

COLLABORATIVE RESEARCH INTO THE NEXT GENERATION SPATIAL INFRASTRUCTURE

Tai Chan^{1,2}, Geoff West^{1,3}, David A. McMeekin^{1,3}, Peter Woodgate¹, Peter Loughrey¹

¹ Cooperative Research Centre for Spatial Information, Australia & New Zealand

² Victorian Department of Sustainability & Environment, Melbourne, Australia

³ Curtin University Department of Spatial Sciences, Perth, Australia

Abstract

The Spatial Infrastructure Program (Program 3) is one of three core research programs of the CRCSI. Owing to a delay in research strategy development, the CRCSI built a project team to deliver a timely Program 3 research program. Within a nine-month period, the team engaged with over 100 key stakeholders and CRCSI participants, which were interested in working collaboratively, directly and indirectly, through Program 3 to develop the next generation spatial infrastructure to allow them to better deliver their services. The team established broad stakeholder consensus on the research direction and got approval for a research strategy. An integrated research proposal was put forward based on the interests of the key stakeholders and participants of the CRCSI.

The key drivers of the Program were that the next generation spatial infrastructure had to be based on a web architecture that supported automation and step-change usability throughout the system. The underpinning disciplines were the Semantic Web, Supply Chains and Artificial Intelligence.

In order to make the research outputs more relevant to the participants, one approach the program has adopted is to develop a research platform, based on the best-of-breed infrastructures available in Australia and New Zealand. This approach is complemented by an improved project governance arrangement involving an agile approach to research management. This is to ensure that the research outputs are relevant and that project participants can test the outputs in operational environments to determine suitable utilisation pathways for incorporation into existing spatial infrastructures.

Keywords: *next, generation, research, spatial, infrastructure,*

1. INTRODUCTION

This paper describes the challenges the CRCSI faced when developing a research program for its Spatial Infrastructure Program, the approach used for engagement with its participants, and the resulting collaborative research program.

1.1 The CRCSI

The CRCSI is an unincorporated joint venture set up under the Cooperative Research Centre Program of the Australian Government. The purpose is to build critical mass in research ventures between end users and researchers tackling clearly articulated, major challenges for the end-users.

The CRCSI conducts user-driven research in emerging areas of spatial information that address issues of national importance. It undertakes core research in areas of positioning (Program 1), automated information generation (Program 2) and spatial infrastructure (Program 3). Drawing on outputs from core research, applied research (Program 4) is also performed in areas of agriculture/natural resources/climate change, power distribution

utilities assets, health and urban planning. The CRCSI conducts research that builds on strong collaborative relationships, strives for excellence, and always aims to be transformational in impact. For more details, please go to the CRCSI website at <http://www.crcsi.com.au/About>.

1.2 Program 3 Spatial Infrastructure

Program 3 focuses on core research around spatial infrastructure. The expected benefit is two-fold. One is to help build a greatly improved Spatial Data Infrastructure SDI for Australia and New Zealand, which can solve business problems of CRCSI core participants and grow the spatial industry. Two is to grow business by providing the private sector with access to know-how, software and intellectual property to develop new products and services.

When Program 3 was first conceived in 2008-9, it was driven by the same government users who had a more advanced and holistic view of spatial infrastructures and were driving the adoption of the innovative Australia and New Zealand Spatial Marketplace [1] at the time. When the CRCSI started operating in January 2010, the same users continued to drive the Program 3 Board to ensure delivery of relevant outputs. However with a limited research background, they found it a challenge to translate the Program 3 deliverables into credible research activities. There was an expectation that a research program could be developed through a combination of research proposals traditionally submitted by spatial research institutions and the ANZLIC¹ effort to develop an Australian New Zealand Spatial Marketplace (ANZSM), which was an innovative concept at the time. The Program 3 Board appointed a Program Director to manage the process. A few research proposals were submitted but the delay of the ANZSM project left the Board with unclear investment priorities. As a result, only one project proposal was funded.

The funded project, entitled, "Alignment Study of Spatial Data Supply Chains" was completed in mid-2011 and it examined the state of maturity of 34 existing spatial data supply chains across Australia and New Zealand. By then, the CRCSI Governing Board and the Program 3 Board decided to act on the delay and develop a practical Spatial Infrastructure research program. While recognising the need to research into both technology and people, the Program 3 Board decided to prioritise the initial effort around IT. In late 2011, the CRCSI appointed a Science Director with a computer science background and strong leadership track record in a number of existing CRCSI research projects. To make up for the lost time, the Science Director, together with the Program Director, a Research Fellow and a newly appointed Industry Advisor embarked on an engagement exercise in earnest in 2012 to develop a research program.

1.3 The Challenges

To develop a Spatial Infrastructure research program, a research strategy was needed to give it direction and purpose. This strategy would have to cater for three challenges faced by the CRCSI and Program 3, i.e. contract, science and utilisation. These three challenges were encapsulated in the contract with the Commonwealth, which highlighted clear deliverables that also cover research output utilisation. The contract also included monitoring processes to ensure that the research deliver scientific excellence.

¹ ANZLIC - ANZLIC - the Spatial Information Council (ANZLIC) is the peak intergovernmental organisation providing leadership in the collection, management and use of spatial information in Australia and New Zealand. <http://www.anzlic.org.au/> accessed 14 January 2013.

1.3.1 Contract

The challenge here was to address the question of “what” and define the scope of research. The CRCSI is a collaborative organisation created and bound by contracts: a) the contract with the Commonwealth Government of Australia to meet milestones set up in the founding agreements of 2010 with an agreed budget in an agreed period of time; b) the contract with the participants, particularly the core partners (“essential participants”), to provide the resources needed to deliver on the first contract while generating outputs that meet their requirements. The CRCSI operates within the bound and resources made available through these contracts with relatively little room to manoeuvre. Compromises have to be made to meet the contractual obligations, which can be conflicting at times.

1.3.2 Science

The challenge here was to address the question of “how”, which underpins the step of knowledge generation and to a certain extent the innovation development and implementation as encapsulated in the Innovation System model [2]. It is about the scientific body of knowledge, or the domain, that underpins the research. The CRCSI is a scientific research organization. Also, it has the obligation to deliver scientific excellence and to conduct world class research. Its outputs would be benchmarked against the best internationally. Not following normal scientific rigor and failure to follow research best practices would risk poor image/credibility and funding withdrawal from the Commonwealth.

The research has to be conducted primarily by CRCSI participant universities. While a research question can be pursued down the paths of a number of domains, judicious choice of domains are more likely to generate outputs that can be applied directly to current situations. For example, despite the constant referral to the term eco-system in the IT industry nowadays, ecological science research is unlikely to generate directly useful outputs for the spatial industry; the same applies to political science research. Also disciplines that can be readily understood and applied by researchers in the CRCSI are more likely to result in successful research projects. The same applies to participants in the public and private sectors, who must understand the potential value of research within a particular scientific discipline before they will participate in any projects.

1.3.3 Utilisation

The challenge here was to address the questions of “why”, “who”, “when” and “where”, which underpins the steps of innovation development and diffusion in the Innovation System model of the CRCSI. For these steps to be successful, close involvement of participants is important in providing inputs and answers to the questions as follows.

- “why is the research done?”: the real and specific needs for research outputs arising from the changing social, political, economic and technical environments in which the participants operate, e.g. organisation “A” needs this search algorithm to allow the novice users to access the spatial data easily as part of government’s new data access policy, or organisation “B” has decided to adopt this Amazon/Google/Microsoft innovation as a consolidated platform, and this search algorithm must run on this innovation.
- “who will benefit from the research?”: the different user/stakeholder groups who will be using the outputs, e.g. this new search function must cater for the different ways search is carried out by data users (novices and experts), managed by custodians and supported by system administrators.

- “when will the research be needed/used?”: the stages in the life cycle of spatial infrastructure management in which the outputs will be used, e.g. while the other partners in the project only need the search function in the design and development of their future infrastructure, organisation “C” wants to apply the function to upgrade the capability of its existing infrastructure.
- “where will the research be deployed?”: the locations where the outputs will be deployed. Location here is taken to mean physical locations, such as inside or outside head office, the organisation, the city, the customer, and virtual locations including the software and hardware hosting platforms, e.g. the search function will have to be deployed beyond department “D” to other departments so that it is available as a whole of government function.

As required by the contract with the Australian Commonwealth Government and required by the participants, the CRCSI recognised the importance of well-defined utilisation pathways for the Program 3 research outputs. From lessons learnt through previous and current research programs, the CRCSI had to put in place formal mechanisms to encourage innovation adoption/utilisation [3] on two levels: technical and institutional. Technically, there should be a common development and test environment, IT or otherwise, in which research outputs could be used experimentally or operationally by the majority of participants. Institutionally, there must be the forums and a decision making process (governance) in which the need for, and value of, the research outputs, are discussed and communicated in a timely manner between users and researchers as appropriate.

2. RESEARCH PROGRAM DEVELOPMENT

In early 2012 the CRCSI formed the Program 3 Project Team and asked the Team to undertake an engagement exercise to develop a research program that had the support of the community and addressed the above challenges. This section describes how the engagement was conducted.

2.1 The Project Team

The Project Team that worked under the direction of the Chair of the Program 3 Board was made up of the Science Director, Program Director, Senior Research Fellow and Industry Advisor. The Science Director is a professor in spatial information with a background in computer science and engineering, and served as a leader for projects in Program 2: Automatic Spatial Information Generation and Program 4.4: Health. The Senior Research Fellow has a strong computer science, software engineering and application development background. The Program Director has a strong background in theoretical SDI research and spatial infrastructure development and implementation in a jurisdictional department. The Industry Advisor is a retired executive of a major spatial software vendor with a strong background in project management and customer engagement.

The team members brought with them different backgrounds, interests and expertise that resulted in robust discussions around often passionately held ideas. They were able to bring original ideas to the engagement process and generate an innovative approach to take Program 3 forward. The materials used to engage with the CRCSI community were developed by the project team and endorsed by the Program Board.

2.2 Engagement Process

The engagement followed a work schedule during the period February to December 2012, which was made up of six stages that are briefly described below. Notes were taken during the engagement with the stakeholders by the project team, which were then compiled together to formulate the research strategy and program.

1. **Ideas Formulation and Needs Gathering.** In this stage (January to April 2012), the Project Team discussed and prepared materials on some initial ideas for the research program. Through face-to-face meetings and telephone/web conferences, individually and in groups, the Team used the materials to trigger responses from a wide range of members of the CRCSI community on how they saw the future research program meeting their needs. In particular, a joint meeting of the CRCSI and ANZLIC was held to obtain specific inputs from this important stakeholder. Although constrained by time, the Team took the opportunity to talk to as many people as they could who were available across Australia and New Zealand.
2. **Ideas Validation.** In this stage (8-10 May 2012), the ideas were consolidated into a broad approach for the research strategy that included the drivers, the research domains and the potential areas of research. These ideas were presented to the CRCSI community in the 3-day CRCSI Annual Conference in May in Brisbane. In a number of conference forums the Team successfully sought feedback and endorsement on the approach it intended to follow.
3. **Strategy Generation.** In this stage (May to June 2012), the Science Director and Research Fellow attended conferences internationally and domestically and went through the relevant literature to design a research strategy that was scientifically sound and technically feasible, and that built on existing work world wide.
4. **Strategy Validation.** In this stage (July to September 2012), a draft Program 3 research strategy was prepared for the initial endorsement by the CRCSI Governing Board and then circulated to key stakeholder groups for their endorsement. The groups included ANZLIC, PSMA, the Program 3 Board, the CRCSI Research Investment Committee and the CRCSI Research and Education Committee.
5. **Research Project Consultation.** In this stage (September to October 2012) and with broad support for the strategy, a research program in the form of a project proposal was drafted and presented to key participants in research workshops organised in the capital cities of Melbourne, Wellington, Sydney, Canberra, Brisbane and Perth respectively. In the process, the strategy was explained to participants and their feedback and interests gathered to help refine the proposal.
6. **Project Approval.** In this stage (October to December 2012), the Science Director finalised the master research project proposal and took that through the normal project governance process to finally obtain the approval by the CRCSI Governing Board in December.

In this way the CRCSI had achieved stakeholder endorsement for and CRCSI Governing Board approval over the course of 2012 for both the Spatial Infrastructures Research Strategy and the more detailed Project Brief.

3. RESULTS AND DISCUSSION

3.1 Interim Findings

The key aspects of the strategy and context are briefly described below.

3.1.1 Commonwealth outputs

The relevant Commonwealth Outputs that form the mandatory context for the research strategy are highlighted below. Unless there are major changes in the operational context in Australia and New Zealand, Program 3 research must deliver outputs that also meet the challenges outlined in Section 1.3 above.

Output 1: Development of national/international standards framework and software tools to enable effective governance and management of online digital rights, privacy and security

The output will be used for existing and emerging spatial infrastructure environments delivering online ready resource trading and business critical information delivery to government and industry.

Output 2: Development and implementation of a federated data model

The output will develop generic tools to aid development of a federated data model that spatially enables data currently locked in government agencies and inconsistently managed and maintained across jurisdictional and agency borders. It will be trialled for use in the Australian and New Zealand Spatial Marketplace.

Output 3: Investigating online processing of distributed spatial information

The output will enable highly interoperable, large scale and high data volume processing of online distributed spatial information sources such as those emerging from advanced positioning technologies, and distributed sensor networks from public and private services.

Output 4: 6 PhD and 4 Masters student completions (in the IT field), and at least 20 publications.

The output specifies the number of Masters and PhDs the Program will generate to boost the capacity of the spatial industry in managing its spatial infrastructures.

3.1.2 Spatial challenges and future SDI requirements

Three key challenges were identified for the spatial community. Firstly, there were too many silos of SDI resulting in substantial duplication of functionality across Australia. Most were considered not user friendly, being troublesome even for experts to compile a multi-source solution. As a result, most spatial resources were still locked up in government agencies. Secondly, the industry needed a bigger market with the small to medium enterprises needing a channel to show their wares through various forms of online solutions. Thirdly, users expected a great experience, courtesy of the established norms of innovative products and services offered by companies such as Google and Apple.

In this context, some specific future SDI requirements identified were:

- Smarter search and discovery tools
- Ability to publish volunteered or in-volunteered geographic information from anyone including non-governmental organisations (note: "in-volunteered" here refers to information published on social media sites, such as, Twitter, which is then harvested by market research companies for purposes not originally intended by the author)
- Implementing e-commerce, licensing rules, terms of use
- Incorporation of processes and applications, not just data, while incorporating more diverse data, real time data, big data, including lidar, 3D models (buildings), time stamped data, versioning and location feeds

3.1.3 Research drivers and underpinning scientific domains

The previous section identifies in a condensed form the key areas of improvement endorsed by the CRCSI community and beyond. They can be further distilled into three drivers of research, namely,

- Usability: unless the future spatial infrastructure is highly user friendly and usable, nobody will use it and any improvement will be futile
- Automation: unless the many activities supported by the existing SDIs are automated to minimise learning and simplify use, both by novices or experts, usability will always be found wanting
- Web-based technologies: as many online activities nowadays are done through the web, any improvements to the SDIs must be web-based for it to be relevant to the users.

These will be addressed through research into the domains of Semantic Web (SW), Artificial Intelligence (AI) and Supply Chains (SCs). The SW promises to satisfy many of the issues including search, data integration, publication, and processing. It is built as a “stack” shown in Figure 1. The lower levels of the stack are mature and in operation e.g. html at the lowest level. Addressing the upper levels is needed to move beyond data provision to more intelligent and sophisticated functionality.

The research activities identified in this proposal will use all the technologies in the SW stack. The Unique Resource Identifiers (URIs), Resource Description Frameworks (RDFs) and ontologies will store the knowledge required to carry out the various operations. The operations required will be invoked by techniques at the Rules level in the SW stack. At this level, AI techniques including rule-based expert systems, case-based reasoning and machine learning will be explored to automate the mainly manual processes currently used and to enable adaptability to the user, knowledge and data available in the future spatial infrastructure.

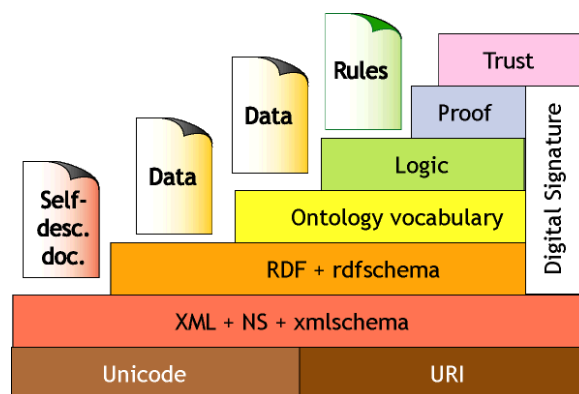


Figure 1. The Semantic Web Technology Stack [4]

Much of the SW is built around World Wide Web Consortium (W3C) standards and can incorporate Open Geospatial Consortium (OGC) standards for spatial data. Many of the representations in the stack are regarded as data and encoded in the eXtensible Markup Language (XML) but the upper levels are more rule and software based.

Supply Chain represents the spatial data generation process from data collection through to the generation of products based on the data. It is implied that this information is stored somewhere. The CRCSI commissioned investigation [5] into spatial data supply chain

(SC)capabilities identified the variability in data from suppliers and products used by consumers and noted the general lack of maturity of most of the 34 spatial infrastructures examined in fulfilling most of the functions of the spatial data SC. SCs are relevant because much use of existing spatial infrastructures is around the supply of various products that are built via a number of processes from acquired data and include important quality assurance requirements.

3.1.4 Research issues and potential research projects

A number of research issues were identified, involving: automatic metadata and ontology generation and evolution, semi-automated and automated data integration, automated schema evolution, open standards, integration of 3D and 4D data, user interface issues and usability, licensing, copyright and terms of use. To illustrate how research into these issues could be applied in practice, four research projects were suggested [6] for engagement with the participants during the research workshops. They were:

1. Semantic Web Technologies for the Spatial Marketplace
2. Semantic Web Technologies for Federated Data Integration
3. Jurisdictional Level Data Integration
4. Automated Determination of Licensing Models for Spatial Information.

It was clear to the project team that the research issues would have to be addressed in an integrated manner and applied to the research projects through relevant user stories to demonstrate the timely delivery and utilisation of outputs. The user stories proposed included the development of national foundation data themes, integration of local government data into jurisdictional datasets or addressing the needs of disaster and emergency management. In this context the research strategy clearly specified that all research would be conducted as one integrated project with specific research undertaken by researchers as sub-projects. The sub-projects reflect the need to schedule the timing of activities with respect to developments in the Semantic Web happening elsewhere, the availability of researchers with the requisite skills and the needs and priorities of key stakeholders. The overall research would be coordinated by the Science Director.

3.2 Final Consultation

CRCSI participants offered a wide range of inputs into the approved Research Strategy. The inputs could be summarised into four groups: governance issues, outcomes desired by private sector/43pl², utilisation and other research issues.

Governance issues (including policy, cultural and institutional issues):

- primary blocker of data sharing; this group also included the contrasting nature of public and private goods, and practical use of creative common model of licensing;
- recognition that technological improvement should go hand-in-hand with governance improvement, existing governance issues could be overtaken by technological events creating new issues to be addressed;
- potential conflict of interest among participants, including a range of issues involving the federation of jurisdictional data into national consistent datasets;

² 43pl is a unit trust that facilitates small to medium enterprise companies participating in the CRCSI. See <http://www.crcsi.com.au/43pl> accessed 14 January 2013.

- suggestions for a MSc project to explore use of other marketplaces or business models to play the role of ANZSM; and
- need to collaborate with international and domestic research bodies such as OGC and CSIRO.

Outcomes desired by private sector/43pl:

- research that meets real needs and is relevant to the participants, such as cost reduction, and performance and standard compliance;
- greater involvement of utilities and local governments; and
- 43pl companies that could not easily benefit from product centric R&D, would prefer to be able to assist with implementing a framework or services.

Utilisation:

- suggestions for a test bed/incubation designed by an architecture group:
 - as a means to bridge the interest of researchers, users and deployment;
 - as “pre-sales”, helping to test ideas innovations for government and/or private sector; and
 - help develop business cases for production investment and research into spatial dividend – real benefits, not just high level economic benefits;
 - with the test beds imbedded in existing operational systems to facilitate rapid operational takeup
- need to implement a system now and build on it later, not wait for research;
- change of paradigm from data supply driven to user driven, e.g. management of disaster and urban environment; and
- spatially enable information developed for major emergencies could be a ready product valuable to insurance companies in future to more targeted premium assessment on the basis of individual property not the whole area
- need to cater for the supply, use and reuse of all spatial resources (data, apps services), not just data.

Other research issues included communication of uncertainty, adding a value chain on top of the Supply Chain and designing a robust backend to cater for peta-byte level of data management.

Participants expected to have means to benefit from Program 3, typically by being able to:

- Follow research progress through forums, workshops and publications to learn about innovations and industry best practices
- Actively participate in and contribute expertise and time to the projects to gain insight into and preferential access to new intellectual property
- Apply new intellectual property to the development of new products and services
- Access new intellectual property, software and know-how during the project.

The participants also identified their interests in Program 3 research that were used in refining the user stories to be adopted in the master research project. The user stories are briefly listed below.

1. Federated data integration (national foundation data themes).
2. Data integration at the jurisdictional level.
3. The Spatial Marketplace (building on the ANZSM demonstrator).
4. SLIP future (the next generation spatial infrastructure of Western Australia).
5. Property models (as driven by Local Government Areas and jurisdictional land administration agencies).
6. Smart response to user queries (eg., how often was this area burnt or flooded?).
7. Health (around CRCSI Program 4.4).
8. Urban Planning (around CRCSI Program 4.5).
9. Biomass Business (around CRCSI Program 4.1).
10. Disaster and Emergency Management.

3.3 The Research Program

The stakeholders endorsed a Next Generation Spatial Infrastructure (NGSI) as the vision for Program 3 research. It was built on the Supply Chain concept of SDIs [4] and visualised as a virtual infrastructure that would be made up of a network of infrastructures with no obvious hierarchy across Australia and New Zealand. The Project Team also noted that many jurisdictions were committed to, or in various stages of planning and implementing, future spatial infrastructures. The NGSI could provide a common rallying point for the spatial community to collaborate in the design, research and development, and implementation of the NGSI, while incorporating the trail-blazing ideas of the ANZSM.

There was a wide range of research issues, interests and opportunities identified to achieve the above potential. However it was recognised it would take a budget many times more than what was available to Program 3 to cater for all of them properly. Time was also running out under the contracts and the key CRCSI stakeholders were very keen to get on with the research. It took many hard decisions for the Science Director to put a research program together that dealt with the “what”, “who” and “how” of Program 3 research.

3.3.1 What is the research?

It was decided that Program 3 would be made up of one master project. Within the scope of outputs agreed with the Commonwealth, the time and budget available, the strong interests and commitments expressed by participants, the project would undertake research in the following seven activities over time [5]. The detailed scope of research, the number of PhDs and MScs will be determined by the participants who sign up to the projects in each stage:

- Activity 1. Web-based Services: Search and Discovery (stage 1 PhD)
- Activity 2. Data Integration – from LGA to National (stage 1 PhD)
- Activity 3. Web Service Orchestration (stage 2 PhD)
- Activity 4. Crowd Sourced and Authoritative Data Integration (stage 2 PhD)
- Activity 5: Querying Big Data including 3D/4D datasets (stage 2 PhD)
- Activity 6. Licensing, Copyright and Terms of Use (stage 3 MSc)
- Activity 7: Mapping to other Marketplaces (stage 3 MSc).

Program 3 research aims at developing the next generation spatial infrastructure. As the Office of Spatial Policy (OSP) is committed to working with a range of stakeholders to address known cultural and institutional issues for sharing of spatial resources [7], it is logical for Program 3 to continue to focus on developing step change IT innovations. Such innovations should complement the effort of OSP and drive the spatial infrastructures of Australia and New Zealand to the next level of technical excellence by tackling the identified user stories.

3.3.2 Who to involve?

The CRCSI has to work with a wide range of stakeholders (Figure 2) and to demonstrate to the Commonwealth Government of Australia the delivery of scientific excellence to end users.

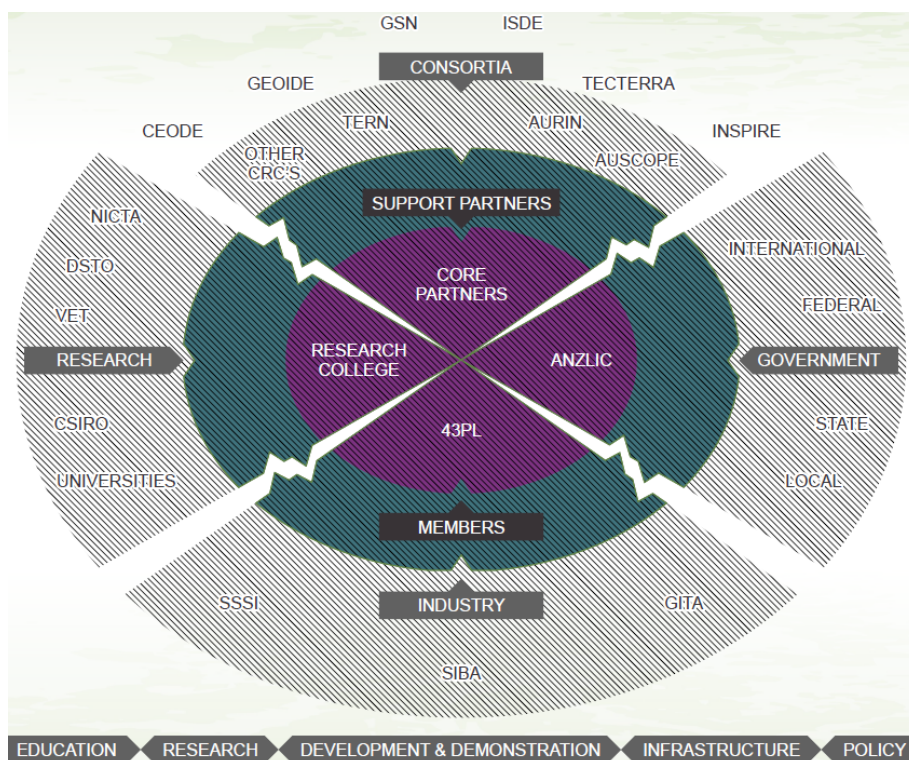


Figure 2. The Stakeholder hierarchy of CRCSI (sourced from CRCSI “PARTNERS” page)

This is done through a collaborative model that It engages with the key sectors (purple quadrants in Figure 2) through ANZLIC (government) and its own research college and 43PL (private, a consortium of small to medium enterprises). At the same time, it must also satisfy the interests of its core partners, who “have made a long term broad commitment to the CRCSI and enjoy benefits across the spread of CRCSI activities, and have a commensurately greater say in the directions of the CRCSI” (see CRCSI “PARTNERS” page). These core partners include the federal government through Geoscience Australia, New South Wales Land Property Information, Queensland Department of Natural Resources and Mines, Victorian Department of Sustainability and Environment, Western Australian Landgate, 43pl, Ergon Energy, Curtin University of Technology, Queensland University of Technology, University of Canterbury and University of New England. These universities will undertake the primary research and be complemented by research conducted by support partners: universities that include RMIT University, the Swinburne University, University of Melbourne and UNSW. As a support partner, New Zealand LINZ has been active in the development of P3 research. Other support partners include a number of government agencies from the federal government, NSW, WA, The CRCSI’s

other research partners, both locally and overseas, CSIRO and OGC are all important organisations that the CRC SI will work with to deliver research excellence.

Traditionally, research was undertaken by the geomatic or spatial disciplines in the universities. However as the P3 research strategy was developed, it became obvious that input from the computer scientists is necessary in addition to achieve the desired outcomes. As a result, a wider range of researchers are in discussion with the Science Director to flesh out the detailed scope of research.

3.3.3 With the complicated network of stakeholders and partners (more than 100 organisations), primary engagement will have to be with the core partners and organisations in the purple quadrants of Figure 2. While the stakeholder groups such as ANZLIC provides strategic directions for national and industry development, the core partners will contribute cash, and in-kind contributions to support research to deliver specific output needed in their businesses. Other partners in the green quadrants will have a say by actively participating in discussions and working closely with the researchers to undertake the research. The typically contribute expertise, know-how, contacts and user stories that focus the research. The wide range of interests of these organisations will have to be prioritised in the context of the research strategy agreed, user stories chosen, in-kind resources made available and priorities identified by the key stakeholder groups. To ensure this process is done transparently and deliver usable outcomes, a suitable management model is needed as described in the next section. How is the research managed?

Figure 3 illustrates the model Program 3 uses to manage its research.

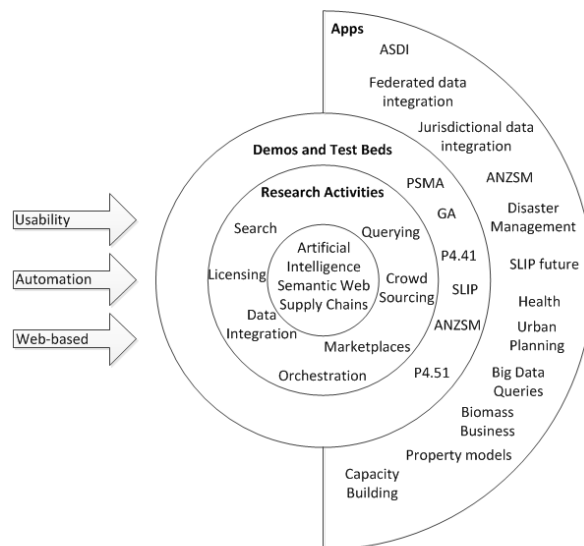


Figure 3. Program 3 utilisation pathway linking drivers, research, test beds and applications

Figure 3 established the tight link between scientific excellence and end-user utilisation. The three research drivers (see sub-section 3.3.1 above) as represented by the three arrows on the left drive the research, development and adoption activities as represented by the concentric circles extending out. The circle in the centre includes the three domains of research that underpin the seven “Research Activities”. Extending outwards, the latter is developed on and demonstrated through “Demos and Test Beds” that are based on the

best-of-breed infrastructures offered as in-kind contributions by the key research partners in the project. These infrastructures were chosen on the grounds that they were deemed to be close to or even key components of the NGSi that would generate the greatest impact. Once proven practical, it is expected that the research outputs would be adopted in the infrastructures, research programs and government programs as identified in “Apps”.

To ensure the links described above work, a new governance model was needed to manage the research. The governance model (Figure 4), as endorsed by the Program 3 Board allows proper management of the expectation of researchers, the end users and the key stakeholders, giving the researchers enough autonomy to undertake world class research while ensuring the relevance of the research outputs to the end users.

The top of the diagram shows the current normal project governance arrangement involving the Program 3 Board and the Project Management Group, which report to the Governing Board in regard to strategic matters and the routine project management respectively.

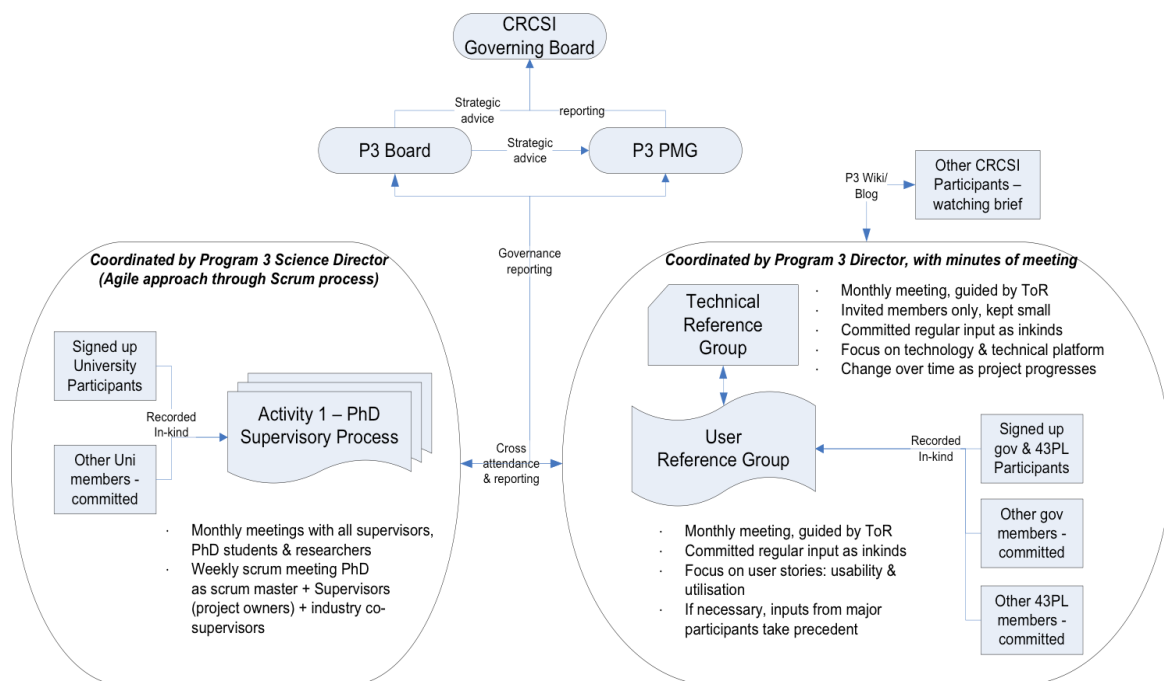


Figure 4. Program 3 governance model

The bottom of the diagram illustrates the innovation in the model. The lower left oval shape involves the Science Director coordinating an agile approach [8] to research management. The researchers will follow a Scrum process with the PhD/MSc candidates and their supervisors operating in Scrum teams. The team’s bite-size research outputs called, sprints, are delivered and reported regularly within each team and among the teams in Scrum meetings. It is through the Scrum meetings that new ideas, directions, technologies and approaches are discussed and incorporated, as appropriate, in the research work.

The lower right oval shape involves the Program Director coordinating activities of two reference groups, one for users and one for technical issues, according to formally agreed terms of reference. The advice and opportunities put forward by the groups will be fed back to the Scrum process of research and guide the development of test beds and, within limits, directions of research and allow the engagement of the various stakeholders with the research.

Apart from overcoming the challenge to coordinate a credible research strategy for collaborative research across the wider CRCSI community as described above, the long term challenge faced by P3 Board is to ensure transparent and targeted collaborative research that is used by the core partners. It was clear from the feedback during engagement that without complementary management and governance models applied consciously, the result would be fragmented at best.

The management model together with input provided through the governance model is designed to ensure that research output is developed and tested on the existing spatial infrastructures managed by core partners and is ready for operational adoption once the research is complete. The Technical Reference Group and the User Reference Group would ensure that the appropriate technical architecture and user stories are put in place to support the research, testing and utilisation on a rolling basis as the research progresses over time. The agile process is meant to cater for new technological development and research opportunities as they arise. All these are to ensure that the research output remains relevant over time and ready for adoption when ready.

4. CONCLUSION

Despite some initial delays, CRCSI's Program 3 is embarking on an ambitious research program to develop the technical capabilities for Next Generation Spatial Infrastructures in the next five and a half years. Innovations will come from multi-disciplinary research involving spatial technologies, semantic web, Artificial Intelligence and Supply Chain management. Through strong collaboration among CRCSI participants, the innovations will fundamentally improve the usability and level of automation of existing web-based spatial infrastructures, generally improving overall performance and productivity.

Within the constraints of resource and contract, the success of Program 3 relies heavily on good collaboration between all project partners through test beds and improved governance mechanisms as described in sections 3.3.2 and 3.3.3 above. Its primary focus will be:

- improving data structures and standards to permit automated web-based spatial data publishing, search and discovery, processing and service orchestration;
- developing rules and routines for linking federated datasets, if possible, big data;
- facilitating streamlined licencing of resources.

Implicit in Program 3 is also an approach that it will not look to develop its own new production spatial infrastructures, set out to create new datasets, or undertake activities that can best be done by the private sector alone.

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