

Glackin, S. (March 2017). *Greening the Greyfields*. Infrastructure Magazine: ISSN2206-7906 PPs 18-20 – http://infrastructuremagazine.com.au/2017/03/20/greening-the-greyfields/

Newman, P. (2016). *Australia needs to follow the US in funding urban rail projects*. The Conversation – http://theconversation.com/australia-needs-to-follow-the-us-in-funding-urban-rail-projects-64666

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Coppa, I., Woodgate, P., Le Marshall, J., and Held, A. (216). *Looking Ahead*. Volume 1B, Earth Observation: Data, Processing and Applications PP 171-201 – http://www.crcsi.com.au/assets/Consultancy-Reports-and-Case-Studies/Volume-1B-Final-Art-144dpi.pdf

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Purbrick-Herbst, J. (2017). *Artificial intelligence for powering the application of spatial information*. Geospatial World – https://www.geospatialworld.net/article/artificial-intelligence-application-of-spatial-information/

Duckham, M., Arnold, L., Armstrong, K., McMeekin, D., Mottolini, D. (2017). *Towards a Spatial Knowledge Infrastructure*. CRCSI White Paper – http://www.crcsi.com.au/spatial-knowledge-infrastructure-white-paper?stage=Stage

10. Appendix 2 – PhD and Masters Student List

Name	Research Program	Project Title	Research Organisation	Country	Start Date	Completion Date
PhD Completions						
Kui Zhang	2	Advanced InSAR Technologies	UNSW	Australia	2008	2010-11
Alex Ng	2	PsinSAR Radar Interferometry	UNSW	Australia	March 2006	2010-11
Matthew Hutchison	3	Developing an Agent-Base Framework for Intelligent Geocoding	Curtin	Australia	May 2004	2010-11
Anna Donets	1	Using Single Receiver GPS Observations to Analyze the Dynamic Motion of Large Engineering Structures	UM	Australia	February 2007	2010-11
Michael Filmer	1	An Examination of the Australian Height Datum	Curtin	Australia	April 2009	2010-11
Eric Zhengrong Li	2	Aerial Image Analysis Using Spiking Neural Networks with Application to Power Line Corridor Monitoring	QUT	Australia	2010	2010-11
Jun Wang	1	RTK Integrity	QUT	Australia	August 2008	2012-13
Marco Marinelli	3	Assessing Error Effects in Critical Application Areas	Curtin	Australia	April 2005	2010-11
Roman Trubka	4	Agglomeration Economies in Australian Cities: Productivity benefits of increasing density and accessibility by way of urban transport infrastructure planning	Curtin	Australia	2010	2011-12
Tao Chen	4	Augmented Reality Integration and Live Communication between GIS and SIEVE	UM	Australia	March 2005	2011-12
Haohui Chen	4	Collaborative Virtual Environment for Knowledge Management - A New Paradigm for Distributed Communications	UM	Australia	February 2008	2011-12
Marcos Nino-Ruiz	4	Application of Rural Landscape visualisation for Decision Making and Policy Development	UM	Australia	September 2008	2012-13
Michael Schaefer	4	Advanced Biomass Sensing Using Active Optical Sensors	UNE	Australia	March 2011	2011-12
Xin Lui	2	Determination of the High Water Mark and its Location along a Coastline	Curtin	Australia	March 2012	2012-13
Eldar Rubinov	1	Stochastic Modelling for Real-Time GNSS Positioning	UM	Australia	January 2010	2012-13
Steven Mills	4	Visual Guidance for fixed-wing unmanned aerial vehicles using feature tracking	QUT	Australia	July 2013	2013-14

Name	Research Program	Project Title	Research Organisation	Country	Start Date	Completion Date
PhD Completions						
Grant Hausler	1	National Positioning Infrastructure: Technical, Organisational and Economic Requirements	UM	Australia	January 2011	2013-14
Jonathan Kok	4	Robust and Efficient Hardware-based Evolutionary Technique forMulti-objective Optimisation in Aerospace	QUT	Australia	June 2010	2013-14
Xiaoying Wu	3	Schema Evolution in a Federated Database Environment	Curtin	Australia	July 2012	2014-15
Mark Broomhall	4	A Method For the Remote Sensing of Aerosol s Based on MODIS Time Series Data Within an Operational System for Near-Real Time Atmospheric Correction	Curtin	Australia	October 2004	2014-15
Yuxiang He	2	Automated Building Reconstruction from Aerial and LiDAR Data	UM	Australia	June 2011	2014-15
Cole Hendrigan	4	Building on Spatial Relationships in the Urban Fabric to Inform Higher-order Transport and Land Use Policy and Planning	Curtin	Australia	July 2012	2014-15
Su Yun Kang	4	Comparison of Spatial Modelling Using Point-process Data and Aerial Data	QUT	Australia	February 2011	2014-15
James McIntosh	4	Funding Sustainable Transport Through an Integrated Land Use and Transport Planning Framework Utilising Value Capture	Curtin	Australia	July 2011	2014-15
Abdul Nurunnabi	2	Mobile Mapping of Transport Corridors and the Extraction of Assets from Video and Range Data	Curtin	Australia	March 2011	2014-15
Robert Odolinski	1	GPS and Galileo Integer Ambiguity Resolution Enabled PPP (PPP – RTK)	Curtin	Australia	February 2011	2014-15
Jessica Roberts	4	Spatially Enabled Livestock Management: Improving Biomass Utilisation in Rotational Systems	UNE	Australia	March 2010	2014-15
William Woodgate	2	Derivation of Leaf Area Index and Associated Metrics from Remotely Sensed and In Situ Data Sources	RMIT	Australia	July 2011	2014-15
Lei Wang	1	Generalised Ambiguity Resolution Approaches to Processing Multiple GNSS Signals	QUT	Australia	April 2012	2015-16
Ebadat Ghanbari	2	Automated Registration of Multi-source, Multi-sensor Data	UM	Australia	July 2011	2015-16

Name	Research Program	Project Title	Research Organisation	Country	Start Date	Completion Date
PhD Completions						
Daniel Hogg	4	Modelling Spatial Variations in Natural Disaster Impact	Canterbury	New Zealand	February 2013	2015-16
Charity Mundava	4	Biomass Assessment Tools to Assist Grazing Management in the Kimberley Region of Western Australia	Curtin	Australia	October 2011	2015-16
Richard Palmer	2	Automated Generalised Methods for the Extraction and Analysis of High Level Information From Mobile Mapping Data	Curtin	Australia	March 2011	2015-16
Niva Kiran Verma	4	Above-ground Biomass and Carbon Determination in Farmscapes Using High Resolution Remote Sensing	UNE	Australia	September 2011	2015-16
Phil Wilkes	2	Scale Variance as Applied toWoody Attribution of Eucalypt Forests	RMIT	Australia/The Netherlands	February 2012	2015-16
Susanna Cramb	4	Spatio-temporal Modelling of Cancer Data in Queensland Using Bayesian Methods	QUT	Australia	July 2011	2015-16
Mohsen Azadbakht	2	Processing LiDAR Waveforms to Extract Features Accurately	UM	Australia	January 2012	2016-17
Jannah Baker	4	Spatial Interactions Between Chronic Diseases, Risk Factor Exploration and Effects of Health Screening	QUT	Australia	January 2012	2016-17
Michael Borck	2	Feature Extraction from Multi-modal Mobile Mapping Data	Curtin	Australia	February 2011	2016-17
Yongchao Wang	1	QZSS/BDS Precise Orbit Determination Using Triple Frequency Code and Phase Measurements	QUT	Australia	July 2012	2016-17
Peiyuan Zhou	1	Ionospheric Delay Variance Modelling	UNSW	Australia	February 2013	2016-17

Name	Research Program	Project Title	Research Organisation	Country	Start Date	Completion Date
Masters Completions						
Jiang Li	4	Intelligent Object Placement and Scaling in Virtual Decision Environments	UM	Australia	January 2008	2010-11
Pan Peter Wang	4	Real-Time Data Visualisation in Collaborative Virtual Environments for Emergency Management	UM	Australia	February 2008	2011-12
James Head-Meares	4	Human Interface Technology: Accurate Wide Area Tracking	Canterbury	New Zealand	April 2013	2013-14
Josh Neville	4	Meeting Housing Demand in Christchurch within the Existing Urban Footprint.	Canterbury	New Zealand	January 2014	2016-17

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